Bison Basin Project

FINAL RESTORATION REPORT

Pilot In-Situ Uranium Mining Operation
Fremont County, Wyoming

April 29, 1980

Ogle Petroleum Inc.

16334

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1. PURPOSE

The purpose of this Report is to present the aquifer restoration data collected in connection with Ogle Petroleum Inc.'s pilot in-situ uranium solution mining project. A discussion of the restoration results is also included with this Final Restoration Report. The data presented in this Report are intended to serve as the factual basis for assessing Ogle Petroleum's capability of restoring the groundwater affected by an in-situ uranium leach mining operation.

2. BACKGROUND

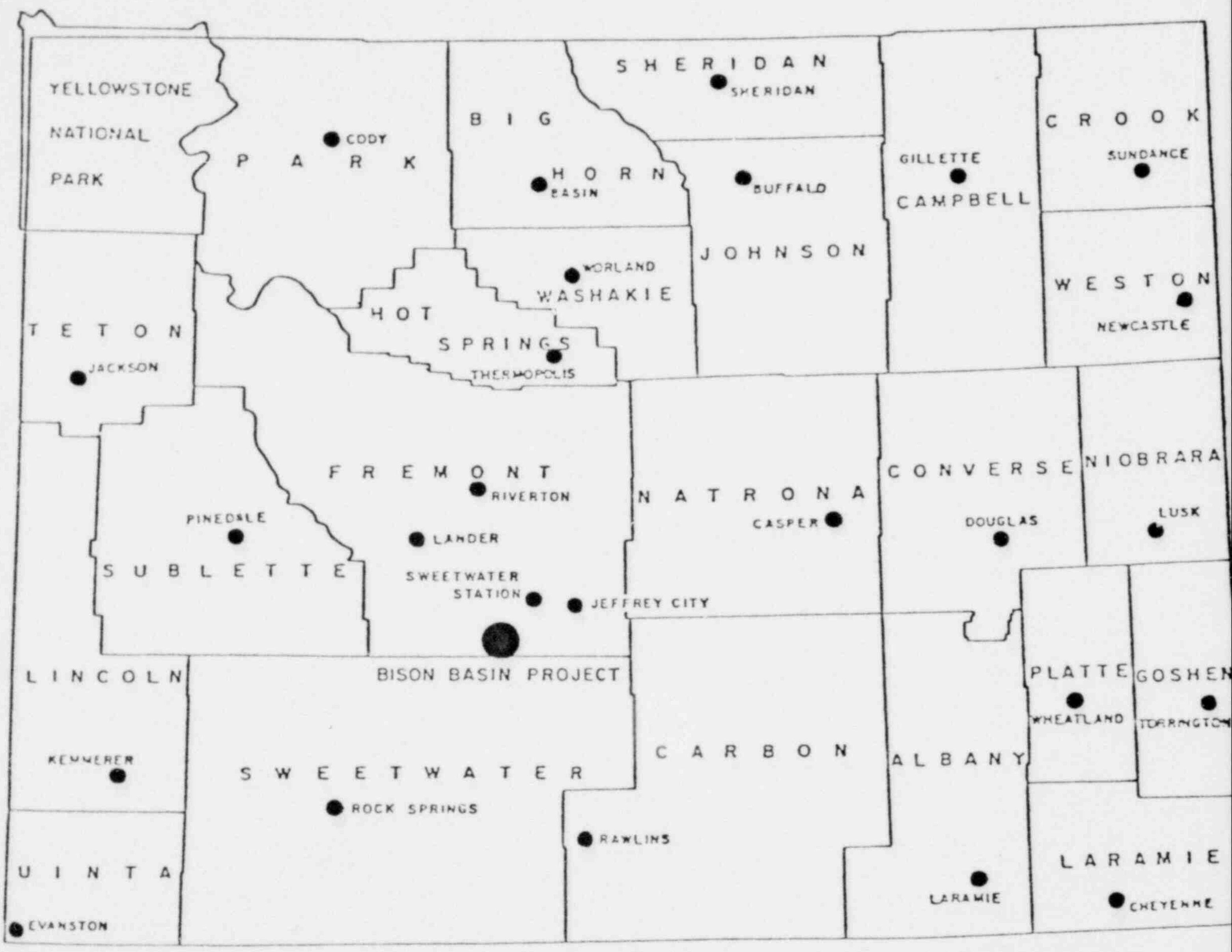
During the period from May 1, 1979 through September 14, 1979, Ogle Petroleum Inc. (OPI) conducted a pilot scale (R & D) in-situ uranium solution mining and aquifer restoration operation in southern Fremont County, Wyoming. The location of the project site is shown in Figure 1, and a map showing the site facilities and orebody outline is presented in Figure 2. The R & D wellfield, consisting of a line-drive type pattern, was located inside a one-acre test area (see Figure 3).

The pilot operation was conducted under License to Explore No. 38 and Source Material License No. SUA-1336 issued by the Wyoming Department of Environmental Quality and the U. S. Nuclear Regulatory Commission, respectively. The major objectives of the pilot test were to:

1. Obtain the hydrologic and chemical process data necessary for the design of the commercial facilities, and
2. Demonstrate to appropriate regulatory agencies the capability of satisfactorily restoring the groundwater quality in an aquifer affected by the in-situ leaching of uranium.

The mining phase of the pilot test operation commenced on May 1, 1979. Sodium carbonate/bicarbonate was used as the leaching agent, and oxygen was used as the oxidant except for a few brief periods during which hydrogen peroxide was used as the oxidant. Approximately 1,830 pounds of uranium (U_3O_8) were recovered during the three-month period that lasted until August 1, 1979. The average flow rate and uranium head grade during the pilot test were 19.4 gallons per minute and 82 mg/l, respectively.

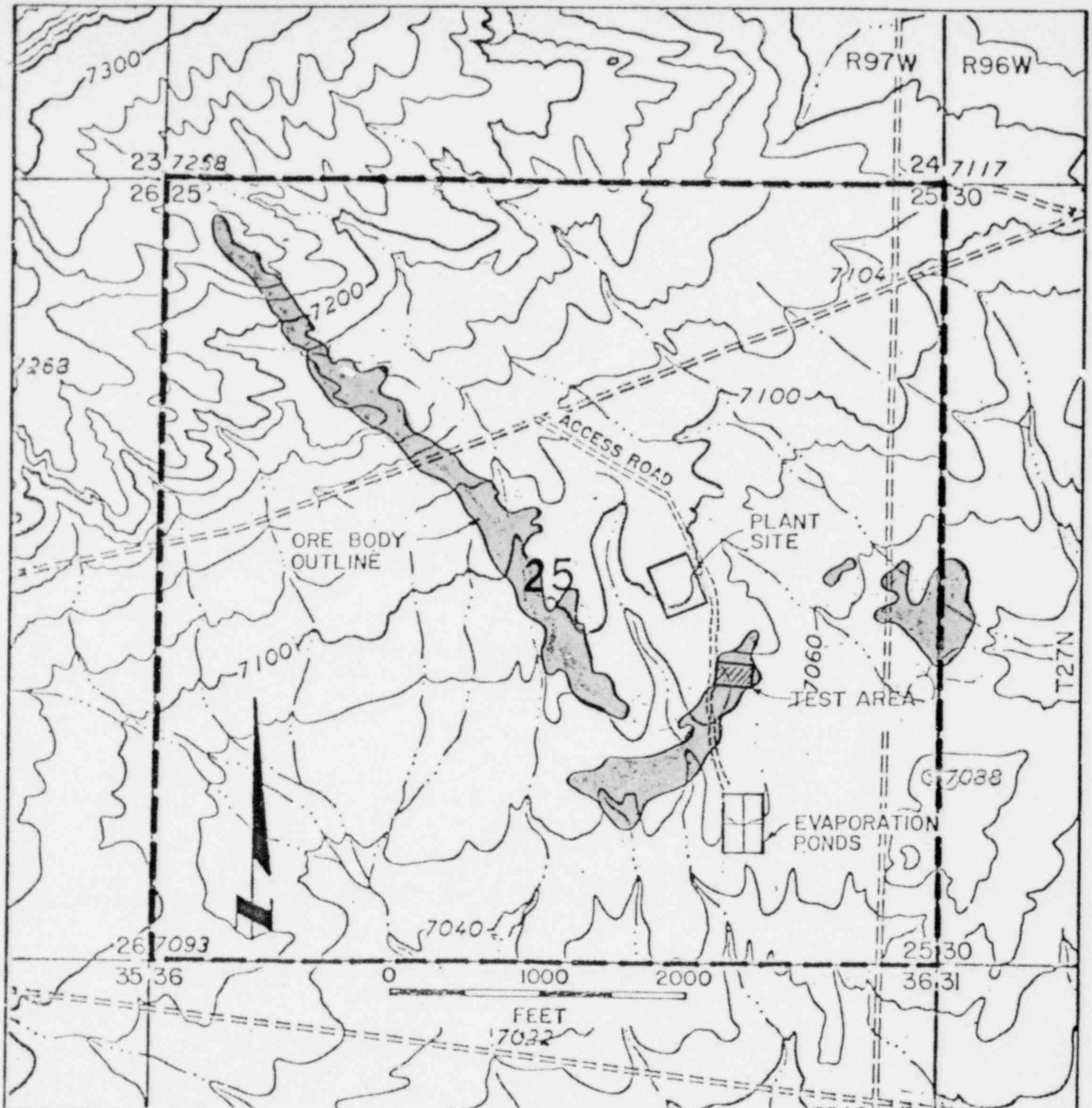
FIGURE 1



LOCATION OF BISON BASIN PROJECT

(WYOMING REGIONAL)

Scale: 1" = 47 Miles



EXPLANATION

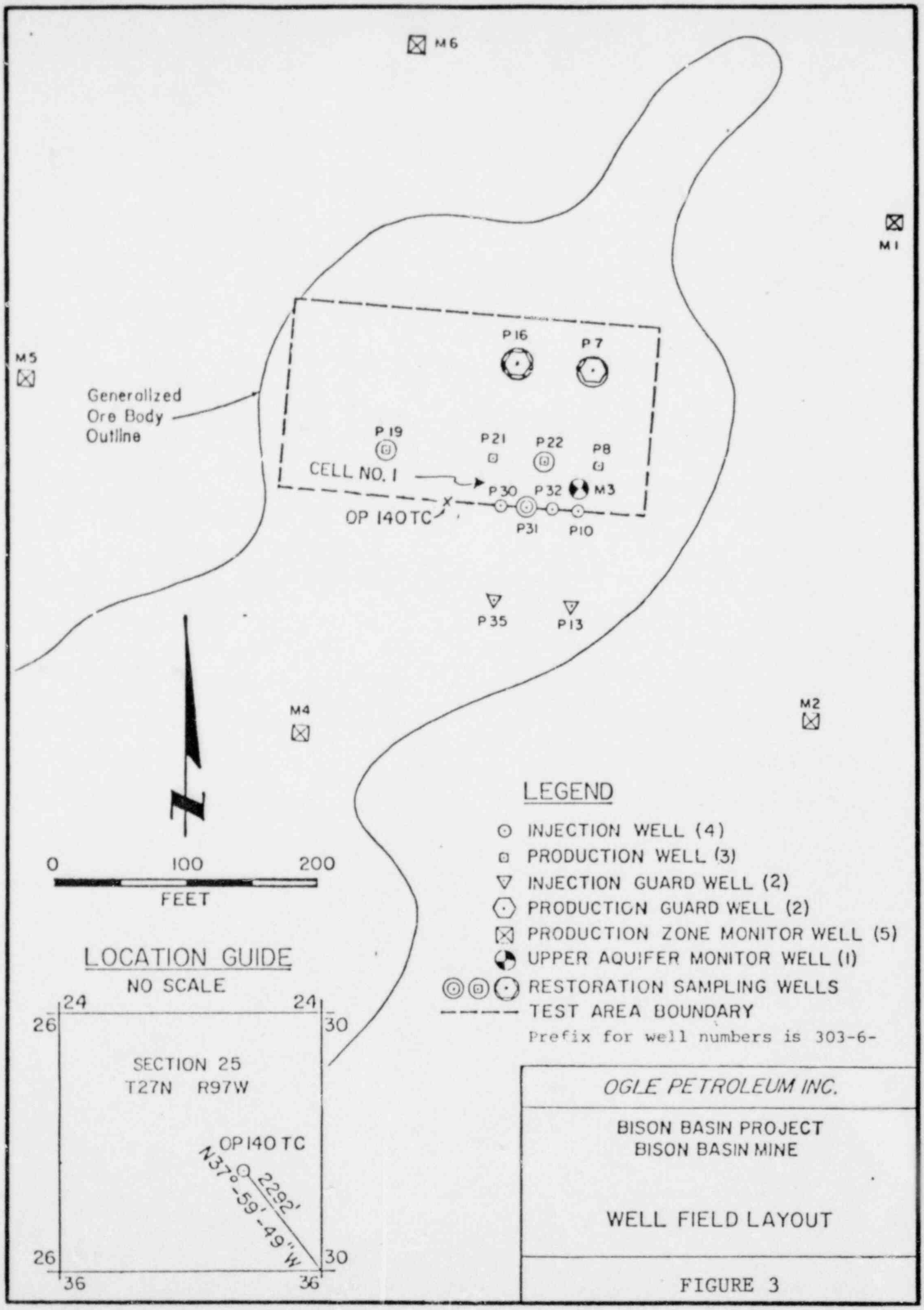
PROJECT AREA BOUNDARY

OGLE PETROLEUM INC.

BISON BASIN PROJECT
BISON BASIN MINE

SITE PLAN

FIGURE 2



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The restoration phase of the project took place during the period August 1, 1979 through September 14, 1979. A reverse osmosis (R. O.) unit was used to restore the quality of the groundwater affected by the solution mining operation. During the 36-day restoration period, the circulation of approximately eight aquifer pore volumes through the R. O. unit and the wellfield reduced the concentration of all chemical species tested to less than baseline values or drinking water standards with the exception of total carbonate which does not have a drinking water standard. Approximately 150 additional pounds of uranium were recovered during the restoration phase bringing the total uranium recovery for the project to 1,980 pounds U_3O_8.

3. BASELINE WATER QUALITY

The background water quality in the aquifer to be affected by OPI's in-situ mining operation is unsuitable for any use other than industrial primarily due to high pH and the high concentrations of sulfate, sodium, and radium-226. Additionally, the low yield of this aquifer (approximately 12 gallons per minute) would not be sufficient for normal crop irrigation. The baseline values for the restoration sampling wells are contained in Tables 1 through 5 presented in Section 4 of this report. A summary of the background water quality in the mining zone and the production zone outside the mineralized area is presented in Appendix 1. The locations of the wells used to collect these data are also presented in Appendix 1. A tabulation of water quality standards for various uses is presented in Figure 4.

It is necessary to treat the natural occurring groundwater in the production zone aquifer in order to make it suitable for either livestock watering, drinking water, or irrigation purposes. For example, to meet livestock criteria it would be necessary to reduce the pH to the 6.5 to 8.5 range, and radium-226 would have to be reduced to less than 5.0 pCi/l. The same requirements apply to making the natural groundwater suitable for drinking water plus total dissolved solids and sulfate levels would also have to be reduced. The relatively high sodium values would make the natural mining zone groundwater undesirable for irrigation purposes. To reduce the above parameters to acceptable limits, it would be necessary to treat the water with a device such as a R. O. unit. A conventional water softener would not be adequate since a water

CLASSIFICATION SYSTEM FOR GROUNDWATERS OF WYOMING

GROUNDWATER CLASS	I	II	III	IV	VA	VB
Potential Use	Domestic	Fish/Aquatic Life	Agriculture	Livestock	Industry	
Constituent or Parameter	Concentration or Range -- mg/l unless otherwise indicated					
Aluminum (Al)		0.10	5.0	5.0		
Ammonia (NH_3)	0.5[8]	0.02[1]				
Arsenic (As)	0.05	0.05	0.10	0.2		
Barium (Ba)	1.0	5.0				
Beryllium (Be)		0.011-1.1[3]	0.10			
Boron (B)	0.75		0.75	5.0		
Cadmium (Cd)	0.01	0.0004-0.015[3]	0.01	0.05		
Chloride (Cl)	250.		100.	2,000.		
Chromium (Cr)	0.05	0.05	0.10	0.05		
Cobalt (Co)			0.05	1.0		
Copper (Cu)	1.0	0.010-0.040[3]	0.20	0.50		
Cyanide (CN)	0.2	0.005				
Fluoride (F)	1.4-2.4[7]					
Hydrogen Sulfide (H_2S)	0.05	0.002[2]				
Iron (Fe)	0.30	0.50	5.0			
Lead (Pb)	0.05	0.004-0.150[3]	5.0	0.10		
Lithium (Li)			2.5			
Manganese (Mn)	0.05	1.0	0.20			
Mercury (Hg)	0.002	0.00005		0.00005		
Nickel (Ni)		0.05-0.400[3]	0.20			
Nitrate (NO_3 as Nitrogen)	10.					
Nitrite (NO_2 as Nitrogen)	1.0			10.		
(NO_3+NO_2, as N)				100.		
Oil & Grease	10.	virtually free	10.	10.		
Phenol	0.001	0.001				
Selenium (Se)	0.01	0.05	0.02	0.05		
Silver (Ag)	0.05	0.00010-0.00025[3]				
Sulfate (SO_4)	250.		200.	3,000.		
Total Dissolved Solids (TDS)	500.	500.[4] 1,000.[5] 2,000.[6]	2,000.	5,000.	10,000	>10,000
Uranium (U)	5.0	0.30-1.40[3]	5.0	5.0		
Vanadium (V)			0.10	0.10		
Zinc (Zn)	5.0	0.050-0.060[3]	2.0	25.		
pH	6.5-8.5s.u.	6.5-9.0s.u.	4.5-9.0s.u.	6.5-8.5s.u.		

	I	II	III	IV	VA	VB
SAR			8			
RSC			1.25 meq/l			
Combined Total Radium-226 and Radium-228	5 pCi/l	5 pCi/l	5 pCi/l	5 pCi/l		
Total Strontium-90	8 pCi/l	8 pCi/l	8 pCi/l	8 pCi/l		
Gross alpha particle radioactivity (including Radium-226 but excluding Radon and Uranium)	15 pCi/l	15 pCi/l	15 pCi/l	15 pCi/l		
	Underground water of this class shall not contain bacteriological, biological, hazardous, toxic or potentially toxic materials or substances including pesticides, insecticides or herbicides in concentrations or amounts which exceed maximum allowable concentrations based upon the latest available information and in conformity with the latest criteria or standards established by the U.S. Environmental Protection Agency or its successor agency.					

SOURCE: Water Quality Division (DEQ) Proposed Rules and Regulations.

[1]Unionized ammonia: When ammonia dissolves in water, some of the ammonia reacts with water to form ammonium ions. A chemical equilibruim is established which contains unionized ammonia (NH_3), ionized ammonia (NH_4^+), and hydroxide ions (OH^-). The toxicity of aqueous solutions of ammonia is attributed to NH_3; therefore the standard is for unionized ammonia. (Note: 0.02 mg/l NH_3 is equivalent to 0.016 NH_3 as N).

[2]Undissociated H_2S: The toxicity of sulfides derives primarily from H_2S rather than from the dissociated (HS) or (S) ions; therefore the standard is for the toxic undissociated H_2S.

[3]Dependent on hardness: The toxicity of metals in natural waters varies with the hardness of the water; generally, the limiting concentration is greater in hard water than in soft water.

[4]Egg hatching [5]Fish rearing [6]Fish and aquatic l...

[7]Dependent on the annual average of the maximum daily air temperature. [8]Total ammonia-nitrogen.

POOR ORIGINAL

softener merely exchanges less desirable ions for more desirable ions and does not improve water quality in terms of purity.

4. RESTORATION RESULTS

The groundwater restoration activity commenced in early August and terminated in mid-September, 1979. The restoration program consisted of the following:

1. August 1, 1979 through August 4, 1979: The addition of leaching chemicals to the lixiviant ceased; however, the fluids continued to be circulated through the wellfield and the processing plant to lower the concentration of uranium.
2. August 5, 1979 through August 9, 1979: One aquifer pore volume, approximately 115,000 gallons, was pumped from the wellfield to the evaporation pond after routing the fluid through the processing plant to remove uranium.
3. August 10, 1979 through September 14, 1979: Fluids from the recovery wells were routed to a R. O. unit. The clean water (permeate) from the R. O. unit was reinjected at the wellfield. The concentrated brine (reject) from the R. O. unit was discharged to the evaporation pond.

Restoration of the groundwater affected by OPI's pilot in-situ uranium leach project was achieved on September 14, 1979. In accordance with regulatory requirements, the groundwater quality in the restored aquifer was monitored for six months to assess the water quality stability. OPI sampled the restoration sampling wells monthly during the six-month stability period. The location of restoration sampling wells are shown in Figure 3. The results of this post-restoration monitoring as well as the baseline and restoration period data are presented in tabular form in Tables 1 through 5. The analytical laboratory water quality reports for the

TABLE 1

RESTORATION INFORMATION
WELL 303-6-P 7

(Units: mg/l unless otherwise indicated)

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES							
	Sample Round Number 1 09-03-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-12-78	Sample Round Number 4 10-23-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80
pH (pH units)	9.2	9.5	9.8	9.7	9.5	8.1	9.2	8.6	7.9				
Total Dissolved Solids	1358	1612	1400	1486	1464	1376	1372	1458	1350				
Specific Conductivity (micromhos/cm)	1770	1785	1775	1750	1770	1725	1725	1725	1725				
Ammonia (as N)	0.25	0.07	0.22	2.0	0.64	- 0.1	0.62	-0.10	- 0.1				
Nitrate (as N)	-0.01	0.03	-0.01	0.26	0.08	-0.01	0.02	0.01	0.03				
Nitrite (as N)	-0.01	-0.01	-0.01	-0.01	-0.01	0.10	-0.01	0.02	-0.01				
Bicarbonate	98	85	73	61	79	110	61	85	110				
Carbonate	24	36	36	36	33	0	36	24	0				
Calcium	28	12	18	18	19	40	35	37	26				
Chloride	34	32	34	36	34	36	26	30	30				
Boron	- 1.0	- 1.0			- 1.0			- 1.0					
Fluoride	1.05	1.20			1.13			0.91					
Magnesium	4	4	3	2	3	0	9	2	8				
Potassium	8	13	9	10	10	11	10	8	7				
Sodium	414	480	437	465	449	410	434	436	459				
Sulfate	800	975	850	900	881	860	816	826	890				
Aluminum	-0.05	-0.05			-0.05			-0.05					
Arsenic	-0.01	-0.01			-0.01			-0.01	-0.01				

SAMPLES FROM WELL 303-6-P 7 WILL NOT BE COLLECTED FOR ROUND NOS. 5, 6, 7, and 8 DUE TO A STUCK PUMP SITUATION DISCUSSED IN THE THIRD QUARTERLY REPORT. THIS PROCEDURE HAS BEEN APPROVED BY THE NRC AND THE DEQ.

(continued)

TABLE 1 (continued)

WELL 303-6-P 7

PARAMETER	BASELINE VALUES Sample Round Number 1 09-03-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-12-78	Sample Round Number 4 10-23-78	Baseline Mean	RESTORATION AND POST RESTORATION VALUES Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80
Barium	-0.05	-0.05			-0.05			-0.05					
Cadmium	-0.002	-0.002			-0.002			-0.002					
Chromium	-0.01	-0.01			-0.01			-0.01					
Copper	-0.01	-0.01			-0.01			-0.01		SAMPLES FROM WELL 303-6-P 7 WILL NOT			
Iron	0.02	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01	0.26				
Lead	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	BE COLLECTED FOR ROUND NOS.			
Manganese	-0.01	-0.01			-0.01			-0.01		5, 6, 7, and 8 DUE TO A			
Mercury	-0.001	-0.001			-0.001			-0.001		STUCK PUMP SITUATION			
Nickel	-0.04	-0.04			-0.04			-0.04					
Selenium	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	DISCUSSED IN THE THIRD QUARTERLY			
Zinc	-0.01	-0.01	-0.01	-0.01	-0.01	0.06	0.06	0.07	0.07	REPORT. THIS PROCEDURE HAS BEEN			
Molybdenum	-0.05	-0.05			-0.05			-0.05		APPROVED BY THE NRC AND THE DEQ.			
Vanadium	-0.05	-0.05			-0.05			-0.05					
Uranium	-0.001	-0.001	-0.001	-0.001	-0.001	0.006	0.003	-0.001	0.056				
Radium-226 (pCi/l)	7.1±0.3	10.2±0.3	2.2±0.4	1.4±0.3	5.23	3.7±0.4	2.03±0.32	2.70±1.24	5.24±0.55				
Thorium-230 (pCi/l)	2.8±1.7	14.6±5.0	0.6±0.7	2.5±1.2	5.13			12.0±5.31					

NOTES: Mining terminated on July 31, 1979. Restoration started on August 5, 1979 and terminated on September 14, 1979.

Blank space indicates analysis of parameter not required.

- means not detected at level indicated.

N.A. means data not yet available from commercial laboratory.

TABLE 2

RESTORATION INFORMATION
WELL 303-6-P 16

(Units: mg/l unless otherwise indicated)

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number 1 09-13-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-19-78	Sample Round Number 4 10-28-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
pH (pH units)	9.3	9.2	9.0	9.4	9.2	8.3	8.5	8.6	8.0	8.2	7.5	8.0	8.0	
Total Dissolved Solids	1458	1620	1338	1526	1485	1272	1350	1442	1310	1402	1386	1346	1338	(1316)
Specific Conductivity (micromhos/cm)	1740	1850	1750	1785	1781	1800	1725	1615	1925	1800	1850	1850	1925	
Ammonia (as N)	0.12	0.10	0.15	2.9	0.82	0.25	0.44	-0.10	- 0.1	0.18	0.25	0.24	0.20	
Nitrate (as N)	0.16	0.39	-0.01	0.33	0.22	0.02	0.02	-0.01	0.02	0.04	0.02	0.13	0.20	
Nitrite (as N)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	
Bicarbonate	98	85	98	85	91	85	122	146	115	129	120	127	127	(90.4)
Carbonate	36	36	36	48	39	24	12	0	0	0	0	0	0	(6.0)
Calcium	32	25	29	29	29	51	38	30	34	44	40	43	39	(30.3)
Chloride	36	30	30	30	31	28	30	38	32	34	22	34	36	(5)
Boron	- 1.0	- 1.0			- 1.0			- 1.0					- 1.0	(0.19)
Fluoride	0.80	1.20			1.0			1.03					1.09	(0.32)
Magnesium	4	6	5	3	4	3	1	6	8	8	9	9	10	(6.2)
Potassium	7	11	8	9	9	11	9	7	6	6	6	12	9	(7.5)
Sodium	429	485	320	433	417	425	417	433	434	389	413	412	402	(390)
Sulfate	830	1000	770	870	867	806	759	804	817	800	790	814	833	(825)
Aluminum	-0.05	-0.05			-0.05			-0.05					- 0.1	(-0.01)
Arsenic	-0.01	-0.01			-0.01			-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.02)

(continued)

TABLE 2 (continued)

WELL 303-6-P 16

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number 1 09-13-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-19-78	Sample Round Number 4 10-28-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
Barium	-0.05	-0.05			-0.05			-0.05					-0.05	(-0.01)
Cadmium	-0.002	-0.002			-0.002			-0.002					-0.01	(-0.01)
Chromium	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Copper	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Iron	0.02	-0.01	0.13	-0.01	0.04	0.03	0.01	0.01	0.07	0.03	0.10	0.03	0.03	(-0.01)
Lead	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	(-0.01)
Manganese	-0.01	-0.01			-0.01			-0.01					-0.01	(-0.01)
Mercury	-0.001	-0.001			-0.001			-0.001					-0.001	(-1ppb)
Nickel	-0.04	-0.04			-0.04			-0.04					-0.04	(-0.01)
Selenium	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.02)
Zinc	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.01)
Molybdenum	-0.05	-0.05			-0.05			-0.05					-0.05	
Vanadium	-0.05	-0.05			-0.05			-0.05					-0.05	
Uranium	-0.001	-0.001	-0.001	-0.001	-0.001	0.007	0.003	-0.01	0.002	-0.001	0.005	0.011	0.044	
Radium-226 (pCi/1)	10.5±0.4	7.0±0.3	8.7±0.4	12.1±0.3	9.58	5.4±0.4	7.17±0.55	6.92±0.93	5.68±0.59	8.6±0.7	5.0±0.4	10.2±1.7	8.92±2.39	
Thorium-230 (pCi/1)*	1.4±1.2	6.6±2.9	1.0±0.7	0±0.5	3.00			14.14±5.3					-0.2	

NOTES: Mining terminated on July 31, 1979. Restoration started on August 5, 1979 and terminated on September 14, 1979.

Blank space indicates analysis of parameter not required.

- means not detected at level indicated.

* Mean Baseline based on Sample Rounds 1, 2, and 3.

Number in parens represents value (mg/1) that Wyoming DEQ obtained from a commercial lab that analyzed duplicate (split) samples collected on March 18, 1980.

TABLE 3

RESTORATION INFORMATION
WELL 303-6-P 19

(Units: mg/l unless otherwise indicated)

PARAMETER	BASELINE VALUES: Sample Round Number 1 09-03-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-12-78	Sample Pound Number 4 10-24-78	Baseline Mean	RESTORATION AND POST RESTORATION VALUES: Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Pound Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
pH (pH units)	11.3	11.4	10.1	10.8	10.9	8.4	8.6	8.8	8.0	8.4	7.8	8.2	7.9	
Total Dissolved Solids	1348	1560	1462	1520	1472	1314	1418	1560	1640	1836	1784	1678	1616	(1723)
Specific Conductivity (micromhos/cm)	2080	1750	2100	1850	1945	1800	1800	1900	1825	2075	2275	2275	2000	
Ammonia (as N)	0.25	0.10	0.18	2.2	0.68	0.24	0.44	-0.10	- 0.1	0.30	0.22	0.26	0.22	
Nitrate (as N)	0.16	0.37	-0.01	0.23	0.19	-0.01	0.04	0.03	0.03	0.02	-0.01	-0.01	0.03	
Nitrite (as N)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	
Bicarbonate *	0	0	31	0	31	85	122	98	93	114	93	98	93	(63)
Carbonate	24	36	24	24	27	24	24	12	0	0	0	0	0	(5)
Calcium	49	62	56	31	49	56	26	32	34	56	54	53	51	(42.2)
Chloride	52	40	40	32	41	30	28	22	24	22	24	22	22	(18)
Boron	- 1.0	- 1.0			- 1.0			- 1.0					- 1.0	(0.11)
Fluoride	1.09	1.05			1.07			0.70					0.83	(0.22)
Magnesium **	0	0	0	0	0	3	5	8	17	11	14	11	14	(10.3)
Potassium	14	16	11	10	13	11	10	9	10	9	9	10	11	(10.9)
Sodium	441	442	447	448	444	416	434	500	508	485	498	481	486	(480)
Sulfate	820	960	900	950	907	807	774	, 1013	1075	1150	1100	1082	1082	(1086)
Aluminum	-0.05	-0.05			-0.05			-0.05					- 0.1	(-0.01)
Arsenic	-0.01	-0.01			-0.01			-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(- 0.2)

*Mean Baseline value based on Sample Round 3, analytical error suspected in Rounds 1, 2, and 4.
**Analytical error also suspected for Magnesium during the baseline period.

(continued)

TABLE 3 (continued)

WELL 303-6-P 19

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number 1 09-03-78	Sample Round Number 2 09-28-78	Sample Round Number 3 10-12-78	Sample Round Number 4 10-24-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
Barium	-0.05	-0.05			-0.05			-0.05					-0.05	(-0.01)
Cadmium	-0.002	-0.002			-0.002			-0.002					-0.01	(-0.01)
Chromium	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Copper	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Iron	0.02	-0.01	-0.01	-0.01	0.01	-0.01	0.01	0.01	0.08	0.03	0.06	0.03	0.03	(-0.01)
Lead	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	(-0.01)
Manganese	-0.01	-0.01			-0.01			-0.01					-0.01	(-0.01)
Mercury	-0.001	-0.001			-0.001			-0.001					-0.001	(-1ppb)
Nickel	-0.04	-0.04			-0.04			-0.04					-0.04	(-0.01)
Selenium	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.02)
Zinc	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.02	-0.01	-0.01	0.01	0.01	(-0.01)
Molybdenum	-0.05	-0.05			-0.05			-0.05					-0.05	
Vanadium	-0.05	-0.05			-0.05			-0.05					-0.05	
Uranium	0.004	-0.001	-0.001	-0.001	0.002	0.07	0.008	-0.001	0.006	0.002	0.003	-0.001	0.034	
Radium-226 (pCi/l)	18.0±0.3	9.5±0.3	14.5±0.4	7.4±0.3	12.35	17.2±1.1	9.98±0.66	15.6±1.7	14.1±0.83	6.6±1.8	24.4±0.9	14.2±2.0	13.0±2.39	
Thorium-230 (pCi/l) *	0±0.5	6.1±3.1	2.0±1.3	7.6±2.5	5.23			2.21±2.85					-0.2	

NOTES: Mining terminated on July 31, 1979. Restoration started on August 5, 1979 and terminated on September 14, 1979.

Blank space indicates analysis of parameter not required.

\- means not detected at level indicated.

* Baseline Mean value based on Sample Rounds 2, 3, and 4.

Number in parens represents value (mg/l) that Wyoming DEQ obtained from a commercial lab that analyzed duplicate (split) samples collected on March 18, 1980.

TABLE 4

RESTORATION INFORMATION
WELL 303-6-P 22

(Units: mg/l unless otherwise indicated)

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number 1 09-12-78	Sample Round Number 2 10-06-78	Sample Round Number 3 10-19-78	Sample Round Number 4 10-28-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
pH (pH units)	9.5	9.5	10.6	10.7	10.1	7.8	7.0	8.2	7.9	8.0	8.0	7.8	7.7	
Total Dissolved Solids	1486	1499	1612	1812	1602	2842	1192	1476	1530	1422	1730	1508	1546	(1539)
Specific Conductivity (micromhos/cm)	1850	1900	2100	2125	1994	3850	1725	1775	1775	2250	2[illegible]50	1725	2125	
Ammonia (as N)	0.10	0.20	0.19	2.9	0.85	0.21	0.41	-0.10	- 0.1	0.29	0.28	0.23	0.21	
Nitrate (as N)	-0.01	-0.01	-0.01	0.07	0.03	0.04	0.03	0.03	0.03	-0.01	-0.01	-0.0[illegible]	0.02	
Nitrite (as N)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	
Bicarbonate *	61	61	0	0	61	683	293	159	163	149	110	134	122	(91)
Carbonate	18	36	24	36	28	0	0	0	0	0	0	0	0	(0)
Calcium	29	29	39	41	34	112	47	46	43	65	57	56	56	(45.4)
Chloride	36	30	28	30	31	394	68	30	52	48	32	56	36	(38)
Boron	- 1.0	- 1.0			- 1.0			- 1.0					- 1.0	(0.08)
Fluoride	0.70	0.98			0.84			0.81					0.95	(0.20)
Magnesium	4	6	4	3	4	40	2	9	12	13	14	12	14	(11.6)
Potassium	10	9	10	11	10	19	9	8	8	8	7	10	9	(9.5)
Sodium	437	468	490	493	472	841	379	471	508	406	461	458	447	(430)
Sulfate	860	965	1040	1100	996	394	532	914	944	790	1020	937	982	(987)
Aluminum	-0.05	-0.05			-0.05			-0.05					- 0.1	(-0.01)
Arsenic	-0.01	-0.01			-0.01			-0.01	-0.01	-0.0[illegible]	-0.01	-0.01	-0.01	(-0.02)

*Mean Baseline value based on Sample Rounds 1 and 2, analytical error suspected in Rounds 3 and 4.

(continued)

TABLE 4 (continued)

WELL 303-6-P 22

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number 1 09-21-78	Sample Round Number 2 10-06-78	Sample Round Number 3 10-19-78	Sample Round Number 4 10-28-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
Barium	-0.05	-0.05			-0.05			-0.05					-0.05	(-0.01)
Cadmium	-0.002	-0.002			-0.002			-0.002					-0.01	(-0.01)
Chromium	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Copper	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Iron	0.02	-0.01	0.10	-0.01	0.04	0.01	0.01	0.01	0.05	0.03	0.05	-0.03	0.03	(-0.01)
Lead	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	(-0.01)
Manganese	-0.01	-0.01			-0.01			-0.01					-0.01	(-0.01)
Mercury	-0.001	-0.001			-0.001			-0.001					-0.001	(-1ppb)
Nickel	-0.04	-0.04			-0.04			-0.04					-0.04	(-0.01)
Selenium	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.02)
Zinc	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.01	(-0.01)
Molybdenum	-0.05	-0.05			-0.05			-0.05					-0.05	
Vanadium	-0.05	-0.05			-0.05			-0.05					-0.05	
Uranium	-0.001	-0.001	-0.001	-0.001	-0.001	2.70	0.105	0.145	0.115	0.105	0.031	0.12	0.113	
Radium-226 (pCi/l)	23.7±0.4	8.3±0.3	21.0±0.4	29.6±0.3	20.65	182.6±4.4	1.94±0.28	5.3±0.83	11.8±0.86	7.6±0.6	5.9±0.4	21.4±2.6	7.82±3.07	
Thorium-230 (pCi/l) *	0±0.5	1.4±1.1	5.8±2.2	0±0.5	3.60			25.5±7.9					-0.2	

NOTES: Mining terminated on July 31, 1979. Restoration started on August 5, 1979 and terminated on September 14, 1979.

Blank space indicates analysis of parameter not required.

- means not detected at level indicated.

* Baseline Mean value based on Samples Rounds 2 and 3.

Number in parens represents value (mg/l) that Wyoming DEQ obtained from a commercial lab that analyzed duplicate (split) samples collected on March 18, 1980.

TABLE 5

RESTORATION INFORMATION
WELL 303-6-P 31

(Units: mg/? ess otherwise indicated)

PARAMETER	BASELINE VALUES					RESTORATION AND POST RESTORATION VALUES								
	Sample Round Number _ 09-12-78	Sample Round Number 2 09-26-78	Sample Round Number 3 10-20-78	Sample Round Number 4 10-28-78	Baseline Mean	Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
pH (pH units)	9.2	8.8	8.8	8.8	8.9	7.6	7.0	7.6	7.4	7.1	7.4	7.2	7.3	
Total Dissolved Solids	1428	1336	1402	1606	1443	3282	85	822	1340	1420	1402	1318	1470	(1303)
Specific Conductivity (micromhos/cm)	1750	1825	1770	1750	1774	4350	115	1115	1700	1850	1675	1750	1825	
Ammonia (as N)	0.10	0.15	0.14	1.8	0.55	0.10	-0.01	-0.10	- 0.1	0.53	0.16	0.23	0.18	
Nitrate (as N)	0.26	-0.01	0.05	0.15	0.14	0.10	0.04	0.03	0.02	0.02	0.04	0.02	0.01	
Nitrite (as N)	-0.01	-0.01	-0.01	-0.01	-0.01	0.04	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	
Bicarbonate	104	104	110	98	104	830	37	207	242	268	242	217	232	(169)
Carbonate	30	18	24	24	24	0	0	0	0	0	0	0	0	(0)
Calcium	36	31	31	31	32	112	2	107	195	251	118	96	85	(78.4)
Chloride	34	32	34	34	33	590	24	56	84	78	54	52	48	(15)
Boron	- 1.0	- 1.0			- 1.0			- 1.0					- 1.0	(0.17)
Fluoride	0.80	0.98			0.89			0.63					0.83	(0.28)
Magnesium	3	8	6	4	5	21	0	10	15	16	15	10	12	(9.8)
Potassium	7	7	8	8	7	20	1	3	3	3	3	9	7	(4.1)
Sodium	424	406	452	456	434	1146	23	152	238	234	340	348	363	(348)
Sulfate	820	810	840	940	852	1067	0	359	675	710	825	719	766	(765)
Aluminum	-0.05	-0.05			-0.05			-0.05					- 0.1	(-0.01)
Arsenic	-0.01	-0.01			-0.01			0.056	0.02	-0.01	-0.01	-0.01	-0.01	(0.06)

(continued)

TABLE 5 (continued)

WELL 303-6-P 31

PARAMETER	BASELINE VALUES Sample Round Number 1 09-12-78	Sample Round Number 2 09-26-78	Sample Round Number 3 10-20-78	Sample Round Number 4 10-28-78	Baseline Mean	RESTORATION AND POST RESTORATION VALUES Sample Round Number 1 08-05-79	Sample Round Number 2 09-05-79	Sample Round Number 3 10-05-79	Sample Round Number 4 11-05-79	Sample Round Number 5 12-07-79	Sample Round Number 6 01-08-80	Sample Round Number 7 02-05-80	Sample Round Number 8 03-18-80	
Barium	-0.05	-0.05			-0.05			-0.05					-0.05	(-0.01)
Cadmium	-0.002	-0.002			-0.002			-0.002					-0.01	(-0.01)
Chromium	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Copper	-0.01	-0.01			-0.01			-0.01					-0.02	(-0.01)
Iron	0.02	-0.01	0.05	-0.01	0.02	0.01	0.01	0.24	1.30	1.38	0.38	2.39	1.37	(-0.01)
Lead	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	(-0.01)
Manganese	-0.01	-0.01			-0.01			0.15					0.13	(-0.01)
Mercury	-0.001	-0.001			-0.001			-0.001					-0.001	(-1ppb)
Nickel	-0.04	-0.04			-0.04			-0.04					-0.04	(-0.01)
Selenium	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	(-0.02)
Zinc	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.08	0.08	0.01	0.01	0.46	0.97	(0.84)
Molybdenum	-0.05	-0.05			-0.05			-0.05					-0.05	
Vanadium	-0.05	-0.05			-0.05			-0.05					-0.05	
Uranium	-0.001	0.005	0.011	-0.001	0.005	1.45	0.011	0.500	0.590	0.755	0.315	2.05	2.75	
Radium-226 (pCi/l)	419.3±0.4	335±0.3	296±0.3	291±0.3	335.3	834.4±9.1	5.05±0.53	364±4	456±21	1121±7.0	410.1±10.3	340±11.2	276.8±8.52	
Thorium-230 (pCi/l)	6.7±2.3	10.0±4.6	4.0±1.5	0.5±0.7	5.30			2.26±2.3					-0.2	

NOTES: Mining terminated on July 31, 1979. Restoration started on August 5, 1979 and terminated on September 14, 1979.

Blank space indicates analysis of parameter not required.

\- means not detected at level indicated.

Number in parens represents value (mg/l) that Wyoming DEQ obtained from a commercial lab that analyzed duplicate (split) samples collected on March 18, 1980.

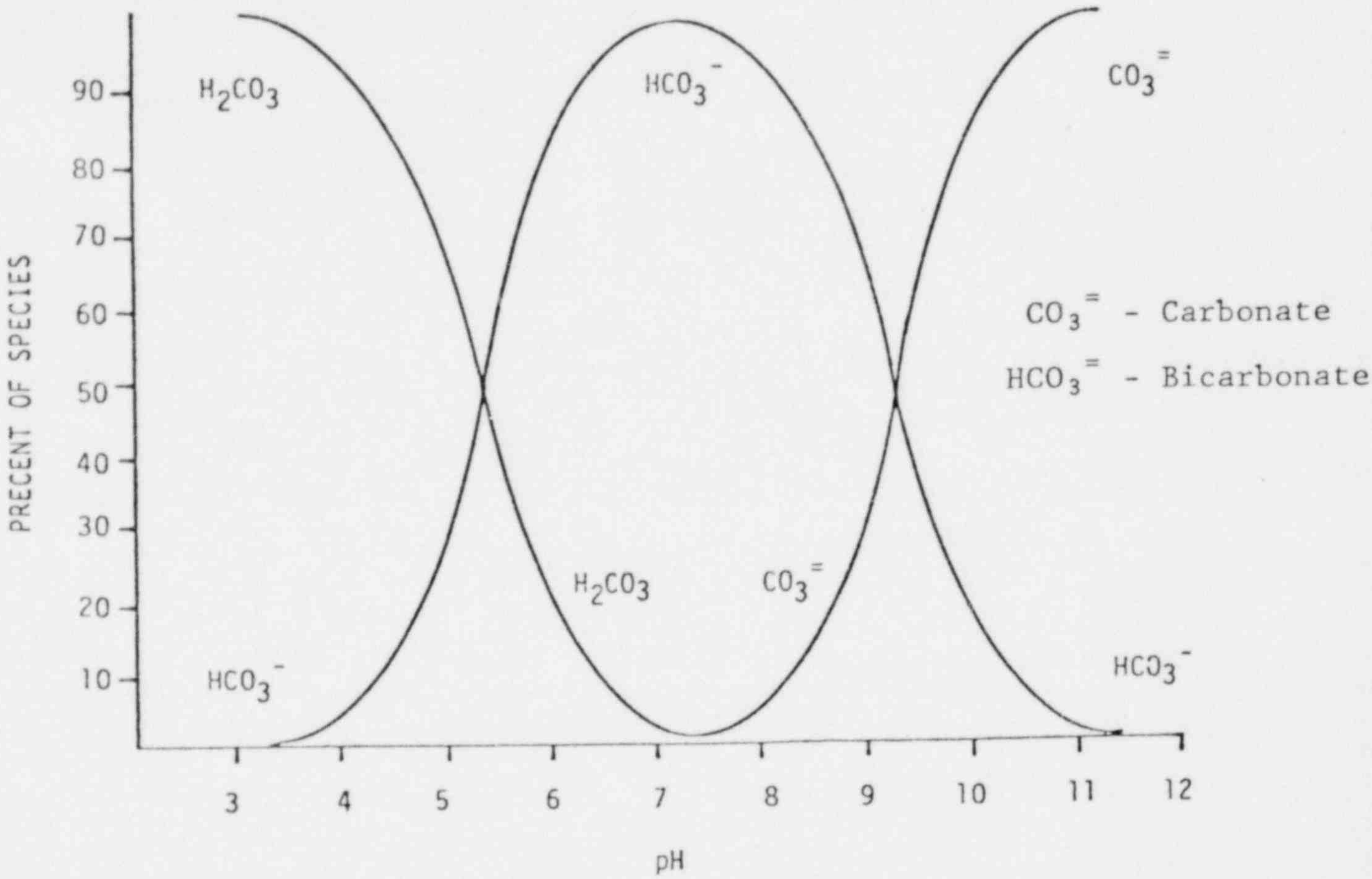
individual wells including baseline and restoration data are presented in Appendix 2.

5. DISCUSSION OF RESTORATION RESULTS

In general, the results of the restoration and post-restoration sampling show that most of the parameters were returned to less than baseline plus 10% or drinking water standards. The pH, which naturally exceeds drinking water and livestock watering standards, was reduced to within the 6.5 to 8.5 range due to the influence of circulating R. O. unit treated water (approximately neutral pH) through the mined aquifer.

It appears from the restoration data that the above mentioned reduction in pH has affected the carbonate/bicarbonate ratio as dictated by the graph presented in Figure 5 which shows the impact of pH on different species of carbonate chemistry. A re-alignment of the concentrations of the various anion and cations has also taken place as a result of the introduction of the high purity R. O. unit water into the production zone in order to maintain electrochemical neutrality. This effect is most notable in the post-restoration values for calcium and magnesium which are somewhat elevated above baseline values. From a water usability standpoint, these two constituents only add to the total hardness and are not considered toxic. OPI is not aware of any drinking water standard for calcium, magnesium, or total carbonate; and it is not unusual to find concentrations of these three elements in drinking water supplies at or above the final restoration values. The U. S. Department of Commerce has published a guide for evaluating the quality of water used by livestock which presents the limiting concentrations for bicarbonate, calcium, and magnesium of 500 mg/l, 1,000 mg/l, and 500 mg/l, respectively. The pertinent portion of

Figure 5



Impact of pH on Different Species of Carbonate Chemistry.

SOURCE: Incorporating Reverse Osmosis Technology,
Bulletin 605, Distributed by
Trace Metal Data Institute
8616 Lakehurst
El Paso, Texas 79912

this publication is presented in Appendix 3. An EPA publication, entitled "Quality Criteria for Water," states that "alkalinity resulting from naturally occurring materials such as carbonate and bicarbonate is not considered a health hazard in drinking water supplies, per se, and naturally occurring maximum levels up to approximately 400 mg/l as calcium carbonate are not considered a problem to human health (National Academy of Sciences, 1974)." The pertinent portion of this EPA publication along with information on other chemical species is also included in Appendix 3.

The restoration results have demonstrated that the mobilization of toxic metals such as mercury, lead, arsenic, and selenium during the in-situ leaching of uranium is not occurring to any measurable degree. The post-restoration analytical data indicate that the concentration levels for these toxic metals are the same as the baseline values.

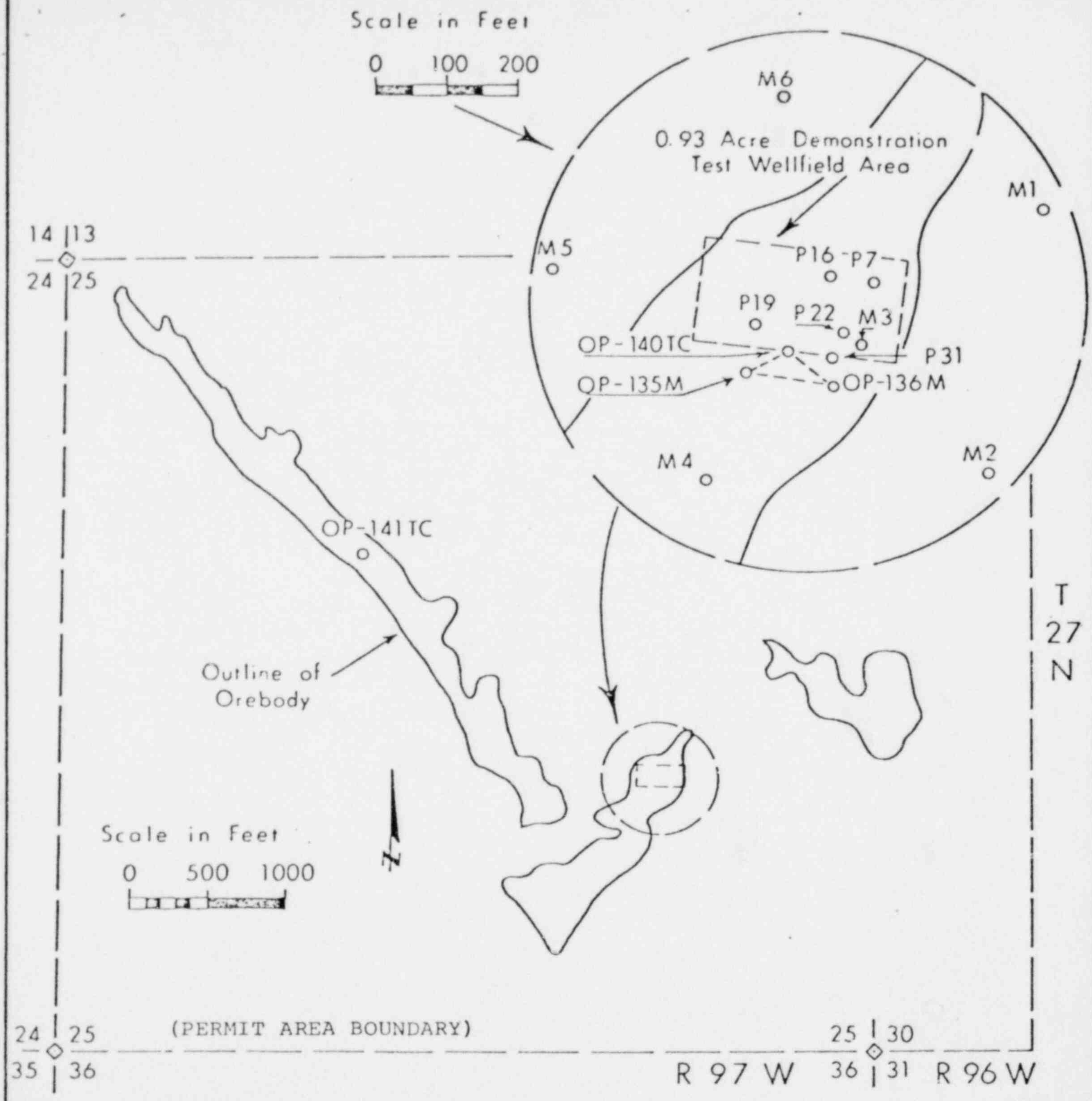
6. SUMMARY

One of the primary objectives of OPI's pilot scale operation conducted in the Bison Basin area of Wyoming was to demonstrate the capability of satisfactorily restoring the water quality in an aquifer affected by the in-situ leach mining of uranium. A comparison of the post-restoration results with the baseline data clearly documents the fact that OPI has the operational know-how and technical expertise to satisfactorily restore the groundwater affected by in-situ leach mining.

APPENDIX 1

Summary of Baseline

Water Quality Data



LOCATION OF WELLS SAMPLED FOR BASELINE WATER QUALITY

(PERMIT AREA)

APPENDIX 1

Baseline Water Quality | Bison Basin, Wyoming

(Figures in mg/l except as noted)

Hole Number:	OP 140 TC		OP 141 TC		OP 135	OP 136
Date sampled:	6-1-77	6-7-77	6-16-77		6-2-77	6-1-77
Hour sampled:	1130 hr	1700 hr	1421 hr	1600 hr	1400 hr	1845 hr
pH	(8.92)[1]	8.80	8.23	8.09		
Temp. Deg. C		12.5	12.0	11.6		
Eh mV	(400)[1]	184	92	92		
Sp. Conductance[2]	2300	1850	2450	2400		
Total Diss. Sol.	1370	1330	1790	1780	1380	1390
Hardness[3]	98.9	101.1	194.8	193.9	101.8	96.8
Al	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
As	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
B	0.27	0.26	0.32	0.38	0.28	0.26
Ca	27.7	28.9	54.0	54.0	27.7	26.2
Cd	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Cl	25	29	11	9	24	26
Cr	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Cu	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
F	1.01	1.02	0.68	0.66	1.07	1.04
Fe-total	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Fe-dissolved	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Hg	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
K	5.3	6.1	6.7	6.4	5.0	4.9
Mg	7.0	6.8	14.2	14.0	7.7	7.4
Mn	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Mo	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Na	440	445	495	487	452	455
Ni	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
P	-0.1	-0.1	0.1	0.1	0.1	-0.1
Pb	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Ra-226 (pCi/1)	230	210	260	280		
Se	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Sr	0.77	0.82	1.27	1.27	0.74	0.72
U_3O_8[4]	0.01	0.02	0.04	0.04	-0.01	-0.01
V	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Zn	-0.01	-0.01	0.02	0.01	-0.01	-0.01
Bicarbonate	(90)[1]	110	180	190		
Carbonate	(20)[1]	20	-10	-10		
Sulfate	825	725	1100	1090	825	725
Ammonia[5]	0.4	0.1	-0.1	0.2		
Nitrate[6]	0 2	-0.2	-0.2	-0.2	-0.2	-0.2

1 Values in () were taken several days after sample collection, and are less reliable than the other reported values.
2 Specific conductance in micromhos/cm at 25 degress C.
3 Hardness in mg/l, expressed as equivalent $CaCo_3$.
4 Total uranium, expressed as equivalent U_3O_8.
5 Total ammonia, expressed as N equivalent.
6 Total nitrate, expressed as N equivalent.

Blank space = not determined. Data by Rocky Mountain Geochemical Corporation, Salt Lake City, Utah. (Tabulated by D. B. Roberts, 9-7-77.

OGLE PETROLEUM INC.

APPENDIX 1

STATISTICAL SUMMARY
MONITOR WELLS BASELINE WATER QUALITY[1]
(For 5 monitor wells completed in "D" sand)

(All values are in mg/l unless otherwise indicated)

	Number of Data Points (N)	Concentration Range	Concentration Mean ($\bar{X}$)	Concentration Standard Deviation (σ n-1)
ph (pH units)	20	8.5-10.7	9.40	0.64
Total Dissolved Solids	20	1270-1554	1375.4	63.04
Specific Conductivity (micromhos/cm at 25°C)	20	1675-1925	1804.29	77.95
Aluminum	10	All data below detection limit of 0.05		
Ammonia (as N)	20	0.01-10.1	0.88	2.33
Nitrate (as N)	20	(-)[2] 0.01-7.80	0.56	1.71
Nitrite (as N)	20	All data below detection limit of 0.01		
Arsenic	10	All data below detection limit of 0.01		
Barium	10	All data below detection limit of 0.05		
Bicarbonate	20	0-134	79.6	41.78
Boron	10	All data below detection limit of 1.0		
Cadmium	10	All data below detection limit of 0.002		
Calcium	20	10-34	22.45	8.20
Carbonate	20	12-48	30.90	9.73
Chloride	20	28-70	38.42	10.62
Chromium	10	All data below detection limit of 0.01		
Copper	10	All data below detection limit of 0.01		
Fluoride	10	0.06-1.30	0.93	0.35
Iron (total)	20	(-)0.01-0.06	-	-
Lead	20	All data below detection limit of 0.05		
Magnesium	20	2-6	3.85	1.18
Manganese	10	All data below detection limit of 0.002		
Mercury	10	All data below detection limit of 0.001		
Molybdenum	10	All data below detection limit of 0.05		
Nickel	10	All data below detection limit of 0.04		
Potassium	20	7-16	10.25	2.10
Selenium	20	All data below detection limit of 0.01		
Sodium	20	421-481	436.90	15.11
Sulfate	20	590-950	807.50	70.25
Uranium	20	(-)0.001-0.016	-	-
Vanadium	10	All data below detection limit of 0.05		
Zinc	20	All data below detection limit of 0.01		
Radium-226 (pCi/l)	20	0.74-165.4	24.23	43.49
Thorium-230 (pCi/l)	20	0.00-23.9	8.28	16.31

(1) Tabulated statistical values based upon data obtained from the sampling of 5 monitor wells completed in the "D" sand for the Demonstration Test project (well Nos. 303-6-M1, 303-6-M2, 303-6-M4, 303-6-M5 and 303-6-M6). These five wells were completed in the monitor zone. The period of time during which the data were collected was August, 1978 thru October, 1978.

(2) (-) means not detected at level indicated.

APPENDIX 1

STATISTICAL SUMMARY
TEST AREA BASELINE WATER QUALITY[1]
(For 5 wells completed in orebody aquifer ("D" sand) and which will undergo restoration in Demonstration Project)

(All values in mg/l unless otherwise indicated)

	Number of Data Points (N)	Concentration Range	Concentration Mean ($\bar{X}$)	Concentration Standard Deviation (σ n-1)
pH (pH units)	20	8.8-11.4	9.73	0.82
Total Dissolved Solids	20	1336-1812	1493	120.7
Specific Conductivity (micromhos/cm at 25°C)	20	1740-2125	1853	134.8
Aluminum	10	All data below detection limit of 0.05		
Ammonia (as N)	20	0.07-2.9	0.71	1.01
Nitrate (as N)	20	0.01-0.39	0.13	0.13
Nitrite (as N)	20	All data below detection limit of 0.01		
Arsenic	10	All data below detection limit of 0.01		
Barium	10	All data below detection limit of 0.05		
Bicarbonate	20	0-110	62.6	41.6
Boron	10	All data below detection limit of 1.0		
Cadmium	10	All data below detection limit of 0.002		
Calcium	20	12-62	32.8	12.1
Carbonate	20	18-48	30.3	7.9
Chloride	20	28-52	34.2	5.3
Chromium	10	All data below detection limit of 0.01		
Copper	10	All data below detection limit of 0.01		
Fluoride	10	0.7-1.2	0.98	0.17
Iron (total)	20	0.01-0.13	0.025	0.032
Lead	20	All data below detection limit of 0.05		
Magnesium	20	0-8	3.45	2.24
Manganese	10	All data below detection limit of 0.01		
Mercury	10	All data below detection limit of 0.001		
Nickel	10	All data below detection limit of 0.05		
Potassium	20	7-16	9.8	2.4
Selenium	20	All data below detection limit of 0.01		
Sodium	20	320-493	443	37.9
Sulfate	20	770-1100	901	88
Uranium	20	0.001-0.011	0.0018	0.0024
Vanadium	10	All data below detection limit of 0.05		
Zinc	20	All data below detection limit of 0.01		
Radium-226 (pCi/l)	20	2.2-419.3	76.63	134.96
Thorium-230 (pCi/l)	20	0-14.6	3.68	3.97

(1) Tabulated statistical values based upon data obtained from the sampling of five restoration sampling wells in the Demonstration Test area (well Nos. 303-6-7C, 303-6-P16, 303-6-P19, 303-6-P22C and 303-6-P31C). These five wells were completed in the ore zone. The period of time during which the data were collected was August, 1978 thru October, 1978.

APPENDIX 1

APPENDIX 2

Individual Laboratory Water
Quality Analytical Reports

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 5, 1978

Other Pertinent Data

Analyzed by Staff Date September 30, 1978 Lab No. 28612-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-7 Interval "D"
Sample taken September 3, 1978

	mg/l		mg/l
otal dissolved solids (calculated)	1362	Boron (B)	ND(1.0)
otal dissolved solids (observed)	1358	Barium (Ba)	ND(0.05)
otal suspended solids	4.7	Cadmium (Cd)	ND(0.002)
onductivity, micromhos @ 68°F.	1770	Chromium (Cr)	ND(0.01)
otal alkalinity as $CaCO_3$	121	Copper (Cu)	ND(0.01)
al hardness as $CaCO_3$	87	Fluoride (F)	1.05
odium (Na) (calculated)	416	Iron (Fe) (total)	0.02
odium (Na) (observed)	414	Lead (Pb)	ND(0.05)
otassium (K)	8	Manganese (Mn)	ND(0.01)
lcium (Ca)	28	Mercury (Hg)	ND(0.001)
gnesium (Mg)	4	Nickel (Ni)	ND(0.04)
loride (Cl)	34	Nitrate (as N)	ND(0.01)
lfate (SO_4)	800	Nitrite (as N)	ND(0.01)
rbonate (CO_3)	24	Selenium (Se)	ND(0.01)
carbonate (HCO_3)	98	Zinc (Zn)	ND(0.01)
, units	9.2	Molybdenum (Mo)	ND(0.05)
uminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
monia (N)	0.25	Uranium (U_3O_8)	ND(0.001)
senic (As)	ND(0.01)		

dium-226, pCi/l ---------- 7.1±0.3
orium-230, pCi/l ---------- 2.8±1.7

= Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

ove tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and C methods.

EMICAL & GEOLOGICAL LABORATORIES

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E. Davis

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 13, 1978

Other Pertinent Data

Analyzed by Staff Date September 30, 1978 Lab No. 28749-1

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-16 Interval "D"
Sample taken September 13, 1978

	mg/l		mg/l
tal dissolved solids (calculated)	1429	Boron (B)	ND(1.0)
tal dissolved solids (observed)	1458	Barium (Ba)	ND(0.05)
tal suspended solids	3.8	Cadmium (Cd)	ND(0.002)
nductivity, micromhos @ 68°F.	1740	Chromium (Cr)	ND(0.01)
tal alkalinity as $CaCO_3$	141	Copper (Cu)	ND(0.01)
al hardness as $CaCO_3$	97	Fluoride (F)	0.80
dium (Na) (calculated)	436	Iron (Fe) (total)	0.02
dium (Na) (observed)	429	Lead (Pb)	ND(0.05)
tassium (K)	7	Manganese (Mn)	ND(0.01)
lcium (Ca)	32	Mercury (Hg)	ND(0.001)
gnesium (Mg)	4	Nickel (Ni)	ND(0.04)
oride (Cl)	36	Nitrate (as N)	0.16
lfate (SO_4)	830	Nitrite (as N)	ND(0.01)
rbonate (CO_3)	36	Selenium (Se)	ND(0.01)
arbonate (HCO_3)	98	Zinc (Zn)	ND(0.01)
units	9.3	Molybdenum (Mo)	ND(0.05)
minum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
onia (N)	0.12	Uranium (U_3O_8)	ND(0.001)
enic (As)	ND(0.01)		

dium-226, pCi/l	10.5±0.4
rium-230, pCi/l	1.4±1.2

= Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

ve tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and methods.

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E. Davis

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 5, 1978

Other Pertinent Data

Analyzed by Staff Date September 30, 1978 Lab No. 28612-3

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-19 Interval "D"
Sample taken September 3, 1978

	mg/l		mg/l
otal dissolved solids (calculated)	1395	Boron (B)	ND(1.0)
otal dissolved solids (observed)	1348	Barium (Ba)	ND(0.05)
otal suspended solids	6.5	Cadmium (Cd)	ND(0.002)
onductivity, micromhos @ 68°F.	2080	Chromium (Cr)	ND(0.01)
otal alkalinity as $CaCO_3$	111	Copper (Cu)	ND(0.01)
tal hardness as $CaCO_3$	123	Fluoride (F)	1.09
odium (Na) (calculated)	412	Iron (Fe) (total)	0.02
odium (Na) (observed)	441	Lead (Pb)	ND(0.05)
otassium (K)	14	Manganese (Mn)	ND(0.01)
alcium (Ca)	49	Mercury (Hg)	ND(0.001)
agnesium (Mg)	0	Nickel (Ni)	ND(0.04)
loride (Cl)	52	Nitrate (as N)	0.16
ulfate (SO_4)	820	Nitrite (as N)	ND(0.01)
arbonate (CO_3)	24	Selenium (Se)	ND(0.01)
icarbonate (HCO_3)	0	Zinc (Zn)	ND(0.01)
H, units	11.3	Molybdenum (Mo)	ND(0.05)
luminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
monia (N)	0.25	Uranium (U_3O_8)	0.004
rsenic (As)	ND(0.01)	Hydroxide (OH)	24

adium-226, pCi/l ---------- 18.0±0.3

horium-230, pCi/l ---------- 0±0.5

D = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

bove tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and EC methods.

REMARKS: Hydroxide present.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 13, 1978

Other Pertinent Data

Analyzed by Staff Date September 30, 1978 Lab No. 28749-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-22 Interval "D"
Sample taken September 13, 1978

	mg/1		mg/1
otal dissolved solids (calculated)	1441	Boron (B)	ND(1.0)
otal dissolved solids (observed)	1486	Barium (Ba)	ND(0.05)
otal suspended solids	312	Cadmium (Cd)	ND(0.002)
onductivity, micromhos @ 68°F.	1850	Chromium (Cr)	ND(0.01)
otal alkalinity as $CaCO_3$	80	Copper (Cu)	ND(0.01)
al hardness as $CaCO_3$	89	Fluoride (F)	0.70
odium (Na) (calculated)	434	Iron (Fe) (total)	0.02
odium (Na) (observed)	437	Lead (Pb)	ND(0.05)
otassium (K)	10	Manganese (Mn)	ND(0.01)
alcium (Ca)	29	Mercury (Hg)	ND(0.001)
agnesium (Mg)	4	Nickel (Ni)	ND(0.04)
loride (Cl)	36	Nitrate (as N)	ND(0.01)
ulfate (SO_4)	880	Nitrite (as N)	ND(0.01)
arbonate (CO_3)	18	Selenium (Se)	ND(0.01)
carbonate (HCO_3)	61	Zinc (Zn)	ND(0.01)
H, units	9.5	Molybdenum (Mo)	ND(0.05)
luminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
monia (N)	0.10	Uranium (U_3O_8)	ND(0.001)
rsenic (As)	ND(0.01)		

dium-226, pCi/1	23.7±0.4
horium-230, pCi/1	0±0.5

) = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

bove tests were made in accordance with Standard Methods, 14th [illegible]on, 1975, ASTM, WQO and
C methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 13, 1978

Other Pertinent Data

Analyzed by Staff Date September 30, 1978 Lab No. 28749-3

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-31 Interval "D"
Sample taken September 13, 1978

	mg/l		mg/l
otal dissolved solids (calculated)	1406	Boron (B)	ND(1.0)
otal dissolved solids (observed)	1428	Barium (Ba)	ND(0.05)
otal suspended solids	2.9	Cadmium (Cd)	ND(0.002)
onductivity, micromhos @ 68°F.	1750	Chromium (Cr)	ND(0.01)
otal alkalinity as $CaCO_3$	136	Copper (Cu)	ND(0.01)
otal hardness as $CaCO_3$	103	Fluoride (F)	0.80
odium (Na) (calculated)	425	Iron (Fe) (total)	0.02
odium (Na) (observed)	424	Lead (Pb)	ND(0.05)
otassium (K)	7	Manganese (Mn)	ND(0.01)
alcium (Ca)	36	Mercury (Hg)	ND(0.001)
agnesium (Mg)	3	Nickel (Ni)	ND(0.04)
loride (Cl)	34	Nitrate (as N)	0.26
ulfate (SO_4)	820	Nitrite (as N)	ND(0.01)
arbonate (CO_3)	30	Selenium (Se)	ND(0.01)
icarbonate (HCO_3)	104	Zinc (Zn)	ND(0.01)
H, units	9.2	Molybdenum (Mo)	ND(0.05)
luminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
monia (N)	0.10	Uranium (U_3O_8)	ND(0.001)
rsenic (As)	ND(0.01)		

adium-226, pCi/l ---------- 419.3±0.4
horium-230, pCi/l ---------- 6.7±2.3

D = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

bove tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and EC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 30, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 28938-1

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P7
Sample taken September 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1631	Boron (B)	ND(1.0)
Total dissolved solids (observed)	1612	Barium (Ba)	ND(0.05)
Total suspended solids	1.9	Cadmium (Cd)	ND(0.002)
Conductivity, micromhos @ 68°F.	1785	Chromium (Cr)	ND(0.01)
Total alkalinity as $CaCO_3$	130	Copper (Cu)	ND(0.01)
Total hardness as $CaCO_3$	50	Fluoride (F)	1.20
Sodium (Na) (calculated)	517	Iron (Fe) (total)	ND(0.01)
Sodium (Na) (observed)	480	Lead (Pb)	ND(0.05)
Potassium (K)	13	Manganese (Mn)	ND(0.01)
Calcium (Ca)	12	Mercury (Hg)	ND(0.001)
Magnesium (Mg)	4	Nickel (Ni)	ND(0.04)
Chloride (Cl)	32	Nitrate (as N)	0.03
Sulfate (SO_4)	975	Nitrite (as N)	ND(0.01)
Carbonate (CO_3)	36	Selenium (Se)	ND(0.01)
Bicarbonate (HCO_3)	85	Zinc (Zn)	ND(0.01)
pH, units	9.5	Molybdenum (Mo)	ND(0.05)
Aluminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
Ammonia (N)	0.07	Uranium (U_3O_8)	ND(0.001)
Arsenic (As)	ND(0.01)		

Radium-226, pCi/l	10.2±0.3
Thorium-230, pCi/l	14.6±5.0

ND = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM. & Ecology audits, Inc., Dallas, TX.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and EC methods.

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E. Davis

OPI-WESTERN JOINT VENTURE
12-20-78

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 30, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 28938-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P16
Sample taken September 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1661	Boron (B)	ND(1.0)
Total dissolved solids (observed)	1620	Barium (Ba)	ND(0.05)
Total suspended solids	2.6	Cadmium (Cd)	ND(0.002)
Conductivity, micromhos @ 68°F.	1850	Chromium (Cr)	ND(0.01)
Total alkalinity as $CaCO_3$	130	Copper (Cu)	ND(0.01)
Total hardness as $CaCO_3$	87	Fluoride (F)	1.20
Sodium (Na) (calculated)	511	Iron (Fe) (total)	ND(0.01)
Sodium (Na) (observed)	485	Lead (Pb)	ND(0.05)
Potassium (K)	11	Manganese (Mn)	ND(0.01)
Calcium (Ca)	25	Mercury (Hg)	ND(0.001)
Magnesium (Mg)	6	Nickel (Ni)	ND(0.04)
Chloride (Cl)	30	Nitrate (as N)	0.39
Sulfate (SO_4)	1000	Nitrite (as N)	ND(0.01)
Carbonate (CO_3)	36	Selenium (Se)	ND(0.01)
Bicarbonate (HCO_3)	85	Zinc (Zn)	ND(0.01)
pH, units	9.2	Molybdenum (Mo)	ND(0.05)
Aluminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
Ammonia (N)	0.10	Uranium (U_3O_8)	ND(0.001)
Arsenic (As)	ND(0.01)		

Radium-226, pCi/l	7.0±0.3
Thorium-230, pCi/l	6.6±2.9

ND = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM. & Ecology Audits, Inc., Dallas, TX.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CHEMICAL & GEOLOGICAL LABORATORIES

OPI-WESTERN JOINT VENTURE

12-20-78

C. E. Davis

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture — Product: Water

Address: Casper, Wyoming — Date: September 30, 1978

Other Pertinent Data

Analyzed by: Staff — Date: October 30, 1978 — Lab No. 28938-3

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P19
Sample taken September 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1603	Boron (B)	ND(1.0)
Total dissolved solids (observed)	1560	Barium (Ba)	ND(0.05)
Total suspended solids	3.4	Cadmium (Cd)	ND(0.002)
Conductivity, micromhos @ 68°F.	1750	Chromium (Cr)	ND(0.01)
Total alkalinity as $CaCO_3$	131	Copper (Cu)	ND(0.01)
Total hardness as $CaCO_3$	155	Fluoride (F)	1.05
Sodium (Na) (calculated)	465	Iron (Fe) (total)	ND(0.01)
Sodium (Na) (observed)	442	Lead (Pb)	ND(0.05)
Potassium (K)	16	Manganese (Mn)	ND(0.01)
Calcium (Ca)	62	Mercury (Hg)	ND(0.001)
Magnesium (Mg)	0	Nickel (Ni)	ND(0.04)
Chloride (Cl)	40	Nitrate (as N)	0.37
Sulfate (SO_4)	960	Nitrite (as N)	ND(0.01)
Carbonate (CO_3)	36	Selenium (Se)	ND(0.01)
Bicarbonate (HCO_3)	0	Zinc (Zn)	ND(0.01)
pH, units	11.4	Molybdenum (Mo)	ND(0.05)
Aluminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
Ammonia (N)	0.10	Uranium (U_3O_8)	ND(0.001)
Arsenic (As)	ND(0.01)	Hydroxide (OH)	24

Radium-226, pCi/l — 9.5±0.3
Thorium-230, pCi/l — 6.1±3.1

ND = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM. & Ecology Audits, Inc., Dallas, TX.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CHEMICAL & GEOLOGICAL LABORATORIES

C. E. Davis

OPI-WESTERN JOINT VENTURE
12-20-78

CHE...ICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date October 7, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 29020-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P22 Interval "D"
Sample taken October 6, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1587	Boron (B)	ND(1.0)
Total dissolved solids (observed)	1499	Barium (Ba)	ND(0.05)
Total suspended solids	4.8	Cadmium (Cd)	ND(0.002
Conductivity, micromhos @ 68°F.	1900	Chromium (Cr)	ND(0.01)
Total alkalinity as $CaCO_3$	110	Copper (Cu)	ND(0.01)
Total hardness as $CaCO_3$	97	Fluoride (F)	0.98
Sodium (Na) (calculated)	482	Iron (Fe) (total)	0.01
Sodium (Na) (observed)	468	Lead (Pb)	ND(0.05)
Potassium (K)	9	Manganese (Mn)	0.01
Calcium (Ca)	29	Mercury (Hg)	ND(0.001
Magnesium (Mg)	6	Nickel (Ni)	ND(0.04)
Chloride (Cl)	30	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	965	Nitrite (as N)	ND(0.01)
Carbonate (CO_3)	36	Selenium (Se)	ND(0.01)
Bicarbonate (HCO_3)	61	Zinc (Zn)	ND(0.01)
pH, units	9.5	Molybdenum (Mo)	ND(0.05)
Aluminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
Ammonia (N)	0.20	Uranium (U_3O_8)	ND(0.001
Arsenic (As)	ND(0.01)		

Radium-226, pCi/l	8.3±0.3
Thorium-230, pCi/l	1.4±1.1

ND = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM. & Ecology Audits, Inc., Dallas, TX.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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[signature]

C. E. Davis

OPI-WESTERN JOINT VENTURE

12-20-77

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date September 27, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 28887-3

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-31 Interval "D"
Sample taken September 26, 1978

	mg/l		mg/l
otal dissolved solids (calculated)	1363	Boron (B)	ND(1.0)
otal dissolved solids (observed)	1336	Barium (Ba)	ND(0.05)
otal suspended solids	1.2	Cadmium (Cd)	ND(0.002)
onductivity, micromhos @ 68°F.	1825	Chromium (Cr)	ND(0.01)
otal alkalinity as $CaCO_3$	116	Copper (Cu)	ND(0.01)
tal hardness as $CaCO_3$	111	Fluoride (F)	0.98
odium (Na) (calculated)	406	Iron (Fe) (total)	ND(0.01)
odium (Na) (observed)	406	Lead (Pb)	ND(0.05)
otassium (K)	7	Manganese (Mn)	ND(0.01)
alcium (Ca)	31	Mercury (Hg)	ND(0.001)
agnesium (Mg)	8	Nickel (Ni)	ND(0.04)
loride (Cl)	32	Nitrate (as N)	ND(0.01)
ulfate (SO_4)	810	Nitrite (as N)	ND(0.01)
arbonate (CO_3)	18	Selenium (Se)	ND(0.01)
icarbonate (HCO_3)	104	Zinc (Zn)	ND(0.01)
H, units	8.8	Molybdenum (Mo)	ND(0.05)
luminum (Al)	ND(0.05)	Vanadium (V_2O_5)	ND(0.05)
monia (N)	0.15	Uranium (U_3O_8)	0.005
rsenic (As)	ND(0.01)		

adium-226, pCi/l	335±0.3
horium-230, pCi/l	10.0±4.6

D = Not detected at level given in parentheses. Radiochemical by Core Lab., Albuquerque, NM.

bove tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and EC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture — Product: Water

Address: Casper, Wyoming — Date: October 14, 1978

Other Pertinent Data:

Analyzed by: Staff — Date: October 30, 1978 — Lab No. 29096-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-7C Interval "D"
Sample taken October 12, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1438	Ammonia (as N)	0.22
Total dissolved solids (observed)	1400	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	452	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	437	Nitrate (as N)	ND(0.01)
Potassium (K)	9	Nitrite (as N)	ND(0.01)
Calcium (Ca)	18	Selenium (Se)	ND(0.01)
Magnesium (Mg)	3	Zinc (Zn)	ND(0.01)
Chloride (Cl)	34	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	850	Conductivity, micromhos@68°F.	1775
Carbonate (CO_3)	36	Total alkalinity as $CaCO_3$	120
Bicarbonate (HCO_3)	73	Total hardness as $CaCO_3$	58
		pH, units	9.8

Radium-226, pCi/l ---------- 2.2±0.4
Thorium-230, pCi/l ---------- 0.6±0.7

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture　Product Water

Address Casper, Wyoming　Date October 20, 1978

Other Pertinent Data

Analyzed by Staff　Date October 30, 1978　Lab No. 29153-1

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-16 Interval "D"
Sample taken October 19, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1331	Ammonia (as N)	0.15
Total dissolved solids (observed)	1338	Iron (Fe)	0.13
Sodium (Na) (calculated)	405	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	320	Nitrate (as N)	ND(0.01)
Potassium (K)	8	Nitrite (as N)	ND(0.01)
Calcium (Ca)	29	Selenium (Se)	ND(0.01)
Magnesium (Mg)	5	Zinc (Zn)	ND(0.01)
Chloride (Cl)	30	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	770	Conductivity, micromhos@68°F.	1750
Carbonate (CO_3)	36	Total alkalinity as $CaCO_3$	141
Bicarbonate (HCO_3)	98	Total hardness as $CaCO_3$	143
		pH, units	9.0

Radium-226, pCi/l ---------- 8.7±0.4

Thorium-230, pCi/l ---------- 1.0±0.7

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date October 14, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 29096-3

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-19 Interval "D"
Sample taken October 12, 1978

	mg/1		mg/1
Total dissolved solids (calculated)	1508	Ammonia (as N)	0.18
Total dissolved solids (observed)	1462	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	446	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	447	Nitrate (as N)	ND(0.01)
Potassium (K)	11	Nitrite (as N)	ND(0.01)
Calcium (Ca)	56	Selenium (Se)	ND(0.01)
Magnesium (Mg)	0	Zinc (Zn)	ND(0.01)
Chloride (Cl)	40	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	900	Conductivity, micromhos@68°F.	2100
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	131
Bicarbonate (HCO_3)	31	Total hardness as $CaCO_3$	140
		pH, units	10.1

Radium-226, pCi/1	14.5±0.4
Thorium-230, pCi/1	2.0±1.3

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date October 20, 1978

Other Pertinent Data

Analyzed by Staff Date October 30, 1978 Lab No. 29153-2

WATER ANALYSIS

Bison Basin, Wyoming
303-6-P-22 Interval "D"
Sample taken October 19, 1978

	mg/1		mg/1
Total dissolved solids (calculated)	1653	Ammonia (as N)	0.19
Total dissolved solids (observed)	1612	Iron (Fe)	0.10
Sodium (Na) (calculated)	494	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	490	Nitrate (as N)	ND(0.01)
Potassium (K)	10	Nitrite (as N)	ND(0.01)
Calcium (Ca)	39	Selenium (Se)	ND(0.01)
Magnesium (Mg)	4	Zinc (Zn)	ND(0.01)
Chloride (Cl)	28	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	1040	Conductivity, micromhos@68°F.	2100
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	81
Bicarbonate (HCO_3)	0	Total hardness as $CaCO_3$	114
Hydroxide (OH)	14	pH, units	10.6

Radium-226, pCi/1 ---------- 21.0±0.4
Thorium-230, pCi/1 ---------- 5.8±2.2

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture — Product Water

Address Casper, Wyoming — Date October 23, 1978

Other Pertinent Data

Analyzed by Staff — Date October 30, 1978 — Lab No. 29172-4

WATER ANALYSIS

Bison Basin, Wyoming
[illegible]-6-P-31 Interval "D"
Sample taken October 20, 1978

	mg/1		mg/1
Total dissolved solids (calculated) -	1429	Ammonia (as N) -------------------	0.14
Total dissolved solids (observed) ---	1402	Iron (Fe) -----------------------	0.05
Sodium (Na) (calculated) ------------	432	Lead (Pb) -----------------------	ND(0.05)
Sodium (Na) (observed) --------------	452	Nitrate (as N) ------------------	0.05
Potassium (K) -----------------------	8	Nitrite (as N) ------------------	ND(0.01)
Calcium (Ca) ------------------------	31	Selenium (Se) -------------------	ND(0.01)
Magnesium (Mg) ----------------------	6	Zinc (Zn) -----------------------	ND(0.01)
Chloride (Cl) -----------------------	34	Uranium (U_3O_8) --------------	0.011
Sulfate (SO_4) --------------------	840	Conductivity, micromhos@68°F. -----	1770
Carbonate (CO_3) ------------------	24	Total alkalinity as $CaCO_3$ --------	130
Bicarbonate (HCO_3) ---------------	110	Total hardness as $CaCO_3$ ----------	102
		pH, units ------------------------	8.8

Radium-226, pCi/1 -- 296±0.3
Thorium-230, pCi/1 --- 4.0±1.5

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture — Product: Water

Address: Casper, Wyoming — Date: October 23, 1978

Other Pertinent Data

Analyzed by: Staff — Date: November 3, 1978 — Lab No. 29215-3

WATER ANALYSIS

Bison Basin
303-6-P7 Interval "D"
Sample taken October 23, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1506	Ammonia (as N)	2.0
Total dissolved solids (observed)	1486	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	474	Lead Pb	ND(0.05)
Sodium (Na) (observed)	465	Nitrate (as N)	0.26
Potassium (K)	10	Nitrite (as N)	ND(0.01)
Calcium (Ca)	18	Selenium (Se)	ND(0.01)
Magnesium (Mg)	2	Zinc (Zn)	0.01
Chloride (Cl)	36	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	900	Conductivity, micromhos @ 68°F	1750
Carbonate (CO_3)	36	Total alkalinity as $CaCO_3$	110
Bicarbonate (HCO_3)	61	Total hardness as $CaCO_3$	53
		pH, units	9.7

Radium-226, pCi/l	1.4±0.3
Thorium-230, pCi/l	2.5±1.2

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture — Product Water

Address Casper, Wyoming — Date October 30, 1978

Other Pertinent Data

Analyzed by Staff — Date November 3, 1978 — Lab No. 29250-2

WATER ANALYSIS

Bison Basin
303-6-P16
Sample taken October 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1491	Ammonia (as N)	2.9
Total dissolved solids (observed)	1526	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	460	Lead Pb	ND(0.05)
Sodium (Na) (observed)	433	Nitrate (as N)	0.33
Potassium (K)	9	Nitrite (as N)	ND(0.01)
Calcium (Ca)	29	Selenium (Se)	ND(0.01)
Magnesium (Mg)	3	Zinc (Zn)	ND(0.01)
Chloride (Cl)	30	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	870	Conductivity, micromhos @ 68°F	1785
Carbonate (CO_3)	48	Total alkalinity as $CaCO_3$	150
Bicarbonate (HCO_3)	85	Total hardness as $CaCO_3$	85
		pH, units	9.4

Radium-226, pCi/l ---------- 12.1±0.3

Thorium-230, pCi/l ---------- 0±0.5

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture — Product Water

Address Casper, Wyoming — Date October 24, 1978

Other Pertinent Data

Analyzed by Staff — Date November 3, 1978 — Lab No. 29215-4

WATER ANALYSIS

Bison Basin
303-6-P19 Interval "D"
Sample taken October 24, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1532	Ammonia (as N)	2.2
Total dissolved solids (observed)	1520	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	471	Lead Pb	ND(0.05)
Sodium (Na) (observed)	448	Nitrate (as N)	0.23
Potassium (K)	10	Nitrite (as N)	ND(0.01)
Calcium (Ca)	31	Selenium (Se)	ND(0.01)
Magnesium (Mg)	0	Zinc (Zn)	0.01
Chloride (Cl)	32	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	950	Conductivity, micromhos @ 68°F	1850
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	81
Bicarbonate (HCO_3)	0	Total hardness as $CaCO_3$	78
Hydroxide (OH)	14	pH, units	10.8

Radium-226, pCi/l	7.4±0.3
Thorium-230, pCi/l	7.6±2.5

Radiochem...al tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture — Product: Water

Address: Casper, Wyoming — Date: October 30, 1978

Other Pertinent Data:

Analyzed by: Staff — Date: November 3, 1978 — Lab No.: 29250-3

WATER ANALYSIS

Bison Basin

303-6-P22C

Sample taken October 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1768	Ammonia (as N)	2.9
Total dissolved solids (observed)	1812	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	533	Lead Pb	ND(0.05)
Sodium (Na) (observed)	493	Nitrate (as N)	0.07
Potassium (K)	11	Nitrite (as N)	ND(0.01)
Calcium (Ca)	41	Selenium (Se)	ND(0.01)
Magnesium (Mg)	3	Zinc (Zn)	ND(0.01)
Chloride (Cl)	30	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	1100	Conductivity, micromhos @ 68°F	2125
Carbonate (CO_3)	36	Total alkalinity as $CaCO_3$	101
Bicarbonate (HCO_3)	0	Total hardness as $CaCO_3$	115
Hydroxide (OH)	14	pH, units	10.7

Radium-226, pCi/l	29.6±0.3
Thorium-230, pCi/l	0±0.5

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date October 30, 1978

Other Pertinent Data

Analyzed by Staff Date November 3, 1978 Lab No. 29250-4

WATER ANALYSIS

Bison Basin
303-6-P31C
Sample taken October 28, 1978

	mg/l		mg/l
Total dissolved solids (calculated)	1568	Ammonia (as N)	1.8
Total dissolved solids (observed)	1606	Iron (Fe)	ND(0.01)
Sodium (Na) (calculated)	479	Lead Pb	ND(0.05)
Sodium (Na) (observed)	456	Nitrate (as N)	0.15
Potassium (K)	8	Nitrite (as N)	ND(0.01)
Calcium (Ca)	31	Selenium (Se)	ND(0.01)
Magnesium (Mg)	4	Zinc (Zn)	ND(0.01)
Chloride (Cl)	34	Uranium (U_3O_8)	ND(0.001)
Sulfate (SO_4)	940	Conductivity, micromhos @ 68°F	1750
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	121
Bicarbonate (HCO_3)	98	Total hardness as $CaCO_3$	94
		pH, units	8.8

Radium-226, pCi/l	291±0.3
Thorium-230, pCi/l	0.5±0.7

Radiochemical tests by:

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

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From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date August 16, 1979

Other Pertinent Data

Analyzed by KCM, JM, SS, LG, DD, GH Date October 3, 1979 Lab No. 31800-5

WATER ANALYSIS

Bison Basin, Fremont Co., Wyoming
303-6-P7
Sample taken August 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	1425	Ammonia (as N)	ND(0.1)
Total dissolved solids (obs.)	1376	Iron (Fe)	0.01
Sodium (Na) (calc.)	424	Lead (Pb)	ND(0.05)
Sodium (Na) (obs.)	410	Nitrate (as N)	ND(0.01)
Potassium (K)	11	Nitrite (as N)	0.10
Calcium (Ca)	40	Selenium (Se)	ND(0.01)
Magnesium (Mg)	0	Zinc (Zn)	0.06
Chloride (Cl)	36	Uranium (U_3O_8)	0.006
Sulfate (SO_4)	860	Conductivity, micromhos @ 68°F.	1725
Carbonate (CO_3)	0	Total alkalinity as $CaCO_3$	90
Bicarbonate (HCO_3)	110	Total hardness as $CaCO_3$	100
pH, units	8.1		

Radium-226, pCi/l ---------- 3.7±0.4

ND = Not detected at level given in parentheses. Radiochemical tests by Core Laboratories, Albuquerque, New Mexico.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CHEMICAL & GEOLOGICAL LABORATORIES

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OCT 04 1979

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date August 16, 1979

Other Pertinent Data

Analyzed by KCM, JM, SS, LG, DD, GH Date October 3, 1979 Lab No. 31800-1

WATER ANALYSIS

Bison Basin, Fremont Co., Wyoming
303-6-P16
Sample taken August 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	1348	Ammonia (as N)	0.25
Total dissolved solids (obs.)	1272	Iron (Fe)	0.03
Sodium (Na) (calc.)	383	Lead (Pb)	ND(0.05)
Sodium (Na) (obs.)	425	Nitrate (as N)	0.02
Potassium (K)	11	Nitrite (as N)	ND(0.01)
Calcium (Ca)	51	Selenium (Se)	ND(0.01)
Magnesium (Mg)	3	Zinc (Zn)	ND(0.01)
Chloride (Cl)	28	Uranium (U_3O_8)	0.007
Sulfate (SO_4)	806	Conductivity, micromhos @ 68°F.	1800
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	110
Bicarbonate (HCO_3)	85	Total hardness as $CaCO_3$	140
pH, units	8.3		

Radium-226, pCi/l ---------- 5.4±0.4

ND = Not detected at level given in parentheses. Radiochemical tests by Core Laboratories, Albuquerque, New Mexico.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OCT 04 1979

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date August 16, 1979

Other Pertinent Data

Analyzed by KCM, JM, SS, LG, DD, GH Date October 3, 1979 Lab No. 31800-2

WATER ANALYSIS

Bison Basin, Fremont Co., Wyoming
303-6-P19
Sample taken August 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	1353	Ammonia (as N)	0.24
Total dissolved solids (obs.)	1314	Iron (Fe)	ND(0.01)
Sodium (Na) (calc.)	380	Lead (Pb)	ND(0.05)
Sodium (Na) (obs.)	416	Nitrate (as N)	ND(0.01)
Potassium (K)	11	Nitrite (as N)	ND(0.01)
Calcium (Ca)	56	Selenium (Se)	ND(0.01)
Magnesium (Mg)	3	Zinc (Zn)	ND(0.01)
Chloride (Cl)	30	Uranium (U_3O_8)	0.007
Sulfate (SO_4)	807	Conductivity, micromhos @ 68°F.	1800
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	110
Bicarbonate (HCO_3)	85	Total hardness as $CaCO_3$	152
pH, units	8.4		

Radium-226, pCi/l ---------- 17.2±1.1

ND = Not detected at level given in parentheses. Radiochemical tests by Core Laboratories, Albuquerque, New Mexico.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OPI-WESTERN JOINT VENTURE
OCT 04 1979

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date August 16, 1979

Other Pertinent Data

Analyzed by KCM, JM, SS, LG, DD, GH Date October 3, 1979 Lab No. 31800-3

WATER ANALYSIS

Bison Basin, Fremont Co., Wyoming
303-6-P22

Sample taken August 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	2857	Ammonia (as N)	0.21
Total dissolved solids (obs.)	2842	Iron (Fe)	0.01
Sodium (Na) (calc.)	834	Lead (Pb)	ND(0.05)
Sodium (Na) (obs.)	841	Nitrate (as N)	0.04
Potassium (K)	19	Nitrite (as N)	ND(0.01)
Calcium (Ca)	112	Selenium (Se)	ND(0.01)
Magnesium (Mg)	40	Zinc (Zn)	ND(0.01)
Chloride (Cl)	394	Uranium (U_3O_8)	2.70
Sulfate (SO_4)	1122	Conductivity, micromhos @ 68°F.	3850
Carbonate (CO_3)	0	Total alkalinity as $CaCO_3$	560
Bicarbonate (HCO_3)	683	Total hardness as $CaCO_3$	444
pH, units	7.8		

Radium-226, pCi/l ---------- 182.6±4.4

ND = Not detected at level given in parentheses. Radiochemical tests by Core Laboratories, Albuquerque, New Mexico.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OCT 04 1979

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date August 16, 1979

Other Pertinent Data

Analyzed by KCM, JM, SS, LG, DD, GH Date October 3, 1979 Lab No. 31800-4

WATER ANALYSIS

Bison Basin, Fremont Co., Wyoming
303-6-P31
Sample taken August 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	3245	Ammonia (as N)	0.19
Total dissolved solids (obs.)	3282	Iron (Fe)	0.01
Sodium (Na) (calc.)	1026	Lead (Pb)	ND(0.05)
Sodium (Na) (obs.)	1146	Nitrate (as N)	0.10
Potassium (K)	20	Nitrite (as N)	0.04
Calcium (Ca)	112	Selenium (Se)	ND(0.01)
Magnesium (Mg)	21	Zinc (Zn)	ND(0.01)
Chloride (Cl)	590	Uranium (U_3O_8)	1.45
Sulfate (SO_4)	1067	Conductivity, micromhos @ 68°F.	4350
Carbonate (CO_3)	0	Total alkalinity as $CaCO_3$	681
Bicarbonate (HCO_3)	830	Total hardness as $CaCO_3$	366
pH, units	7.6		

Radium-226, pCi/l ---------- 834.4±9.1

ND = Not detected at level given in parentheses. Radiochemical tests by Core Laboratories, Albuquerque, New Mexico.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OPI-WESTERN JOINT VENTURE
OCT 04 1979

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date September 6, 1979

Other Pertinent Data

Analyzed by LG, LB, SS, JM Date Sept. 17, 1979 Lab No. 31971-1

WATER ANALYSIS

303-6-P7
Sample taken September 5, 1979

	mg/l		mg/l
Total dissolved solids (calculated)	1356	Ammonia (as N)	0.62
Total dissolved solids (observed)	1372	Iron (Fe)	0.01
Sodium (Na) (calculated)	394	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	434	Nitrate (as N)	0.02
Potassium (K)	10	Nitrite (as N)	ND(0.01)
Calcium (Ca)	35	Selenium (Se)	ND(0.01)
Magnesium (Mg)	9	Zinc (Zn)	0.06
Chloride (Cl)	26	Uranium (U_3O_8)	0.003
Sulfate (SO_4)	816	Conductivity, micromhos at 68° F.	1725
Carbonate (CO_3)	36	Total alkalinity as $CaCO_3$	110
Bicarbonate (HCO_3)	61	Total hardness as $CaCO_3$	125
		pH, units	9.2

Radium-226, pCi/l ---------- 2.03±0.32

Radiochemical tests by Ecology Audits, Inc., Casper, Wyoming.

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO, and AEC methods.

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OCT 30 1979

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date September 6, 1979

Other Pertinent Data

Analyzed by LG, LB, SS, JM Date Sept. 17, 1979 Lab No. 31971-2

WATER ANALYSIS

303-6-P16
Sample taken September 5, 1979

	mg/l		mg/l
Total dissolved solids (calculated)	1296	Ammonia (as N)	0.44
Total dissolved solids (observed)	1350	Iron (Fe)	0.01
Sodium (Na) (calculated)	387	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	417	Nitrate (as N)	0.02
Potassium (K)	9	Nitrite (as N)	ND(0.01)
Calcium (Ca)	38	Selenium (Se)	ND(0.01)
Magnesium (Mg)	1	Zinc (Zn)	ND(0.01)
Chloride (Cl)	30	Uranium (U_3O_8)	0.003
Sulfate (SO_4)	759	Conductivity, micromhos at 68° F.	1725
Carbonate (CO_3)	12	Total alkalinity as $CaCO_3$	120
Bicarbonate (HCO_3)	122	Total hardness as $CaCO_3$	99
		pH, units	8.5

Radium-226, pCi/l ---- 7.17±0.55

Radiochemical tests by Ecology Audits, Inc., Casper, Wyoming.

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO, and AEC methods.

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OCT 30 1979

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Casper, Wyoming

ANALYTICAL REPORT

From: OPI - Western Joint Venture　Product: Water

Address: Casper, Wyoming　Date: September 6, 1979

Other Pertinent Data

Analyzed by: LG, LB, SS, JM　Date: Sept. 17, 1979　Lab No. 31971-3

WATER ANALYSIS

303-6-P19
Sample taken September 5, 1979

	mg/l		mg/l
Total dissolved solids (calculated)	1334	Ammonia (as N)	0.44
Total dissolved solids (observed)	1418	Iron (Fe)	0.01
Sodium (Na) (calculated)	407	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	434	Nitrate (as N)	0.04
Potassium (K)	10	Nitrite (as N)	ND(0.01)
Calcium (Ca)	26	Selenium (Se)	ND(0.01)
Magnesium (Mg)	5	Zinc (Zn)	ND(0.01)
Chloride (Cl)	28	Uranium (U_3O_8)	0.008
Sulfate (SO_4)	774	Conductivity, micromhos at 68° F.	1800
Carbonate (CO_3)	24	Total alkalinity as $CaCO_3$	140
Bicarbonate (HCO_3)	122	Total hardness as $CaCO_3$	86
		pH, units	8.6

Radium-226, pCi/l ---------- 9.98±0.66

Radiochemical tests by Ecology Audits, Inc., Casper, Wyoming.

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO, and AEC methods.

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OCT 30 1979

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Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date September 6, 1979

Other Pertinent Data

Analyzed by LG, LB, SS, JM Date Sept. 17, 1979 Lab No. 31971-4

WATER ANALYSIS

303-6-P22
Sample taken September 5, 1979

	mg/l		mg/l
Total dissolved solids (calculated)	1148	Ammonia (as N)	0.41
Total dissolved solids (observed)	1192	Iron (Fe)	0.01
Sodium (Na) (calculated)	346	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	379	Nitrate (as N)	0.03
Potassium (K)	9	Nitrite (as N)	ND(0.01)
Calcium (Ca)	47	Selenium (Se)	ND(0.01)
Magnesium (Mg)	2	Zinc (Zn)	0.01
Chloride (Cl)	68	Uranium (U_3O_8)	0.105
Sulfate (SO_4)	532	Conductivity, micromhos at 68° F.	1725
Carbonate (CO_3)	0	Total alkalinity as $CaCO_3$	241
Bicarbonate (HCO_3)	293	Total hardness as $CaCO_3$	126
		pH, units	7.9

Radium-226, pCi/l ---------- 1.94±0.28

Radiochemical tests by Ecology Audits, Inc., Casper, Wyoming.

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO, and AEC methods.

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OCT 30 1979

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ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date September 6, 1979

Other Pertinent Data

Analyzed by LG, LB, SS, JM Date Sept. 17, 1979 Lab No. 31971-5

WATER ANALYSIS

303-6-P31
Sample taken September 5, 1979

	mg/l		mg/l
Total dissolved solids (calculated)	72	Ammonia (as N)	ND(0.01)
Total dissolved solids (observed)	85	Iron (Fe)	0.01
Sodium (Na) (calculated)	27	Lead (Pb)	ND(0.05)
Sodium (Na) (observed)	23	Nitrate (as N)	0.04
Potassium (K)	1	Nitrite (as N)	ND(0.01)
Calcium (Ca)	2	Selenium (Se)	ND(0.01)
Magnesium (Mg)	0	Zinc (Zn)	0.01
Chloride (Cl)	24	Uranium (U_3O_8)	0.011
Sulfate (SO_4)	0	Conductivity, micromhos at 68° F.	115
Carbonate (CO_3)	0	Total alkalinity as $CaCO_3$	31
Bicarbonate (HCO_3)	37	Total hardness as $CaCO_3$	5
		pH, units	7.0

Radium-226, pCi/l ---------- 5.05±0.53

Radiochemical tests by Ecology Audits, Inc., Casper, Wyoming.

ND = Not detected at level given in parentheses.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WHO, and AEC methods.

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OCT 30 1979

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Casper, Wyoming

ANALYTICAL REPORT

From	OPI-Western Joint Venture	Product	Water
Address	Casper, Wyoming	Date	October 5, 1979
Other Pertinent Data			
Analyzed by	MD, LG, GH, DD	Date	October 30, 1979 Lab No. 32270-1

WATER ANALYSIS

Wyoming
303-6-P-7

Sample received October 5, 1979

	mg/l		mg/l
Total dissolved solids {calc.}	1383	Boron {B}	ND{1.0}
Total dissolved solids {obs.}	1458	Barium {Ba}	ND{0.05}
Conductivity, micromhos at 68° F.	1725	Cadmium {Cd}	ND{0.002}
Total alkalinity as $CaCO_3$	120	Chromium {Cr}	ND{0.01}
Total hardness as $CaCO_3$	101	Copper {Cu}	ND{0.01}
Sodium {Na} {calc.}	414	Fluoride {F}	0.91
Sodium {Na} {obs.}	436	Iron {Fe} {Total}	0.01
Potassium {K}	8	Lead {Pb}	ND{0.05}
Calcium {Ca}	37	Manganese {Mn}	ND{0.01}
Magnesium {Mg}	2	Mercury {Hg}	ND{0.001}
Chloride {Cl}	30	Nickel {Ni}	ND{0.04}
Sulfate {SO_4}	826	Nitrate {as N}	0.01
Carbonate {CO_3}	24	Nitrite {as N}	0.02
Bicarbonate {HCO_3}	85	Selenium {Se}	ND{0.01}
pH, units	8.6	Zinc {Zn}	0.07
Aluminum {Al}	ND{0.05}	Molybdenum {Mo}	ND{0.05}
Ammonia {N}	ND{0.10}	Vanadium {V_2O_5}	ND{0.05}
Arsenic {As}	ND{0.01}	Uranium {U_3O_8}	ND{0.001}

Radium-226, pCi/l	2.70±1.24
Thorium-230, pCi/l	12.0±5.31

ND = Not detected at level given in parentheses. Radiochemical by EAI, Casper, Wyoming.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture — Product: Water

Address: Casper, Wyoming — Date: October 5, 1979

Other Pertinent Data

Analyzed by: MD, LG, GH, DD — Date: October 30, 1979 — Lab No. 32270-2

WATER ANALYSIS

Wyoming
303-6-P-16
Sample received October 5, 1979

	mg/1		mg/1
Total dissolved solids {calc.}	1355	Boron {B}	ND{1.0}
Total dissolved solids {obs.}	1442	Barium {Ba}	ND{0.05}
Conductivity, micromhos at 68° F.	1615	Cadmium {Cd}	ND{0.002}
Total alkalinity as $CaCO_3$	120	Chromium {Cr}	ND{0.01}
Total hardness as $CaCO_3$	100	Copper {Cu}	ND{0.01}
Sodium {Na} {calc.}	408	Fluoride {F}	1.03
Sodium {Na} {obs.}	433	Iron {Fe} {Total}	0.01
Potassium {K}	7	Lead {Pb}	ND{0.05}
Calcium {Ca}	30	Manganese {Mn}	ND{0.01}
Magnesium {Mg}	6	Mercury {Hg}	ND{0.001}
Chloride {Cl}	28	Nickel {Ni}	ND{0.04}
Sulfate {SO_4}	804	Nitrate {as N}	ND{0.01}
Carbonate {CO_3}	0	Nitrite {as N}	0.02
Bicarbonate {HCO_3}	146	Selenium {Se}	ND{0.01}
pH, units	8.6	Zinc {Zn}	ND{0.01}
Aluminum {Al}	ND{0.05}	Molybdenum {Mo}	ND{0.05}
Ammonia {N}	ND{0.10}	Vanadium {V_2O_5}	ND{0.05}
Arsenic {As}	ND{0.01}	Uranium {U_3O_8}	ND{0.001}

Radium-226, pCi/l ---------- 6.92±0.93
Thorium-230, pCi/l ---------- 14.14±5.3

ND = Not detected at level given in parentheses. Radiochemical by EAI, Casper, Wyoming.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO and AEC methods.

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JAN 14 1980

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Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture Product Water

Address Casper, Wyoming Date October 5, 1979

Other Pertinent Data

Analyzed by MD, LG, GH, DD Date October 30, 1979 Lab No. 32270-3

WATER ANALYSIS

Wyoming
303-6-P-19
Sample received October 5, 1979

	mg/1		mg/1
Total dissolved solids {calc.}	1632	Boron {B}	ND{1.0}
Total dissolved solids {obs.}	1560	Barium {Ba}	ND{0.05}
Conductivity, micromhos at 68° F.	1900	Cadmium {Cd}	ND{0.002}
Total alkalinity as $CaCO_3$	101	Chromium {Cr}	ND{0.01}
Total hardness as $CaCO_3$	113	Copper {Cu}	ND{0.01}
Sodium {Na} {calc.}	488	Fluoride {F}	0.70
Sodium {Na} {obs.}	500	Iron {Fe} {Total}	0.01
Potassium {K}	9	Lead {Pb}	ND{0.05}
Calcium {Ca}	32	Manganese {Mn}	ND{0.01}
Magnesium {Mg}	8	Mercury {Hg}	ND{0.001}
Chloride {Cl}	22	Nickel {Ni}	ND{0.04}
Sulfate {SO_4}	1013	Nitrate {as N}	0.03
Carbonate {CO_3}	12	Nitrite {as N}	ND{0.01}
Bicarbonate {HCO_3}	98	Selenium {Se}	ND{0.01}
pH, units	8.8	Zinc {Zn}	ND{0.01}
Aluminum {Al}	ND{0.05}	Molybdenum {Mo}	ND{0.05}
Ammonia {N}	ND{0.10}	Vanadium {V_2O_5}	ND{0.05}
Arsenic {As}	ND{0.01}	Uranium {U_3O_8}	ND{0.001}

Radium-226, pCi/l	15.6±1.7
Thorium-230, pCi/l	2.21±2.85

ND = Not detected at level given in parentheses. Radiochemical by EAI, Casper, Wyoming.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From: OPI-Western Joint Venture   Product: Water

Address: Casper, Wyoming   Date: October 5, 1979

Other Pertinent Data

Analyzed by: MD, LG, GH, DD   Date: October 30, 1979   Lab No. 32270-4

WATER ANALYSIS

Wyoming

303-6-P-22

Sample received October 5, 1979

	mg/1		mg/1
Total dissolved solids (calc.)	1527	Boron (B)	ND(1.0)
Total dissolved solids (obs.)	1476	Barium (Ba)	ND(0.05)
Conductivity, micromhos at 68° F.	1775	Cadmium (Cd)	ND(0.002)
Total alkalinity as $CaCO_3$	131	Chromium (Cr)	ND(0.01)
Total hardness as $CaCO_3$	152	Copper (Cu)	ND(0.01)
Sodium (Na) (calc.)	442	Fluoride (F)	0.87
Sodium (Na) (obs.)	471	Iron (Fe) (Total)	0.01
Potassium (K)	8	Lead (Pb)	ND(0.05)
Calcium (Ca)	46	Manganese (Mn)	ND(0.01)
Magnesium (Mg)	9	Mercury (Hg)	ND(0.001)
Chloride (Cl)	30	Nickel (Ni)	ND(0.04)
Sulfate (SO_4)	914	Nitrate (as N)	0.03
Carbonate (CO_3)	0	Nitrite (as N)	ND(0.01)
Bicarbonate (HCO_3)	159	Selenium (Se)	ND(0.01)
pH, units	8.2	Zinc (Zn)	ND(0.01)
Aluminum (Al)	ND(0.05)	Molybdenum (Mo)	ND(0.05)
Ammonia (N)	ND(0.10)	Vanadium (V_2O_5)	ND(0.05)
Arsenic (As)	ND(0.01)	Uranium (U_3O_8)	0.145

Radium-226, pCi/l	5.3±0.83
Thorium-230, pCi/l	25.5±7.9

ND = Not detected at level given in parentheses. Radiochemical by EAI, Casper, Wyoming.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO and AEC methods.

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JAN 14 1980

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI-Western Joint Venture   Product Water

Address Casper, Wyoming   Date October 5, 1979

Other Pertinent Data

Analyzed by MD, LG, GH, DD   Date October 30, 1979   Lab No. 32270-5

WATER ANALYSIS

Wyoming
303-6-P-31

Sample received October 5, 1979

	mg/l		mg/l
Total dissolved solids (calc.)	780	Boron (B)	ND(1.0)
Total dissolved solids (obs.)	822	Barium (Ba)	ND(0.05)
Conductivity, micromhos at 68° F.	1115	Cadmium (Cd)	ND(0.002)
Total alkalinity as $CaCO_3$	170	Chromium (Cr)	ND(0.01)
Total hardness as $CaCO_3$	380	Copper (Cu)	ND(0.01)
Sodium (Na) (calc.)	143	Fluoride (F)	0.63
Sodium (Na) (obs.)	152	Iron (Fe) (Total)	0.24
Potassium (K)	3	Lead (Pb)	ND(0.05)
Calcium (Ca)	107	Manganese (Mn)	0.15
Magnesium (Mg)	10	Mercury (Hg)	ND(0.001)
Chloride (Cl)	56	Nickel (Ni)	ND(0.04)
Sulfate (SO_4)	359	Nitrate (as N)	0.03
Carbonate (CO_3)	0	Nitrite (as N)	ND(0.01)
Bicarbonate (HCO_3)	207	Selenium (Se)	ND(0.01)
pH, units	7.6	Zinc (Zn)	0.03
Aluminum (Al)	ND(0.05)	Molybdenum (Mo)	ND(0.05)
Ammonia (N)	ND(0.10)	Vanadium (V_2O_5)	ND(0.05)
Arsenic (As)	0.056	Uranium (U_3O_8)	0.500

Radium-226, pCi/l	364±4
Thorium-230, pCi/l	2.26±2.3

ND = Not detected at level given in parentheses. Radiochemical by EAI, Casper, Wyoming.

Above tests were made in accordance with Standard Methods, 14th. Edition, 1975, ASTM, WQO and AEC methods.

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JAN 14 1980

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date November 12, 1979

Other Pertinent Data

Analyzed by JB, JM, PT, BW Date Dec. 19, 1979 Lab No. 32623-1

WATER ANALYSIS

Bison Basin, Wyoming
303 6-P-7
Sample taken November 5, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1446	Copper (Cu)	*
Total dissolved solids (obs.)	1350	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1725	Iron (Fe)(total)	0.26
Total alkalinity as $CaCO_3$	90	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	98	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	424	Manganese (Mn)	*
Sodium (Na) (obs.)	459	Mercury (Hg)	*
Potassium (K)	7	Molybdenum (Mo)	*
Calcium (Ca)	26	Nickel (Ni)	*
Magnesium (Mg)	8	Nitrate (as N)	0.03
Sulfate (SO_4)	890	Nitrite (as N)	ND(0.01)
Chloride (Cl)	30	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	110	Selenium (Se)	ND(0.01)
pH, units	7.9	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	ND(0.1)	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.07
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.056
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	5.24±0.55
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by Ecology Audits, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date November 12, 1979

Other Pertinent Data

Analyzed by JE, JM, PT, BW Date Dec. 19, 1979 Lab No. 32623-2

WATER ANALYSIS

Bison Basin, Wyoming
303 -P-16
Sample taken November 5, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1354	Copper (Cu)	*
Total dissolved solids (obs.)	1310	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1925	Iron (Fe)(total)	0.07
Total alkalinity as $CaCO_3$	95	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	118	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	403	Manganese (Mn)	*
Sodium (Na) (obs.)	434	Mercury (Hg)	*
Potassium (K)	6	Molybdenum (Mo)	*
Calcium (Ca)	34	Nickel (Ni)	*
Magnesium (Mg)	8	Nitrate (as N)	0.02
Sulfate (SO_4)	817	Nitrite (as N)	ND(0.01)
Chloride (Cl)	32	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	115	Selenium (Se)	ND(0.01)
pH, units	8.0	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	ND(0.1)	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.002
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	5.68±0.59
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by Ecology Audits, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OPI WESTERN JOINT VENTURE
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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture — Product Water

Address Casper, Wyoming — Date November 12, 1979

Other Pertinent Data

Analyzed by JM, JB, PT, BW — Date Dec. 19, 1979 Lab No. 32623-3

WATER ANALYSIS

Bison Basin, Wyoming
303 6-P-19
Sample taken November 5, 1979

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1694	Copper (Cu)	*
Total dissolved solids (obs.)	1640	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1825	Iron (Fe)(total)	0.08
Total alkalinity as $CaCO_3$	77	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	127	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	488	Manganese (Mn)	*
Sodium (Na) (obs.)	508	Mercury (Hg)	*
Potassium (K)	10	Molybdenum (Mo)	*
Calcium (Ca)	34	Nickel (Ni)	*
Magnesium (Mg)	12	Nitrate (as N)	0.01
Sulfate (SO_4)	1075	Nitrite (as N)	ND(0.[illegible])
Chloride (Cl)	24	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	93	Selenium (Se)	ND(0.01)
pH, units	8.0	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	ND(0.1)	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.02
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.006
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	14.1±0.83
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by Ecology Audits, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From	OPI Western Joint Venture	Product	Water
Address	Casper, Wyoming	Date	November 12, 1979
Other Pertinent Data			
Analyzed by	JM, JB, PT, BW	Date	Dec. 19, 1979 Lab No. 32623-4

WATER ANALYSIS

Bison Basin, Wyoming
303 6-P-22
Sample taken November 5, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1606	Copper (Cu)	*
Total dissolved solids (obs.)	1530	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1775	Iron (Fe)(total)	0.05
Total alkalinity as $CaCO_3$	134	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	168	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	460	Manganese (Mn)	*
Sodium (Na) (obs.)	508	Mercury (Hg)	*
Potassium (K)	8	Molybdenum (Mo)	*
Calcium (Ca)	47	Nickel (Ni)	*
Magnesium (Mg)	12	Nitrate (as N)	0.03
Sulfate (SO_4)	944	Nitrite (as N)	ND(0.01)
Chloride (Cl)	52	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	163	Selenium (Se)	ND(0.01)
pH, units	7.9	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	ND(0.1)	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.115
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	11.8±0.86
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by Ecology Audits, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date November 12, 1979

Other Pertinent Data

Analyzed by JM, JB, PT, BW Date Dec. 19, 1979 Lab No. 32623-5

WATER ANALYSIS

Bison Basin, Wyoming
303 6-P-31
Sample taken November 5, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1307	Copper (Cu)	*
Total dissolved solids (obs.)	1340	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1700	Iron (Fe)(total)	1.30
Total alkalinity as $CaCO_3$	199	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	550	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	217	Manganese (Mn)	*
Sodium (Na) (obs.)	238	Mercury (Hg)	*
Potassium (K)	3	Molybdenum (Mo)	*
Calcium (Ca)	195	Nickel (Ni)	*
Magnesium (Mg)	15	Nitrate (as N)	0.02
Sulfate (SO_4)	675	Nitrite (as N)	ND(0.01)
Chloride (Cl)	84	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	242	Selenium (Se)	ND(0.01)
pH, units	7.4	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	ND(0.1)	Sulfide (S)	*
Arsenic (As)	0.02	Zinc (Zn)	0.08
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.590
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	456±21
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by Ecology Audits, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date 12-13-79

Other Pertinent Data

Analyzed by PT, JB, JM, BW Date 1-18-80 Lab No. 32875-1

WATER ANALYSIS

303-6-P-16
Sample taken December 7, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1340	Copper (Cu)	*
Total dissolved solids (obs.)	1402	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1800	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	106	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	143	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	384	Manganese (Mn)	*
Sodium (Na) (obs.)	389	Mercury (Hg)	*
Potassium (K)	6	Molybdenum (Mo)	*
Calcium (Ca)	44	Nickel (Ni)	*
Magnesium (Mg)	8	Nitrate (as N)	0.04
Sulfate (SO_4)	800	Nitrite (as N)	ND(0.01)
Chloride (Cl)	34	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	129	Selenium (Se)	ND(0.01)
pH, units	8.2	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.18	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	ND(0.001)
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	8.6±0.7
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by EAI, Casper, Wyoming.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture   Product Water

Address Casper, Wyoming   Date 12-13-79

Other Pertinent Data

Analyzed by PT, JB, JM, BW   Date 1-18-80   Lab No. 32875-2

WATER ANALYSIS

303-6-P-19
Sample taken December 7, 1979

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1822	Copper (Cu)	*
Total dissolved solids (obs.)	1836	Fluoride (F)	*
Conductivity @ 68°F., micromhos	2075	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	94	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	185	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	517	Manganese (Mn)	*
Sodium (Na) (obs.)	485	Mercury (Hg)	*
Potassium (K)	9	Molybdenum (Mo)	*
Calcium (Ca)	56	Nickel (Ni)	*
Magnesium (Mg)	11	Nitrate (as N)	0.02
Sulfate (SO_4)	1150	Nitrite (as N)	ND(0.01)
Chloride (Cl)	22	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	114	Selenium (Se)	ND(0.01)
pH, units	8.4	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.30	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.002
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/1	6.6±1.8
Gross Alpha, pCi/1	*
Gross Beta, pCi/1	*
Thorium-230, pCi/1	*
Lead-210, pCi/1	*
Polonium-210, pCi/1	*

ND = Not detected at level given in parentheses. Radiochemical tests by EAI, Casper, Wyoming.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From	OPI - Western Joint Venture	Product	Water
Address	Casper, Wyoming	Date	12-13-79
Other Pertinent Data			
Analyzed by	PT, JB, JM, BW	Date	1-18-80 Lab No. 32875-3

WATER ANALYSIS

303-6-P-22
Sample taken December 7, 1979

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1358	Copper (Cu)	*
Total dissolved solids (obs.)	1422	Fluoride (F)	*
Conductivity @ 68°F., micromhos	2250	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	122	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	216	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	361	Manganese (Mn)	*
Sodium (Na) (obs.)	406	Mercury (Hg)	*
Potassium (K)	8	Molybdenum (Mo)	*
Calcium (Ca)	65	Nickel (Ni)	*
Magnesium (Mg)	13	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	790	Nitrite (as N)	ND(0.01)
Chloride (Cl)	48	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	149	Selenium (Se)	ND(0.01)
pH, units	6.0	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.29	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.105
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	7.6±0.6
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by EAI, Casper, Wyoming.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture   Product Water

Address Casper, Wyoming   Date 12-13-79

Other Pertinent Data

Analyzed by PT, JB, JM, BW   Date 1-18-80   Lab No. 32875-4

WATER ANALYSIS

303-6-P-31

Sample taken December 7, 1979

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1361	Copper (Cu)	*
Total dissolved solids (obs.)	1420	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1850	Iron (Fe)(total)	1.38
Total alkalinity as $CaCO_3$	220	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	765	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	172	Manganese (Mn)	*
Sodium (Na) (obs.)	234	Mercury (Hg)	*
Potassium (K)	3	Molybdenum (Mo)	*
Calcium (Ca)	250	Nickel (Ni)	*
Magnesium (Mg)	16	Nitrate (as N)	0.02
Sulfate (SO_4)	710	Nitrite (as N)	ND(0.01)
Chloride (Cl)	78	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	268	Selenium (Se)	ND(0.01)
pH, units	7/1	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.53	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.755
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	1121±7.0
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by EAI, Casper, Wyo.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture   Product Water

Address Casper, Wyoming   Date 1-16-80

Other Pertinent Data

Analyzed by JM, PT, JB, CM   Date   Lab No. 33131-1

WATER ANALYSIS

Bison Basin

303-6-P-16

Sample taken January 8, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1297	Copper (Cu)	*
Total dissolved solids (obs.)	1386	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1850	Iron (Fe)(total)	0.10
Total alkalinity as $CaCO_3$	98	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	137	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	371	Manganese (Mn)	*
Sodium (Na) (obs.)	413	Mercury (Hg)	*
Potassium (K)	6	Molybdenum (Mo)	*
Calcium (Ca)	40	Nickel (Ni)	*
Magnesium (Mg)	9	Nitrate (as N)	0.02
Sulfate (SO_4)	790	Nitrite (as N)	ND(0.01)
Chloride (Cl)	22	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	120	Selenium (Se)	ND(0.01)
pH, units	7.5	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.25	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.005
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	5.0 ± 0.4
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI; Environmental, Services, Casper, Wy.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CORRECTED PRELIMS. FEBRUARY 11, 1980.

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OPI-WESTERN JOINT VENTURE

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

ANALYTICAL REPORT

From: OPI - Western Joint Venture
Product: Water
Address: Casper, Wyoming
Date: 1-16-80
Other Pertinent Data

Analyzed by: JM, PT, JB, CM
Date
Lab No. 33131-2

WATER ANALYSIS

Bison Basin
303-6-P-19
Sample taken January 8, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1730	Copper (Cu)	*
Total dissolved solids (obs.)	1784	Fluoride (F)	*
Conductivity @ 68°F., micromhos	2275	Iron (Fe)(total)	0.06
Total alkalinity as $CaCO_3$	76	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	192	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	483	Manganese (Mn)	*
Sodium (Na) (obs.)	498	Mercury (Hg)	*
Potassium (K)	9	Molybdenum (Mo)	*
Calcium (Ca)	54	Nickel (Ni)	*
Magnesium (Mg)	14	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	1100	Nitrite (as N)	ND(0.01)
Chloride (Cl)	24	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	93	Selenium (Se)	ND(0.01)
pH, units	7.8	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.22	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.003
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	24.4±0.9
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI, Environmental Services, Casper, Wy.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CORRECTED PRELIMS. FEBRUARY 11, 1980.
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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water

Address Casper, Wyoming Date 1-16-80

Other Pertinent Data

Analyzed by JM, PT, JB, CM Date Lab No. 33131-3

WATER ANALYSIS

Bison Basin
303-6-P-22
Sample taken January 8, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1638	Copper (Cu)	*
Total dissolved solids (obs.)	1730	Fluoride (F)	*
Conductivity @ 68°F., micromhos	2150	Iron (Fe)(total)	0.05
Total alkalinity as $CaCO_3$	90	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	200	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	454	Manganese (Mn)	*
Sodium (Na) (obs.)	461	Mercury (Hg)	*
Potassium (K)	7	Molybdenum (Mo)	*
Calcium (Ca)	57	Nickel (Ni)	*
Magnesium (Mg)	14	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	1020	Nitrite (as N)	ND(0.01)
Chloride (Cl)	32	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	110	Selenium (Se)	ND(0.01)
pH, units	8.0	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.28	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.031
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	5.9±0.4
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at lev given in parentheses. Radiochemical tests by CLI; Environmental Services, Casper, Wy.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI - Western Joint Venture Product Water
Address Casper, Wyoming Date 1-16-80
Other Pertinent Data

Analyzed by JM, PT, JB, CM Date Lab No. 33131-4

WATER ANALYSIS

Bison Basin
303-6-P-31
Sample taken January 8, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1489	Copper (Cu)	*
Total dissolved solids (obs.)	1402	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1675	Iron (Fe)(total)	0.38
Total alkalinity as $CaCO_3$	198	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	356	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	355	Manganese (Mn)	*
Sodium (Na) (obs.)	340	Mercury (Hg)	*
Potassium (K)	3	Molybdenum (Mo)	*
Calcium (Ca)	118	Nickel (Ni)	*
Magnesium (Mg)	15	Nitrate (as N)	0.04
Sulfate (SO_4)	825	Nitrite (as N)	ND(0.01)
Chloride (Cl)	54	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	242	Selenium (Se)	ND(0.01)
pH, units	7.4	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.16	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.315
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	410.1±10.3
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI; Environmental Services, Casper, Wy.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

CORRECTED PRELIMS. FEBRUARY 11, 1980.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From	OPI Western Joint Venture	Product	Water
Address	Casper, Wyoming	Date	2-11-80
Other Pertinent Data			
Analyzed by	JB, CM, JM, BW, KCM	Date	3-20-80 Lab No. 33333-1

WATER ANALYSIS

Bison Basin
303-6- P16
Sample taken February 5, 1980

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1360	Copper (Cu)	*
Total dissolved solids (obs.)	1346	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1850	Iron (Fe)(total)	*
Total alkalinity as $CaCO_3$	104	Iron (Fe)(dissolved)	0.03
Total hardness as $CaCO_3$	145	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	386	Manganese (Mn)	*
Sodium (Na) (obs.)	412	Mercury (Hg)	*
Potassium (K)	12	Molybdenum (Mo)	*
Calcium (Ca)	43	Nickel (Ni)	*
Magnesium (Mg)	9	Nitrate (as N)	0.13
Sulfate (SO_4)	814	Nitrite (as N)	ND(0.01)
Chloride (Cl)	34	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	127	Selenium (Se)	ND(0.01)
pH, units	8.0	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.24	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.011
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/1	10.2±1.7
Gross Alpha, pCi/1	*
Gross Beta, pCi/1	*
Thorium-230, pCi/1	*
Lead-210, pCi/1	*
Polonium-210, pCi/1	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI, Corpus Christi.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture — Product Water

Address Casper, Wyoming — Date 2-11-80

Other Pertinent Data

Analyzed by JB, CM, JM, BW, KCM — Date 3-20-80 — Lab No. 33333-2

WATER ANALYSIS

Bison Basin
303-6- P19
Sample taken February 5, 1980

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1710	Copper (Cu)	*
Total dissolved solids (obs.)	1678	Fluoride (F)	*
Conductivity @ 68°F., micromhos	2275	Iron (Fe)(total)	*
Total alkalinity as $CaCO_3$	80	Iron (Fe)(dissolved)	0.03
Total hardness as $CaCO_3$	177	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	481	Manganese (Mn)	*
Sodium (Na) (obs.)	481	Mercury (Hg)	*
Potassium (K)	10	Molybdenum (Mo)	*
Calcium (Ca)	53	Nickel (Ni)	*
Magnesium (Mg)	11	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	1082	Nitrite (as N)	ND(0.01)
Chloride (Cl)	22	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	98	Selenium (Se)	ND(0.01)
pH, units	8.2	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.26	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	ND(0.001)
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	14.2±2.0
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI, Corpus Christi.

* = Test not requested.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From	OPI Western Joint Venture	Product	Water
Address	Casper, Wyoming	Date	2-11-80
Other Pertinent Data			
Analyzed by	JB, CM, JM, BW, KCM	Date	3-20-80 Lab No. 33333-3

WATER ANALYSIS

Bison Basin
303-6-22
Sample taken February 5, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1581	Copper (Cu)	*
Total dissolved solids (obs.)	1508	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1725	Iron (Fe)(total)	*
Total alkalinity as $CaCO_3$	110	Iron (Fe)(dissolved)	ND(0.03)
Total hardness as $CaCO_3$	189	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	439	Manganese (Mn)	*
Sodium (Na) (obs.)	458	Mercury (Hg)	*
Potassium (K)	10	Molybdenum (Mo)	*
Calcium (Ca)	56	Nickel (Ni)	*
Magnesium (Mg)	12	Nitrate (as N)	ND(0.01)
Sulfate (SO_4)	937	Nitrite (as N)	ND(0.01)
Chloride (Cl)	56	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	134	Selenium (Se)	ND(0.01)
pH, units	7.8	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.23	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	0.12
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	21.4±2.6
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI, Corpus Christi.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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OPI WESTERN JOINT VENTURE

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P. O. Box 2794
Casper, Wyoming

ANALYTICAL REPORT

From Opi Western Joint Venture Product Water
Address Casper, Wyoming Date 2-11-80
Other Pertinent Data

Analyzed by JB, CM, JM, BW, KCM Date 3-20-80 Lab No. 33333-4

WATER ANALYSIS

Bison Basin
303-6-P31
Sample taken February 5, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	*
Total dissolved solids (calc.)	1278	Copper (Cu)	*
Total dissolved solids (obs.)	1318	Fluoride (F)	*
Conductivity @ 68°F., micromhos	1750	Iron (Fe)(total)	*
Total alkalinity as $CaCO_3$	178	Iron (Fe)(dissolved)	2.39
Total hardness as $CaCO_3$	281	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	325	Manganese (Mn)	*
Sodium (Na) (obs.)	348	Mercury (Hg)	*
Potassium (K)	9	Molybdenum (Mo)	*
Calcium (Ca)	96	Nickel (Ni)	*
Magnesium (Mg)	10	Nitrate (as N)	0.02
Sulfate (SO_4)	719	Nitrite (as N)	ND(0.01)
Chloride (Cl)	52	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	217	Selenium (Se)	ND(0.01)
pH, units	7.2	Silica (SiO_2)	*
Aluminum (Al)	*	Silver (Ag)	*
Ammonia (as N)	0.23	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.46
Boron (B)	*	Vanadium (V_2O_5)	*
Barium (Ba)	*	Uranium (U_3O_8)	2.05
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	*	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	340±11.2
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLI, Corpus Christi.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date 3-19-80

Other Pertinent Data

Analyzed by JB, CM, PH, KCM, BW, JM, JL Date Lab No. 33644-1

WATER ANALYSIS

Bison Basin, Wyoming
P-16
Sample taken March 18, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	ND(0.02)
Total dissolved solids (calc.)	1390	Copper (Cu)	ND(0.02)
Total dissolved solids (obs.)	1338	Fluoride (F)	1.09
Conductivity @ 68°F., micromhos	1925	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	104	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	139	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	401	Manganese (Mn)	ND(0.01)
Sodium (Na) (obs.)	402	Mercury (Hg)	ND(0.001)
Potassium (K)	9	Molybdenum (Mo)	ND(0.05)
Calcium (Ca)	39	Nickel (Ni)	ND(0.04)
Magnesium (Mg)	10	Nitrate (as N)	0.02
Sulfate (SO_4)	833	Nitrite (as N)	ND(0.01)
Chloride (Cl)	36	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	127	Selenium (Se)	ND(0.01)
pH, units	8.0	Silica (SiO_2)	*
Aluminum (Al)	ND(0.1)	Silver (Ag)	*
Ammonia (as N)	0.20	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	ND(0.01)
Boron (B)	ND(1.0)	Vanadium (V_2O_5)	ND(0.05)
Barium (Ba)	ND(0.05)	Uranium (U_3O_8)	0.044
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	ND(0.01)	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	
Gross Alpha, pCi/l	
Gross Beta, pCi/l	*
Thorium-230, pCi/l	*
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLIES.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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P. O. Box 2794
Casper, Wyoming

ANALYTICAL REPORT

From: OPI Western Joint Venture   Product: Water
Address: Casper, Wyoming   Date: 3-19-80
Other Pertinent Data

Analyzed by JB, CM, PH, KCM, BW, JM, JL   Date   Lab No. 33644-2

WATER ANALYSIS

Bison Basin, Wyoming
P-19
Sample taken March 18, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	ND(0.02)
Total dissolved solids (calc.)	1701	Copper (Cu)	ND(0.02)
Total dissolved solids (obs.)	1616	Fluoride (F)	0.83
Conductivity @ 68°F., micromhos	2000	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	76	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	185	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	475	Manganese (Mn)	ND(0.01)
Sodium (Na) (obs.)	486	Mercury (Hg)	ND(0.001)
Potassium (K)	11	Molybdenum (Mo)	ND(0.05)
Calcium (Ca)	51	Nickel (Ni)	ND(0.04)
Magnesium (Mg)	14	Nitrate (as N)	0.03
Sulfate (SO_4)	1082	Nitrite (as N)	ND(0.01)
Chloride (Cl)	22	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	93	Selenium (Se)	ND(0.01)
pH, units	7.9	Silica (SiO_2)	*
Aluminum (Al)	ND(0.1)	Silver (Ag)	*
Ammonia (as N)	0.22	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	ND(1.0)	Vanadium (V_2O_5)	ND(0.05)
Barium (Ba)	ND(0.05)	Uranium (U_3O_8)	0.034
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	ND(0.01)	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLIES.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date 3-19-80

Other Pertinent Data

Analyzed by JB, CM, PH, KCM, BW, JM, JL Date Lab No. 33644-3

WATER ANALYSIS

Bison Basin, Wyoming
P-22
Sample taken March 18, 1980

	mg/1		mg/1
Total suspended solids	*	Chromium (Cr)	ND(0.02)
Total dissolved solids (calc.)	1600	Copper (Cu)	ND(0.02)
Total dissolved solids (obs.)	1546	Fluoride (F)	0.95
Conductivity @ 68°F., micromhos	2125	Iron (Fe)(total)	0.03
Total alkalinity as $CaCO_3$	100	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	197	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	443	Manganese (Mn)	ND(0.01)
Sodium (Na) (obs.)	447	Mercury (Hg)	ND(0.001)
Potassium (K)	9	Molybdenum (Mo)	ND(0.05)
Calcium (Ca)	56	Nickel (Ni)	ND(0.04)
Magnesium (Mg)	14	Nitrate (as N)	0.02
Sulfate (SO_4)	982	Nitrite (as N)	ND(0.01)
Chloride (Cl)	36	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	122	Selenium (Se)	ND(0.01)
pH, units	7.7	Silica (SiO_2)	*
Aluminum (Al)	ND(0.1)	Silver (Ag)	*
Ammonia (as N)	0.21	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.01
Boron (B)	ND(1.0)	Vanadium (V_2O_5)	ND(0.05)
Barium (Ba)	ND(0.05)	Uranium (U_3O_8)	0.113
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	ND(0.01)	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/1	
Gross Alpha, pCi/1	*
Gross Beta, pCi/1	*
Thorium-230, pCi/1	
Lead-210, pCi/1	*
Polonium-210, pCi/1	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLIES.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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CLI-10

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794

Casper, Wyoming

ANALYTICAL REPORT

From OPI Western Joint Venture Product Water

Address Casper, Wyoming Date 3-19-80

Other Pertinent Data

Analyzed by JB, CM, PH, KCM, BW, JM, JL Date Lab No. 33644-4

WATER ANALYSIS

Bison Basin, Wyoming
P-31
Sample taken March 18, 1980

	mg/l		mg/l
Total suspended solids	*	Chromium (Cr)	ND(0.02)
Total dissolved solids (calc.)	1392	Copper (Cu)	ND(0.02)
Total dissolved solids (obs.)	1470	Fluoride (F)	0.83
Conductivity @ 68°F., micromhos	1825	Iron (Fe)(total)	1.37
Total alkalinity as $CaCO_3$	190	Iron (Fe)(dissolved)	*
Total hardness as $CaCO_3$	262	Lead (Pb)	ND(0.05)
Sodium (Na) (calc.)	360	Manganese (Mn)	0.13
Sodium (Na) (obs.)	363	Mercury (Hg)	ND(0.001)
Potassium (K)	7	Molybdenum (Mo)	ND(0.05)
Calcium (Ca)	85	Nickel (Ni)	ND(0.04)
Magnesium (Mg)	12	Nitrate (as N)	0.01
Sulfate (SO_4)	766	Nitrite (as N)	ND(0.01)
Chloride (Cl)	48	Phenols	*
Carbonate (CO_3)	0	Phosphorus (PO_4)	*
Bicarbonate (HCO_3)	232	Selenium (Se)	ND(0.01)
pH, units	7.3	Silica (SiO_2)	*
Aluminum (Al)	ND(0.1)	Silver (Ag)	*
Ammonia (as N)	0.18	Sulfide (S)	*
Arsenic (As)	ND(0.01)	Zinc (Zn)	0.97
Boron (B)	ND(1.0)	Vanadium (V_2O_5)	ND(0.05)
Barium (Ba)	ND(0.05)	Uranium (U_3O_8)	2.75
Beryllium (Be)	*	Eh, millivolts	*
Bromide (Br)	*	Turbidity (JTU's)	*
Cation-Anion Balance	*	Oil and grease (Freon Method)	*
Cadmium (Cd)	ND(0.01)	Chemical Oxygen Demand (COD)	*
Cyanide (CN)	*		

Radium-226, pCi/l	
Gross Alpha, pCi/l	*
Gross Beta, pCi/l	*
Thorium-230, pCi/l	
Lead-210, pCi/l	*
Polonium-210, pCi/l	*

ND = Not detected at level given in parentheses. Radiochemical tests by CLIES.

* = Test not requested.

Above tests were made in accordance with Standard Methods, 14th Edition, 1975, ASTM, WQO and AEC methods.

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APPENDIX 3

Excerpts from

Government Publications

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-256 068

Monitoring Groundwater Quality Monitoring Methodology

General Electric Co.

Prepared For
Environmental Monitoring & Support Lab.

June 1976

NTISI
PB-256
068

Quality classifications of water for irrigation usually stress certain ranges for sodium, total dissolved solids, and boron. A general guide for evaluating the quality of water used for irrigation is shown in Table 14.

Livestock Water

Poultry and farm animals can live on water of considerably lower quality than human beings. Quality criteria depend on factors such as the type of animal and its age, climate, and feeding regimen. A general guide for evaluating the quality of water used by livestock is shown in Table 15.

TABLE 15. GUIDE FOR EVALUATING THE QUALITY OF WATER USED BY LIVESTOCK (Todd, 1970)

Quality Factor	Threshold Concentration*	Limiting Concentration†
Total Dissolved Solids (TDS), mg/liter	2500	5000
Cadmium, mg/l	5	
Calcium, mg/l	500	1000
Magnesium, mg/l	250	500‡
Sodium, mg/l	1000	2000‡
Arsenic, mg/l	1	
Bicarbonate, mg/l	500	500
Chloride, mg/l	1500	3000
Fluoride, mg/l	1	6
Nitrate, mg/l	200	400
Nitrite, mg/l	None	None
Sulfate, mg/l	500	1000‡
Range of pH	6.0-8.5	5.6-9.0

*Threshold values represent concentrations at which poultry or sensitive animals might show slight effects from prolonged use of such water. Lower concentrations are of little or no concern.

†Limiting concentrations based on interim criteria, South Africa. Animals in lactation or production might show definite adverse reactions.

‡Total magnesium compounds plus sodium sulfate should not exceed 50 percent of the total dissolved solids.

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QUALITY CRITERIA FOR WATER

July 1976

U.S. ENVIRONMENTAL PROTECTION AGENCY, WASHINGTON, D.C. 20460

ALKALINITY

CRITERION

20 mg/l or more as $CaCO_3$ for freshwater aquatic life except where natural concentrations are less.

INTRODUCTION

Alkalinity is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5. It is measured by titration with standardized acid to a pH value of about 4.5 and it is expressed commonly as milligrams per liter of calcium carbonate. Alkalinity, therefore, is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality. Examples of commonly occurring materials in natural waters that increase the alkalinity are carbonates, bicarbonates, phosphates, and hydroxides.

RATIONALE

The alkalinity of water used for municipal water supplies is important because it affects the amounts of chemicals that need to be added for coagulation, softening, and control of corrosion in distribution systems. The alkalinity of water assists in the neutralization of excess acid produced when such materials as aluminum sulfate are added during chemical coagulation. Waters having sufficient alkalinity need not be supplemented with artificially added materials to increase the alkalinity. Alkalinity resulting from naturally occurring materials such as carbonate and bicarbonate is not considered a health hazard in drinking water supplies, per se, and naturally occurring maximum levels up to approximately 400 mg/l as calcium carbonate are not considered a problem to human health (National Academy of Sciences, 1974).

Alkalinity is important for fish and other aquatic life in freshwater systems because it buffers pH changes that occur naturally as a result of photosynthetic activity of the chlorophyll-bearing vegetation. Components of alkalinity such as carbonate and bicarbonate will complex some toxic heavy metals and reduce their toxicity markedly. For these reasons, the National Technical Advisory Committee (1968) recommended a minimum alkalinity of 20 mg/l and the subsequent NAS report (1974) recommended that natural alkalinity not be reduced by more than 25 percent but did not place an absolute minimal value for

WATER QUALITY CRITERIA

Second Edition

by

McKEE *and* WOLF

THE RESOURCES AGENCY OF CALIFORNIA
STATE WATER QUALITY CONTROL BOARD
SACRAMENTO, CALIFORNIA

Publication No. 3-A

Sewage (469) as "the nitrogen equivalent of ammonia formed or liberated from nitrogenous matter by the action of alkaline permanganate in water after expulsion of ammonia nitrogen by distillation." Its significance is difficult to determine or to define, for it merely represents a portion of the organic nitrogen that is readily released by a chemical reaction. Formerly determined and reported in most analyses of polluted waters, albuminoid ammonia (or albuminoid nitrogen if the results are reported as N rather than NH_3) is seldom used in modern analytical work in the U. S., and consequently most of the references thereto are in out-dated or foreign publications.

ALCOHOLS, GENERAL

(see also Allyl Alcohol, Amyl Alcohol, Benzyl Alcohol, Butyl Alcohol, Ethyl Alcohol, Cetyl Alcohol, Methyl Alcohol, Octyl Alcohols, Phytosterol, Propyl Alcohol, and other specific alcohols)

Under this heading are abstracted articles covering several alcohols for comparative purposes. Most of the criteria relating to specific alcohols are listed under the designated compound.

According to Welch and Slocum (3248) the acute oral toxicity of primary alcohols toward rats is as follows: methyl, 9.1 mg/kg of body weight; ethyl, 7.4 mg/kg; propyl, 3.3 mg/kg; butyl, 2.75 mg/kg; amyl, 3.3 mg/kg; hexyl, 4.1 mg/kg; and heptyl, 6.6 mg/kg.

Toxicity tests with creek chub, a fish considered to be average in tolerance, at 15 to 21° C in well-aerated water, revealed the "critical ranges" shown in the following table. Critical range is defined as the range in concentration below which all four test fish lived for 24 hours and above which all died (1442).

Alcohol	*Critical Range in mg/l*
n-propyl alcohol	350–500
n-amyl alcohol	350–500
mixed primary isoamyl alcohols	400–600
isopropyl alcohol	900–1100
n-butyl alcohol	1000–1400
tertiary amyl alcohol	1300–2000
tertiary butyl alcohol	3000–6000
ethyl alcohol	7000–9000
methyl alcohol	8000–17000

Hodgson (2956) determined the concentrations of primary alcohols required to stimulate the movement of the water beetle *(Laccophilus)*, with the following results:

Alcohol	*Critical Range in mg/l*
methyl	115,000
ethyl	198,000
n-propyl	192,000
n-butyl	3,410
n-pentyl	644
n-hexyl	112

ALCOHOL SULFATES

(see Chapter X)

ALDEHYDES

(see Acetaldehyde, Benzaldehyde, Formaldehyde, Furfural, and Vanillin)

ALDRIN

(see Chapter IX)

ALGICIDES

(see specific compound in Chapter IX)

ALIPHATIC AROMATIC SULFONATES

ALIPHATIC SULFONATES

(see Chapter X)

ALKALINITY

1. General. Like acidity, alkalinity is not a specific polluting substance, but rather a combined effect of several substances and conditions. It is a measure of the power of a solution to neutralize hydrogen ions and it is expressed in terms of an equivalent amount of calcium carbonate. Alkalinity is caused by the presence of carbonates, bicarbonates, hydroxides, and to a lesser extent by borates, silicates, phosphates, and organic substances. It is determined by titrating with 0.02N sulfuric acid to the phenolphthalein and methyl-orange end-points, the former measuring the so-called caustic alkalinity and the latter the total alkalinity. Like acidity, alkalinity is related to pH but high alkalinities should not be confused with high pH values. Thus, a relatively pure water with a pH value of 7.0 will have a low total alkalinity whereas a buffered water at pH 6.0 will have a high total alkalinity. For a more thorough discussion of alkalinity and an evaluation of the hydroxyl, carbonate, and bicarbonate components thereof, see Standard Methods For the Analysis of Water and Wastewater (469).

Some natural waters, especially those in the southwestern U. S., are highly alkaline while others, such as those in western Washington or the New England states, are low in alkalinity. The alkalinities of streams are frequently increased by the addition of municipal sewage and many industrial wastes, too numerous to list herein.

2. Cross References. Acidity, pH, Hardness, Dissolved Solids, Carbonates, Bicarbonates, Hydroxides, and other specific substances that may affect akalinity.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. In itself, alkalinity is not considered to be detrimental to humans but it is generally associated with high pH values, hardness, and excessive dissolved solids, all of which may be deleterious.

b. Industrial Water Supplies. Alkalinity is detrimental in many industrial processes, especially those involving the production of food and beverages. It is particularly frowned upon in the production of carbonated and acid-fruit beverages because it neutralizes the natural taste-producing substances and makes the beverage more susceptible to bacterial action (179). The ranges of recommended threshold values of total alkalinities in industrial water supplies are presented in Table 6-2.

In contrast, alkalinity is desirable in many industrial waters, especially if it serves to inhibit corrosion by creating a favorable calcium-carbonate balance. In oil-field work, Nelson (349) recommends that the alkalinity of unaerated water should be at least 20 mg/l.

c. Irrigation Water. Excessive alkalinity in irrigation water is detrimental in that it adds to the total salinity and is frequently accompanied by high pH values. In conventional chemical analyses of irrigation waters, however, alkalinity is frequently not listed (see Chapter V).

d. Stock and Wildlife Watering. High alkalinities in water are reported to have been detrimental to stock. When the caustic alkalinity reaches 50 mg/l, trouble with diarrhea in chickens begins (1019), and at a total alkalinity of 170 mg/l animals were reported to develop diarrhea (1020).

e. Fish and Other Aquatic Life. Doudoroff and Katz (361) cite references indicating that none of the strong alkalies, such as calcium, potassium, and sodium hydroxide, has been shown clearly to be lethal to fully developed fish in natural waters when its concentration is insufficient to raise the pH well above 9.0. Interference with normal development and other damage to fish life sometimes may occur, however, at lower pH values. When caused almost entirely by bicarbonates, alkalinity does not seem to have any harmful effect upon plankton and other aquatic life (1021).

TABLE 6-2

RANGES OF RECOMMENDED THRESHOLD VALUES OF TOTAL ALKALINITIES IN INDUSTRIAL PROCESS WATERS

Industry and Process	*Recommended Threshold Values in mg/l*	*Reference*
Brewing		
Light beer	75-80	152, 173
Dark beer	80-150	152, 173
Carbonated beverages	30-85	173
Carbonated beverages	50	152, 180
Carbonated beverages	51.3	1016
Carbonated beverages	60-100	1017
Carbonated beverages	85	185
Carbonated beverages	100	184, 188
Carbonated beverages	125	179
Carbonated beverages	128.5	186
Carbonated beverages	170	185
Food products	30-250	173
Fruit juice	100	164
Laundrying (diapers)	60	993
Pulp and paper making		
Groundwood pulp	150	244
Kraft paper, bleached	75	351
Kraft paper, unbleached	150	351
Fine papers	45-75	551, 350
Soda and sulfate pulp	75	245
Rayon manufacture	50	152
Rayon manufacture	75	550, 405
Tanning	128.2	1018
Tanning	135	152

Stiemke and Eckenfelder (270) found that the average lethal doses of various alkaline solutions toward bluegill fingerlings were as follows:

Sustance	*Alkalinity as Calcium Carbonate in mg/l*	*pH*
Sodium hydroxide	70	10.55
Ammonium hydroxide	31	9.60
Sodium carbonate	120	----
Potassium iodide and sodium hydroxide	57	----

According to Warrick et al. (599) high alkalinity is antagonistic toward the toxicity of copper sulfate to fish. The relative toxicity of 25 mg/l of copper sulfate to brown trout fry varied inversely with the alkalinity, with all fish dying in 2.5 hours when the alkalinity was only 6.0 mg/l whereas some fish survived after 12.5 hours when the alkalinity was 248 mg/l.

It is generally recognized that the best waters for the support of diversified aquatic life are those with pH values between 7 and 8, having a total alkalinity of 100 to 120 mg/l or more (3249, 3250). This alkalinity serves as a buffer to help prevent any sudden change in pH value, which might cause death to fish or other aquatic life. In Michigan, the addition of lime to Stoner Lake increased the alkalinity from 6 to 15 mg/l, improved the biological productivity, and even caused some extensive phytoplankton blooms.

ALKENYL DIMETHYL ETHYL AMMONIUM BROMIDE

ALKYL ARYL COMPOUNDS

ALKYL BENZENE SULFONATE

ALKYL DIMETHYL COMPOUNDS

ALKYL SULFATE

ALKYL SULFONATE

(See Chapter X)

ALLYL ALCOHOL $CH_2=CHCH_2OH$

A colorless liquid with a pungent mustard-like odor, allyl alcohol is miscible with water. It is used in war gases, resins, and plasticizers. It is very irritating to mucous membranes and skin (364). The oral LD_{50} is reported as 40 mg/kg of body weight for dogs (364) and 100 mg/kg for rats (3251). When fed in the drinking water of rats, retardation of weight gain began at 250 mg/l, but other effects were minor even at 1000 mg/l (3252). According to Woelke (2989), allyl alcohol is lethal toward bivalve larvae at 2.5 mg/l. Hubault (3253) reported the threshold of harmfulness of allyl alcohol toward rudd to be 10 mg/l.

ALUM

(see Aluminum Sulfate, Aluminum Ammonium Sulfate, and other aluminum compounds that are sometimes called alum)

ALUMINA

(see Aluminum Oxide)

ALUMINUM Al

1. General. One of the most abundant elements on the face of the earth, aluminum occurs in many rocks and ores but never as a pure metal in nature. Although the metal itself is insoluble, many of its salts are readily soluble. Other aluminum salts, however, are quite insoluble and consequently aluminum is not likely to occur for long in surface waters because it precipitates and settles or is absorbed as aluminum hydroxide, aluminum carbonate, etc. In streams the presence of aluminum ions may result from industrial wastes or more likely from wash water from water-treatment plants. This section of the report deals with references to aluminum ions in water, where no mention is made of the salts from which

days. A 5-percent waste solution was not toxic to fish, but a 10-percent solution was toxic. It has been suggested that the toxicity might be attributable to the high salt concentration of the lagoon water rather than to the presence of berryllium (1478).

Tarzwell and Henderson (2125, 2154) tested the toxicity of three beryllium salts toward fathead minnows and bluegills in hard and soft waters with the following 96-hour TL_m results in terms of beryllium:

	Concentration of Beryllium in mg/l			
	Fathead Minnows		Bluegills	
Compound	*Soft*	*Hard*	*Soft*	*Hard*
Beryllium chloride	0.15	15	--	--
Beryllium sulfate	0.2	11	1.3	12
Beryllium nitrate	0.15	20	--	--

These results demonstrate that beryllium is considerably more toxic in soft water than in hard water. According to Hodgson (2956) a barium nitrate concentration of 30,000 mg/l is required to evoke a stimulatory reaction in the water beetle, *Laccophilus*.

e. Swimming and Other Recreational Uses. No information is available concerning the specific effect of beryllium in swimming waters. However, Pomelee has stated that water-soluble beryllium salts can cause ulcers if they enter a break in the skin (1478).

BHC

(see Chapter IX)

BICARBONATES HCO_3

(see also Alkalinity, pH, Carbonates, Hydroxides, Chapter V-Irrigation)

The concentration of bicarbonates in natural and polluted waters is a function not only of the bicarbonates added thereto but also of the temperature, pH, and concentration of other dissolved solids. A full discussion of carbonate equilibria is beyond the scope of this report and the reader is referred to the work of Langelier (692). For this study of water-quality criteria, however, it is important to note that bicarbonates tend to reach an equilibrium with carbonates in accordance with the reactions:

$$H^+ + CO_3^{--} \rightleftharpoons HCO_3^-$$

$$\frac{[H^+][CO_3^{--}]}{[HCO_3^-]} = K$$

where K is reported (911) to be 4.4×10^{-11} at 25°C. Thus, at pH 7 the ratio of bicarbonate ions to carbonate ions will be 2270 to 1, but at pH 10 it will be only 2.27 to 1 and at pH 11, the ratio will be 1 to 4.4. The concentration of bicarbonates therefore, depends on the pH value and the concentration of carbonates.

At medium and low pH values, a second equilibrium reaction occurs, for bicarbonates tend to unite with hydrogen ions to form H_2CO_3 which, in turn, releases free CO_2, thus

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3 \rightleftharpoons CO_2 + H_2O$$

The equilibrium equation for this reaction is

$$\frac{[HCO_3^-][H^+]}{[H_2CO_3]} = K_1$$

where K_1 is reported (911) to be 3.5×10^{-7} at 18°C. Thus at pH 8 the ratio of carbonic acid to bicarbonate ions is only 0.0286, but at pH 7 it is 0.286 and at pH 6 it is 2.86.

Bicarbonates may reach water from many natural sources, including absorption of CO_2 from the air and the decomposition of organic matter, or they may be discharged by innumerable industrial processes, for bicarbonates are among the most commonly used salts.

Other than the fact that excessive bicarbonates add to the salinity and total solids content of water, and through the complex operations of the carbonate equilibria tend to form carbonates and scale at high temperatures, bicarbonates in water are seldom considered to be detrimental. Hibbard (250) recommends the following concentrations of bicarbonates:

Use	*Concentration mg/l*	*Remarks*
Domestic water supplies		
Drinking	150	desirable or permissible
Cooking	150	desirable or permissible
Washing	60	desirable or permissible
Laundering	none	desirable or permissible
Industrial water supplies		
Textile	200	undesirable or objectionable
Sugar	100	undesirable or objectionable
Pottery	200	desirable or permissible
Steam Boilers	100	undesirable or objectionable

In concentrations of 257 mg/l or less, sodium bicarbonate caused a white shell in ice manufacturing (229). For limitations in boiler feed water, see Chapter V. High bicarbonate contents are reported to affect the stability of vitamins in the manufacture of preserves and to cause swelling of skins in tanneries (2368).

In a general discussion of alkali waters in Montana, Cobleigh (1059) points out that carbonates and bicarbonates in drinking waters react with gastric acids sometimes to the benefit of the drinker. He refers to a modified list of USGS data which gives 700 mg/l as the concentration of bicarbonates unhealthful to most people. Lockhart et al. (3241) report the taste threshold in distilled water of the bicarbonate ion (added as $NaHCO_3$) to be 770 mg/l.

The 10-year weighted average analyses of Colorado River water, according to Kelley (1060), show 172 mg/l of bicarbonate. It did not appear to Kelley that the use of this water for irrigation would seriously affect the underground supply, growth of citrus trees, or condition of the soil in southern California. Harley and Lindner (1061), on the other hand, found that irrigation waters in north central Washington containing 200 mg/l and more of bicarbonates caused a marked decline in the vigor of apple and pear trees after a number of years.

Chapter V of this report includes a discussion of "residual sodium carbonate", defined as carbonates plus bicarbonates minus the sum of calcium and magnesium, all in milliequivalents per liter. Where the residual sodium carbonate is high, i.e., over 2.5 milliequivalents per liter, calcium and magnesium ions tend to be precipitated as carbonates, leaving a high ratio of sodium to calcium ions. In irrigation water, bicarbonates in themselves do not cause difficulty, but by aiding in the precipitation of calcium carbonate they adversely affect the sodium ratio.

CALCIUM Ca

1. General. Elemental calcium does not occur in nature because it oxidizes readily in air and reacts with water to release hydrogen gas. Calcium salts and calcium ions, however, are among the most commonly encountered substances in water. They may result from the leaching of soil and other natural sources or they may be contained in sewage and many types of industrial wastes.

Under this heading are grouped the references that pertain to calcium or calcium ions. Where the literature deals with calcium salts, the references are grouped under the specified salt. The effects of calcium are also to be noted under the heading of "Hardness".

2. Cross References. Hardness; Calcium salts, Chapter V, and Chapter VII (Insects).

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The human body requires approximately 0.7 to 2.0 grams of calcium per day as a food element (36, 152), an amount considerably in excess of the calcium concentration of normally consumed quantities of even hard water. According to many people, calcium deficiency is the most common nutritional lack in the U. S. (3362). It is assumed that in the adult, the calcium requirement in the diet should equal the calcium excretion, which is about 10 mg per kg per day (3362). Some investigators believe that calcium in water can be used by the body as a supplement to the calcium in the diet (1065); however, the nutritional value of calcium in water has not yet been established and is still questionable (623, 653). Concentrations up to 1800 mg/l of calcium in drinking water have been reported to be harmless (353). The calcium concentration of vegetables cooked in water of high calcium content has been found to be higher than that of vegetables cooked in low-calcium water (921, 1066, 1067).

Excessive calcium and magnesium in drinking water have been implicated as factors predisposing to the formation of concretions in the body, such as kidney or bladder stones (3365). On the other hand, there is also evidence of adverse physiological effects from an insufficiency of calcium in water. Urovsk disease, a severe type of rickets, occurs in regions where the concentration of calcium in drinking water is low (3366, 3367). Morris et al. (3368, 3369) report an inverse correlation between the calcium content of waters and cardiovascular disease, i.e., high calcium is associated with a low incidence of heart attacks, but Schroder and Duran (3370) failed to find a similar relationship in Japan. While several effects of calcium in drinking water and physiological reactions have been suspected, no definite causal relationship has been proved as yet. So far as can be determined at the present time, calcium limits are desirable for domestic supplies not because of a hazard to health, but because calcium may be disadvantageous for other household uses, such as washing, bathing, and laundering, and because it tends to cause incrustations on cooking utensils and water heaters.

Hibbard (250) has recommended the following limiting concentrations of calcium in waters for domestic use:

Drinking and cooking	30 mg/l
Washing	10 mg/l
Laundry	0 mg/l

The Spanish Royal Decree of 1920 fixed the limit of calcium in potable waters at 150 mg/l, as CaO (631, 997). Baylis (499) has recommended the following limiting calcium concentrations for the several classes of water: Class A, the ideal, 50 mg/l, Class B, minimum aim, 75 mg/l, Class C to D, permissible with restrictions, 100-150 mg/l.

The USPHS Drinking Water Standards (2036) of 1962 and the WHO European Standards (2329) of 1961 do not contain any limits for calcium; but the WHO International Standards (2328) of 1958 indicate that 75 mg/l is a permissible limit and 200 mg/l an excessive limit in drinking water.

b. Industrial Water Supplies. (see also Hardness). Calcium in the water used for preparing developer solutions for photography may cause the precipitation of calcium sulfite, resulting in spots on the films unless the precipitate is allowed to settle out of solution (242). Calcium in brewery water causes the precipitation of calcium phosphate (166). Nordell (2338) points out that high calcium can cause undesirable effects by (a) forming scale, (b) reacting with alkaline solutions to form precipitates and curds, especially in washing operations using soap, (c) interfering with the preparation of emulsions, where the calcium tends to break the emulsions, (d) interfering with the processing of other colloids, (e) causing difficulties in electroplating rinsing operations, and (f) upsetting certain fermentation processes.

On the other hand, calcium is beneficial in water as one of the factors that tend to inhibit corrosion of cast iron and steel (3363, 3364).

The following concentrations of calcium have been recommended as limits for various industrial uses:

Use	Threshold Concentration in mg/l	Reference
Brewing, light beer	100-200	152
Brewing, dark beer	200-500	152
Soda and sulfate pulping	20	245
Sugar mfg.	20	250
Textile mfg.	10	250

c. Irrigation Water. Calcium in irrigation water has been covered in detail in Chapter V. Calcium is essential for normal plant growth and for the maintenance of good tilth in the soil, and is desirable in water for irrigation (268, 278, 635, 3371, 3372).

d. Stock and Wildlife Watering. Stander (3373) has suggested an interim threshold limit of 1,000 mg/l of calcium in water used by livestock. For more details, see Hardness.

e. Fish and Other Aquatic Life. Calcium in water reduces the toxicity of many chemical compounds to fish and other aquatic fauna; for example, mature fish have been killed by 0.1 mg/l of lead in water containing only one mg/l of calcium, but have not been harmed by this amount of lead in water containing 50 mg/l of calcium. A concentration of 50 mg/l of calcium has cancelled the toxic effect upon some fish of 2 mg/l of zinc; 0.7 mg/l of lead; and 10 mg/l of lead (573). Aluminum has been found to be toxic to river crabs in water containing little calcium (575).

The data of various independent investigators indicated that calcium chloride and nitrate, when added to distilled or soft waters, could be toxic to fish at concentrations between 300 and 1000 mg/l as calcium. Other available data concerning lethality of higher concentrations of calcium salts, generally calcium chloride, in various waters indicate that fish have survived from one to three days at concentrations of 2500 to 4000 mg/l of calcium (1459).

According to a reference cited by Hart et al. (310), of the U.S. waters supporting a good mixed fish fauna, ordinarily about 5 percent have less than 15 mg/l of calcium; 50 percent have less than 28 mg/l; and 95 percent have less than 52 mg/l.

Marine fish have been shown to concentrate Ca-45 from sea water at a factor of 10 or 20 to 1 (3374, 3375). Furthermore, marine fish discriminate against strontium in favor of calcium (3374). *Daphnia* and *Cyclops* also concentrate Ca-45 from fresh water, but when transferred to non-radioactive solutions, they quickly excrete the Ca-45. See also Chapter VIII.

For a flatworm, *Polycelis nigra,* the threshold of toxicity of calcium has been reported as 2600 mg/l when calcium is present as calcium chloride; and 1200 mg/l when calcium is present as calcium nitrate (608).

The lethal threshold concentration of calcium for stickleback is reported to be 800 mg/l (353, 2941).

f. Shellfish Culture. Thinness of shells of fresh-water mussels is associated with a deficiency of calcium in the water (331).

CALCIUM CARBONATE $CaCO_3$

(see also Calcium, Carbonates)

Commonly found in nature in the form of limestone or calcite, this salt is difficultly soluble, having a solubility product of 0.87×10^{-8} at 25°C (911). Its concentration in natural or treated waters is intimately linked with the complex carbonate equilibria (see Carbonates). In addition to its natural sources, calcium carbonate in molecular or dissociated form may be contained in innumerable industrial wastes. The references described below pertain only to calcium carbonate molecules and not to the effects of calcium or carbonate ions, which are reported elsewhere.

The taste threshold of calcium carbonate has been reported as 50 to 200 mg/l (621). Water to be used in making ice should be treated if the total concentration of calcium and magnesium carbonates is more than 70 mg/l (168). Calcium carbonate in water appears to be necessary to permit complete utilization of food by aquatic animals (1068). For the effects of adding lime on the productivity of lakes, see Calcium Hydroxide.

Wallen et al. (2940) studied the effect of adding calcium carbonate to highly turbid waters containing the mosquito-fish (*Gambusia affinis*) at 19-21°C. They found that the 96-hour TL_m was greater than 56,000 mg/l of calcium carbonate. At this dosage, the turbidity was reduced from an initial value of 260 mg/l to 35 mg/l.

CALCIUM CHLORIDE $CaCl_2$

1. General. This salt of calcium is highly soluble in water. Calcium chloride is used in brewing and in manufacturing mineral waters. It is found in wastes from bromine and salt works, oil wells, and surface run-off from roads treated against dust. Calcium chloride in natural waters is invariably associated with larger quantities of other calcium and magnesium salts, which together may render the water too highly mineralized for drinking and domestic purposes, but do not alone render water hazardous to people.

2. Cross References. Dissolved Solids, Specific Conductance, Distilled Water.

3. Effects on Beneficial Uses.

a. Domestic Water Supplies. The taste threshhold of calcium chloride in drinking water is said to be 150 to 350 mg/l (621). According to Lockhart et al. (3241) the taste threshhold of calcium ion is 125 mg/l and of the chloride ion 222 mg/l; hence the chloride ion controls and $CaCl_2$ can be tasted at 347 mg/l. In order to prevent unpleasant salty tastes and disturbances of appetite, it has been recommended that water should not contain more than 500 mg/l of calcium chloride (284). On the other hand, it has also been stated that small quantities of calcium and magnesium chloride, even concentrations of 40 to 50 mg/l, are objectionable in domestic water supplies because of taste and hardness (32).

b. Industrial Uses. The following are reported maximum concentrations of calcium chloride permissible in brewing waters:

Use	*Concentration in mg/l*	*Reference*
Brewing, light and dark	200	173
Brewing	100	170
Brewing, pale ales, I	30	170
pale ales, II	35-55	170
mild ales	55-110	170
stout	110-165	170

c. Irrigation Use. In high concentrations, calcium chloride in nutrient solutions will reduce plant growth. Gauch and Wadleigh (3376, 3377) showed that an increase of one atmosphere in the total osmotic concentration as the result of adding $CaCl_2$ (about 1775 mg/l) to the nutrient solution reduced the dry weight of red kidney bean plants by 15.5 percent while 3550 mg/l caused a 26 percent reduction. On the other hand, the guayule plant was shown to be very tolerant of $CaCl_2$, making satisfactory growth in the presence of 3 atmospheres of osmotic pressure from added $CaCl_2$ (about 5390 mg/l) (3378). One atmosphere (1775 mg/l) of added $CaCl_2$ reduced the dry weight of rice straw, rice grains, and rice roots at maturity (3379). Two atmospheres of added $CaCl_2$ injured four varieties of table grapes grown in sand culture (3380). It should be recognized that the foregoing concentrations of one and two atmospheres are far higher than any likely to be found in irrigation waters.

d. Stock and Wildlife Watering. The following concentrations of calcium chloride have produced the noted effects on animals:

Concentration of $CaCl_2$ in mg/l	*Animal*	*Effect*	*Reference*
8,325	rats	decreased water consumption	2339
10,000	rats	interfered with production of normal litters	287, [illegible]
10,000-15,000	cows	moderate effect on nerves and appetite	[illegible]
10,000-25,000	rats	interfered with reproduction	287, [illegible]
15,000	rats	decreased growth rate	[illegible]
15,000-20,000	chickens	interfered with growth	287, [illegible]
20,000	rats	interfered with lactation	[illegible]
20,000-25,000	sheep	tolerated for six weeks	287, [illegible]
25,000	rats	caused death	

atomic weapons. See Chapter VIII for information on concentration factors.

Organic carbon, the carbon oxidized by dichromate or another strong oxidizing agent, is frequently determined in polluted waters and benthic deposits. As in the case of B.O.D., this test measures one significant criterion of the strength of a waste, but it is not per se a potential pollutant.

CARBONATES CO_3^{--}

1. General. The concentration of carbonates in natural and polluted waters is a function not only of the substances added thereto but also of the temperature, pH, cations, and other dissolved salts. A full discussion of carbonate equilibria is beyond the scope of this report and the reader is referred to the work of Langelier (692). For a review of the relationship between carbonates, bicarbonates, and pH, see Bicarbonates in Chapter VI. Inasmuch as many of the carbonates are quite insoluble in water, generally more so than the chlorides, nitrates, or sulfates, there is a tendency for certain carbonate salts to be removed from polluted waters by precipitation and adsorption. For these reasons, carbonates are less widely present than chlorides and sulfates in western irrigation waters (275).

2. Cross References. Alkalinity, pH, Bicarbonate, Hydroxides, Chapter V—Irrigation.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The USPHS Drinking Water Standards of 1962 (2036) place no restrictions on carbonates in natural waters, nor in chemically treated waters as was done in the 1946 standards. Hibbard (250) recommends that the concentration of carbonate ion in drinking and cooking water be kept below 20 mg/l (33.3 mg/l as alkalinity). In his discussion of alkali waters in Montana, Cobleigh (670) points out that carbonates and bicarbonates in drinking waters react with gastric juices sometimes to the consumer's benefit. He presents a modified list of USGS data that gives 350 mg/l of carbonates as the concentration unhealthful to most people. According to Lockhart (3241) the taste threshold of carbonate in distilled water, when added as sodium carbonate, is 44 mg/l.

b. Industrial Water Supplies. Excessive carbonates interfere with acid and carbonated beverages (see Alkalinity), with brewing, with ice making, and with boiler water (see Chapter V). For boiler feed water, the permissible carbonate concentration is a function of pressure in the boiler, as follows (152):

Pressures, psi	*Carbonate Concentration in mg/l*
0-150	200
150-250	100
250-400	40
Over 400	20

For brewing, carbonate concentrations should not exceed 50 to 60 mg/l (see Chapter V).

c. Fish and Other Aquatic Life. For the effects of ammonia, potassium, and sodium carbonates on fish and *Daphnia*, see the appropriate cation in this chapter. Hedgepeth (1085) claims that the presence of free carbonates may be responsible for the absence of *Diaptomus franciscanus*, a crustacean, from certain ponds near San Francisco. In general, it may be expected that carbonates, in themselves, are not detrimental to fish life but their buffering action and effect upon pH may contribute to the toxicity of high pH value.

CARBON CHLOROFORM EXTRACT

The 1962 USPHS Drinking Water Standards (2036) set a recommended limit of 0.2 mg/l on carbon chloroform extract based on analytical techniques developed at the Robert A. Taft Sanitary Engineering Center (3004, 3353, 3354, 3355, 3356). In this procedure, a sample of water varying from 100 to 75,000 gallons, depending on the source of the sample and the anticipated amount of extractable material, is filtered through 1200 to 1500 grams of granular activated carbon at a filter rate of 2 to 10 gpm per square foot. The carbon is then air-dried and extracted with chloroform. This solvent does not recover all of the adsorbed material nor are all organic substances adsorbed, but the materials recovered by this technique are representative of the taste- and odor-producing components of waste water.

CCE concentrations of Ohio River water have been reported to range from 0.1 to 0.36 mg/l, and the raw water at Nitro, West Virginia had CCE values of 0.17 to 3.05 mg/l (3357). In contrast, only 0.024 mg/l of CCE material could be recovered from the Columbia River (3102). Gasoline can cause taste and odor if the hydrocarbons are present in amounts of a few micrograms per liter (3102). Water from clean sources rarely exceeds 0.05 mg/l of CCE substances while water that exceeds 0.20 mg/l usually is of poor quality from a taste and odor standpoint (3358). Middleton and Lichtenberg (3356) report that CCE concentrations of 0.1 mg/l or less occurred in the following percentages of samples from five major rivers:

Ohio River	50 percent
Mississippi River	72 percent
Missouri River	90 percent
Colorado River	92 percent
Columbia River	96 percent

According to Derby et al. (2062) analysis of available data indicates that water supplies containing over 0.2 mg/l of CCE represent an exceptional and unwarranted exposure of the water consumer to ill-defined chemicals.

CARBON DIOXIDE CO_2

1. General. A colorless, odorless, non-combustible gas, constituting about 0.04 percent of normal air (330), carbon dioxide is highly soluble in water. At one atmosphere of partial pressure, pure water will absorb 1688 mg/l of CO_2, (911) but at 0.0004 atmospheres the dissolved CO_2 will be only about 0.7 mg/l. The source of free carbon dioxide in water is seldom that from the air phase, however, for CO_2 is a product of aerobic or anaerobic decomposition of organic matter and it is intimately bound in the complex carbonate equilibria (see Bicarbonates and Carbonates).

solution. Its disinfecting power, therefore, is not attributable to the HOI molecule or to iodide, but rather to molecular iodine or possibly to tri-iodides (1216). Extensive unpublished research on the mechanism of disinfection by iodine and the effects of iodine upon human physiology has been performed by Fair and others at Harvard University. Iodine has been used successfully for the disinfection of water in swimming pools (3504) with residual concentrations of free iodine in the range of 0.2 to 0.6 mg/l.

There is extensive literature dealing with the relationship between iodine deficiencies in water or food and the incidence of goiter, but a thorough review of it is not within the province of this survey. To overcome an iodine deficiency and to minimize goiter in the community, Rochester, New York, added iodine to its water supply from 1923 to 1933; but, owing to economic factors, the availability of a superior vehicle (salt) for the dispersing of iodine, and the adverse effect upon certain individuals sensitive to iodine, the Rochester experiment was abandoned and further mass treatment for iodine deficiency was discouraged (152, 330). The iodine content of blood appears to be independent of the iodine in domestic water supplies (3505, 3506).

It has been reported (1586) that 8 mg/l of iodine destroys all forms of water-borne pathogens, but no adverse affects were noted when personnel in the tropics used drinking water containing NaI at a rate of 12 mg of iodine per man per day for 16 weeks and 19.2 mg per day for the next 10 weeks (1587).

Ellis (313) quotes references to the effect that 28.5 mg/l of iodine killed minnows and goldfish.

With the advent of nuclear testing and the extensive use of radioisotopes in medicine and industrial research, radioiodine (I-131) has become a significant environmental factor. The maximum permissible level of I-131 in drinking water has been given as 0.03 microcurie per liter (3375, 3507, 3508). Algae and other plankton concentrate radioiodine from water by factors in excess of 100,000 within a few days after the iodine becomes available (3509). For further information on concentration factors, see Chapter VIII.

IODOACETIC ACID CH_2ICOOH

This white crystalline substance is highly soluble in water. Hiatt et al. (3350) found that 10 mg/l of iodoacetic acid produced a moderate irritant activity in marine fish.

IPC

(see Chapter IX)

IRON BACTERIA

(see Chapter VII)

IRON Fe

1. General. Metallic iron and its common alloys are of interest in this survey primarily because they are corroded by water in the presence of oxygen. The resulting products of corrosion, in which the iron is in the ionic or molecular state, may in themselves be pollutants of water. In addition to corrosion products, natural waters may be polluted by iron-bearing industrial wastes such as those from pickling operations and by the leaching of soluble iron salts from soil and rocks, e.g. acid-mine drainage and iron-bearing ground water.

Although many of the ferric and ferrous salts such as the chlorides are highly soluble in water, the ferrous ions are readily oxidized in natural surface waters to the ferric condition and form insoluble hydroxides (3510). These precipitates tend to agglomerate, flocculate, and settle or be absorbed on surfaces; hence, the concentration of iron in well-aerated waters is seldom high. In ground water, the pH and Eh may be such that high concentrations of iron remain in solution (3510, 3520).

The following material deals with references to iron or iron ions when no designation of a salt or anion has been made. For literature covering the various ferric and ferrous salts, see the cross references.

2. Cross References. Ferric Chloride, Ferric Oxide, Ferric Potassium Sulfate, Ferric Sulfate, Ferrous Carbonate, Ferrous Chloride, Ferrous Sulfate, Chapter VII-Iron Bacteria.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The 1962 Drinking Water Standards of the USPHS (2036) included a recommended limit of 0.3 mg/l for iron. The 1958 WHO International Standards (2328) contain a "permissible limit" of 0.3 mg/l and an "excessive limit" of 1.0 mg/l but prescribe no maximum allowable limit. The 1961 WHO European Standards set a recommended limit of 0.1 mg/l for iron. Some authorities (1217, 1218) maintain that drinking water should not contain more than 0.1 mg/l of iron.

The WHO and USPHS limits are based not upon physiological considerations for iron in trace amounts is essential for nutrition. Indeed, larger quantities of iron are taken for therapeutic purposes (555, 1077). The daily nutritional requirement is 1 to 2 mg, and most diets contain 7 to 35 mg per day, with an average of 16. Consequently, drinking water containing iron in unpalatable and unesthetic concentrations, say 1.0 mg/l, would have little effect on the total daily intake.

Instead of physiological reasons, therefore, the limit is based on esthetic and taste considerations. Iron and manganese tend to precipitate as hydroxides and stain laundry and porcelain fixtures. It has also been reported (1160) that ferric iron combines with the tannin in tea to produce a dark violet color.

The taste threshold of iron in water has been given (3511) as 0.1 and 0.2 mg/l of iron from ferrous sulfate and ferrous chloride respectively. It has also been reported (3300) that ferrous iron imparts a taste at 0.1 mg/l and ferric iron at 0.2 mg/l. In contrast, Lockhart et al. (3241) indicated that the taste threshold of ferric sulfate was 10 mg/l of iron. Using a statistically controlled taste panel, Cohen et al. (3301) found that the median taste threshold for ferrous sulfate in spring water occurred at 1.8 mg/l of iron, but for the most sensitive individuals it was 0.12 mg/l. Similarly, for ferrous sulfate in distilled water, the median taste threshold concentration was 3.4 mg/l of iron but the most sensitive individuals tasted 0.04 mg/l.

Iron in domestic water supplies containing organic matter may be present in chelated form and consequently will not precipitate readily (2338, 3510, 3512). Furthermore, it may occur in microbial protoplasm as described under part 3e, following.

b. Industrial Water Supplies. The ranges of recommended threshold values for iron in process and cooling waters are given in Chapter V. Most of this information has been reassembled and tabulated below:

Industrial Use	*Range of Recommended Threshold Values in mg/l*
Baking	0.2
Brewing	0.1 to 1.0
Carbonated beverages	0.1 to 0.2
Cooling water	0.5
Confectionary	0.2
Electroplating	traces
Food canning and freezing	0.2
Food equipment washing	0.2
Food processing, general	0.2
Laundering	0.2-1.0
Oil-well flooding	0.1
Photographic processes	0.1
Pulp and paper making	
Ground wood pulp	0.3
Soda pulp	0.1
Kraft pulp, bleached	0.2
Kraft pulp, unbleached	1.0
Fine paper pulp	0.1
Rayon manufacture	0.0 to 0.05
Sugar making	0.1
Tanning processes	0.1 to 2.0
Textile manufacture	0.1 to 1.0

c. Irrigation. Iron is one of the minor constituents of irrigation water, usually occurring in low concentrations. It is generally of little importance in irrigation practice (268). Chelated iron has been used to combat chlorosis in plants.

d. Stock and Wildlife Watering. Iron is an essential constituent of animal diets (553), but animals are sensitive to changes in iron concentration (945). Cows will not drink enough water if it is high in iron, and consequently, milk production is affected (549).

e. Fish and Other Aquatic Life. Most of the references dealing with this beneficial use are expressed in terms of specific iron salts (see cross references). When iron is added to water in the form of chlorides, sulfates, or nitrates, the salt dissociates but the resulting ferrous or ferric ions combine with hydroxyl ions to form precipitates. Hence, very little of the iron remains in solution; but if the dosage is sufficient and the water is not strongly buffered, the addition of a soluble iron salt may lower the pH of the water to a toxic level. Furthermore, the deposition of iron hydroxides on the gills of fish may cause an irritation and blocking of the respiratory channels. Finally, heavy precipitates of ferric hydroxide may smother fish eggs (346, 2109, 3513).

Knight (540) tested the effects of wastes from nail-making plants on trout, stickleback, and perch. These wastes contained high concentrations of chloride, hydrogen, ferric, and ferrous ions, but the pH values were not specified. Concentrations of 1000 mg/l of these mixed salts killed most fish within a few hours, but hardy stickleback were not killed until five hours exposure to 2500 mg/l. Much of the killing action was attributed to coatings of iron oxide or hydroxide precipitates on the gills. According to Southgate (346), the toxicity of iron and iron salts depends on whether the iron is present in the ferrous or ferric state and whether it is in solution or suspension. The following limiting concentrations have been noted:

Concentration of Iron, in mg/l	*Remarks*	*Reference*
0.2	Threshold concentration for lethality to three types of fish	1023
0.9	Carp will die at this concentration if pH is 5.5 or lower	306
1-2	Death of pike, tench, and trout at pH 5.0-6.7	1459, 1588
1-2	No deaths among dogfish during one week	3415
1-2	Indicative of acid pollution and other conditions unfavorable to fish	247
5	Killed dogfish in 3 hours	3514
10	Caused serious injury or death to rainbow trout in 5 minutes	604
40	Not lethal to fingerling channel catfish in 96 hours when added as ferrous disodium versanate	2981
50	Upper limit for fish life	801

Waters that support good fish fauna in the United States, according to Ellis (310), have the following concentrations of iron:

Concentration of Iron, in mg/l	*Percent of Waters Having This Concentration, or Less*
0.0	5
0.3	50
0.7	95

Crenothrix, *Gallionella*, and other iron bacteria utilize iron as a source of energy and store it in their microbial protoplasm. They may accumulate in wells, treatment plants, pipelines, and other waterworks structures; or they may pass into the distribution system and cause customer complaints (2700, 2701, 2705). At Wilmington, California, where the residual iron content was only 0.025 mg/l, Wilson (1219) found growths of *Crenothrix*. Trouble with this organism is experienced frequently when the iron exceeds 0.2 mg/l.

Radioactive iron, Fe-59, may be concentrated by certain microorganisms in aquatic and marine environments. For further details on concentration factors for radionuclides, see Chapter VIII. The following concentration factors have been reported for Fe-59:

Concentration Factor	*Organism*	*Reference*
720-1030	flagellate, *Platymonas*	3386
1000	vertebrates, soft parts	2440
1550-4480	alga, *Ochromonas*	3386
4220	diatom, *Navicula conf.*	3386
5000	vertebrates, skeleton	2440
5533	diatom, *Nitzschia*	3386
6000	flagellate, *Chlamydomonas*	3386
7500	flagellate, *Rhodomonas*	3386
10,000	fish	2436
10,000	invertebrates, soft parts	2440
20,000	algae, non-calcareous	2440
100,000	insect larva	2436
100,000	filamentous algae	2436
100,000	invertebrates, skeleton	2440
200,000	phytoplankton	2436

4. Summary. On the basis of the foregoing information, the following concentrations of iron should not be deleterious to the designated beneficial uses:

a. Domestic water supply .... 0.3 mg/l
b. Industrial water supply .... 0.1 mg/l

IRON HUMATE

(see Humic Acid)

ISODRIN

(see Chapter IX)

ISOPRENE C_5H_8

This unstable, oxidizable liquid, insoluble in water, is used in the manufacture of synthetic rubber (364). According to Klimkina (3413), it has an odor threshold in water at a concentration of 0.005 mg/l. For warm-blooded animals, the threshold limit in drinking water is 5 mg/l, but deoxygenation of wastes is not inhibited by 30 mg/l.

IVORY SNOW

(see Chapter X)

JAUNDICE

(see Chapter VII—Infectious Hepatitis)

KELTHANE

(see Chapter IX)

KEROSENE

(see Oil, Petroleum)

KRAFT PULP MILL WASTES

1. General. Certain types of wood, primarily coniferous, are pulped in digesters with a strong caustic solution containing sodium hydroxide, sodium sulfate, and sodium sulfide. This procedure is known as the "Kraft" process. When sulfur compounds are not used, as in the pulping of deciduous wood, the digestion is known as the "soda" process. In either process, the concentrated alkaline wastes that are drained and washed from the pulped wood are known as "black liquor". Economy of operation dictates that such black liquors be kept as concentrated as possible and that they be processed for the recovery and re-use of the sodium salts. In well-operated soda or Kraft mills, therefore, the only liquid wastes result from rinse or wash waters that are too dilute to be recovered economically.

Black liquors from Kraft mills, although having a much lower B.O.D. than sulfite waste liquors, have been shown to be much more toxic to aquatic life (465, 683, 684). This toxicity appears to be related to the sulfur compounds, especially the mercaptans, and the resinous and fatty-acid components (685). Kraft-mill black liquors contain mercaptans, dimethyl sulfide, turpentine, methyl alcohol, ammonia, lignin, fatty and resinous acids, formic acid, acetic acid, lactonic acid, and sodium salts of organic and inorganic acids. Most of the organic constituents of black liquors are derived from the cellulose-binding substances in the wood, such as the lignins, pectins, and hemicelluloses.

2. Cross References. Sulfite Waste Liquors, Soaps, Resins, Mercaptans, and other substances noted above.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. Kraft-mill wastes discolor water, cause tastes and odors, and raise the pH. A report by the Technical Association of the Pulp and Paper Industries (686) states that a Kraft-mill waste contained 33 mg/l of sulfide and 12 mg/l of mercaptans. To render it odorless, a dilution of 1:50,000 was required; but after chlorination of the waste to a 1.5 mg/l residual, the required dilution was only 1:40. Insofar as domestic water supply is concerned, the elimination of tastes and odors appears to be the controlling factor.

b. Irrigation. Stabilized Kraft-mill effluents have been used directly for spray irrigation of several crops. The yield of crops was increased and there was no damage to the soil resulting from continued application for several years (3522).

c. Fish and Other Aquatic Life. Most of the references dealing with effect of Kraft-mill wastes on fish are expressed in terms of dilution, and inasmuch as the strengths of the wastes are not known the results in the following table are not strictly comparable.

Dilution	*Aquatic Organism*	*Remarks*	*Reference*
1:2	Fish	Killed in 7 minutes	683
1:20.8	Sockeye salmon	Maximum non-lethal concentration	3521
1:200	Fish	Killed	687
1:200	Fish	Killed	311, 688
1:500	Fish	Irritated but not killed	311, 688
1:500 to 1:1000	Fish	Killed in 10 days or less	673
1:1000	Fry and fingerlings	Killed	1225
1:2000	Fish	Killed	689

The Department of Fisheries of the State of Washington (2091) conducted tests with synthesized Kraft-mill effluents and salmon. It was found that older chinook salmon in flowing sea water were least tolerant, requiring a dilution of 60 to 1 to prevent a kill. Silver salmon in flowing fresh water required only 30 to 1. For black liquor, itself, chinook salmon required a dilution of 1093 to 1 in aerated sea water.

In a report of the National Council for Stream Improvement, (690, 3523) the toxicities of various components of Kraft mill waste were compared, as shown in the following table:

Waste Component	*Minimum Lethal Concentrations, mg/l*		
	Minnows	*Daphnia*	*Insect Larvae*
Sodium hydroxide	100	100	125-1000
Sodium sulfate	100	5000	--
Sodium sulfide	3	10	2-1000
Sodium carbonate	250	300	--
Sodium sulfite	--	300	--
Methyl mercaptan	0.5	1	50
Crude sulfate soap	5.0	5–10	50
Resin acid soap	1.0	3	50-100
Hydrogen sulfide	1.0	1	--

In a subsequent report (3501, 3503) the N. C. S. I. listed the minimum lethal concentrations (for 100 per cent kill) and the maximum concentrations for no kill of seven components of the Kraft-mill effluents toward king salmon, silver salmon, and cutthroat trout. The results are shown herein under the specific chemicals, viz. hydrogen sulfide, methyl mercaptan, sodium sulfide, sodium sulfhydrate, sodium hydroxide, sodium carbonate and sodium sulfate.

fineries. Turnbull et al. (2093) conducted bioassays with this substance in Philadelphia tapwater, using bluegill sunfish (*Lepomis macrochirus*) as the test fish. They found a 24-hour TL_m of 2.0 mg/l as lead and a 48-hour TL_m of 1.4 mg/l. They estimated the safe concentration at 0.20 mg/l.

LIGNASAN

(see Mercuro-Organic Compounds)

LINOLEIC ACID AND LINOLEATES

(see Fatty Acids)

LISSAPOL (NONYLPHENOL ETHYLENE OXIDE CONDENSATE)

(see Chapter X)

LIME

(see Calcium Hydroxide)

LINDANE

(see Chapter IX—Benzene Hexachloride)

LITHIUM Li

(see also Lithium Chloride)

As one of the alkali metals, related to sodium and potassium, lithium is not widely distributed in nature, being found in a few minerals and in certain spring waters. Being very active, the metal does not occur in the elemental state and when purified as such it must be protected from water or oxygen. It is used in metallurgy, in medicinal waters, in some types of glass, and as lithium hydroxide in storage batteries. Hibbard (250) recommends, without references, that lithium in water for drinking and cooking purposes should not exceed 5 mg/l.

Lithium toxicity in citrus has been identified in Santa Barbara County, California. In green-house experiments, 2 and 5 mg/l of lithium sulfate (in air-dried soil) caused the appearance of toxic symptoms in orange seedlings within 6 months. In the field, 1, 2, and 4 mg/l of lithium chloride in the soil have caused symptoms of lithium toxicity.

Various irrigation waters in the area were found to contain 0.045-0.080 mg/l of lithium. Possibly lithium poisoning has resulted from the accumulation in ground of toxic concentrations over a long period of time. Aldrich (1591) and his collaborators are making further studies of the effects of 0.05-0.1 mg/l of lithium in irrigation water.

LITHIUM CARBONATE Li_2CO_3

This light white alkaline powder, quite soluble in water, is used in the production of glazes on ceramic and electrical porcelain (364). It was reported in 1923 that concentrations of 295-516 mg/l of lithium carbonate retarded larval and pupal development of *Drosophila melanogaster* (1592).

LITHIUM CHLORIDE LiCl

(see also Lithium)

A white deliquescent crystalline solid, lithium chloride is highly soluble in water. It is used in pyrotechnics and in the soldering of aluminum. It is also used in the manufacture of mineral waters and it may be found in some natural mineral springs (364).

In a concentration of 3750 mg/l, lithium chloride in distilled water killed goldfish in 22 to 27 hours (313). For mature small fresh-water fish, the lethal concentration in 24 hours of exposure was found to be 2600 mg/l. The data gathered by Powers and by Iwao indicate that lithium chloride at concentrations between 1950 and 3770 mg/l can kill fresh-water fish in about one day, or sooner at warmer temperatures (1459). In contrast with these high concentrations required for lethal effect, one German publication (2977) reports that 100 mg/l of LiCl is toxic but 33 mg/l is harmless to fish.

The threshold concentration for immobilization of *Daphnia magna* in Lake Erie water was found to be less than 7.2 mg/l (598); but in River Havel water at 23°C the threshold of poisonous effect was observed at 16 mg/l during 48 hours contact (2158). With the protozoan *Microregma* as the test organism, food intake was inhibited at 66 mg/l (3343). Toward *Scenedesmus* and *Escherichia coli*, no toxicity was evident at concentrations less than 1000 mg/l (2158). In order to evoke stimulation and movement of the water beetle, *Laccophilus maculosis*, a LiCl concentration of 19,500 mg/l was required (2956).

It has been reported that dilute concentrations of LiCl are deleterious to the eggs of various aquatic organisms, retarding their development and producing monstrosities (1467). King demonstrated that concentrations of 848 mg/l were highly toxic to fly larvae, preventing emergence of offspring and retarding development of both larvae and pupae (1592).

LITHIUM FLUORIDE LiF

This moderately soluble salt is used as a flux for soldering and welding aluminum and in the manufacture of vitreous enamels and glazes (364). The oral LD_{50} for guinea pigs is 200 mg/kg of body weight (3271). The lethal dose in 48 hours for the fish, *Tinca vulgaris*, is reported as 20,000 mg/l (3271).

LITHIUM SULFATE

(see Lithium)

LOROL METASODIUM SULFOBENZOATE

(see Chapter X)

MAGNESIUM Mg

1. General. As one of the most common elements in the crust of the earth, constituting about 2.1 percent of it, magnesium is widely distributed in ores and minerals (364). Because it is very active chemically, it is not found in the elemental state in nature. With the exception of the hydroxide at high pH values, its salts are very soluble; even the carbonate will dissolve to the extent of 100 to 300 mg/l at normal temperatures (364, 911). The solubility of magnesium hydroxide is governed by the equation:

$$[Mg^{++}]\ [OH^-]^2 = 1.2 \times 10^{-11} \text{ at } 18°C$$

Thus, at pH 7, magnesium ions theoretically can be present to the extent of 1200 mols per liter or 28,800 grams per liter, but at pH 10 the maximum possible concentration of magnesium ions would be 28.8 mg/l and at pH 11 only 0.288 mg/l. This phenomenon is useful in treatment processes to remove magnesium from water, but insofar as natural waters are concerned it is described herein merely to show that at common pH values magnesium ion may be present in high concentrations despite the apparently low solubility product.

The industrial and commercial uses of magnesium and its salts are many, as described hereinafter for the salts. Magnesium metal is used as a constituent of light alloys, in other phases of metallurgy, and in the manufacture of electrical and optical apparatus (364). Magnesium ions are of particular importance in water pollution in that they occur in significant concentration in natural waters, and along with calcium form the bulk of the hardness reaction (see Hardness).

The literature decribed herein deals with articles in which magnesium ions were referred to without mention of associated cations. Where salts were tested and described, the material is covered under the appropriate salt.

2. Cross References. Calcium, Hardness, Dissolved Solids, Tastes.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. Magnesium is an essential mineral element for human beings, the daily requirement of magnesium is about 0.7 grams (295). Magnesium is considered relatively non-toxic to man and not a public-health hazard because, before toxic concentrations are reached in water, the taste becomes quite unpleasant (633) (see also Tastes). At high concentrations, magnesium salts have a laxative effect, particularly upon new users, although the human body can develop a tolerance to magnesium over a period of time.

The 1946 USPHS Drinking Water Standards recommended a limit of 125 mg/l but there is no limit in the 1962 standards (2036). The 1958 WHO International Standards (2328) have a "permissible limit" of 50 mg/l and an "excessive limit" of 150 mg/l, but no maximum allowable concentration. The 1961 WHO European Standards (2329) have a recommended limit of 125 mg/l, but if the sulfate exceeds 250 mg/l, the magnesium is limited to 30 mg/l.

Limits ranging from 100 to 200 mg/l have also been proposed for domestic water supplies (942, 1059). Hibbard recommended a limiting concentration of magnesium of 10 mg/l in water for drinking and cooking; 5 mg/l for washing; and no magnesium for laundry (250). Baylis suggested limiting concentrations of magnesium ranging from 50 to 150 mg/l for four grades of drinking water (499). In his system for classifying ground waters, Goudey suggested limits from 15 to 125 mg/l, according to domestic and industrial uses (992).

The taste threshold for magnesium (in $MgSO_4$) has been reported (3241) as 100 mg/l and for the average individual it is given as about 500 mg/l (3392).

The negative correlation between hardness in water and cardiovascular disease does not appear to hold for magnesium as it does for calcium (3368, 3369); yet one investigator (3537) reports the favorable use of magnesium sulfate to treat such cases and claims that magnesium, rather than calcium, is the beneficial element in reducing cardiovascular attacks (see Hardness).

b. Industrial Water Supplies. Like calcium, magnesium in small amounts is beneficial in the mash water for pale beer (175, 1074, 3344). Magnesium in water used for preparing developer solutions causes spots on films, if it is precipitated out of solution (242).

The limiting or threshold concentrations of magnesium that have been recommended for various industrial waters are described in Chapter V. The following table is extracted from that chapter:

Process	Recommended Limits, in mg/l for			
	Magnesium	$MgSO_4$	$MgCl_2$	$Mg(HCO_3)_2$
Brewing	30	100-200	100-200	--
Ice manufacture	--	130-300	171-300	50
Soda pulp	12	--	--	--
Sugar making	10	--	--	--
Textile manufacture	5	--	--	--

c. Irrigation. Magnesium is essential to normal plant growth (635); and magnesium and calcium cations in irrigation water tend to keep soil permeable and in good tilth (268, 281, 348, 1252). It has been reported that magnesium in water in concentrations up to 24 mg/l will probably not affect seriously the condition of underground water basins, growth of trees, or condition of the soil (1060). In very high concentrations (3000-5000 mg/l) $MgCl_2$ and $MgSO_4$ have been toxic to the bean plant (3376).

d. Stock and Wildlife Watering. Animals require magnesium salts in their diet. According to Maynard, calves require about 0.6 grams of magnesium per 100 lbs. body weight, or 600 mg/kg in the dry ration. Chicks require about 400 mg/kg of magnesium in the dry ration. The specific needs of other animals are not known (995).

In the body, calcium and magnesium are antagonistic to a certain degree and calcium may alleviate symptoms of magnesium excess. Diets high in magnesium and low in calcium can cause rickets (284, 295). Provided that both calcium and phosphorus in the diet are sufficient, however, the ingestion of a moderate excess of magnesium in the food or water will not markedly disturb calcium retention, although it may increase the calcium requirement (284, 295).

Magnesium salts act as cathartics and diuretics among animals as well as human beings, and high concentrations in drinking water may cause scouring diseases among stock. Water containing less than 5000 mg/l of magnesium compounds is harmless to cattle which have become accustomed to it (292). An interim threshold limit of 500 mg/l has been suggested by Stander (3373). Ingestion of mixtures of sodium salts and magnesium and nitrate ions caused poisoning among ducks (288).

e. Fish and Other Aquatic Life. The relative concentrations of magnesium and calcium in water may be one factor controlling the distribution of certain crustacean fishfood organisms, such as copepods, in streams (1085). Hart et al. cite a report that among U.S. waters supporting a good fish fauna, ordinarily 5 percent have less than 3.5 mg/l of magnesium; 50 percent have less than 7 mg/l; and 95 percent have less than 14 mg/l (310).

Magnesium chloride and nitrate can be toxic to fish in distilled water or tap water at concentrations between 100 and 400 mg/l as magnesium. However, magnesium chloride, nitrate, and sulfate, at concentrations between 1000 and 3000 mg/l as magnesium have been tolerated for 2-11 days. Some fresh-water fish have been found in very saline lake water containing over 1000 mg/l of magnesium as well as additional sodium and calcium salts (1459).

As magnesium nitrate, 400 mg/l of magnesium is toxic to a flatworm, *Polycelis nigra*, as magnesium chloride (353). A concentration of 300 mg/l of magnesium has been reported to be toxic to stickleback (353, 2941). Magnesium salts in water affect the toxicity of copper toward fish (1076). For further details on fish toxicity, see the specific magnesium salts.

f. Shellfish Culture. Magnesium was found to be more toxic than calcium to mussels but less toxic than sodium and potassium (353).

MAGNESIUM ACETATE $Mg(C_2H_3O_2)_2 \cdot 4H_2O$

(see also Magnesium, Acetates)

This colorless salt is freely soluble in water. Heller found that 15,000 mg/l of magnesium acetate in drinking water permitted satisfactory growth and reproduction among rats (287, 2980).

MAGNESIUM BICARBONATE

(see Magnesium)

MAGNESIUM CHLORIDE $MgCl_2 \cdot 6H_2O$

1. General. Highly soluble in water, magnesium chloride may occur in water either naturally or as a component of waste waters from oil wells, road run-off, and industry. It is used in manufacturing chemicals, artificial leather, cements, fire extinguishers and fireproofing materials, sweeping compounds, and road coverings (364).

2. Cross References. Hardness, Magnesium, Taste, Chapter V.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The taste threshold of magnesium chloride in water has been reported to be 200 to 750 mg/l (621). Steyn et al. recommended that in order to prevent unpleasant salty tastes and possible appetite disturbances, water should not contain more than 168 mg/l of magnesium chloride (284). Thresh states that much smaller quantities of magnesium chloride, even 40 to 50 mg/l, can render a water useless for many domestic purposes because of its hardness (32).

b. Industrial Water Supplies. Magnesium chloride in water may interfere with its suitability for some industrial uses. In boiler waters it is corrosive (855).

The following maximum concentrations have been recommended:

Use	*Concentration in mg/l*	*Reference*
Brewing	200	173
Brewing	100	170
Ice, raw water	171	173

c. Irrigation Use. Irrigation with effluents of high magnesium chloride content did not appreciably affect the yields and composition of hay (1253). At concentrations in excess of 2000 mg/l, $MgCl_2$ inhibited the growth of bean plants (3376) and guayule (3378).

d. Stock and Wildlife Watering. In experimental animals 4.0 grams of magnesium chloride per 100 grams of diet causes diarrhea, loss of appetite and even death (295). It has been reported that daily oral administration of 20 grams of magnesium chloride to pigs; 60 grams to sheep; and 400 grams to horses had no detrimental effects. A dose of 1.5 grams has been toxic to ducks (284).

Magnesium chloride in water had no effect on tooth decay among rats (1069). Water containing 10,000 to 15,000 mg/l of magnesium chloride interfered with the growth of rats (287). Water containing 10,000 mg/l of magnesium chloride and 5000 mg/l of calcium chloride was not harmful to mature rats, although it did interfere with lactation (287). Water containing 5000 mg/l of magnesium chloride and 20,000 mg/l of sodium chloride inhibited rat growth (284). Concentrations of $MgCl_2$ up to 9500 mg/l in the drinking water had no effect on the food or water intake of male rats (2398).

e. Fish and Other Aquatic Life. Garrey found that magnesium chloride added to water decreased the toxicity of calcium and potassium chlorides toward fresh-water fish, and that calcium chloride decreased the toxicity of magnesium chloride (307).

The following concentrations of magnesium chloride have been reported to have killed fresh-water fish:

Concentration in mg/l	*Type of Water*	*Time of Exposure*	*Type of Fish*	*Reference*
476	distilled	4-6 days	minnows	313
5000	--	96.5 hours	golden shiners	645
6757	distilled	3-21 days	goldfish	313
8132	--	--	carp	3538
10000	--	4.6 hours	shiners	645
15000	--	0.8 hours	shiners	645
16500	turbid	96-hour TL_m	mosquito fish	2940
20000	--	0.5 hours	shiners	645
23800	--	24 hours	*Orizias*	1459

The highest concentration of $MgCl_2$ tolerated by young eels for more than 50 hours was reported to be about 9500 mg/l (1459). Some fish-food organisms, such as *Daphnia* and other cladocera, are less tolerant of magnesium chloride and have been immobilized or killed within two days by concentrations of magnesium chloride from 740 to 3500 mg/l (598).

f. Shellfish Culture. In 1890, Dean reported that the most favorable salt content for oyster growth is about 30,800 mg/l of chlorides, of which magnesium and potassium chlorides constitute about 20 percent (314).

MAGNESIUM FLUORIDE MgF_2

This colorless salt is soluble in water only to the extent of 87 mg/l at 18°C. It finds commercial application in the ceramics and glass industries. The oral LD_{50} for guinea pigs is 1000 mg/kg of body weight (364). To kill tench, a concentration of 10,000 mg/l was required (3271).

MAGNESIUM NITRATE $Mg(NO_3)_2 \cdot 6H_2O$

(see also Magnesium, Nitrates)

This freely soluble compound is used in pyrotechnics. The taste threshold of magnesium nitrate in water is reported to be 500 to 800 mg/l (621). The following ntrations of magnesium nitrate have been reported l fish:

ntration ng/l	Time of Exposure	Type of Fish	Reference
300	long time	stickleback	1460
400	--	stickleback	2920
500	4 days	stickleback	1460
500	2 days	stickleback	1460
820	14-16 hours	stickleback	598
000	one day	stickleback	1460
500	--	goldfish	313

NESIUM OXIDE MgO

e also Magnesium)

own in the dry state as "magnesia", this oxide ines with water to form magnesium hydroxide, is sparingly soluble at high pH values. It is used inally as an antacid and laxative, in doses of 0.25 grams. One authority (1254) reports that drinking should contain some magnesium and calcium s; the most satisfactory ratio of calcium oxide to esium oxide is said to be 7:1. In the soft-drink in- y, magnesium oxide in the wash water gradually ds" the bottles, causing unsightliness (180).

NESIUM SILICOFLUORIDE $MgSiF_6 \cdot 6H_2O$

is highly soluble salt is used for mothproofing fab- The oral LD_{50} in guinea pigs is given as 200 mg/kg dy weight (364). A concentration of 50 mg/l is ted to kill tench (3271).

NESIUM SULFATE $MgSO_4 \cdot 7H_2O$

General. Known also as Epsom salt, this compound ely soluble in water. It occurs in natural deposits oils, thereby contributing to the concentration in al waters. It is used in weighting cotton and silk, eing and printing calico, in tanning processes, and tilizers, explosives, and matches (364).

Cross References. Dissolved Solids, Magnesium, tes.

Effects on Beneficial Uses.

Domestic Water Supplies. The taste threshold of esium sulfate is 400 to 600 mg/l (621, 3241). A of 30 grams of magnesium sulfate is toxic and 120 fatal for man (284).

gnesium sulfate in excessive concentrations in ing water may have purgative effects (623). The sensitive individuals are affected at about 400 mg/l he average person at about 1000 mg/l (3392). s containing 1200 mg/l of magnesium sulfate and g/l of sodium sulfate have caused diarrhea in hu- Ordinarily, according to Taylor (36) waters con- g half this quantity would be regarded as unsuit- for domestic use.

sages of 1 to 2 grams of magnesium sulfate have a tive effect; therefore, in drinking-water standards esium sulfate should be limited to 1000 to 2000 Concentrations below this limit are physiologically ss (621).

Industrial Water Supplies. The following concen- ns of magnesium sulfate have been recommended dustrial waters:

Process	Concentration, mg/l Optimum	Maximum	Reference
Brewing, pale ales, I	60-90	---	170
pale ales, II	60-120	---	170
mild ales	60	---	170
stout	60	---	170
Brewing	100	---	170
Brewing, light or dark	---	200	173
Ice, raw water	---	130	173

c. Irrigation. See Calcium, Hardness, and Chapter V-Irrigation.

d. Stock and Wildlife Watering. High concentrations of magnesium sulfate in the drinking water of rats and other small animals have retarded growth, caused emaciation, rough coat, diarrhea, and increased mortality among the young (284, 287, 640). Concentrations from 10,000 to 25,000 mg/l have been harmful to rats. A combination of 5000 mg/l of magnesium sulfate and 20,000 mg/l of sodium chloride has inhibited the growth of rats (640) (see also Dissolved Solids). On the other hand, 000 mg/l in drinking water has not been harmful to rats (287). Livestock will tolerate 2050 mg/l of magnesium sulfate without laxative effects (2394). In drinking water, 12,000 mg/l had no effect on the water and food consumption of male rats (2398).

e. Fish and Other Aquatic Life. The following concentrations of magnesium sulfate have been reported to have killed fish:

Concentration in mg/l	Type of Water	Time of Exposure	Type of Fish	Reference
15,500	turbid	96-hour TL_m	mosquito-fish	2940
20,900-28,400	cistern	14 days	perch	644
24,500-27,500	well	78 days	perch	644

The maximum concentration of magnesium sulfate tolerated by young eels for over 25 hours was reported to be about 12,000 mg/l (1459).

MALATHION

(see Chapter IX)

MALEIC ANHYDRIDE $C_4H_2O_3$

This solid dissolves readily in water, forming maleic acid, HOOCHC = CHCOOH. It is used in the manufacture of alkyd-type resins, dye intermediates, and pharmaceuticals (364). Wallen et al. (2940) exposed mosquito-fish (*Gambusia affinis*) to maleic anhydride in turbid water at 20-23°C. They found the 24- and 48-hour TL_m values to be 240 mg/l and the 96-hour TL_m was 230 mg/l. The pH value was lowered from 8.0 to 5.8 and the 128 mg/l of turbidity was coagulated and removed by this compound. Using bluegill sunfish (*Lepomis macrochirus*) in Philadelphia tap water at 20°C, Turnbull et al. (2093) found the 24-hour TL_m to be 150 mg/l and the 48-hour TL_m to be 138 mg/l. They estimated a safe concentration to be 35 mg/l.

MANGANESE Mn

1. General. Manganese metal is not found pure in nature, but its ores are very common and widely distributed. The metal or its salts are used extensively in steel alloys, for dry-cell batteries, in glass and ceramics, in the manufacture of paints and varnishes, in inks and dyes, in matches and fireworks, and in agriculture to

enrich manganese-deficient soils (2121). Like iron, it occurs in the divalent and trivalent form. The chlorides, nitrates, and sulfates are highly soluble in water; but the oxides, carbonates, and hydroxides are only sparingly soluble. For this reason, manganic or manganous ions are seldom present in natural surface waters in concentrations above 1.0 mg/l. In ground water subject to reducing conditions, manganese can be leached from the soil and occur in high concentrations. Manganese frequently accompanies iron in such ground waters and in the literature the two are often linked together.

2. Cross References. Iron, Manganese Salts, Potassium Permanganate, Turbidity, Tastes.

3. Effects Upon Beneficial Uses.

a. Domestic Water Supplies. The 1962 Drinking Water Standards of the USPHS (2036) set a recommended limit for manganese of 0.05 mg/l. The 1958 WHO International Standards (2328) prescribe a "permissible limit" of 0.1 mg/l and an "excessive limit" of 0.5 mg/l, but no maximum allowable limit is given. The 1961 WHO European Standards have a recommended limit of 0.1 mg/l.

These limits have been established on the basis of esthetic and economic considerations rather than physiological hazards. Manganese is essential for the nutrition of both plants and animals (2121, 2129). Diets deficient in manganese result in impaired or abnormal growth, symptoms of central nervous system disturbance, anemia, and possibly interference with reproductive functions (2121, 2129). The daily intake from a normal human diet is about 10 mg (2129). It is absorbed very slightly and deposits mainly in the liver and kidneys (2129).

In concentrations not causing unpleasant tastes, manganese is regarded by most investigators to be of no toxicological significance in drinking water (633, 1077). However, some cases of manganese poisoning have been reported in the literature. A small outbreak of an encephalitis-like disease, with early symptoms of lethargy and edema, was traced to manganese in the drinking water in a village outside of Tokyo; three persons died as a result of poisoning by well water contaminated by manganese derived from dry-cell batteries buried nearby (36, 1225). Excess manganese in the drinking water is also believed to be the cause of a rare disease endemic in Manchukuo. That manganese may be toxic is also indicated by the reports that 0.5 to 6.0 grams of manganese per kilogram of body weight administered daily to rabbits had stunted growth and interfered with bone development (921).

Despite the possible toxic effects of manganese under unusual circumstances, it cannot be considered a physiological hazard because the normal dietary intake is far higher than the amount that would be tolerated esthetically in drinking water.

Manganese is undesirable in domestic water supplies because it causes unpleasant tastes, deposits on food during cooking, stains and discolors laundry and plumbing fixtures, and fosters the growth of some micro-organisms in reservoirs, filters, and distribution systems (1593, 3539, 3540, 3541, 3542) (see Fish and Other Aquatic Life, below).

It has been reported by one observer that manganese salts impart a metallic taste to water at concentrations above 0.5 mg/l (945); and by another reference at above 20 mg/l (759). Cohen et al. (3301) found the taste threshold for manganous ion in spring water to occur at about 150 mg/l for the median of a large panel, but at 32 mg/l for the most sensitive members. In distilled water the taste thresholds were much lower, about 35 mg/l for the median and about 0.9 mg/l for the most sensitive panel members (3301). Manganese in excess of 0.15 mg/l has also been reported to cause turbidity in water (1594).

For domestic water supplies a maximum concentration of manganese, or of iron and manganese together, as low as 0.017 mg/l has been recommended (1256). Concentrations as low as 0.1 mg/l are reported to cause laundry trouble (219, 284); concentrations of 0.2 to 0.4 mg/l are likely to cause complaints (36); and, in general, limiting concentrations from 0.02 to 0.5 mg/l have been recommended (499, 555, 628, 1257, 3541).

b. Industrial Water Supplies. Excessive manganese is undesirable in water for use in many industries, including textiles (255, 256, 257); dyeing (261); food processing, distilling, and brewing (240, 224, 284); ice (234); paper (212, 879); and many others (see Chapter V). The following tabulation summarizes the recommendations as to maximum permissible concentrations of manganese in industrial waters:

	Maximum Permissible Concentration		
Industrial Use	*Manganese in mg/l*	*Iron + Manganese in mg/l*	*Reference*
Air conditioning	0.5	0.5	162
	0.5	--	152
Baking	0.2	0.2	162, 152
Brewing, light and dark	0.1	0.1	162, 152
Canning	0.2	0.2	162, 152
Carbonated beverages	0.2	0.2	162, 152, 18[illegible]
	--	0.1	179
Confectionary	0.2	0.2	162, 152
Cooling water	0.2	0.2	152
	0.5	0.5	162
Dyeing	0	0	36
Food processing	0.2	0.2	162, 152
Ice	0.2	0.2	162, 152, 234
Milk industry	0.03-0.1	--	2344
Paper and pulp	0	0	36
Groundwood	0.5	1.0	162, 152
	0.1	--	244
Kraft pulp	0.1	0.2	162, 152
Soda and sulfate	0.05	0.1	162, 152
	0.05	--	245
Highgrade paper	0.05	0.1	162, 152
Fine paper	0.05	0.1	350
Kraft paper			
bleached	0.1	--	351
unbleached	0.5	--	351
Photography	0	0	36
Plastics (clear)	0.02	0.02	162, 152
Rayon and viscose			
Pulp production	0.03	0.05	162, 152
Manufacture	0	0	162, 152
	0.02	--	550, 406
Tanning	0.2	0.2	162, 152
Textiles, general	0.25	0.25	162, 152
	--	0.1	852
	0.1	--	236
dyeing	0.25	0.25	162, 152
wool scouring	1.0	1.0	162, 152
bandages	0.2	0.2	162, 152

c. Irrigation. Manganese is essential for plant growth, apparently as an enzyme activator (3543). It is especially abundant in the reproductive parts of plants, seeds being highest while woody sections contain the least manganese (3544). Nuts contain the highest concentrations (22.7 mg/kg) and sea foods the lowest (0.25 mg/kg). Tea diffuses enough so that the normal liquid has 1 to 7 mg/l (2121). Manganese has been used to enrich soil, yet in some concentrations it may be phytotoxic (219, 277, 563).

Manganese in the nutrient solutions has been reported to be toxic to many plants, as grown in solution cultures. The sensitivity and response of the plants to the presence of manganese varies both with the species of plant and the composition of the nutrient solution. Symptoms of manganese injury have been intensified in the presence of molybdenum, vanadium (1595), or nitrate (1596). Symptoms of manganese injury have been diminished in the presence of cobalt (1499), iron, molybdenum, aluminum, phosphorus deficiency (1458), ammonium or ammonium nitrate (1596). The following concentrations of manganese have been reported to be harmful to plants in solution culture:

Concentration of Manganese in mg/l	Type of Plant	Reference
0.5	Various plants	1597
1-10	Various legumes	1597
3.5	Various plants	1597
5	Orange and mandarin seedlings	1524
5-10	Tomatoes	1499
10-25	Soybean, flax	1595
25-100	Flax	1458
50	Flax	1596
62.5	Various plants	1597
150-500	Oats	1462

It has also been reported that 0.25 mg/l of manganese has permitted good growth of tomatoes, and that up to 5.0 mg/l of manganese has reduced the severity of cobalt poisoning in tomatoes (1499). In the presence of ammonium or of ammonium nitrate, 50 mg/l of manganese was not harmful to flax, although this concentration was harmful in the presence of nitrate without ammonium (1596). Manganese sulfate, at a concentration of 100 mg/l as manganese caused no apparent injury to oat plants (1462).

d. Stock and Wildlife Watering. A deficiency of manganese in animals produces ovarian disfunction, testicular degeneration, poor lactation, lack of growth, bone abnormalties, and symptoms of central nervous disturbance (2121). Cattle are reported to have received dosages of 50 to 600 mg/kg in the diet for 20 to 45 days without serious effects. Birds have received single oral dosages of up to 600 mg/kg without adverse effects, but the continuous excess of manganese in fodder was suspected as an etiological factor in the occurrence of infectious anemia in horses. Manganese appears to oxidize vitamin B in the horse body, producing avitaminosis (1049).

The metabolism of manganese is closely related to that of calcium, phosphorus, iron, copper, and possibly other minerals, and the proper balance must be maintained. The manganese requirement for chicks has been reported to be 30-50 mg/kg (dry ration); for hens, 40-50 mg/kg. However, 1000 mg/kg in the dry ration was not toxic (1551).

e. Fish and Other Aquatic Life. The toxicity of manganese toward fish is dependent upon many factors. Jones (2941) gives the lethal concentration for the stickleback as 40 mg/l; however, the toxic action is slow and manganese does not appear to precipitate the gill secretions. According to Oshima (3545) and Iwao (3546) the toxicities of manganous chloride and manganous sulfate are slight, being about 2400 and 1240 mg/l of manganese respectively. Manganese appears to be somewhat antagonistic to the toxic action of nickel toward fish (1468).

The following concentrations of manganese have been tolerated by fish under the stated conditions:

Concentration in mg/l	Time of Exposure	Type of Fish	Reference
1	--	river crayfish	2977
15	7 days	tench, carp, trout	2151
40*	4 days	fingerling catfish	2981
50**	3 days	stickleback	1459
2700	50 hours	eels	1459

* from manganese disodium versenate
**from manganese sulfate

Manganese and iron in concentrations above 0.1 mg/l stimulate the growth of certain organisms, such as *Crenothrix*, *Gallionella*, and other related forms in reservoirs, filters, and distribution systems (152, 921, 945, 1258). The addition of as little as 0.0005 mg/l of manganese resulted in increased growth and multiplication of various microbiota in sea water (1259). Guseva (584, 1260), on the other hand, found that concentrations of manganese above 0.005 mg/l had a toxic effect on some algae.

The threshold concentration of manganese for the flatworm *Polycelis nigra* has been reported to be 700 mg/l as manganese chloride and 660 mg/l as manganese nitrate (608). Crustacea, worms, and insect larvae were not harmed by 15 mg/l of manganese during a 7-day exposure (2151).

The permanganates are much more toxic to fish than the manganous salts. Permanganates killed fish in 8 to 18 hours at concentrations of 2.2 to 4.1 mg/l of manganese (3545, 3546). However, permanganates are not stable for long in water.

4. Summary. On the basis of the literature surveyed, it appears that the following concentrations of manganese will not be deleterious to the stated beneficial uses:

a. Domestic water supply	0.05 mg/l
b. Industrial water supply	0.05 mg/l
c. Irrigation	0.50 mg/l
d. Stock watering	10.0 mg/l
e. Fish and aquatic life	1.0 mg/l

MANGANESE CHLORIDE $MnCl_2$ and $MnCl_3$

(see also Manganese, Chlorides)

This highly soluble salt, occurring generally in the manganous form, is used in dyeing operations, in disinfecting, in linseed oil driers, and in electric batteries (364). In fresh water, 12 mg/l has been reported as fatal to minnows (*Fundulus*) within six days (1459), but other fish have been found to be much more tolerant of $MnCl_2$. For the small fresh-water fish (*Orizias*), the 24-hour lethal concentration was about 7850 mg/l (1459) and for other fish 5500 mg/l (3545, 3546). The highest concen-