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MASTER

EVALUATION OF MINE WATER EFFLUENT FROM IOWA COAL PROJECT DEMONSTRATION MINE # 1 AND ENVIRONMENTAL RAMIFICATIONS

L.V.A. Sendlein

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IOWA STATE UNIVERSITY Ames, Iowa 50011

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Evaluation of Mine Water Effluent From Iowa Coal Project Demonstration Mine # 1 and Environmental Ramifications

A Report for
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by

L. V. A. Sendlein
Professor of Geology
Iowa State University
Ames, Iowa 50011
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INTRODUCTION

This report documents the initial work performed at Iowa Coal Project Demonstration Mine # 1 (ICPDM #1) over the period July 21, 1975 to December 31, 1976. Data are presently being collected and will be continued through June 20, 1977 with the possibility that sampling will continue through 1982 on selected well and stream stations.

ACKNOWLEDGEMENTS

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STUDY SITE

The Iowa Coal Project research mine is located in the small watershed of Coal Creek, a tributary of the Des Moines River (Figure 1). The mine is located on a 40 acre site and will produce 135,000 tons of coal over a two year period, ending July 1, 1977.

The Iowa Coal Project Demonstration Mine #1 contains two coal seams beneath the 40 acre site. The upper seam of usable coal is approximately five feet thick and covers an area of about five acres. The lower seam is about three feet thick and covers approximately 20 acres. The site chosen was leased for five years by the coal project, and is considered to be an excellent area for demonstration because it is located between two strip mines operated under different conditions.

In order to monitor water quality of the site, surface and subsurface sampling stations were established. Figures 2a and 2b show the location of these stations. Overburden characteristics were determined by analyses of rock cores obtained from eight holes located on Figure 2b. The final configuration of the land surface is shown in Figure 3a and the idealized cross section is shown in Figure 3b.

RESULTS

The results are tabulated in the appendix and divided into:

1. surface water
2. ground water
3. overburden analysis
4. coal analysis

Surface Water: The sampling network shown in Figure 2a was set up in July, 1975. The mining activities began in August of 1975 so very little baseline data were obtained prior to mining. The first coal was not removed until September, 1975. The sampling network was designed to measure the active mines in the watershed. Station 10 is upstream from an active coal mining pit, Station 21 is downstream from the active mine and upstream from ICPDM #1, Stations 32 and 40 are 10 meters upstream and 10 meters downstream from the discharge pipe from the ICPDM #1 sediment pond which is the only outlet for effluent from ICPDM #1. Station 53 is approximately 2,000 feet downstream from ICPDM #1.

Preliminary presence of trace elements in the stream was obtained by Neutron Activation and Inductively - Coupled Plasma Optical Emmission Spectroscopy and reported in Appendix Table 1-A. Quantitative determinations will be made on a station series periodically during mining. These determinations are under analysis at the present time.

After looking at several complete analyses (Table 1-B), it was decided that pH, acidity/alkalinity, conductance and SO_4 would measure the sediment pond and stream quality variation over time (Table I-C). Figure 4 illustrates the variation of pH for the sediment pond and stream station 32, 10 meters upstream from the discharge pipe. Several observations can be made:

1. The stream quality is highly variable.

2. The stream and pond quality are not related. On only one occasion, when the pond failed, did the effluent from ICPDM #1 appear to affect the stream quality.

3. The sediment pond went acid very abruptly. This was due to a very dry period prior to March 30, 1976 and heavy rains during the period from March 30 to April 23, 1976.

Figure 5 illustrates the difference in pH between the two stations which bracket the ICPDM #1 effluent pipe. Note that there were times when it appeared that the pond effluent increased pH and the pond failure caused a decrease in the stream pH but over the longer period of operation no real difference was apparent.

Ground Water: The groundwater network is shown in Figure 2b. Sampling wells have been placed in replaced spoil, undisturbed overburden, undisturbed bedrock, and at various elevations in the aquifers to obtain water level and water quality data. Appendix Table II-A includes all the data collected to date. Trace elements will be run on all wells at the same time surface water analyses are made.

The ground water research at the ICPDM #1 has shown a five-foot recovery of the water table in the spoil replaced in previous mining cuts. The quality of this water ranges from very poor near a black shale storage pile to a quality approaching that of the premining environment. Sulfate and total hardness values range from 100 mg/l to 250 mg/l respectively near the southwest edge of the refill mining area and 950 mg/l to 1860 mg/l near black shale storage piles along the eastern side of the replaced spoil. The water quality from piezometers around the sediment retention pond shows no significant change since the beginning of mining except for an increase in iron concentrations from a few tenths of milligrams per liter to a few milligrams per liter. Along the north and east side of the mining site, the ground water quality has remained fairly constant although the water levels in piezometers along the north side of the mine have dropped as the cuts have moved closer to them.

Overburden: The overburden was studied in detail prior to mining. The site has geologic materials which include the following:

loess	0-1 meter
glacial till	0-5 meters
weathered shales	0-2 meters
alluvium	0-10 meters
shale (black)	15-20 meters
siltstone	0-8 meters
limestone	0-2 meters
coal	1-2.5 meters

Figure 6 is a typical cross section through the site to give an idea of the stratigraphic position of the above materials.

The analysis of the overburden was carried out on only the rock overburden because we plan to return all non-rock overburden to the surface because of its non-toxic character. This means that approximately 3 meters of non-toxic glacial till-loess-weathered shale overburden will be placed over the toxic black shales and siltstones.

The overburden analysis is included in Appendix Table III and includes the rationale for methods used to arrive at the data presented.

Coal Analysis: In order to determine the quality of coal in situ an extensive sampling program is being carried out at ICPDM #1. Figure 7 illustrates the sample pattern where 500 pound samples were obtained and will be obtained as mining continues. The proximate analysis for 35 samples analyzed to present is shown in Appendix Table IV-A.

The trace analyses of low temperature ash of coal are presented in Appendix Table IV-B.

Summary: The monitoring of ICPDM #1 will continue through October, 1977 under the present funding. Continued support will be available as long as agricultural experiments are carried out on the site. This research is expected to continue until 1982. The long term accumulation of data should provide the kind of data required to establish the affect of strip mining on surface and subsurface water.

This report represents the ongoing data collection program and illustrates that, during the period measured, uncontrolled mining (no sediment control structure) caused the stream to be affected over a short distance (approximately 4,000 feet) whereas effluent from the sediment pond of ICPDM #1 did not negatively affect the stream except during failure of the pond. It should be pointed out that data need be collected over a longer period of time while the pond is in an acid condition to determine if treatment of the pond will be required.

Figure 1 Coal Mining Activities Coal Creek Watershed

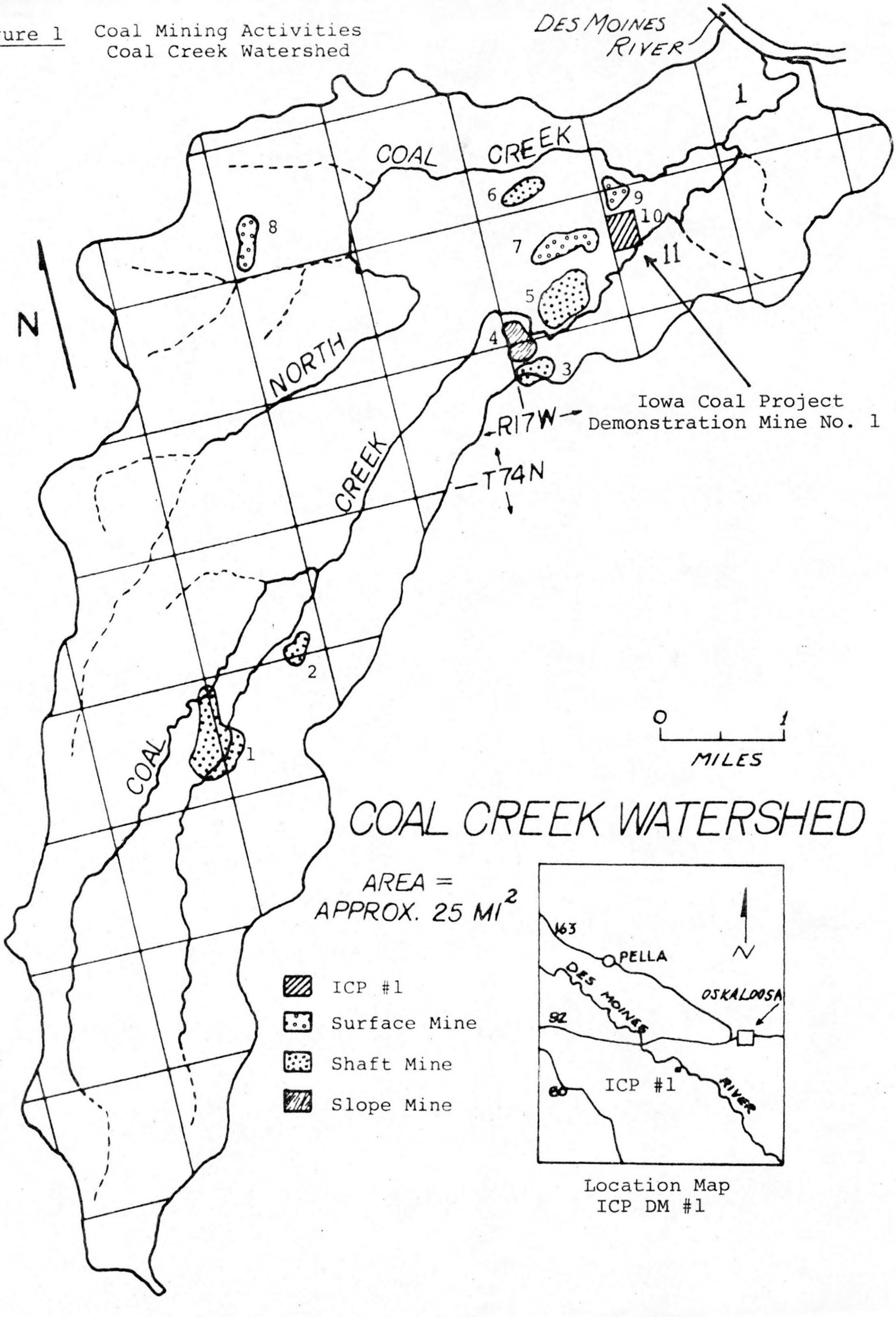


Figure 2a

Surface Water Monitoring Stations
Iowa Coal Project No. 1

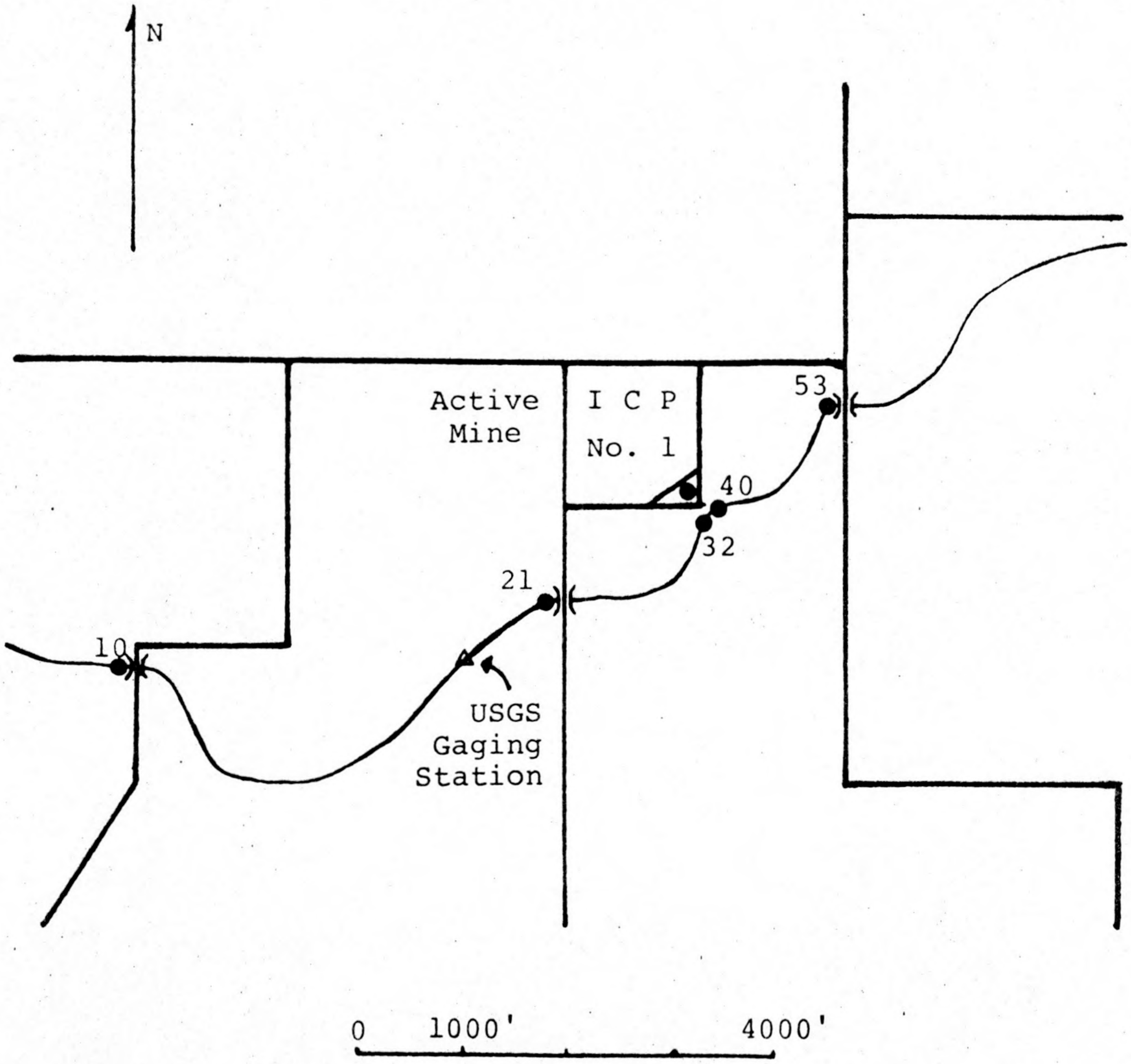


Figure 2b Overburden Core Holes and Ground Water Wells

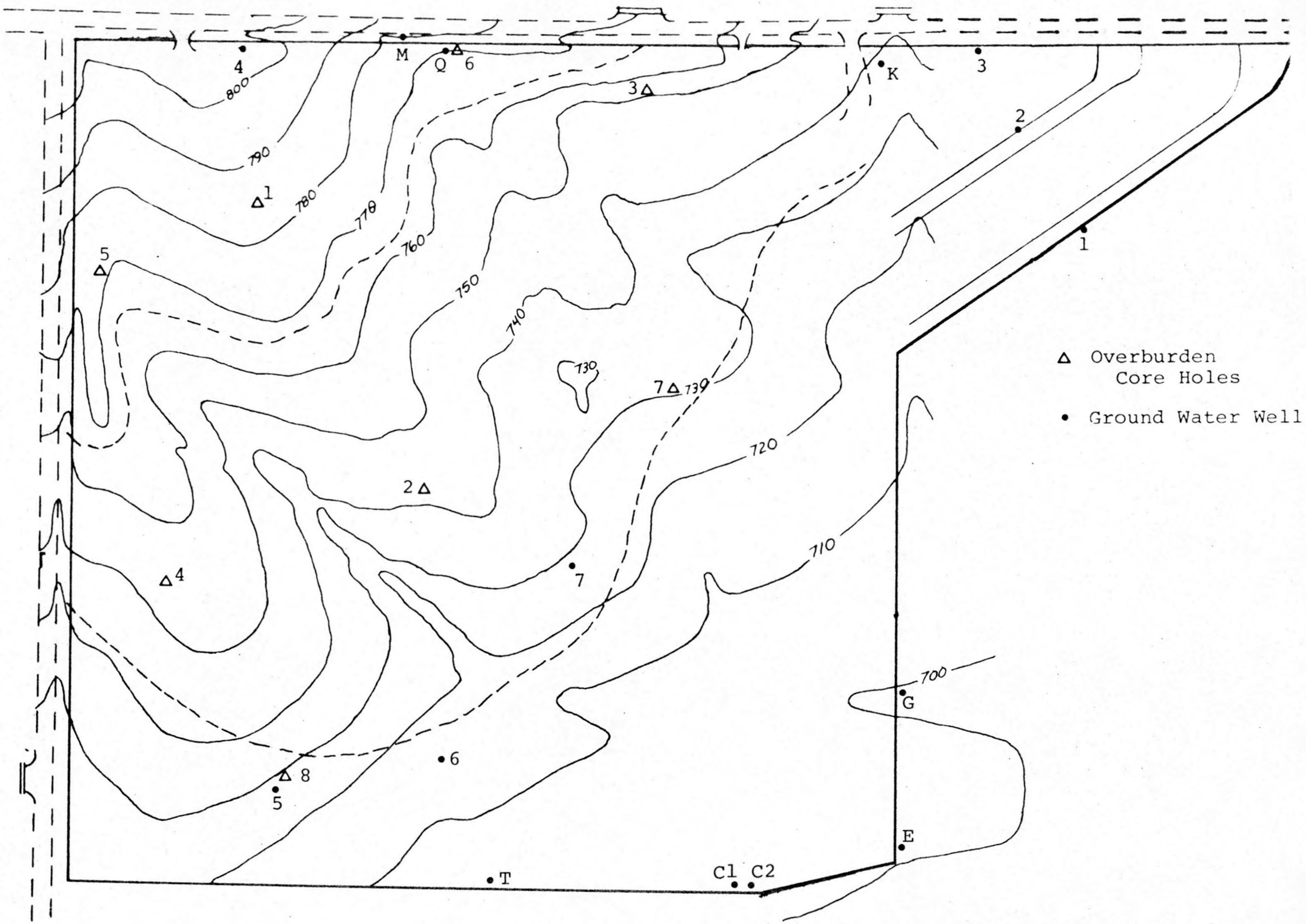


Figure 3a Final Terraced Restoration Plan

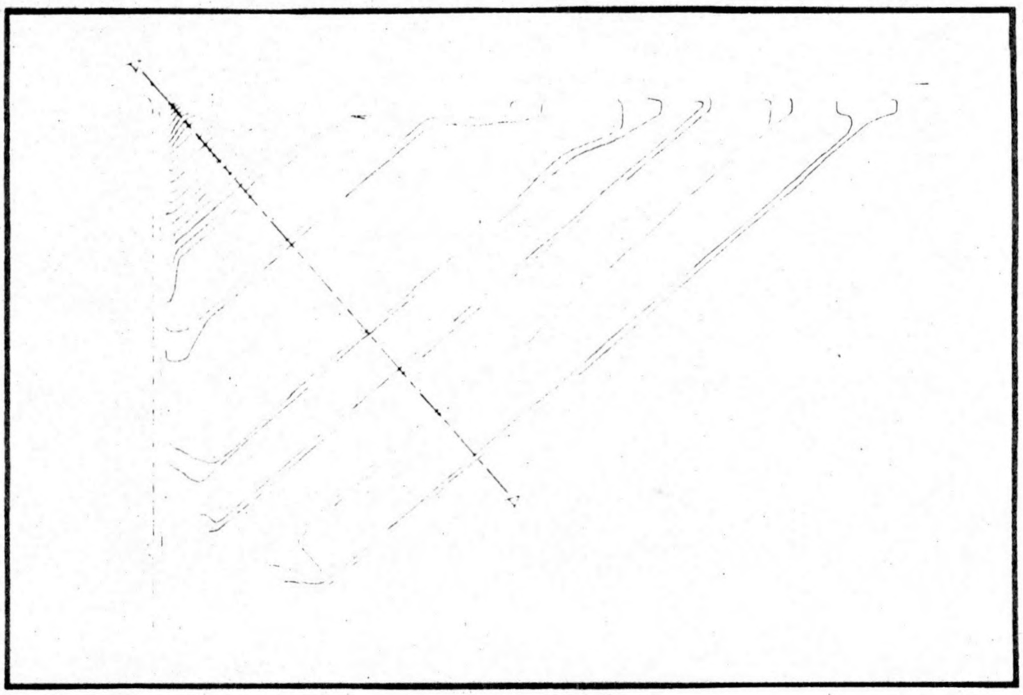


Figure 3b Cross Section of Restoration Plan

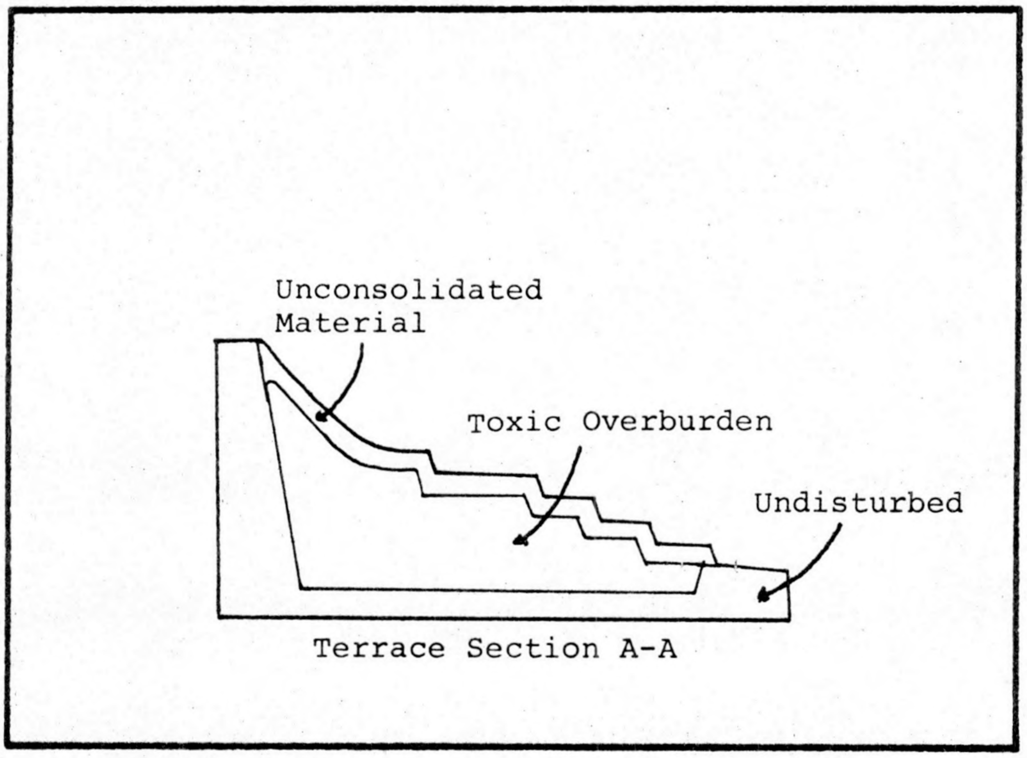


Figure 4 pH Variation Between the Sediment Pond and Coal Creek Station 32

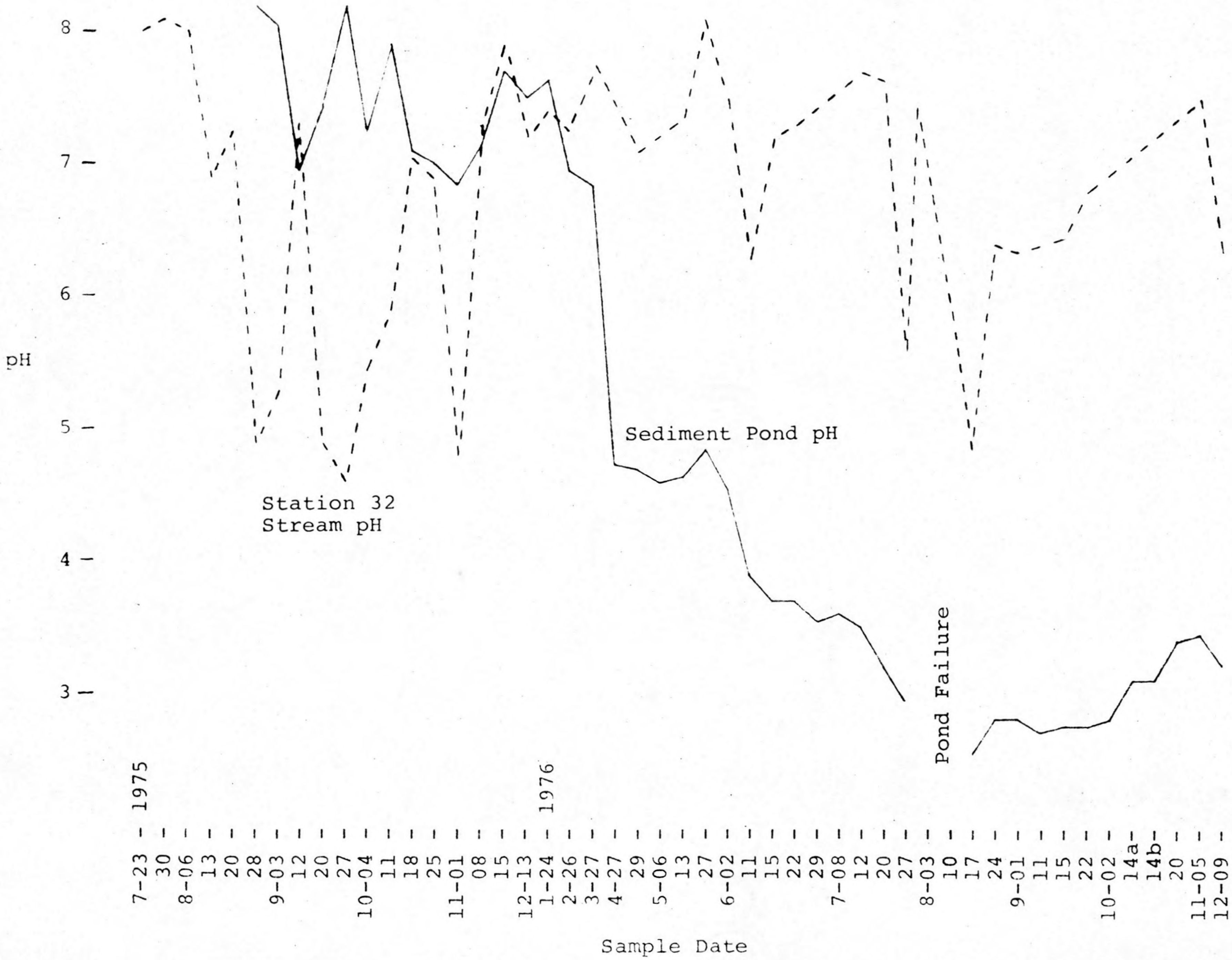


Figure 5 pH Difference Between Coal Creek Stations 32 and 40

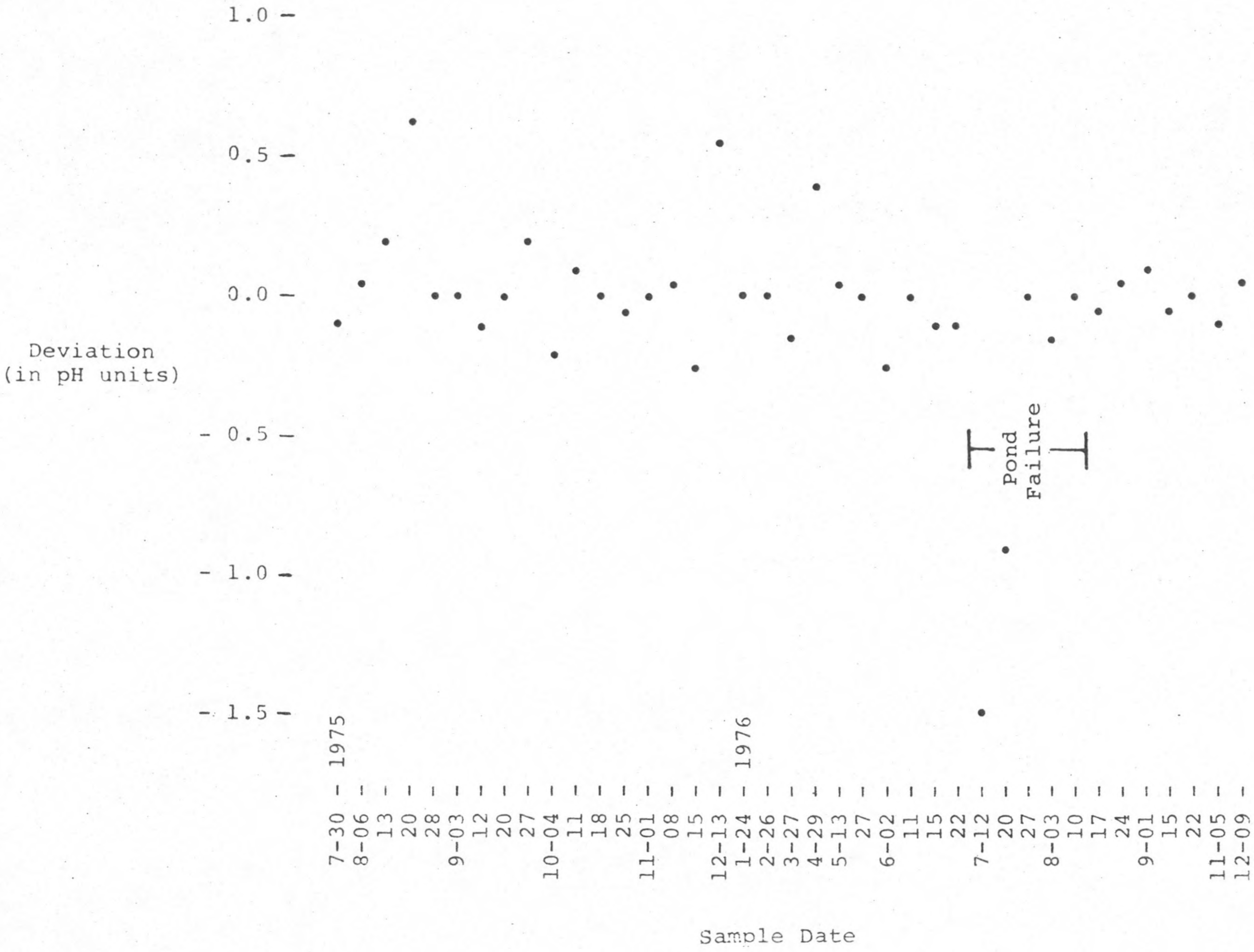


Figure 6 Overburden Cross Section

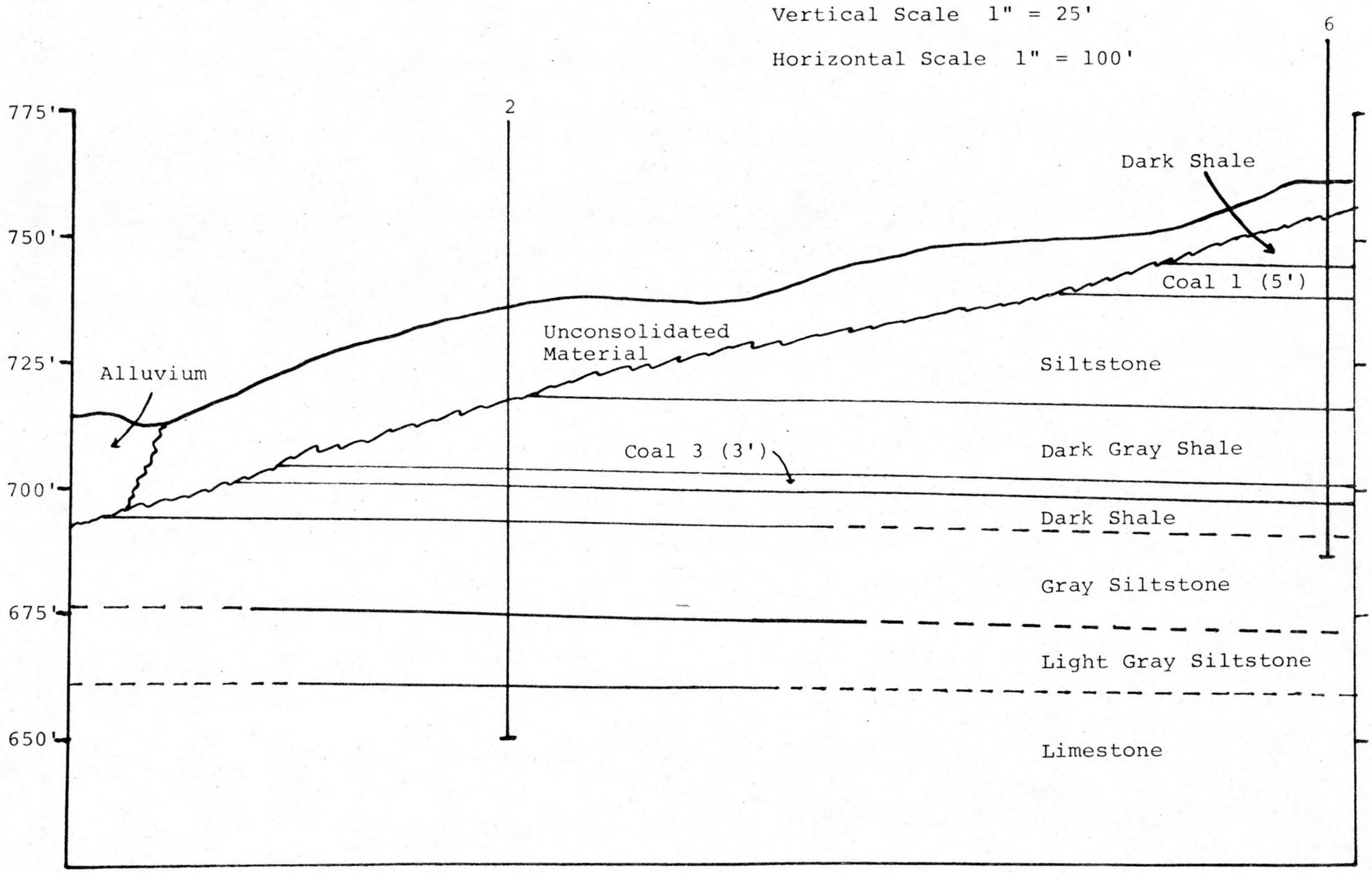
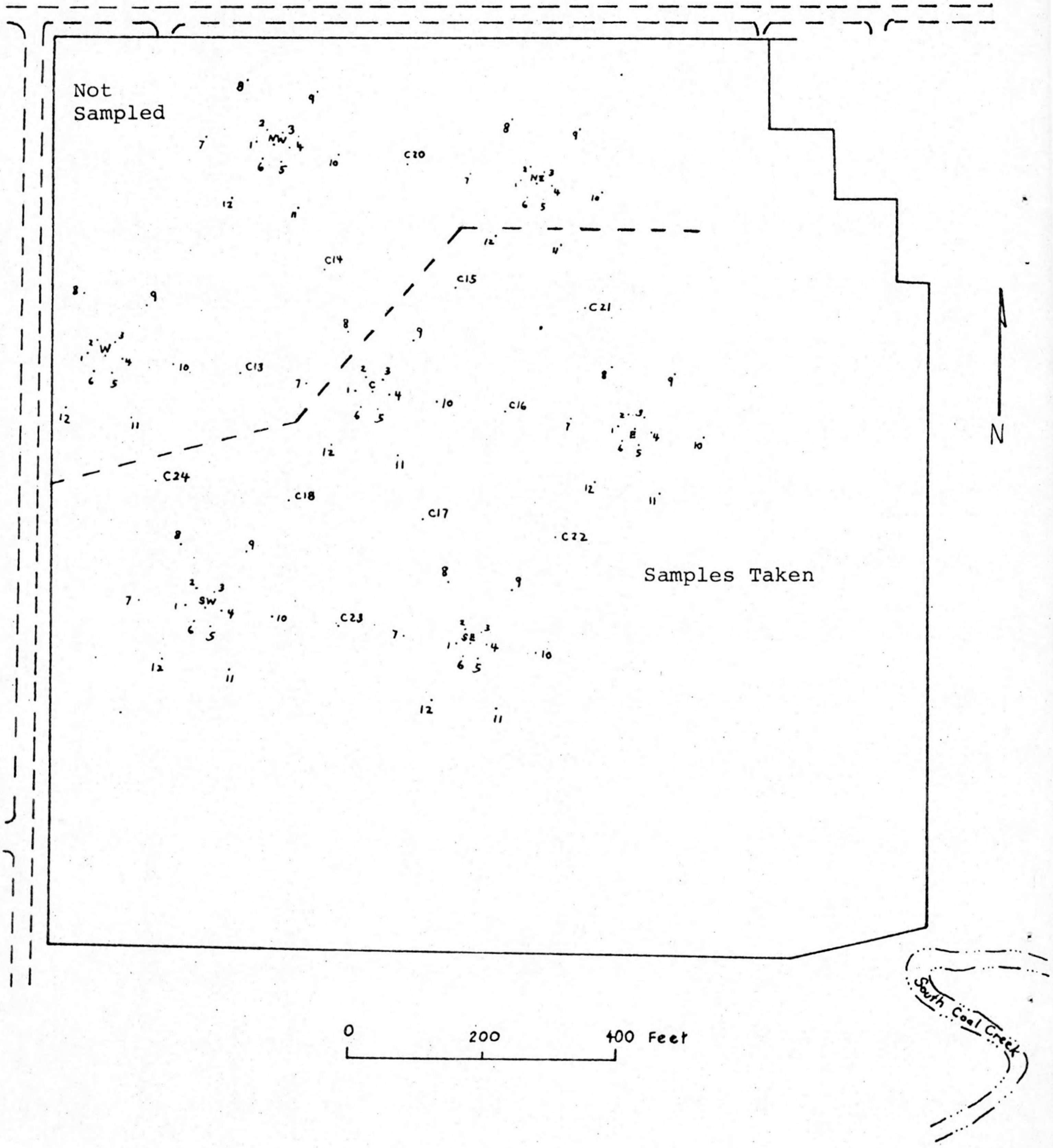


Figure 7 Coal Sampling Grid

Coal Sampling Project
Demonstration Mine Number 1



APPENDIX Research Results

I Surface Water

II Ground Water

III Overburden Analysis

IV Coal Analysis

Table I-A Trace Metal Analyses for the Settling Pond and Three Coal Creek Stations (all units µg/liter)

Element	S.P.	10	21	53
Ag	P	P	P	P
Al	24000	3300	18000	5800
As	2.3		22	
Ce	49		349	39
Co	5.4	6.7	875	229
Cr		580		
Eu	0.67		19	1.7
Fe	9340	13100	100000	5130
Hg	8.8	6.3		9.3
K	5100	11000	9000	12000
La	120	2.4	48	46
Lu	0.1		2.7	0.2
Mn	100	870	28000	18000
Na	2500	18000	17000	12000
Nd	8.6		120	10
Sb		6.1		
Sc	4.7	0.27	20	28
Se		23		
Sm	3.9	47	37	5.6
Tb	1.0		15	1.5
V	36			40
Yb			13	3.8
Zn			3530	900

analysis by Neutron Activation

Al	2400	700	27000	4500
B	30	200	340	280
Ba	90	110	46	76
Be			7	2
Ca	9800	100000	290000	222000
Cd			20	
Cr			45	21
Cu	3	26	32	11
Fe	1700	500	30000	400
Mg	4200	26000	140000	90000
Mn	<100	400	15000	7800
Ni			1100	530
Sr	100	480	810	710
Zn			1800	860
K	~2000	~12000	~11000	~12000
Na	~6000	~40000	~40000	~40000

analysis by Inductively-Coupled Plasma Optical Emission Spectroscopy

Table I-B Surface Water Quality Analysis, July 30, 1975

Parameter	Coal Creek Stations 10	 21	 32	 40	 53
pH	8.18	8.13	8.10	8.00	8.35
Conductivity (μmhos/cm)	950	1000	1150	1400	1100
Alkalinity (mg $CaCO_3$/l)	235	140	140	120	130
Sulfate (mg/l)	500	650	650	1000	675
Water Temperature (^oC)	26	27	27	27	27
Dissolved Oxygen (mg/l)	9.6	12.5	10.4	11.6	12.8
Hardness (mg $CaCO_3$/l)	490	540	535	820	640
Nitrogen, ammonia (mg/l)	0.33	0.65	0.51	0.62	0.43
Nitrogen, nitrate (mg/l)	0.9	0.4	0.5	0.4	0.5
Phosphate, ortho (mg/l)	0.19	0.16	0.23	0.25	0.22
Turbidity (FTU)	22	19	18	12	20
Residue, Total (mg/l)	1034	1094	1116	1609	1135
Residue, Non-filterable (mg/l)	36	19	43	13	41
Residue, Filterable (mg/l) (by subtraction)	998	1075	1073	1596	1094
Iron[a] (mg/l)	0.61	3.58	2.14	1.03	0.53
Aluminum[a] (mg/l)	0.7	6.7	6.4	6.5	2.8
Manganese[a] (mg/l)	0.93	9.6	8.9	8.9	6.2
Zinc[a] (mg/l)	0.005	0.50	0.38	0.38	0.25

[a] Means of 8 samples during July and August, 1975. Analysis by Atomic Absorption.

Table I-C   Surface Water Quality Data

Selected water quality parameters, Iowa Coal Project Demonstration Mine #1 settling pond, August 28, 1975 to December 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)		Sulfate (mg/l)
8-28	8.20	110	15	0	75
9-3	8.05	120	10	5	30
9-12	6.95	110	5	5	43
9-20	7.45	145	5	5	50
9-27	8.20	200	10	0	44
10-4	7.25	200	5	5	50
10-11	7.90	195	10	5	54
10-18	7.10	150	5	0	54
10-25	7.00	150	5	5	80
11-1	6.85	135	5	5	80
11-8	7.15	200	5	5	60
11-15	7.70	180	5	0	80
12-13	7.50	145	10	0	100
1-24	7.65	280	5	0	115
2-26	6.95	230	10	5	90
3-27	6.85	240	5	5	96
4-27	4.75	325		12	154
4-29	4.70	400		14	188
5-6	4.60	500		18	192
5-13	4.65	500		9	260
5-27	4.85	500		19	287

ICP Settling Pond Continued:

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)	Sulfate (mg/l)
6-2	4.55	500	20	245
6-11	3.90	640	30	275
6-15	3.70	750	38	260
6-22	3.70	845	38	430
6-29	3.55	900	47	570
7-8	3.60	840	55	610
7-12	3.50	900	46	625
7-20	3.20	1250	100	890
7-27	2.95	1260		
8-17	2.55	2000	348	1200
8-24	2.80	2000	356	1190
9-1	2.80	1870	353	1365
9-11	2.70	1700	480	1675
9-15	2.75	2500	543	1850
9-22	2.75	2500	501	1830
10-2	2.80	2000	503	1780
10-7	Pond treated with 4200 pounds of agricultural limestone			
10-14[a]	3.10	1850	414	1305
10-14[b]	3.10	1800	341	1230
10-20	3.40	1850	338	1200
11-5	3.45	2000	270	1200
12-9	3.20	2500	327	1230

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[a] Before 2nd limestone treatment (3500 lbs. agricultural limestone)

[b] After 2nd treatment

Selected water quality parameters, Station 10 (2.4 km upstream from Iowa Coal Project Demonstration Mine #1), July 30, 1975 to December 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l)
7-30	8.18	950	235	500
8-6	8.05	1000	250	475
8-13	8.10	1050	214	575
8-20	7.67	1100	210	725
8-28	7.50	1000	215	650
9-3	8.50	700	185	425
9-12	7.50	850	190	400
9-20	7.30	675	140	375
9-27	7.10	750	140	400
10-4	7.20	600	160	225
10-11	7.00	700	170	350
10-18	7.10	900	220	500
10-25	7.25	750	230	575
11-1	7.45	950	250	875
11-8	7.30	1200	260	800
11-15	7.70	950	240	600
12-13	7.25	800	210	270
1-24	7.55	1300	320	600
2-26	7.15	600	120	225
3-27	7.85	900	165	385
4-29	7.20	670	138	128
5-13	7.50	810	169	345

Station 10 Continued:

Date	pH	Conductivity (micromhos/cm)	Alkalinity (mg/l as $CaCO_3$)	Sulfate (mg/l)
5-27	8.20	780	197	303
6-2	7.60	750	182	850
6-11	6.30	650	110	900
6-15	7.25	360		
6-22	7.70	890	205	850
7-12	8.00	900	203	830
7-20	7.85	520	195	900
7-27	5.65	660	43	1100
8-3	8.00	480	205	665
8-10	5.70	800	45	240
8-17	4.75	400	20	260
8-24	6.40	590	115	400
9-1	5.95	610	53	380
9-15	6.50	700	160	600
9-22	6.90	850	249	860
11-5	7.75	1300	294	830
12-9	6.40	1500	150	680

Selected water quality parameters, Station 21 (0.8 km upstream from Iowa Coal Project Demonstration Mine #1), July 23, 1975 to Dec. 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)		Sulfate (mg/l)
7-23	8.00	1800	80		1150
7-30	8.13	1000	140		650
8-6	8.00	1250	135		675
8-13	4.10	1925		91	1750
8-20	7.02	1150	55		850
8-28	3.90	1650		200	1575
9-3	4.30	1560		250	1575
9-12	7.20	750	100		425
9-20	5.00	1450		190	1125
9-27	3.45	2100		340	1850
10-4	5.30	1300		80	1000
10-11	6.05	1150	5	50	950
10-18	6.30	1350	5	65	1025
10-25	6.85	950	70		625
11-1	6.30	1000	20	5	900
11-8	7.45	1100	180		650
11-15	7.55	1050	210		550
12-13	7.20	850	140		230
1-24	7.35	1450	275		750
2-26	7.15	600	115		250
3-27	7.90	860	135		395
4-29	7.05	740	128		150

Station 21 Continued:

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)	Sulfate (mg/l)
5-13	6.90	1200	102	683
5-27	8.00	800	149	347
6-2	7.35	850	135	960
6-11	6.25	750	110	1225
6-15	7.10	600		
6-22	7.00	925	118	
7-12	7.60	1150	123	730
7-20	7.75	1300	145	1050
7-27	5.60	860	80	1100
8-3	7.85	490	147	810
8-10	5.70	600	85	830
8-17	4.50	1700		1275
8-24	6.50	440	123	850
9-1	6.30	650	108	900
9-15	6.45	1700	105	1150
9-22	6.80	1325	105	1050
11-5	7.55	1100	202	925
12-9	6.30	1450	110	900

Selected water quality parameters, Station 32, (10 m upstream from Iowa Coal Project Demonstration Mine #1), July 23, 1975 to Dec. 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)		Sulfate (mg/l)
7-23	8.00	1750	90		1125
7-30	8.10	1150	140		650
8-6	8.00	1600	130		1000
8-13	6.90	1975	60		1750
8-20	7.25	1200	15		1100
8-28	4.90	1550		85	1475
9-3	5.30	1600		235	1575
9-12	7.30	750	85		425
9-20	4.90	1250		25	1125
9-27	4.60	2000		150	1200
10-4	5.45	1350		50	975
10-11	5.90	1225	10	10	875
10-18	7.05	1250	80		1250
10-25	6.90	1000	60		775
11-1	4.80	1900		390	1975
11-8	7.30	1150	165		775
11-15	7.90	1100	220		600
12-13	7.20	950	150		240
1-24	7.40	1450	250		750
2-26	7.25	600	95		275
3-27	7.75	960	118		450

Station 32 Continued:

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)	Sulfate (mg/l)
4-29	7.10	720	138	400
5-13	7.35	925	125	478
5-27	8.10	800	158	350
6-2	7.50	850	129	800
6-11	6.30	700	110	1220
6-15	7.20	480		
6-22	7.30	945	115	650
7-12	7.70	1225	97	800
7-20	7.65	670	139	415
7-27	5.60	840	78	260
8-3	7.45	600	111	905
8-10	5.90	670	73	260
8-17	4.85	1100		1170
8-24	6.40	730	118	650
9-1	6.35	870	115	600
9-15	6.45	1350	93	850
9-22	6.80	1150	140	650
11-5	7.50	1100	185	800
12-9	6.35	1525	125	320

Selected water quality parameters, Station 40 (10 m downstream from Iowa Coal Project Demonstration Mine #1), July 30, 1975 to December 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)		Sulfate (mg/l)
7-30	8.00	1400	120		1000
8-6	8.05	1750	130		1000
8-13	7.10	1975	64		1610
8-20	7.89	1200	15		1100
8-28	4.90	1500		85	1475
9-3	5.30	1500		235	1600
9-12	7.20	750	85		425
9-20	4.90	1300		30	1125
9-27	4.80	2000		145	1250
10-4	5.25	1350		50	975
10-11	6.00	1150	10	10	925
10-18	7.05	1200	19		1225
10-25	6.85	1050	55		800
11-1	4.80	1900		345	1975
11-8	7.35	1100	170		700
11-15	7.65	1150	200		600
12-13	7.75	1050	135		230
1-24	7.40	1550	250		750
2-26	7.25	600	95		275
3-27	7.60	960	115		470

Station 40 Continued:

Date	pH	Conductivity (micromhos /cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)	Sulfate (mg/l)
4-29	7.50	700	119	300
5-13	7.40	950	114	457
5-27	8.10	800	140	348
6-2	7.25	800	119	900
6-11	6.30	680	115	1225
6-15	7.10	480		
6-22	7.20	930	100	685
7-12	6.20	1100	84	755
7-20	6.75	840	92	675
7-27	5.60	850	73	250
8-3	7.30	580	105	855
8-10	5.90	660	75	265
8-17	4.80	1150	7	1050
8-24	6.45	730	130	650
9-1	6.45	800	125	600
9-15	6.40	1425	91	895
9-22	6.80	1175	111	650
11-5	7.40	1100	182	850
12-9	6.40	1475	137	360

Selected water quality parameters, Station 53 (1.1 km downstream from Iowa Coal Project Demonstration Mine #1), July 23, 1975 to December 9, 1976.

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)		Sulfate (mg/l)
7-23	8.15	1250	115		600
7-30	8.35	1100	130		675
8-6	8.25	1350	150		625
8-13	7.50	1190	105		675
8-20	7.65	1425	25		1500
8-28	6.20	1100	50		900
9-3	5.75	1900	5	105	1500
9-12	7.25	650	80		425
9-20	4.95	1350		20	1125
9-27	5.20	1500	5	70	1000
10-4	4.70	1700		55	1225
10-11	5.15	1550	5	50	1225
10-18	6.90	1400	10	20	1250
10-25	6.20	1300	20	5	1225
11-1	5.50	1200	20	5	925
11-8	6.70	1150	95		875
11-15	7.60	1200	200		650
12-13	7.30	950	135		220
1-24	7.40	1500	260		650
2-26	7.30	600	100		275
3-27	7.60	930	135		410

Table II Ground Water Quality Data

Station 53 Continued:

Date	pH	Conductivity (micromhos/cm)	Alkalinity/Acidity (mg/l as $CaCO_3$)	Sulfate (mg/l)
4-29	7.05	720	113	147
5-13	7.40	920	124	418
5-27	8.00	780	149	342
6-2	7.60	800	130	960
6-11	6.30	770	110	1250
6-15	7.20	450		
6-22	7.30	1120	93	720
7-12	6.30	1150	68	860
7-20	4.15	1030		890
7-27	5.85	590	38	860
8-3	7.40	575	118	1115
8-10	5.90	1350	71	860
8-17	4.95	525	12	1175
8-24	6.45	925	103	800
9-1	6.40	775	91	895
9-15	6.55	1250	105	1050
9-22	6.70	1175	178	825
11-5	7.25	1100	174	825
12-9	6.50	1550	138	475

IOWA COAL PROJECT DEMONSTRATION MINE NUMBER ONE

GROUNDWATER QUALITY DATA

Units of Analysis

Specific Conductance as parts per million Sodium Cloride

Chloride as milligrams per liter

Total Alkalinity as milligrams per liter as $CaCO_3$

Sulfate as milligrams per liter

Nitrate as milligrams per liter as Nitrate-Nitrogen

Total iron as milligrams per liter

Chemical Oxygen Demand as milligrams per liter

Total, Calcium, and Magnesium Hardness as milligrams per liter as $CaCO_3$

Water Depth in feet

Temperature in degrees Celsius

SAMPLE LOCATION: piez. C_1

SAMPLE DATE

CHEMICAL ANALYSIS	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	1/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
SPECIFIC CONDUCTANCE	110	125	215	---	---	190	210	175	160	140	200	305	210	250	245	275
pH	8.9	8.5	7.0	7.1	---	7.3	7.5	7.6	7.6	7.2	7.1	7.4	7.6	---	7.2	7.4
CHLORIDE	6.0	7.0	5.0	---	---	3.0	2.5	3.0	3.8	7.5	5.0	7.0	8.0	5.0	5.0	5.0
ALKALINITY	90	160	220	---	---	200	210	220	170	190	216	291	248	205	220	255
SULFATE	30.5	17.0	65.0	---	---	25.0	1.0	2.0	7.0	10.0	9.5	32.5	41.0	44.0	62.0	56.0
NITRATE	****	****	****	----	----	2.30	2.20	0.60	---	0.11	0.59	0.50	0.24	2.10	1.70	1.15
TOTAL IRON	21.0	0.4	0.5	----	----	1.0	1.6	1.1	2.0	2.5	5.5	0.2	18.0	----	10.0	6.0
CHEMICAL OXYGEN DEMAND	135.0	-----	-----	-----	-----	-----	13.1	13.5	13.7	9.3	42.7	-----	26.4	-----	15.0	-----
TOTAL HARDNESS as mg/l $CaCO_3$	100	120	220	---	---	160	175	150	150	150	173	200	240	150	260	230
CALCIUM HARDNESS as mg/l $CaCO_3$	60	90	140	---	---	110	120	100	100	100	122	144	155	70	90	140
MAGNESIUM HARDNESS as mg/l $CaCO_3$	40	30	80	---	---	50	55	50	50	50	51	56	85	80	170	90
WATER DEPTH	9.0	14.0	14.5	14.0	15.5	13.0	12.0	12.8	13.0	12.8	8.5	6.0	9.8	15.8	15.0	14.8
TEMPERATURE °C	17	15	16	14	11	10	11	9	11	12	11	12	13	11	14	12

SAMPLE LOCATION: piez. C_2

	SAMPLE DATE															
	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	1 /10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE	110	70	115	175	175	170	170	165	170	190	200	230	135	200	175	200
pH	8.7	9.0	7.6	7.3	7.1	7.5	7.5	7.2	7.2	7.1	7.1	7.0	7.2	---	7.1	7.1
CHLORIDE	2.5	2.5	3.0	7.5	1.5	1.5	1.5	2.0	1.9	2.5	4.5	5.0	6.0	5.0	5.0	5.0
ALKALINITY	135	100	160	195	200	210	200	215	210	230	222	156	208	205	200	210
SULFATE	12.6	7.0	9.0	14.0	4.0	1.0	1.0	1.0	3.0	0.0	1.5	1.0	3.0	3.0	1.0	2.0
NITRATE	****	****	****	****	5.70	3.00	4.00	1.50	----	0.22	0.59	0.63	0.12	0.95	1.25	0.90
TOTAL IRON	5.0	0.3	0.1	0.6	1.6	1.5	2.8	0.8	1.9	3.3	5.5	1.4	14.0	---	6.0	4.0
CHEMICAL OXYGEN DEMAND	353.0	----	62.6	20.6	15.0	7.5	19.0	23.3	26.2	22.7	30.6	----	18.6	15.0	15.0	----
TOTAL HARDNESS as mg/l $CaCO_3$	100	140	170	170	175	165	152	150	155	155	77	145	160	130	160	150
CALCIUM HARDNESS as mg/l $CaCO_3$	60	90	110	140	140	130	110	110	115	110	63	102	111	100	100	100
MAGNESIUM HARDNESS as mg/l $CaCO_3$	40	50	60	30	35	35	42	40	40	45	14	43	49	30	60	50
WATER DEPTH	10.0	9.0	9.0	7.0	6.0	6.0	7.3	6.0	5.0	2.3	2.3	4.2	6.8	7.9	7.8	7.0
TEMPERATURE ^oC	16	15	16	14	11	9	7	8	12	12	11	12	14	14	14	12

SAMPLE LOCATION: piez. E

	SAMPLE DATE															
	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	1/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE	190	190	110	175	170	175	180	155	160	155	200	235	140	200	185	200
pH	8.6	8.1	7.1	7.2	7.1	7.2	7.2	6.8	7.2	7.1	7.1	7.0	7.5	---	7.0	7.1
CHLORIDE	2.0	1.5	3.0	7.5	1.5	1.3	1.0	2.0	1.9	3.5	5.0	4.5	5.0	5.0	5.0	5.0
ALKALINITY	140	180	210	195	195	185	190	180	175	190	184	183	193	190	180	180
SULFATE	123.0	55.0	9.0	13.0	7.0	5.0	3.0	2.0	5.0	6.0	8.0	8.5	10.8	12.0	12.0	12.0
NITRATE	****	****	****	****	5.70	2.00	2.20	0.44	----	0.22	0.18	0.34	0.16	0.60	0.90	0.65
TOTAL IRON	2.0	---	0.1	0.1	1.1	4.0	3.0	7.0	13.0	11.3	8.5	5.7	14.0	---	5.0	2.5
CHEMICAL OXYGEN DEMAND	68.5	----	7.2	19.7	15.0	5.7	2.0	22.2	45.8	15.7	16.6	----	12.6	19.6	19.8	----
TOTAL HARDNESS as mg/l $CaCO_3$	260	200	180	170	165	165	155	150	155	150	168	155	167	150	145	150
CALCIUM HARDNESS as mg/l $CaCO_3$	180	150	140	140	135	140	113	110	110	115	115	114	100	100	110	110
MAGNESIUM HARDNESS as mg/l $CaCO_3$	80	50	40	30	30	25	42	40	45	35	53	41	67	50	35	40
WATER DEPTH	13.0	10.0	6.0	7.0	6.0	6.0	8.5	6.2	5.8	3.6	3.4	4.5	7.2	7.4	7.3	7.2
TEMPERATURE ^{o}C	15	16	17	15	11	10	10	9	9	11	12	13	16	--	15	13

SAMPLE LOCATION : Piez G

CHEMICAL ANALYSIS

TEMPERATURE oC	WATER DEPTH	MAGNESIUM HARDNESS as mg/1 $CaCO_3$	CALCIUM HARDNESS as mg/1 $CaCO_3$	TOTAL HARDNESS as mg/1 $CaCO_3$	CHEMICAL OXYGEN DEMAND	TOTAL IRON	NITRATE	SULFATE	ALKALINITY	CHLORIDE	pH	SPECIFIC CONDUCTANCE	SAMPLE DATE
15	14.0	60	100	160	465	15.0	***	81	120	5	8.5	170	8/ 8/75
17	5.0	20	120	140		.6	***	70	140	5	8.0	150	8/30/75
21	+1.0	20	110	120	11.3	.1	***	90	150	1.5	8.1	190	10/ 2/75
22	+8"	90	80	170	9.1	.1	***	73	140	10	7.2	175	11/ 4/75
0	+3'	50	100	150	13	1.1	4.4	70	140	3.5	6.8	170	12/ 7/75
0	+3'	Well Frozen											11/10/76
0	-6'	40	100	140	55.	1.3	.44	65	150	2.5	6.7	170	2/ 7/76
1.6	+1	30	90	120	10	7.5	.22	55	100	3.0	6.2	170	3/ 4/76
11	+1	30	90	120	21.0	8.0	***	70	100	3.8	6.6	150	4/ 3/76
12	+1	30	90	120	8.2	7.5	.10	65	130	3.5	6.1	140	5/ 1/76
11.5	+1.25	27	93	120	10.0	7.5	.20	56	114	6.0	6.8	200	6/ 3/76
12	+2.1	34	84	118		4.6	.18	57.5	122	6.0	6.6	235	7/16/76
18	1.3'	31	100	131	17.4	10	.14	61.0	121	6.0	6.5	140	8/11/76
	1.6'	35	90	125	15.0		.45	72.0	125	5.0		175	9/12/76
16	1'	20	100	120	12.2	3.0	.35	70.0	140	5.0	6.8	215	10/10/76
10	1.1	25	100	125		2.0	.40	75	110	5.0	6.9	235	11/23/76

SAMPLE LOCATION Piez K

SAMPLE DATE	CHEMICAL ANALYSIS SPECIFIC CONDUCTANCE	pH	CHLORIDE	ALKALINITY	SULFATE	NITRATE	TOTAL IRON	CHEMICAL OXYGEN DEMAND	TOTAL HARDNESS as mg/1 $CaCO_3$	CALCIUM HARDNESS as mg/1 $CaCO_3$	MAGNESIUM HARDNESS as mg/1 $CaCO_3$	WATER DEPTH	TEMPERATURE ^{o}C
8/ 8/75					157		2					15	17
8/30/75	165	8.1	5	120	140	***	.6		246	194	52	15	17
10/ 2/75	300	7.7	12	200	190	***	.5	41.8	340	250	90	12	18
11/ 4/75		7.5						32				14.5	15
12/ 7/75												15	11.6
11/10/76	280	7.9	2.0	210	190	1.0	.3	4.5	300	230	70	15	10
2/ 7/76												14.5	10.5
3/ 4/76	270	8.3	4.0	230	70	.88	.25	35.7	260	185	75	16	9.4
4/ 3/76		8.0	9.4	255	35		1.8		290	190	100	16	13.5
5/ 1/76			4.0	160	42				190	130	60	16	12
6/ 3/76												10' pipe added	
7/16/76												28.2	
8/11/76	252		8.0	140	180	.12			366	250	116		
9/12/76													
10/10/76	415	<4.3	5.0	0	380	.20	1.0	48.8	367	258	109	26	15
11/23/76	50	6.9	5.0	110	190	.20	8.0		330	230	100	26.7	12

SAMPLE LOCATION Piez Q SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE										150	175	230	175	125	315	235
pH										6.7	7.1	7.2	7.5		7.6	7.5
CHLORIDE										3.5	5.0	5.0	8.0	5.0	3.0	5.0
ALKALINITY										55	88	79	136	130	190	180
SULFATE										70	77.5	74.0	87.0	28.0	125	125
NITRATE										1.1	.23	.31	.26	.50	0.75	0.65
TOTAL IRON										2.0	.15	.32	.9		0.1	1.0
CHEMICAL OXYGEN DEMAND										8.4	9.4		10.3	16.0	5.1	
TOTAL HARDNESS as mg/l $CaCO_3$										155	184	174	209	210	285	350
CALCIUM HARDNESS as mg/l $CaCO_3$										100	120	122	154	140	195	195
MAGNESIUM HARDNESS as mg/l $CaCO_3$										55	64	52	55	60	90	155
WATER DEPTH										10.1	11.5	5.4	8.6	17.4	8.8	11.4
TEMPERATURE °C										11	11	14	16		16	14

SAMPLE LOCATION Piez M

SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE	250	205	110	325	330	325	350	350	325	200	275	350	225	325	390	345
pH	8.7	8.6	7.2	7.3	6.9	7.2	7.0	6.5	7.0	7.0	7.1	7.3	7.0		7.2	7.2
CHLORIDE	5	6	6	10	3.0	2.3	2.0	2.0	3.8	6.3	8.5	5.5	7.0	5.0	5.0	10
ALKALINITY	80	85	126	175	195	185	200	190	200	115	79	126	169	175	200	160
SULFATE	190	175	190	190	190	190	200	190	160	100	86	145	128	180	165	165
NITRATE	***	***	***	***	20.7	13.3	9.0	9.9		2.2	.75	2.1	1.76	2.5	2.25	2
TOTAL IRON	1	.1	***	.4	.25	.75	1.4	.25	.20	1.3	.6	.68	1.5		.15	1.0
CHEMICAL OXYGEN DEMAND	425		13.6	5.7	7	3.1	6.0	28.4	30.2	10.0	17.9		19.0	15.0	19.5	
TOTAL HARDNESS as mg/l $CaCO_3$	280	266	280	320	320	375	350	390	390	212	313	340	336	340	380	350
CALCIUM HARDNESS as mg/l $CaCO_3$	200	184	190	250	230	260	295	270	250	135	135	220	232	170	250	240
MAGNESIUM HARDNESS as mg/l $CaCO_3$	80	82	90	70	90	115	55	120	140	77	178	120	104	170	130	110
WATER DEPTH	10	9	9.5	9.5	9	10	10.2	10.3	9.8	6.5	8.5	8.3	9.1	9.8	10.8	11.4
TEMPERATURE °C	17	17	16	14	11.4	8.8	10	8.9	12	11	12	13.5	15		17	14

SAMPLE LOCATION Piez T SAMPLE DATE

CHEMICAL ANALYSIS	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
SPECIFIC CONDUCTANCE	180	170	245	225	250	270	310	250	250	260	240					
pH	8.6	7.6	7.6	7.5	8.3	8.3	8.2	8.1	8.8	8.2	7.6					
CHLORIDE	4	3	5	9.5	3.5	2.5	3.0	3.0	1.9	7.5	6.5					
ALKALINITY	100	170	265	270	230	245	220	260	300	270	282					
SULFATE	100	39	39	14	15	5	20	13	5	9	5					
NITRATE	***	***	***	***	4.4	.88	2.2	.6		.11	.54					
TOTAL IRON	***	.5	.5	.15	.15	1.5	2.35	1.0	1.3	.62	.7					
CHEMICAL OXYGEN DEMAND	246		74.7	21.6	21	14.4										
TOTAL HARDNESS as mg/l $CaCO_3$	200	160	220	370	300	280	160	270	230	210	205					
CALCIUM HARDNESS as mg/l $CaCO_3$	100	100	140	130	125	135	100	135	150	100	134					
MAGNESIUM HARDNESS as mg/l $CaCO_3$	100	60	80	240	75	145	60	135	80	110	71					
WATER DEPTH	14	13	12	14	15	13	17.6	17.8	17.5	18.4	18.5					
TEMPERATURE °C	17	17	15	14	11.1	10	11.1	9.4	14.5	15	11					

SAMPLE LOCATION Piez 1 SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE												230	120	200	215	225
pH												7.2	7.1	7.1	7.1	7.2
CHLORIDE												6.0	7.5	5.0	5.0	5.0
ALKALINITY												140	130	130	135	130
SULFATE												34.0	34.0	46.0	49.0	74
NITRATE												.37	1.59	1.60	3.4	3.35
TOTAL IRON												.40	.50		1.0	0.1
CHEMICAL OXYGEN DEMAND													7.41	7.0	7.6	
TOTAL HARDNESS as mg/l $CaCO_3$												160	257	90	180	170
CALCIUM HARDNESS as mg/l $CaCO_3$												114	103	65	120	105
MAGNESIUM HARDNESS as mg/l $CaCO_3$												46	154	25	60	65
WATER DEPTH												3.3	3.2	4.5	4	5.7
TEMPERATURE °C												13	18		17	14

SAMPLE LOCATION Piez 2 SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE												330	243	225	375	375
pH												8.3	7.5	7.5	7.5	7.4
CHLORIDE												9.0	6.5	5.0	7.5	5.0
ALKALINITY												236	302	320	335	290
SULFATE												92	72	45	85	94
NITRATE												.22	.11	.65	.55	.4
TOTAL IRON												2.4	1.0		0.3	0.1
CHEMICAL OXYGEN DEMAND													9.15	11.0	6.3	
TOTAL HARDNESS as mg/l $CaCO_3$												285	341	270	290	320
CALCIUM HARDNESS as mg/l $CaCO_3$												208	260	150	265	215
MAGNESIUM HARDNESS as mg/l $CaCO_3$												77	81	120	25	105
WATER DEPTH												18.7	20.6	19.7	18.8	19.9
TEMPERATURE ^{o}C												11	12		14	13

SAMPLE LOCATION Piez 3

SAMPLE DATE	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE												325	140	265	225	215
pH												7.2	6.7	6.8	6.8	6.9
CHLORIDE												5.5	6.0	5.0	5.0	5.0
ALKALINITY												152	154	90	160	155
SULFATE												105	54	110	48	53
NITRATE												.19	.18	.60	.50	.25
TOTAL IRON												.15	2.0		0.2	0.1
CHEMICAL OXYGEN DEMAND													7.09	6.0	5.4	
TOTAL HARDNESS as mg/l $CaCO_3$												212	152	195	150	210
CALCIUM HARDNESS as mg/l $CaCO_3$												143	96	120	100	100
MAGNESIUM HARDNESS as mg/l $CaCO_3$												69	56	75	50	110
WATER DEPTH												9.4	7.8	9.9	9.6	10.9
TEMPERATURE °C												12	16		15	13

SAMPLE LOCATION Piez 4 SAMPLE DATE

CHEMICAL ANALYSIS	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
SPECIFIC CONDUCTANCE												420	233	225		
pH													7.3			
CHLORIDE												8.0	7.0	5.0		
ALKALINITY												316	269	135		
SULFATE												115	69	82		
NITRATE												.90	.98	1.00		
TOTAL IRON												.75				
CHEMICAL OXYGEN DEMAND													13.6			
TOTAL HARDNESS as mg/l $CaCO_3$												380	300	155		
CALCIUM HARDNESS as mg/l $CaCO_3$												265	215	60		
MAGNESIUM HARDNESS as mg/l $CaCO_3$												115	85	95	42.1	
WATER DEPTH												39.6	40.3			
TEMPERATURE °C													12			

SAMPLE LOCATION Piez 5 SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	9/12/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE												465	345	525	415	450
pH													7.1	7.1	7.3	7.2
CHLORIDE												7.5	7.0	7.5	7.5	7.5
ALKALINITY												371	452	385	450	470
SULFATE												120	90.5	125	95	100
NITRATE												.60	.11	.50	.10	.2
TOTAL IRON												.05	1.0		.1	.2
CHEMICAL OXYGEN DEMAND													41.7	13	41.4	
TOTAL HARDNESS as mg/l $CaCO_3$												264	282	125	235	200
CALCIUM HARDNESS as mg/l $CaCO_3$												202	195	65	158	140
MAGNESIUM HARDNESS as mg/l $CaCO_3$												62	87	60	77	60
WATER DEPTH												33.5	33.1	34.5	32.5	32.8
TEMPERATURE ^oC												9	8	11		13

SAMPLE LOCATION Piez 7 SAMPLE DATE

	8/ 8/75	8/30/75	10/ 2/75	11/ 4/75	12/ 7/75	11/10/76	2/ 7/76	3/ 4/76	4/ 3/76	5/ 1/76	6/ 3/76	7/16/76	8/11/76	10/02/76	10/10/76	11/23/76
CHEMICAL ANALYSIS																
SPECIFIC CONDUCTANCE														2100	1700	2000
pH														6.6	6.7	
CHLORIDE														5.0	7.5	5.0
ALKALINITY														430	470	490
SULFATE														500	1350	950
NITRATE															.20	.18
TOTAL IRON															2.1	
CHEMICAL OXYGEN DEMAND															22.6	
TOTAL HARDNESS as mg/l $CaCO_3$														1650	1600	1860
CALCIUM HARDNESS as mg/l $CaCO_3$														1200	1160	1310
MAGNESIUM HARDNESS as mg/l $CaCO_3$														450	440	550
WATER DEPTH														31.5	31.5	31.8
TEMPERATURE ^oC														8		13

Table III

Overburden Character at I.C.P. #1 Mine

by

Donald L. Biggs

Introduction

Efficient planning for the restoration of the overburden at the Iowa Coal Project #1 Mine, required an evaluation of the acid formation and release potential of the disturbed rock mass. Similar problems were studied in West Virginia by Grube et al. (1973). Their approach was to calculate the total sulfur present in a rock specimen as acid potential and contrast the amount of calcium carbonate present with this value to arrive at an expression of excess or deficiency of carbonate necessary to neutralize the acid potential calculated for the rock.

A similar project to evaluate the acid potential of the overburden from the I.C.P. #1 Mine was begun in the spring of 1975. Because of differences in analytical techniques, it was decided that the sulfur present in pyrite would be used in calculating the acid potential. The remaining sulfur in the overburden from the mine site is of small amount and present in sulfate crystals of rather low solubility in the weathering environment.

Methods of Analysis

Cores taken from the site by Dr. Sendlein's group during the early months of 1975 were logged as taken and then turned over to the characterization group for analysis. Criteria used in drawing samples for analysis from the cores were lithologic differences and core length. Each lithologically different horizon was sampled and within each horizon, a sample distance of five feet was maintained to insure that no important change in chemistry not reflected in lithology would be missed. Coal units were not sampled for this investigation.

Samples drawn from the cores were submitted to Mr. Robert Z. Bachman who supervised the analyses. His analytical procedures were as follows:

For total sulfur as %S, ASTM D 271,
For sulfur as sulfate, ASTM D 2492,
For sulfur in pyrite ASTM D 2492,
For calcium carbonate Grube et al (1973).

Bachman's data were reported to the characterization group as percent total sulfur, sulfate sulfur, sulfur present in pyrite, and percent calcium carbonate.

From these data, it has been possible to arrive at a quantitative estimate of the acid production of the rocks if left in the zone of aeration when they are returned to the mine. It is believed that formation of acid will result from the oxidation of the sulfide minerals, of which the most abundant are pyrite and marcasite, the polymorphs of FeS_2. Though the two phases differ in their rates of oxidation and their overall stability relationships, the chemical equation,

$$2FeS_2 + 15/2\ O_2 + 4H_2O \longrightarrow Fe_2O_3 + 4H_2SO_4 \qquad (1)$$

adequately describes the reaction for either polymorph. Whether the iron in the above reaction is indeed hematite, (Fe_2O_3) or some hydrated oxide as $Fe(OH)_3$ is of no consequence in this investigation for both forms are so insoluble in the weathering environment as to effectively remove the iron from further important reaction. The sulfuric acid produced in the reaction is responsible for the lowering of soil pH and pollution of water supplies. It can be neutralized by calcium carbonate, which is commonly present in the rocks and has a reaction rate sufficiently fast to prevent pollution. The pertinent reaction for neutralization is,

$$\underset{\text{liquid}}{H_2SO_4} + \underset{\text{solid}}{CaCO_3} \longrightarrow \underset{\text{solid}}{CaSO_4} + \underset{\text{liquid}}{H_2O} + \underset{\text{gas}}{CO_2} \qquad (2)$$

The calcium sulfate produced in this reaction is of low solubility in the weathering environment and the CO_2 is dissolved in the atmosphere as a harmless gas.

From equations (1) and (2), one mole of calcium carbonate (100 g) will neutralize one mole of sulfur (32 g). Therefore, the neutralization of one gram of sulfur will require 3.125 g of calcium carbonate. Because it seemed to better fit the requirements of mining scale, where a common unit of measure is tons per thousand tons, the conversion factor (3.125) was multiplied by ten so that it could be directly read in parts per thousand, (31.25 o/oo). Thus a sample containing 1% sulfur when multiplied by the factor 31.25 gives the required amount of calcium carbonate required for neutrality.

$$1\%S_{(FeS_2)} \times 31.25 = 31.25‰\,CaC0_3 \text{ required for neutrality} \qquad (3)$$

The calcium carbonate content, reported in percent, can be similarly adjusted by converting percentage to parts per thousand (o/oo). Thus a sample containing 2% $CaC0_3$ when multiplied by ten, gives the amount of calcium carbonate present in o/oo or tons per thousand tons.

$$2\%CaC0_3 \times 10 = 20‰\,CaC0_3 \text{ present} \qquad (4)$$

If the amount of calcium carbonate required for neutrality is subtracted from the amount present, the difference, if positive, is the excess of calcium carbonate present. If the difference is negative, it is the amount of calcium carbonate deficiency that must be supplied if neutrality is to be achieved.

Subtraction of (3) from (4) gives a difference of -11.25 indicating that the sample is deficient in calcium carbonate by 11.25 tons per thousand tons. Such a material must be mixed with one having an excess of calcium carbonate, or have addition of calcium carbonate as limestone for neutrality to be achieved.

Results

The data reported from the analytical laboratory are shown in Table I. In some instances there are slight arithmetic errors in that the total sulfur content does not agree with the sum of sulfate sulfur + pyrite sulfur. Such errors are within the experimental error of the determinations and are not significant. In several instances there was too little calcium carbonate in a given sample to give readable results in the laboratory. Such specimens are marked in the $CaC0_3$ column by the letters ND for "not determined".

It can be seen from the table that most of the rocks in the overburden at the I.C.P. #1 Mine are deficient in $CaCO_3$ content and hence will produce H_2SO_4 upon weathering of the pyrite content in the zone of aeration above the water table. These rocks may be buried so deeply as to have no exposure in the zone of aeration, and thus the supply of acid will not be greater than it has been in the past. If such rocks must be used near the surface, then they can be mixed with some of those showing an excess of $CaCO_3$ so that neutrality can be achieved.

Figure 1 is a diagram showing the lithology of the cores as logged at the time of acquisition and the samples drawn from them with the calcium carbonate deficiency or excess for each sample. This diagram also indicates the position of each core with respect to the elevation of the first core. Thus one can follow the thickness and areal extent of lithologies throughout the deposit.

This investigation indicates that the knowledge of the acid potential of overburden rocks may be an important factor in selecting sites for strip mines. Mine prospect sites that are very deficient in calcium carbonate will surely require addition of neutralizing materials from some other source. Such sites then will depend for their value on other deposits nearby.

References

Grube, Walter E. Jr., Smith, Richard Meriwether, Singh, Rabindar N. and Sobek, Andrew A. (1973) "Characterization of Coal Overburden Materials and Minesoils in Advance of Surface Mining" IN Garvey, James R. (1973) "Papers Presented Before the Research and Applied Technology Symposium on Mined Land Reclamation" Bituminous Coal Research Inc.

Table 1

CALCIUM CARBONATE REQUIREMENTS FROM OVERBURDEN AT ICP #1 MINE

Core	Sample	Interval	Total Sulfur %	Sulfate Sulfur %	Pyrite Sulfur %	$CaCO_3$ %	Pyrite Sulfur o/oo	$CaCO_3$ o/oo	$CaCO_3$ Requirement Deficiency o/oo	Excess o/oo
1	1-1	27'6"	0.89	0.03	0.65	0.867	20.4	8.6	11.8	
	1-2	28'4"	1.03	0.06	0.785	0.81	24.63	8.1	16.5	
	1-3	34'	6.55	0.54	5.275	ND*	165.5		165.5	
	1-4	42'	1.14	0.10	1.105	1.38	34.5	13.8	20.7	
	1-5	45'8"	0.57	0.03	0.375	0.455	11.8	4.5	7.3	
	1-6	47'	0.48	0.04	0.22	0.255	6.9	2.5	4.4	
	1-7	51'	0.26	0.01	0.11	0.31	3.5	3.1	0.4	
2	2-1	21'	2.19	0.16	1.81	1.72	56.6	17.2	39.4	
	2-2	26'	1.12	0.13	1.10	2.09	34.4	20.9	13.5	
	2-3	31'	1.16	0.07	1.37	2.15	42.8	21.5	21.3	
	2-4	38'	0.98	0.08	0.72	2.27	22.6	22.7		0.1
	2-5	45'	1.29	0.02	1.06	3.15	34.4	31.5	2.9	
	2-6	49'6"	1.17	0.05	1.00	1.94	31.2	19.4	11.8	
	2-7	55'	0.94	0.09	0.78	1.16	24.4	11.6	12.8	
	2-8	59'	0.62	0.02	0.75	1.84	23.4	18.4	5.0	
	2-9	65'	6.70	0.02	6.99	2.14	218.4	21.4	197.0	
	2-10	70'	3.62	0.12	4.01	7.06	125	70.6	54.4	
	2-11	76'	0.66	0.06	0.37	7.15	11.72	71.5		60.03
	2-12	81'5"	0.53	0.04	0.46	7.05	14.4	70.5		56.10
3	3-1	12'	0.27	0.16	0.03	ND	0.94		0.94	
	3-2	18'	2.48	0.15	2.09	3.39	65.0	33.9	31.10	
	3-3	22'	5.14	0.46	4.97	0.40	155.3	4.0	151.30	
	3-4	25'6"	0.63	0.55	0.53	0.12	16.6	1.2	15.4	
	3-5	27'6"	0.51	0.01	0.485	ND	15.3		15.3	
	3-6	29'6"	1.10	0.16	0.84	0.0463PPM	26.3		26.3	
	3-7	36'	3.43	0.31	3.155	0.15	110.9	1.5	109.4	
	3-8	41'6"	0.52	0.06	0.39	ND	12.2		12.2	
	3-9	46'6"	ND	0.56	3.54	ND	110.6		110.6	
	3-10	49'10"	2.17	0.42	1.565	ND	49.0		49.0	

*ND - Not Determined

Core	Sample	Interval	Total Sulfur %	Sulfate Sulfur %	Pyrite Sulfur %	$CaCO_3$ %	Pyrite Sulfur o/oo	$CaCO_3$ o/oo	$CaCO_3$ Requirement Deficiency o/oo	Excess o/oo
4	4-1	21'6"	1.50	0.07	0.21	0.228	6.56	2.281	4.28	
	4-2	26'10"	5.56	0.70	5.21	ND	162.81		162.81	
	4-3	32'3"	1.00	0.15	0.80	0.113	25.00	1.1	24.	
	4-4	36'11"	0.93	0.08	0.85	0.076	26.56	0.7	25.9	
	4-5	41'7"	4.87	0.24	4.40	0.306	137.50	3.0	134.5	
	4-6	46'1"	2.95	0.24	2.59	0.835	80.94	8.3	72.64	
	4-7	59'	1.59	0.13	1.24	0.027	38.75	0.2	38.55	
	4-8	63'1"	3.57	0.36	3.10	ND	96.88		96.88	
	4-9	76'9"	2.49	0.13	2.23	1.129	69.69	11.3	58.39	
	4-10	82'8"	1.42	0.18	1.13	0.339	35.31	2.3	33.0	
	4-11	94'9"	0.97	0.12	0.81	0.150	25.31	1.49	23.8	
	4-12	98'7"	0.97	0.05	0.91	9.78	28.44	97.8		66.96
5										
	5-1	16'	7.92	0.87	6.29	0.85	196.56	8.5	188.06	
	5-2	22'9"	1.32	0.13	1.07	0.85	33.44	8.5	24.94	
	5-3	31'11"	0.31	0.05	0.19	0.62	5.94	6.2		0.26
	5-4	34'11"	1.40	0.08	1.23	0.68	38.44	6.8	31.64	
	5-5	43'9"	1.27	0.11	1.18	0.09	36.88	0.9	35.98	
	5-6	45'11"	1.47	0.06	1.36	1.83	42.50	18.3	24.2	
	5-7	49'7"	0.91	0.11	0.84	1.79	26.25	17.9	8.35	
	5-8	52'	2.91	0.22	2.64	1.09	82.50	10.9	71.60	
6	6-1	13'	4.77	0.79	3.42	3.01	106.8	30.1	76.70	
	6-2	2[illegible]'7"	0.97	0.08	0.92	3.56	28.8	35.6		6.80
	6-3	34'11"	1.29	0.05	1.21	0.44	37.81	4.4	33.1	
	6-4	43'2"	2.23	0.11	2.10	2.61	65.63	26.1	39.5	
	6-5	46'1"	2.58	0.20	2.15	0.04	67.19	0.4	66.8	
	6-6	52'2"	2.89	0.27	2.48	ND	77.5		77.5	
	6-7	65'6"	3.17	0.48	2.30	ND	71.88		71.88	
7	7-1	10'	3.105	0.40	2.52	ND	97.0		97.0	
	7-2	16'1"	6.34	0.96	4.60	ND	198.0		198.0	
	7-3	19'1"	1.72	0.20	1.53	ND	53.75		53.75	
8	8-1	14'7"	1.35	0.07	1.33	0.14	41.56	1.4	40.16	
	8-2	18'3"	0.88	0.12	0.82	9.37	25.63	93.7		68.07

Figure I Lithologic Relationships Between Cores at ICP #1 Mine

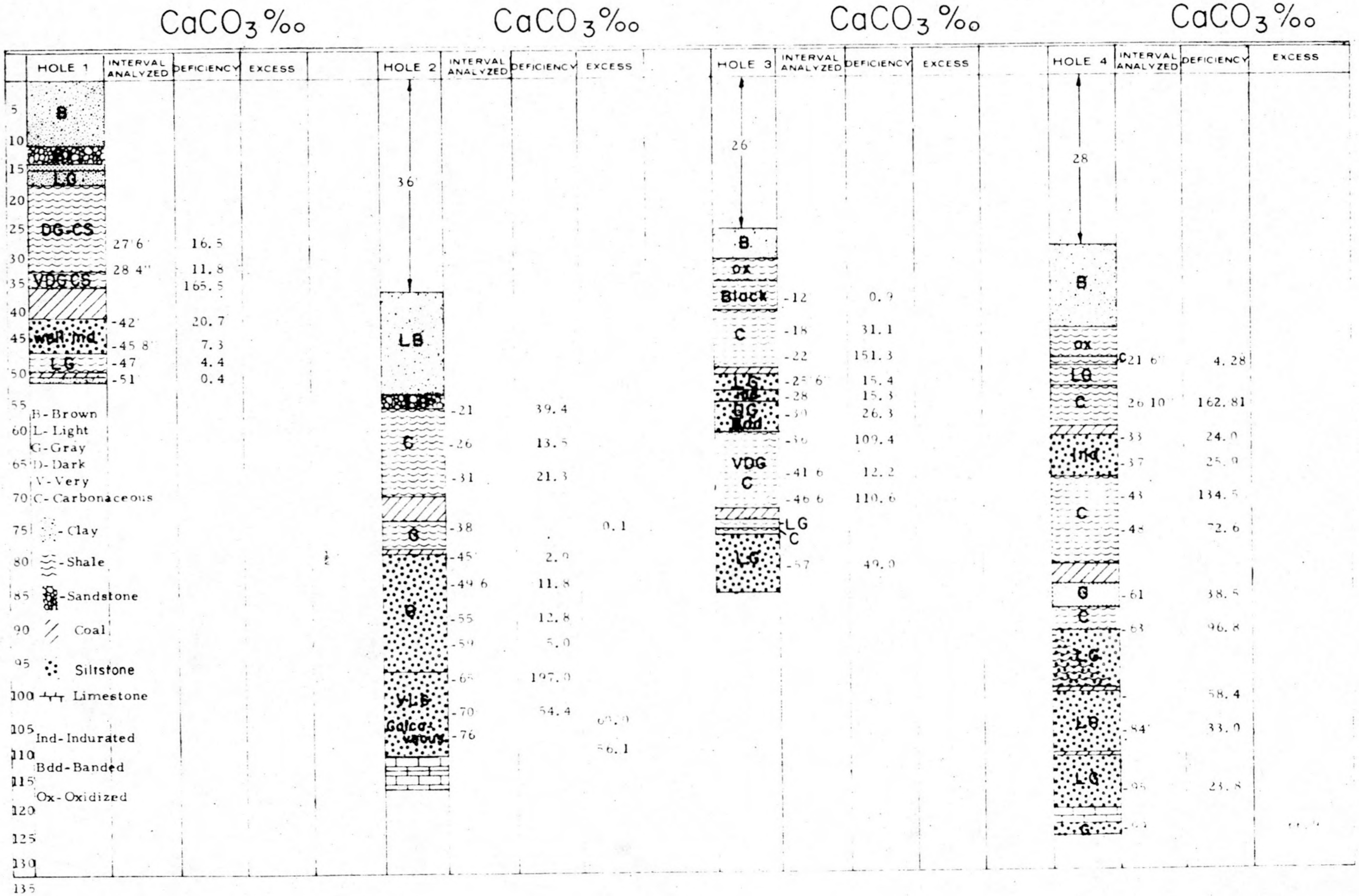

Figure I cont.

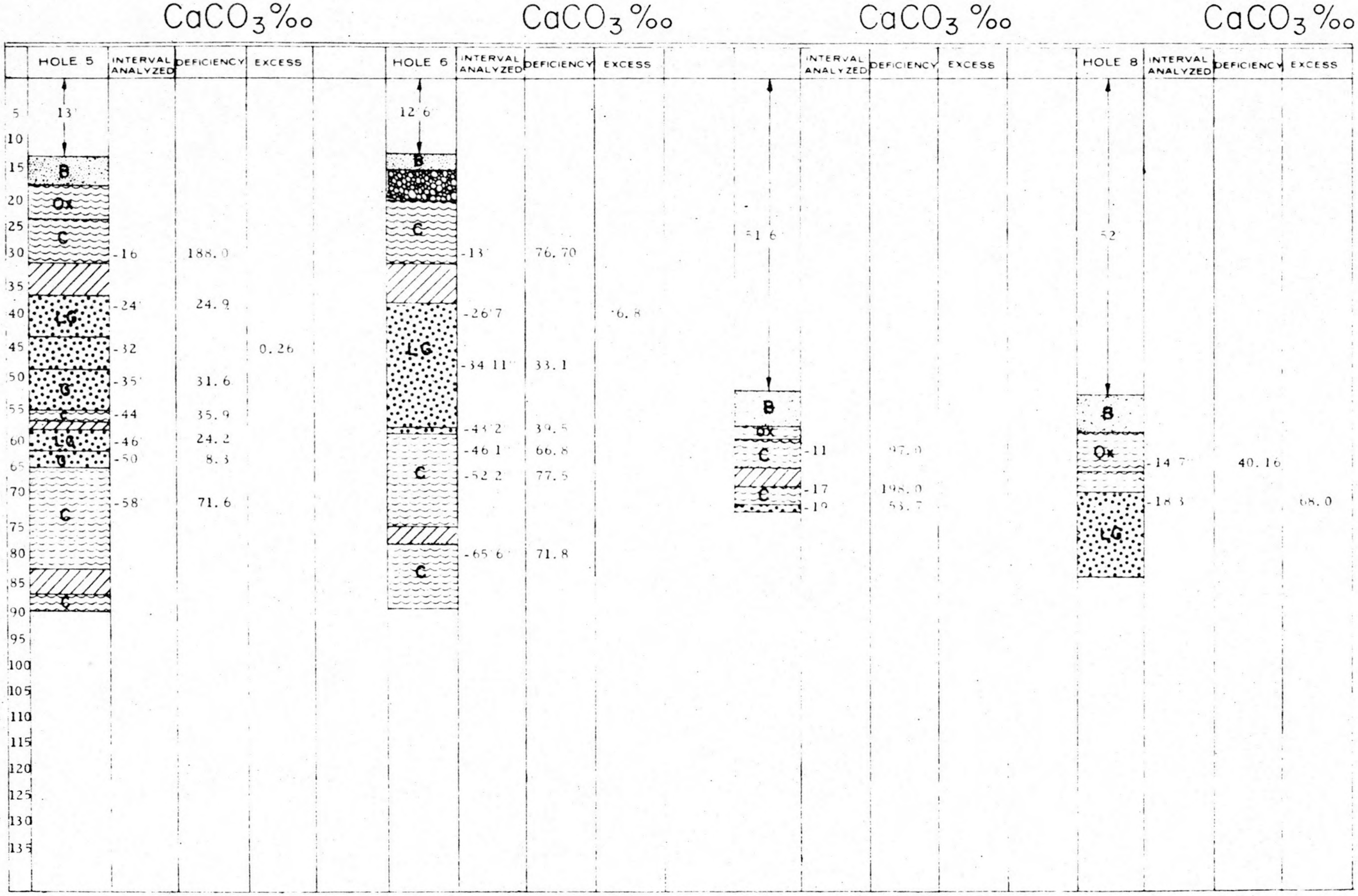

Table IV-A Coal Analysis, 35 samples from ICPDM#1

Parameter	$\overline{x}$	s	s^2
Total Sulfur (%)	7.35	1.74	3.03
BTU/lb.	10591	480.4	230791
Ash (%)	14.67	2.77	7.68
Moisture (%)	10.09	2.64	6.97
Volatile Matter (%)	35.24	1.78	3.15
Fixed Carbo (%)	40.0	3.49	12.19
BTU/lb. (dry)	11779	444.2	197277

Table IV-B Spark Source Mass Spectrometry Analysis
Periodic Table Display
Iowa Coal Project Coal Low Temperature Ash

September 3, 1976
D. Biggs

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIII			IB	IIB	IIIB	IVB	VB	VIB	VIIB	O
Li	Be											B	C	N	O	F	Ne
≤900	200											1000				300	<3
Na	Mg											Al	Si	P	S	Cl	Ar
4000	5100											240000	300000	2000	200000	100	<3000
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
30000	180000	100	7800	460	640	1400	190000	100	1000	1000	2200	79	380	40	40	<6	<60
Re	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
60	900	280	240	<20	40		<6	<.4	<6	<.7	18	.3	28	.9	<.3	<1	<30
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi			
5	700		<5	<2	<8	<3	<4	<2	<2	<.5	<.5	2.4	70	<.2			
Fr	Ra			Th		U											
	<1			40		<6											
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
			1100	800	100	300		20	4	16	9	14	5	11	3	5	<6

Summary Data - Note that values are rounded to two significant figures regardless of precission.
Total concentration of elements identified = 1200000
Total concentration of elements as upper limit = <2800