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Project Summary

Characterization of Oil Shale Mine Waters, Central Piceance Basin, Colorado

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A study was conducted to characterize the oil shale mine waters in the Piceance Basin. The study sites were the Federal Prototype Lease Tracts C-a and C-b, located in the central portion of the basin. The objective was to collect water quality data in order to characterize the mine waters and to assess the effectiveness of the treatment systems located at these facilities. These treatment systems involve in-series retention ponds. Additionally, the effectiveness of a one-pond versus two-pond system was investigated.

The sources of the water routed through the retention ponds were water pumped from the on-site aquifers that were dewatered during mining activities and the water pumped directly from the underground mines. Water samples were taken from both the inflow and outflow points for both the Tract C-a and C-b pond systems and were analyzed for a fairly detailed suite of selected water quality parameters. This suite included total suspended solids (TSS) and total dissolved solids (TDS), pH, the major species of cations and anions, and dissolved trace elements such as selenium, lead, and arsenic. The inflow samples were then compared to the outflow samples to determine changes in water quality and, therefore, the effectiveness of the retention ponds. An additional part to this study was the assessment of the effectiveness of using a flocculant and sulfuric acid for the treatment of excess waters encountered during active mining on Tract C-b. The flocculant was added to reduce the suspended solids concentrations and the acid was used to reduce the high pH values.

The water quality changes observed during this study, when comparing the inflow waters to the outflow waters of the respective pond systems, were found to be generally small. Fluctuations may have been due to such phenomena as pH changes, aeration, evaporation, and oxidation-reduction changes associated with the transformation of the ground water from an underground (aquifer) environment to a surface (retention pond) environment. The retention time, as well as inherent laboratory technique variations, may also help explain the small fluctuations.

The overall conclusion with respect to the effectiveness of the retention pond systems in maintaining or improving water quality is that they appear to make no significant difference unless chemicals are added. The addition of the flocculant in the Tract C-b pond system was effective in reducing the suspended sediment concentrations. In addition, the sulfuric acid treatment effectively reduced the pH values. Concerning the general water quality, such as the trace elements, cations and anions, and other pertinent parameters, there was no noticeable increase or decrease.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The objective of this study was to provide a detailed characterization of the mine waters and treatment systems used on Federal Prototype Lease Tracts C-a and C-b, located in the Piceance Basin, Colorado (Figure 1). These data were collected to assist other oil shale developers and to permit writers to select appropriate controls for the handling of excess mine waters.

The treatment facilities for the excess mine waters at both sites consisted of two in-series retention ponds. To characterize these facilities, samples were collected for determining the chemistry of water derived from mine pumpage and aquifer dewatering activities previous to treatment. In addition, samples were derived from the outflow of the in-series retention ponds to characterize the treatment. Presently, the treated water is disposed of by reinjection into the ground-water system, is utilized for on-site activities, or is discharged to surface-water systems. The approach, data collection procedures, and results are discussed below.

Approach

The procedures for obtaining these data involved collecting grab samples of five sampling points. On Tract C-a, the sample collection included sampling the *mine water inflow into the primary* retention pond (Jeffrey Pond), the outflow of the primary retention pond into the secondary retention pond (West Retention Pond), and the discharge from the secondary pond previous to disposal. It was felt that Jeffrey Pond was fairly inconsequential with respect to the total treatment system due to the very short residence time of the mine waters in this pond. Therefore, the above described sampling scheme would adequately assess the effectiveness of treating the excess mine waters with a one-pond system, namely the West Retention Pond.

In regard to Tract C-b, samples of untreated mine water were collected at the inflow point of the primary retention pond (Pond A). In addition, samples of the treated water were collected from the discharge of the secondary retention pond (Pond B), which is in series with Pond A. During periods of active mining on Tract C-b, sulfuric acid and a magnifloc cationic flocculant were added to the ponds in order to treat the pH and total suspended solids (TSS), respectively. This sampling strategy assessed the effectiveness of treatment consisting of two ponds which are in series. In addition, the sampling program allowed for an evaluation of chemical treatment (i.e., flocculant and sulfuric acid).

The following constituents were measured in the field immediately upon sample withdrawal: pH, temperature, conductivity, and dissolved oxygen. The samples were then filtered (if necessary) and preserved according to the U.S. Environmental Protection Agency (EPA) recommended procedures. The samples were then shipped to the laboratories located at the Colorado State University

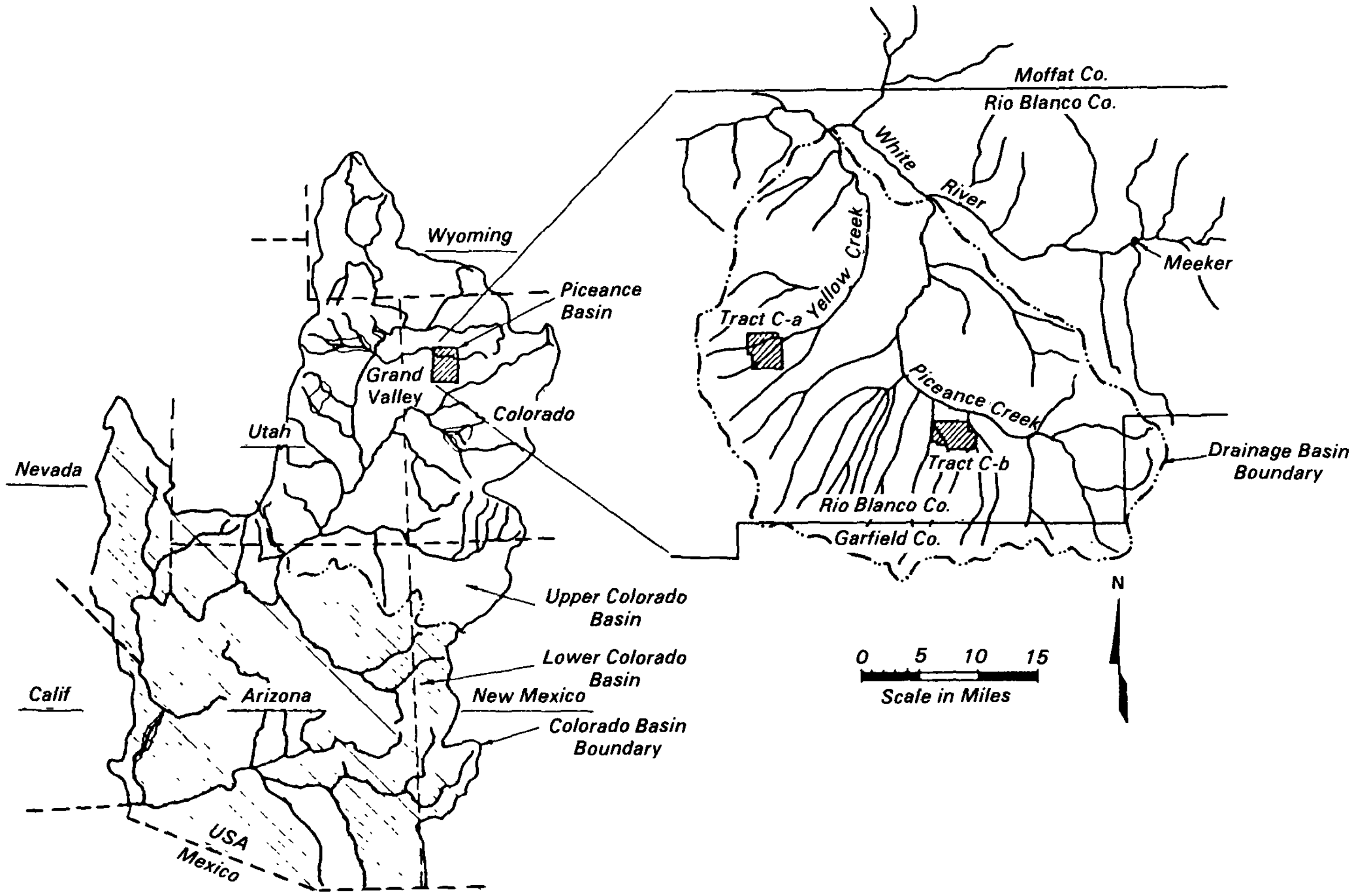

Figure 1. Location of Tracts C-a and C-b study area in Piceance Basin.

in Fort Collins, Colorado, and Core Laboratories in Denver, Colorado. In most cases, the EPA recommended holding times were observed. The holding times for a few constituents of the samples collected in July, 1982 were exceeded. However, the analytical results were generally in agreement with those for other sampling periods. Exceptions to this include nitrate and ammonia, which were higher in concentration than historic trends. Seven samples were collected at each sample collection point between September, 1981 and March, 1983.

A fairly detailed suite of constituents was selected for analysis during this study. This suite of constituents involved two groups, an abbreviated group and a comprehensive group (Table 1). Analysis for the abbreviated group of constituents was conducted during the months of September, 1981; September, 1982; and November, 1982. Analysis for the comprehensive group of constituents, which included the abbreviated group, was conducted during the months of May, 1982; July, 1982; January, 1983; and March, 1983. These constituents were selected after a review of the baseline water quality data collected by the Tract C-a and C-b operators, as well as the chemical characterization studies of simulated and observed *in-situ* oil shale process waters conducted by various researchers.

Table 1. *List of Parameters for Abbreviated and Comprehensive Analysis*

	ABBREVIATED	
Acidity	*Dissolved Oxygen*	*Residues*
Alkalinity	*Fluoride*	*(Total, total*
Ammonia	*Iron*	*dissolved,*
Arsenic	*Magnesium*	*total, suspended,*
Bicarbonate	*Mercury*	*settleable,*
Boron	*Molybdenum*	*and volatile)*
Carbonate	*Nitrate*	*Silica*
Calcium	*pH*	*Sodium*
Chloride	*Potassium*	*Sulfate*
Conductivity		*Temperature*
Dissolved Organic Carbon (DOC)		
	COMPREHENSIVE	
Aluminum	*Lead*	*Thallium*
Barium	*Lithium*	*Thiosulfate*
Beryllium	*Manganese*	*Tin*
Cadmium	*Nickel*	*Titanium*
Chromium	*Phosphorus*	*Turbidity*
Cobalt	*(total and ortho)*	*Uranium*
Copper	*Silver*	*(234, 235, 238)*
Cyanide	*Strontium*	*Vanadium*
Fractionated	*Sulfide*	*Zinc*
DOC		

NOTE: Comprehensive list includes all parameters in the abbreviated list.

Data Discussion

The analytical results for the data collected during this study on Tracts C-a and C-b are presented in Tables 2 and 3, respectively. In order to provide a perspective for evaluating the mine water data, the analytical results were compared to ground-water and surface-water baseline data, as well as Federal Drinking Water Standards. This comparison is not meant to imply that the discharges should meet these standards. The comparisons for the Tract C-a and C-b data are presented in Tables 4 and 5, respectively.

The Tract C-a system involved treating the water in a one-pond system and reinjecting all of the treated water back into the ground-water system. Concerning the effectiveness of the treatment of the mine waters, the following constituents were found to generally exceed baseline ground-water conditions: carbonate, calcium, conductivity, fluoride, magnesium, nitrate, TDS, sulfate, and pH. However, the increase in these constituents above ground-water baseline conditions were small.

The following constituents exceeded the Federal Drinking Water Quality Standards in the discharge from the Tract C-a system: iron, TDS, sulfate, and pH. However, these constituents also exceeded standards in the ground water analyzed to determine baseline water quality conditions. Therefore, this aspect may not be a problem if the water is reinjected.

In regard to the Tract C-b in-series two-pond treatment system, the following constituents in the discharge exceeded baseline ground-water quality concentrations: bicarbonate, carbonate, conductivity, fluoride, molybdenum, nitrate, potassium, TDS, silica, sodium, and pH. However, none of the increases were very great. In addition, during periods of active mining on Tract C-b, flocculant and sulfuric acid were added to the system to settle suspended solids and lower the pH, previous to the discharge to Piceance Creek. This treatment was effective and should be utilized if suspended solids and pH are areas of concern.

The quality of the discharge from Tract C-b also exceeded many constituents in the Federal Drinking Water Standards, as well as the baseline water quality data for Piceance Creek. For example, iron, TDS, and sulfate exceed the Drinking Water Standards. In addition, ammonia, bicarbonate, boron, carbonate, conductivity, fluoride, iron, molybdenum, nitrate, potassium, TDS, temperature, silica, sodium, alkalinity, and pH all exceeded the baseline water quality conditions of Piceance Creek. However, all of these constituents were within reasonable agreement with baseline ground-water quality, which is considered poor. Furthermore, the water discharged to Piceance Creek appears to be adequate for livestock and irrigation use.

The water quality changes observed in the data when comparing inflow and outflow of the treatment systems were generally insignificant. These changes can probably be related to pH changes, aeration, evaporation, and reduction-oxidation changes associated with the transformation of the ground water from an underground environment to a surface environment, as well as the associated retention time in the ponds. In addition, some of the variations may be attributable to laboratory procedures.

Conclusion

The effectiveness of the treatment systems with respect to improving water quality without use of chemicals appeared to be negligible. For the one-pond treatment system on Tract C-a, the overall quality, with the exception of total suspended solids, remained essentially unchanged during treatment. The slight decrease in total suspended solids concentrations from 6.3 mg/l to below detection limits is not significant. The two-pond treatment system on Tract C-b is very similar in results to the one-pond system on Tract C-a. The general water quality did not improve or degrade after treatment. However, the addition of a flocculant and sulfuric acid was effective in reducing total suspended solids by nearly 99% and adjusting pH to desired value.

Table 2. *Tract C-a Water Quality Data*

Constituent*	Inflow to Jeffrey Pond: Number	Mean	High	Low	Stnd. Dev.	West Retention Pond Inflow: Number	Mean	High	Low	Stnd. Dev.	West Retention Pond Outflow: Number	Mean	High	Low	Stnd. Dev.
Ammonia	6	.30	.47	.11	.12	6	.22	.32	.10	.09	6	.24	.42	.16	.11
Arsenic	7	BDL	(<.003)			7	BDL	(<0.003)			7		BDL	(<.003)	
Bicarbonate	7	555	599	527	25.3	7	535	548	523	9.8	7	517	558	368	67
Boron	6	.21	.41	.12	.10	6	.34	.80	.15	.26	7	.33	.9	.16	.29
Carbonate	7	6.33	9.09	1.0	2.85	7	7.09	11.4	1.08	3.43	7	7.5	10.4	<1	2.2
Calcium	7	38.8	48.7	32.6	7.3	7	41.0	63.5	31.0	11.8	7	41.4	62	32	10.8
Chloride	7	8.06	8.52	7.74	.30	7	8.4	9.47	7.58	.67	7	7.96	9.47	5.73	1.13
Conductivity (µ mhos/cm)	7	1,590	2,250	1,400	308	7	1,434	1,510	1,390	53	7	1,409	1,475	1,320	49
Dissolved Organic Carbon	7	3.5	4.7	<2	1.1	7	3.5	4	3	.46	7	3.3	3.8	2.0	.8
Dissolved Oxygen	7	4.0	6.8	3.0	1.3	7	6.7	8.5	5.9	1.0	7	5.8	8.0	3.9	1.4
Fluoride	7	1.35	1.71	1.1	.21	7	1.34	1.7	1.2	.18	7	1.24	1.32	1.11	.07
Iron	7	9.1	1.0	<.01	.36	7	.18	.59	.03	.20	7	.29	.64	<.01	.23
Magnesium	7	80.1	95.0	72.8	8.0	7	82	98.9	74.1	8.2	7	82.3	100.9	73.1	9.1
Molybdenum	7	.06	.11	<.03	.02	7	.16	.3	<.03	.18	7	.23	.24	<.01	.01
Nitrate	7	.53	2.02	<.1	.83	7	1.83	8.59	0.1	3.78	5	.39	.77	.05	.28
Potassium	7	.62	1.26	.14	.36	7	.76	1.24	.36	.33	7	.84	1.49	.36	.43
Residues															
-Total Dissolved	7	994	1,152	614	175	7	1,134	1,446	988	164	7	1,177	1,392	980	177
-Total Suspended	7	BDL	(<4)			7	6.3	10	<4	2.6	7	BDL	(<4)		
-Total Solids	7	1,071	1,208	992	69	7	1,153	1,446	1,016	160	7	1,185	1,395	1,007	170
-Total Volatile	6	197	226	148	31	6	198	252	74	65	6	187	225	86	55
-Settleable Matter	7	BDL	(<.1)			7	BDL	(<.1)			7	BDL	(<.1)		
Temperature (°C)	7	14.3	19	11	2.7	7	14.5	23	10	4.7	7	13.9	20	9.5	3.9
Selenium	7	BDL	(<.01)			7	BDL	(<.01)			7	BDL	(<0.1)		
Silica	6	13.9	23	11	4.5	6	13.2	22	10.9	4.4	5	11.6	12.8	11.0	.7
Sodium	7	191	200	174	8.2	7	190	198	170	9.7	7	192	198	177	7.3
Sulfate	7	402	430	343	31	7	342	441	345	137	7	377	449	302	48
Vanadium	4	BDL		(<.005)		4		BDL	(<.005)		4		BDL	(<.005)	
Acidity	7	5.1	9.45	3.13	2.13	7	3.56	4.99	2.52	1.13	6	3.57	4.96	2.33	1.12
Alkalinity	7	469	506	445	20	7	456	474	442	11	7	439	470	311	57
pH (Units)	7	7.7	9.2	7.17	.77	7	7.6	9.0	7.0	.7	7	7.6	8.9	6.9	.6

**In mg/l, unless otherwise indicated.*
BDL = Below Detection Limits, with detection limits in parenthesis.

Table 3. *Tract C-b Holding Pond Quality Data Collected During This Study*

	Sulfuric Acid and Flocculant		No Chemical Treatment									
	Inflow to Pond A	Outflow from Pond B	Inflow to Pond A					Outflow from Pond B				
Constituent*			Number	Mean	High	Low	Stnd. Dev.	Number	Mean	High	Low	Stnd. Dev.
Ammonia	.90	1.33	5	.37	.688	.21	19	5	.33	.372	.28	.03
Arsenic	<.01	<.01	6	BDL	.003			6	BDL	(<.003)		
Bicarbonate	1,135	1,069	6	1,217	1,350	896	167	6	1,294	1,359	1,210	53
Boron	.86	.79	6	.77	.87	.74	.05	5	78	99	165	.13
Carbonate	10.8	<1 0	6	38.7	53.3	24.1	11.7	6	44.9	63.2	25.9	12.3
Calcium	7.30	6.50	6	5.75	7.00	4.78	.74	6	6.32	10.0	4.78	1.9
Chloride	8.34	8.12	6	7.10	8.14	5.79	.81	6	6.97	8.14	6.09	.77
Conductivity (µ mhos/cm)	2,275	2,200	6	2,113	2,620	1,620	325	6	2,150	2,500	2,000	179
Dissolved Organic Carbon	4.7	3.9	6	3.8	5.0	<2	1 1	6	3.9	6.0	2.0	1.4
Dissolved Oxygen	4.0	9.0	6	4.7	5.7	4.0	.7	6	5.3	7.0	4.3	1.1
Fluoride	15.3	15.3	6	17.5	19.8	11.1	3.3	6	17.7	19.7	12.2	2.8
Iron	.08	.05	6	.09	.21	<.01	.08	6	.14	.31	<.01	.12
Magnesium	4.40	4.60	6	4.50	5.38	3.80	.60	6	4.52	5.7	3.94	.65
Molybdenum	<.1	<.1	6	.38	.88	<.03	.43	6	.33	.80	<.03	.41
Nitrate	1.2	1.5	6	2.95	4.12	1.20	1.35	6	5.72	5.8	<1 0	4.5
Potassium	4.3	4.1	6	2.54	4 67	1.65	1.13	6	2.63	5 7	3.94	1.21
Residues												
-Total Dissolved	1,354	1,517	6	1,269	1,380	912	179	6	1,347	1,398	1,206	71
-Total Suspended	565	6	5	7.0	8.0	<4	1.4	6	5	5.0	<4	
-Total Solids	1,919	1,523	6	1,300	1,424	958	173	6	1,381	1,439	1,342	36
-Total Volatile	320	297	5	141	194	88	42	5	153	244	96	59
-Settleable Matter	4.5	<.1	6	<.1	<.1	<.1		6	BDL	(<.1)		
Temperature (°C)	13.0	15.5	6	19.3	23.5	16	3.3	6	17.5	23	12	4.8
Selenium	<0.1	<.01	6	BDL	(<.002)			6	BDL	(<.01)		
Silica	23	35	5	6.88	7.30	6.12	.49	5	6.5	7.5	5.6	.73
Sodium	540	540	6	520	578	391	66	6	549	578	522	18
Sulfate	176	311	6	15.9	22.6	10.9	3.97	6	20.0	50.3	6.0	15.4
Vanadium	<.5	<.5	3	BDL	(<.005)			3	BDL	(<.005)		
Acidity	<5	<5	6	3.93	5.30	2.63	1.08	6	3.93	6.2	2.6	1.30
Alkalinity	1,147	926	6	1,061	1,160	775	147	6	1,135	1,190	1,070	44
pH (Units)	9.2	7.8	6	8.3	8.8	8.0	.3	6	8.5	9.2	8.2	.4

*In mg/l, unless otherwise indicated.

BDL: Below Detection Limits, with detection limits in parenthesis.

Table 4. *Comparison of Tract C-a Ground-Water Baseline Data and Federal Drinking Water Standards with Holding Pond Data Collected During This Study*

	Baseline Data (Tract C-a)[6]				Tract C-a Data							
	Groundwater Upper Aquifer		Groundwater Lower Aquifer		Inflow to Jeffery Pond		West Retention Pond Inflow		West Retention Pond Outflow		Federal Drinking Water Quality Standards[1]	
Constituent*	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Primary[2] (40CFR Part 141)	Secondary[3] (40CFR Part 143)
Ammonia	0 37	1.8	0.35	2.0	0 30	0 47	0.22	0 32	0 24	0 42		
Arsenic	0 01	0 04	BDL[4]	<0 01	BDL	<0.003	BDL	<0.003	BDL	<0.003	05	
Bicarbonate	744	2,760	599	2,980	555	599	535	548	517	558		
Boron	0 75	4.8	1.21	20 0	0 21	0 41	0 34	0 80	0 33	0.90		
Carbonate	0 98	66	1.25	84	6.33	9.09	7.09	11 4	7 5	10 4		
Calcium	83.5	260	28.2	98 0	38.8	48 7	41 0	63 5	41 4	62		
Chloride	16.9	69	19.2	96	8 06	8.52	8.4	9 47	7.96	9 47		250
Conductivity (µ mhos/cm)	1,702	2,610	1,258	3,600	1,590	2,250	1,434	1,510	1,409	1,475		
Dissolved						250						
Organic Carbon	10 2	35	11 8	37	3 5	4 7	3 5	4	3 3	3 8		
Dissolved Oxygen	-	-	-	-	4.0	6 8	05	8 5	5 8	8.0		
Fluoride	0.37	1 8	6.35	32	1 35	1 71	1.34	1 7	1 24	1 32	2 0 - 2 2[5]	
Iron	6 3	18 0	3 45	16 2	0 19	1 0	0.18	0 59	0.29	0 64	0 3	
Magnesium	59 3	155	38 2	130	80.1	95.0	82.0	98 9	82.3	100 9		
Molybdenum	-	-	-	-	0 06	0 107	0 16	0 3	0 23	0.24		
Nitrate	0.50	4 5	0.47	2.0	0 53	2.02	1 83	8 59	0 39	0 77	10	
Potassium	-	-	-	-	0 62	1 26	0 76	1 24	0 84	1 49		
Residues												
-Total Dissolved	1,267	2,790	976	3,360	994	1,152	1,134	1,446	1,177	1,392		
-Total Suspended	-	-	-	-	BDL	<4	6 3	10	BDL	<4		
-Total Solids	-	-	-	-	1,071	1,208	1,153	1,446	1,185	1,395		
-Total Volatile	-	-	-	-	197	226	198	252	187	225		
-Settleable Matter	-	-	-	-	BDL	<0 1	BDL	<0 1	BDL	<0 1	0 01	
Temperature (°C)	-	-	-	-	14 3	19	14 5	23	13 9	20		
Selenium	BDL	<0.01	BDL	<0 01	BDL	<0 01	BDL	<0.01	BDL	<0.01		
Silica	32 8	58	10.8	32	13 9	23	13 2	22	11 6	12 8		
Sodium	301.8	1,170	284	1,320	191	200	190	198	192	198		
Sulfate	474	900	250	600	402	430	342	441	377	449		250
Vanadium	-	-	-	-	BDL	<0 005	BDL	<0 005	BDL	<0 005		
Acidity	-	-	-	-	5 1	9.45	3 86	4 99	3 57	4 96		
Alkalinity	654	2,343	558	2,540	469	506	456	474	439	470		
pH (Units)	6 78	8.8	7 1	10.2	7 7	9.2	7 6	9.0	7.6	8 9		6 5 - 8 5

*Values in mg/l unless otherwise indicated.
[1]Provided as a reference point. Not intended to imply that discharge should meet Drinking Water Standards.
[2]Federally Enforceable - Federal Register - EPA Water Programs, Wednesday, December 24, 1975 (Vol 40, No 248).
[3]Not Federally Enforceable - Federal Register - EPA Water Programs, Thursday, July 19, 1979 (Vol 44, No 140)
[4]BDL = Below Detection Limit.
[5]Dependent on Temperature (Average of maximum daily air temperatures).
[6]Source Rio Blanco Oil Shale Company, 1977

Table 5. *Comparision of Tract C-b Ground Water and Surface Water Baseline Data and Federal Drinking Water Standards with Holding Pond Data Collected During This Study*

	Baseline Data - (Tract C-b)								Tract C-b Holding Pond Data					
	Ground Water[6]				Surface Water[7]				No Chemical Treatment				Sulfuric Acid and Flocculant	
	Upper Aquifer		Lower Aquifer		Piceance Creek Above Tract C-b		Piceance Creek Below Tract C-b		Inflow to Pond A		Outflow from Pond B		Inflow to Pond A	Outflow from Pond B
Constituents*	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value	Mean Value	High Value		
Ammonia	7.9	1 2	17	200	0 04	0 13	0 02	0 09	0 37	0 69	0.33	0 372	90	1 33
Arsenic	0 01	0 06	0 02	0 02	2 1	5 0	2 1	5 0	BDL[4]	<0 003	BDL	<0 003	<.01	<.01
Bicarbonate	790	2,100	4,000	25,000	523	602	572	678	1,217	1,350	1,294	1,359	1,135	1,069
Boron	1 4	18	36	400	0 194	0 29	0 183	0 270	77	0 87	78	0 99	86	79
Carbonate	21	76	220	2,000	1 5	32	1 5	39	38 7	53 3	44 9	63 2	10 8	<1 0
Calcium	32	120	14	220	68 9	79	78 7	87	5 75	7 00	6.32	10 0	7 30	6 50
Chloride	26	510	1,200	9,800	15 5	24	13 5	16	7 10	8 14	6.97	8 14	8 34	8 12
Conductivity (µ mhos/cm)	1,670	4,200	7,240	45,000	1,099	1,410	1,324	1,560	2,113	2,500	2,150	2,500	2,275	2,200
Dissolved Organic Carbon	-	-	23	175	-	-	-	-	3 8	5 0	3.9	6.0	4 7	3.9
Dissolved Oxygen	-	-	-	-	9 9	13	9 7	16 0	4 7	5 7	5.3	7 0	4 0	9 0
Fluoride	10	190	21	48	0 98	1 3	0 6	0 9	17 5	19 8	17 7	19 7	15 3	15 3
Iron	0.5	7	0 8	8.0	0 07	0 39	0 04	0 46	09	0 21	14	0 311	08	05
Magnesium	42	150	11	110	46 2	56	65 9	82 0	4 50	5 38	4 52	5 7	4 40	4 60
Molybdenum	0 02	0 1	0 04	0 2	0 0104	0 016	0 0097	0 014	38	0 883	33	0 80	<.1	<.1
Nitrate	0 41	2 9	0 46	3 4	0 33	0 83	0 39	0 79	2 95	4 12	5 72	5 8	1 2	1 5
Potassium	2 2	11	21	120	3 7	19	3 7	5 0	2 54	4 67	2 63	5 7	4 3	4 1
Residues														
-Total Dissolved	1,100	3,100	6,190	42,000	698	762	893	1,050	1,269	1,380	1,347	1,398	1,354	1,517
-Total Suspended	-	-	-	-	-	-	-	-	7 0	8 0	5 0	5 0	565	6
-Total Solids	-	-	-	-	-	-	-	-	1,300	1,424	1,381	1,439	1,919	1,523
-Total Volatile	-	-	-	-	-	-	-	-	141	194	153	244	320	297
-Settleable Matter	-	-	-	-	-	-	-	-	<.1	<.1	BDL	<0.1	4 5	<.1
-Temperature (°C)	-	-	-	-	8 7	22	9 1	21 1	19 3	23 5	17 5	23 0	13 0	15 5
Selenium	0 006	0 03	0 004	0 02	0 001	0 002	0 001	0 002	BDL	<0 002	BDL	<0 01	<.01	<.01
Silica	17	32	13	38	15	18	17	20	6 88	7 30	6 5	7 5	23	35
Sodium	330	1,200	2,500	17,000	115 4	150	148	180	520	578	549	578	540	540
Sulfate	220	520	63	350	161	190	239	330	15 9	22 6	20 0	50 3	176	311
Vanadium	0 002	0 006	0 01	0 1	BDL	<0 003	0 002	0 006	BDL	<0 005	BDL	<0 005	<.5	<.5
Acidity	-	-	-	-	-	-	-	-	3 93	5 3	3 93	6 2	<5	<5
Alkalinity	-	-	-	-	432	494	472	544	1,061	1,160	1,135	1,190	1,147	926
pH (Units)	8 6	9 1	8 7	9 3	8 3	8 7	8 3	9 2	8 3	8 8	8 5	9 2	9 2	7 8

*Values in mg/l except as noted

[1] Provided as a reference point Not intended to imply that discharge should meet Drinking Water Standards

[2] Federally Enforceable - Federal Register - EPA Water Programs, Wednesday, December 24, 1975 (Vol 40, No 248)

[3] Not Federally Enforceable - Federal Register - EPA Water Programs, Thursday, July 19, 1979 (Vol 44, No 140)

[4] BDL = Below Detection Limit

[5] Dependent on Temperature (Average of maximum daily air temperatures)

[6] Source C-b Shale Oil Venture, 1977

[7] Source USGS, 1977

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Table 5. *(Continued)*

Constituents*	Federal Drinking Water Quality Standards[1] Primary[2] (40CFR Part 141)	Secondary[3] (40CFR Part 143)
Ammonia		
Arsenic	05	
Bicarbonate		
Boron		
Carbonate		
Calcium		
Chloride		250
Conductivity (μ mhos/cm)		
Dissolved Organic Carbon		
Dissolved Oxygen		
Fluoride	2 0 - 2 2[5]	
Iron	0 3	
Magnesium		
Molybdenum		
Nitrate	10	
Potassium		
Residues		
-Total Dissolved		
-Total Suspended		
-Total Solids		
-Total Volatile		
-Settleable Matter		
-Temperature (°C)		
Selenium	0 01	
Silica		
Sodium		
Sulfate		250
Vanadium		
Acidity		
Alkalinity		
pH (Units)		6 5 - 8 5

*Values in mg/l except as noted
[1] Provided as a reference point Not intended to imply that discharge should meet Drinking Water Standards
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[5] Dependent on Temperature (Average of maximum daily air temperatures)
[6] Source C-b Shale Oil Venture, 1977
[7] Source USGS, 1977

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The complete report, entitled "Characterization of Oil Shale Mine Waters, Central Piceance Basin, Colorado," (Order No. PB 84-211 283; Cost: $11.50, subject to change) will be available only from:
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