IMPACT OF SURFACE COAL MINING AND RECLAMATION
ON THE HYDROGEOLOGY AT IOWA COAL PROJECT
DEMONSTRATION MINE #1,
MAHASKA COUNTY IOWA

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Impact of surface coal mining and reclamation on the
hydrogeology at Iowa Coal Project Demonstration
Mine #1, Mahaska County, Iowa

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by

David William Stangl

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
Statement of Problem	1
Purpose and Scope	4
Area of Study	5
PREVIOUS WORK	8
GENERAL GEOLOGY OF THE ICP#1 AREA	11
METHOD OF INVESTIGATION	20
Piezometer Placement	20
Water Quality Analyses	27
Correlation Analysis	32
PREMINING WATER FLOW	33
Premining Surface Water Flow	33
Premining Groundwater Flow	33
Surficial deposits	40
Consolidated bedrock	44
WATER FLOW DURING MINING	48
Surface Water Flow	48
Groundwater Flow	48
Calculation of maximum seepage from evaporation data	52
Calculation of maximum seepage from permeability and gradient estimates	62
Dynamic piezometric effects of mining at ICP#1	82

	Page
POST MINING WATER FLOW	91
Surface Water Flow	91
Groundwater Flow	91
Spoil character and water flow	91
Spoil undersaturation	94
Recharge rates	97
Recharge areas	100
WATER QUALITY DURING MINING AND RECLAMATION AT ICP#1	114
Sources of Water Quality Alteration	114
Spoil runoff	117
Sediment pond water quality	122
Groundwater Quality	125
Groundwater quality near the sediment pond	126
Groundwater quality in the reclaimed fill	132
Enclave development	141
Comparison of ICP#1 Groundwaters to Others of the Area	142
SUMMARY AND CONCLUSIONS	145
RECOMMENDATIONS FOR FURTHER STUDY	148
REFERENCES	149
ACKNOWLEDGMENTS	153
APPENDIX A: WELL DEVELOPMENT AND SURFACE ELEVATIONS	154
APPENDIX B: WELL AND BORE HOLE LOGS	156
APPENDIX C: SAMPLING DATES AND PRECIPITATION	169
APPENDIX D: CHEMICAL ANALYSIS AND WATER LEVEL DATA	171
APPENDIX E: STATISTICAL CORRELATIONS	210
APPENDIX F: WELL 5a PUMP TEST	319

LIST OF FIGURES

	Page
Figure 1. Location of study area	7
Figure 2. Northwest-southeast cross section of Quaternary and Pennsylvanian strata at ICP#1	13
Figure 3. Alluvial deposits of the Coal Creek flood plain	16
Figure 4. Cross section illustrating the distribution of Quaternary surficial deposits over Pennsylvanian	18
Figure 5. Groundwater piezometer locations	22
Figure 6. Cross section through spoil cored terraces	25
Figure 7. Illustration of piezometer nesting through spoil cored terraces at the northeastern corner of ICP#1	25
Figure 8. ICP#1 coal exploration core holes	29
Figure 9. Auger holes not used for piezometer locations	29
Figure 10. Premining topography	35
Figure 11. Small basins controlling premining surface water drainage of the ICP#1 site	37
Figure 12. Comparison of local and regional groundwater flow	39
Figure 13. Premining water table	47
Figure 14. Postmining water table, summer 1977	47
Figure 15. Schematic of groundwater loss induced by mining at ICP#1	51
Figure 16. ICP#1 mining plan	54
Figure 17. Base of spoil fill and other disturbed areas	58

	Page
Figure 18. Relationship of ICP#1 coals to surrounding low permeability strata	67
Figure 19. Up dip coal seepage	70
Figure 20. Down dip coal seepage	70
Figure 21. Bottom seam structure contour	73
Figure 22. Top seam structure contour	75
Figure 23. Dynamic piezometric effects of surface mining at ICP#1	84
Figure 24. ICO site before and after reclamation	89
Figure 25. ICP#1 post mining topography	93
Figure 26. Comparison of post and premining surfaces	103
Figure 27. ICP#1 groundwater recharge areas	105
Figure 28. ICO - ICP#1 cross section	108
Figure 29. Distribution of low permeability bedrock and coals in the ICP#1 mine	111
Figure 30. Maximum recharge area for opposing natural and ICP#1 induced gradients of .07	113
Figure 31. Dominant premining equilibrium	116
Figure 32. Equilibrium shift due to mining	116
Figure 33. Shale storage pile effluent with time for simulated rainfall of intensity 3.4 in/hr	120
Figure 34. Potential enclave development at ICP#1	136
Figure 35. Locations of groundwater sampling outside the ICP#1 site	144

LIST OF TABLES

	Page
Table 1. Chemical parameters under study	30
Table 2. Estimated accuracy of chemical analyses	30
Table 3. Trace elements studied	31
Table 4. Duration of ICP#1 mining cuts	55
Table 5. Estimated saturated mine cut surfaces	56
Table 6. Estimated monthly and daily evaporation	61
Table 7. Seasonal adjusted evaporation	62
Table 8. Maximum and minimum slopes of ICP#1 coal seams and associated water flow gradients	76
Table 9. Hydrogeologic summary	78
Table 10. Average highwall daily seepage	80
Table 11. ICP#1 rainfall intensity distribution from August 1975 to July 1977	121
Table 12. Sediment pond water quality change	124
Table 13. Selected yearly water quality averages	127
Table 14. Ferrous-total iron relationship for ICP#1	130
Table 15. Water quality comparisons for piezometers 7a and 5a and lower ICP#1 mine cuts	133
Table 16. Periodic averages for water quality parameters in piezometers M and Q	138
Table 17. Selected data from piezometer #4a	140
Table A1. Well development and surface elevations	155
Table B1. Well logs	157
Table B2. Auger hole logs	162

	Page
Table B3. Core hole logs	164
Table C1. Cumulative precipitation between samplings and sampling "day" and date	170
Table D1. Chemical analysis and water level data	172
Table D2. ICP surface water	189
Table D3. ICO surface water quality	192
Table D4. Farm well water quality near ICP#1	194
Table D5. Trace element analysis	196
Table D6. Analysis of artificial runoff from James Gregory study, August 1976	204
Table E1. ICP groundwater correlations	211
Table E2. ICP surface water correlations	296
Table E3. ICO north mining pits and sediment pond	308
Table E4. Well depth correlation	314
Table F1. Well 5a pump test	320

INTRODUCTION

Statement of Problem

The surface mining of Iowa and other Midwestern coals has left many regions scarred with a topography of barren ridges and shallow acid ponds. Acid generated on these surfaces and stored in these ponds flushes into streams and can infiltrate alluvial, glacial, and bedrock materials causing detrimental chemical changes in surface and ground water supplies (Nessler and Bachmann, 1977; Pietz, Petersen and Lue-Hing, 1974).

Recent emphasis in coal stripmining is toward reclamation of lands as they are disturbed by the mining process. The process of reclamation proceeds first with the removal and segregation of different overburden or spoil types from the mining cuts. Through segregation, acid producing (pyritic) overburden can be stored separately from oxidized or nonacid overburden materials. This separation prevents the contamination of nonacid overburden by pyritic overburden and its oxidation products. The most common acid producing overburdens are pyritic bedrock materials which include shales, siltstones, mudstones, claystones, and sandstones. Common oxidized and nonacid producing earth materials include topsoils, loess, glacial tills, alluvium, and often limestones. The second step in the reclamation of mining spoil is the burial of the acid producing constituents below oxidized or

nonacid overburden materials. Pyritic materials are placed in the bottom of mining cuts and then covered by nonacid, oxidized and topsoil overburden (Grim and Hall, 1972).

The burial and surface exposure time of acid overburden materials are critical elements of reclamation. The burial of acid overburden, after short periods of surface exposure, prevents extreme oxidation of very fine sized pyrite (framboidal) by iron and sulfur oxidizing bacteria (Thiobacillus ferrooxidans and Thiobacillus thiooxidans) and atmospheric oxygen (Smith, 1973). The oxidation products of pyrite are sulfuric acid (H_2SO_4), ferric (Fe^{+++}) and ferrous (Fe^{++}) iron, and metals occurring in minor sulfide minerals (marcasite FeS_2 , sphalerite ZnS , and galena PbS). These chemical species, as well as metals from minerals made more soluble by acid conditions (calcium and magnesium from calcite, dolomite, and gypsum), are largely prevented from occurring and infiltrating into ground water by proper reclamation activities.

The production of an acid condition is not the only hydrogeologic disruption that may accompany coal surface mining. Other problems include: 1) temporary or permanent lowering of water levels in wells near the mine site due to drawdown caused by seepage, pumpage, or evaporation from open mine pit areas, 2) temporary or permanent loss of water levels in wells due to disturbance of aquifers in coal seams and overburden strata, and 3) disturbance of horizontal and

vertical permeabilities of overburden materials resulting in a lowered water table down gradient from reclaimed mine pit areas (Groenwold, Moran, and Anderson, 1975).

These problems have varying impacts in different coal producing regions. In the Upper Missouri River Basin and Southwestern coal fields there is little problem with acid drainage because of low sulfur content in the coal overburden. High sodium content, on the other hand, is commonly encountered. In these areas, problems also develop where mining removes thick subbituminous coal and lignite seams that provide water for livestock and irrigation.

In Midwestern and Appalachian states the coals mined are not generally as thick, and the formation waters are not used extensively for water supply. These coal areas, however, are plagued by acid conditions associated with moderate and high pyrite abundance.

All areas of coal surface mining will be affected by permeability contrasts and temporary water losses due to mining and reclamation. The degree to which these problems occur will vary greatly, and will depend to a large extent on the hydrogeology and methods of mining and reclamation at each specific site.

The Iowa Coal Project Demonstration Mine Number One has been set up as an area for the study of a reclamation plan that possibly holds the answer to some of these problems in

Iowa and other parts of the midwestern and eastern United States.

Purpose and Scope

The Iowa Coal Project Demonstration Mine Number One, hereafter ICP#1, was initiated to study the economic feasibility of surface mining and reclamation of Iowa's relatively small coal deposits. Mining and reclamation were conducted using rippers and scrapers as the prime earthmoving equipment as opposed to the dragline excavators used previously in Iowa.

A portion of the ICP#1 study was designated to monitor environmental effects of coal surface mining and reclamation. One purpose of this program was the monitoring of the hydrogeologic impact on the study site and surrounding areas. A monitoring network of 29 groundwater piezometers and sampling tubes was placed between August 1975 and April 1977 to accomplish this aim. The piezometers were used to gather water chemistry and water table fluctuation data and relate it to the coal mining and reclamation occurring on the site. Additional hydrogeologic data pertaining to the saturated geologic materials of the study site were obtained from drilling logs of 35 auger holes (29 of which were used as piezometer locations) and 26 coal exploration core holes.

The purpose of this research is two fold. The first objective is to monitor the groundwater quality of the ICP#1

site for alterations caused by acid effluent from mining cuts, highwalls and spoil storage areas. The second objective is to measure piezometric decline and recovery in geologic materials in and around the mine during and after mining and reclamation.

Area of Study

ICP#1 is located on a 39 acre site about ten miles south west of Oskaloosa Iowa in Mahaska county. The legal location of the site is: S.W. $\frac{1}{4}$, of N.W. $\frac{1}{4}$, of Section 11, Township 74N, Range 17W (Figure 1). The site is located on the top and south facing slope of a generally northeast-southwest trending upland ridge. This upland ridge forms the divide between Coal Creek to the south of ICP#1 and North Coal Creek located approximately one-half mile to the north. The relief of the ridge is about 120 feet. ICP#1 is also located between two other coal surface mines; the abandoned Iowa Coal Company mine (ICO) to the north and the presently operating Star Coal Company mine to the west (Figure 1).

Figure 1. Location of study area

PREVIOUS WORK

In recent years a controversy has developed over the methodology for the prevention of acid production from pyrite oxidation. Lovering (1948) points out that at certain localities in Arizona, pyrite is oxidizing at depths of 600 to 700 feet below the surface. Shumate and Brant (1971) concluded from short duration leaching experiments that acid was not generated from pyrite buried under a few feet or more of soil. Collier, Pickering and Musser (1970) observed that acid generating spoil may be buried as long as two years in cast spoil before producing an acid effluent. Smith (1973) noted that iron and sulfur oxidizing bacteria prosper at pH levels below 5. This suggests that if virgin spoil, i.e. acid overburden that has not been allowed to oxidize significantly by bacteria or the atmosphere, is quickly buried and saturated by near neutral groundwater the conditions would not favor the production of an acid groundwater.

The study of groundwater alterations due to surface mining began over twenty years ago by members of the United States Geological Survey in Kentucky (Collier, Whetstone and Musser, 1964). This study, like more recent studies, concerned itself with the hydrologic effects of surface mining on a river drainage basin. The study found that it could take up to two years for acid to be generated in the cast spoils and move into the bedrock. Most other studies up until 1974

dealt with similar problems and the effects of acid drainage on surface stream waters. A large number of papers dealt with the quality and hydraulics of groundwater flow from underground coal mines (Ahmad, 1974).

Not until the early and mid 1970's did research begin to be published on mine spoil and its effect on groundwater. These papers dealt almost exclusively with orphaned spoil. Pietz, Petersen, and Lue-Hing (1974) showed that groundwater in replaced orphaned spoil contained significantly higher sulfates, alkalinities, specific conductance, and dissolved metals and cations. To date no studies have been found which report groundwater quality in spoils replaced simultaneously with progressive mining in acid spoil terrain.

In the last three years groundwater quality and hydrologic research in coal mining areas have literally exploded. The U.S. Geological Survey and the Bureau of Land Management are presently involved in several western coal studies in Colorado, Wyoming, Montana, North Dakota, Utah and New Mexico (Syvertsen, 1976). Unfortunately, these studies are in non-acid coal areas and only one, the Colorado study, has been completed. Preliminary data from these studies indicate a much different groundwater chemistry than that found at ICP#1. Van Voast, Hedges, and McDermott (1976) indicate that common groundwater levels of dissolved solids are between 3000 and 4000 mg/l for noncoal overburden and near 1000 mg/l for coal

seams. These authors also state that in addition to sulfate and bicarbonate, sodium is also a very significant constituent of western coal spoil waters. The pH values of groundwater associated with western coal spoils are rarely acidic and accordingly have low metal contents.

In the eastern coal areas of the United States the emphasis in past reclamation has been to reverse the effects of previous mining. Major concerns for eastern coal reclamation are the refilling and leveling of surface spoil to reduce infiltration and decrease drainage from underground coal mine works. Other reclamation activities include formation of recreation areas over old spoil sites, and neutralization of coal spoils with sewage effluent.

A literature search has not located any field data published in major geologic journals about the effects of coal surface mining and simultaneous spoil reclamation on groundwater chemical compositions.

GENERAL GEOLOGY OF THE ICP#1 AREA

The bedrock of the site consists of units from the Pennsylvanian and Mississippian Systems. Rocks of the Pennsylvanian are the undifferentiated Cherokee group of the Des Moines Series. The Cherokee group at the site is composed of 50 to 100 feet of: 1) dark gray to black pyritic shales, 2) dark to light gray pyritic siltstone and claystone, 3) light gray and red-brown ferruginous medium to fine grained sandstones, 4) numerous thin high sulfur bituminous coal seams (two seams mined at ICP#1), and 5) elliptical limestone concretions (Figure 2). The base of the Cherokee consists of a widely distributed green shale. This shale, the Cheltenham clay, is considered a residual soil developed on the underlying Mississippian rocks (Branson, 1962).

The Mississippian or Saint Louis rocks which lie beneath the Cherokee group consist mostly of limestones. These rocks outcrop at the surface at two regions along the Skunk and Des Moines Rivers near the study site. The top of the Saint Louis contains numerous layers of thinly bedded limestone and interbedded marls. Lower in the section these rocks are replaced by interbedded sandstones and limestones, and massive limestone beds (Bain, 1894).

The surficial geology of the study site consists of four types of hydrogeologic materials. These materials include:

Figure 2. Northwest-southeast cross section of Quaternary and Pennsylvanian strata at ICP#1

Quaternary alluvium, Kansan glacial drift, Wisconsin loess, and the weathered bedrock surface.

The Quaternary alluvium consists of gravels, sands, silts, and clays deposited along South Coal Creek and in small upland drainage ways. The alluvium along South Coal Creek forms point bar, clay plug, terrace, and overbank deposits, while narrow interfingered wedge shaped silty deposits compose alluvium in upland drainage ways (Figure 3).

The Kansan glacial drift, blanketing the uplands, is made up of about 20 feet of clay till interspersed with cobble to boulder sized erratics and a maximum of 15 feet of sands and gravels. The glacial sand and gravel deposit, as exposed in the ICP#1 north highwall, is over 600 feet wide, and occurs to the west in the Star Coal Company mine. The deposit is about 5 feet thick at the northwest corner of the ICP#1 mine, and about 3 feet thick at its eastern most extent where it grades into a silty alluvial deposit below piezometers M and Q (Figure 4). Near its center the sand and gravel layer thickens to 15 feet. The same sand and gravel body is exposed in the 600 foot wide south highwall of the Childress mine to the north of ICP#1. The Childress exposure is about 150 to 200 feet north of the ICP#1 exposure and appears to be of a uniform thickness of about 10 feet. Small trough crossbeds less than two feet in width and one foot in depth constitute most of the glacial sands and gravels. The troughs indicate

Figure 3. Alluvial deposits of the Coal Creek flood plain

Figure 4. Cross section illustrating the distribution of Quaternary surficial deposits over Pennsylvanian

a general southeastwardly flow direction. Other important features of the sand and gravel deposit include well indurated ferruginous red sands at the top and bottom. The lower ferruginous sand contains large granitic erratics up to two feet in diameter. Three to five feet above the basal contact of the sand and gravel body an undulating limonitic and conglomeritic zone occurs. Within this zone are roughly spherical "hollow" limonite concretions. The centers of the concretions are filled with a fine white clayey sand composed of about 20 percent clay and 80 percent sand.

Another surficial material, Wisconsin loess, has accumulated over the Kansan till in thicknesses up to five feet on the study site. The loess and the Kansan glacial drift dominate the surficial geology of the central and north hill areas of the site.

The last significant surficial material of the study area to be described is the weathered bedrock surface. This material consists of fragments of mechanically and chemically weathered siltstone and shale overlying most of the bedrock of the premining site.

METHOD OF INVESTIGATION

Piezometer Placement

Twenty-nine piezometers were placed to study the dynamic, spacial, and chemical nature of the shallow groundwater body at the ICP#1 site during and after mining and reclamation (Figure 5). Six of the twenty-nine piezometers were used to determine the water quality and rate of recharge of groundwater into reclaimed portions of the mine. The remaining twenty-three piezometers were used to document the changes occurring in the groundwater in the alluvium, loess, and glacial drift composing the surficial geologic materials of the site. The groundwater of the surficial geologic materials was preferentially monitored over that of the upper bedrock for the following reasons:

- 1) The shallow groundwater of the area must be protected from possible damage caused by coal surface mining because the groundwater is a major source for domestic and livestock water supplies.
- 2) The surficial geologic deposits of the mine site have generally higher permeabilities than do bedrock shales, siltstones, mudstones, and claystones. Thus the bulk of shallow groundwater movement occurs in the surficial or unconsolidated geologic materials.

Figure 5. Groundwater piezometer locations

- 3) Surficial geologic deposits transport groundwater at relatively higher rates than do the upper bedrock materials. Thus, the earliest detection of contaminated groundwater can be attained by monitoring the shallow groundwater of the unconsolidated geologic materials.
- 4) Shallow groundwater situated just below the water table will also be the first groundwater affected by the infiltration of surface water from spoil storage areas and a sediment retention pond.

The monitored site is located on a southeast facing hill. The surface water and shallow groundwater drainage is also in a generally southeasterly direction toward South Coal Creek, the local groundwater sink. Piezometers were placed at various locations and depths to intercept this southeasterly flow of the shallow groundwater before, during, and after passage through the mine area. The placement of piezometers at different depths aids in the investigation of hydraulic and chemical conditions that vary with increasing depth and different geologic strata (Figures 6 and 7). Each piezometer was packed with gravel through the sampling interval, and back-filled with bentonite to prevent leakage from shallower strata.

Piezometers located along the north side of the mine site intercept groundwater flowing into the active mining area from the local drainage divide to the north. These piezometers

Figure 6. Cross section through spoil cored terraces

Figure 7. Illustration of piezometer nesting through spoil cored terraces at the northeastern corner of ICP#1.

give an indication of the natural chemical species and concentrations present in groundwater unaffected by mining. Piezometers on the north side of the site also demonstrate the extent of dewatering of the glacial drift caused by surface mining to the south.

Piezometers located to the south of the site monitor chemical and piezometric changes of the groundwater as it flows near and is charged by infiltrating surface waters from spoil storage piles, mining pits, and the sediment retention pond. Monitoring of the sediment pond is especially important because of the increased surface infiltration and groundwater mound associated with it. Piezometers placed in the shale spoil and siltstone spoil cored terraces of the northeast side of the mining site should detect possible deterioration of the groundwater in that area. The source of water degradation in the previously mentioned terraces would be related to the oxidation of the pyritic shale and siltstone spoil materials placed on the previous land surface well above the premining water table (Figures 6 and 7). The shale and siltstone spoils were buried below nonacid overburden, but if they oxidized to any extent the by-products of oxidation could contaminate underlying waters through surface water percolation. Unfortunately, from a monitoring standpoint, this area was once the location of a barnyard, and its water quality shows some alteration from this use (Figures 6 and 7). In addition to

piezometer monitoring several auger and core hole logs from the site proved useful. Their locations appear in Figures 8 and 9.

Water Quality Analyses

Water quality samples were taken on a monthly basis from the piezometer tubes after bailing and total or partial head recovery. Monthly sampling was found to be adequate for groundwater monitoring because of its relatively slow flow rate. Monthly sampling also allowed the piezometers ample time to recover lost head caused by bailing and sampling.

The chemical analyses were performed using Hach DR-EL, pH, iron, and 2200 specific conductance field test kits and units. During the course of the study chemical oxygen demands were analyzed by the Engineering Research Institute Laboratory, and trace element scans were performed by Drs. V. Fassel and R. Kniseleys' research groups of the Ames Laboratory.

Specific chemical parameters under observation are listed in Table 1. The estimated accuracy of the above chemical parameters are listed in Table 2. The trace elements studied are listed in Table 3.

Temperature and water depth were recorded at the time of sampling. Other water level measurements were made before bailing the wells and two to three times a week by Dennis

Figure 8. ICP#1 coal exploration core holes

Figure 9. Auger holes not used for piezometer locations

Table 1. Chemical parameters under study

Chemical analysis	Units	Method ^a
Specific conductance	ppm NaCl	Specific conductivity meter
pH	-log [H ⁺]	Wide range pH
Chloride	mg/l Cl ⁻	Mercuric nitrate titration
Alkalinity	mg/l CaCO ₃	Sulfuric acid titration
Sulfate	mg/ SO ₄ ⁼	Turbidimetric method
Nitrate-nitrogen	mg/l N	Cadmium reduction method
Total iron	mg/l Fe	Phenanthroline method
Ferrous iron	mg/l Fe ⁺⁺	Phenanthroline method
Chemical oxygen demand	mg/l O ₂	Dichromate reflux method ^b
Total hardness	mg/l CaCO ₃	EDTA titration
Calcium hardness	mg/l CaCO ₃	EDTA titration
Manganese	mg/l Mn ⁺⁺	Periodate method

^aHach modifications.^bEngineering Research Institute Laboratory.

Table 2. Estimated accuracy of chemical analyses (modified from Peckenpaugh, 1973)

Analysis	Range	Accuracy
Specific conductance	100-10000	+ 10%
Initial water temperature	--- ^a	+ .25°C
pH	---	+ .1
Alkalinity	---	+ 4 mg/l
Chloride	---	+ 2 mg/l
Sulfate	0-100	+ 10%
	100-300	+ 15%
	300-1000	+ 20%
	1000-2000	+ 25%
Nitrate	---	+ 1 mg/l
Total and ferrous iron	---	+ 5%
Total hardness	10-500	+ 5 mg/l
	500-1000	+ 10 mg/l
Calcium hardness	10-500	+ 5 mg/l
	500-1000	+ 10 mg/l
Manganese	---	+ 5%

^aAccuracy over entire range.

Table 3. Trace elements studied

Aluminum	Iron
Antimony	Magnesium
Arsenic	Manganese
Boron	Nickel
Barium	Lead
Beryllium	Selenium
Calcium	Tin
Chromium	Strontium
Cobalt	Vanadium
Copper	Zinc

Struck or a field assistant. Specific conductance, pH, total and ferrous iron, and occasionally sulfide were measured in the field to avoid changes before analysis. Lab analysis of samples was usually completed within a month after sampling, but occasionally two months elapsed.

Water sampling was done with a PVC bailer. The bailer was rinsed once with distilled water and twice with water from the well to be sampled prior to sample collection. Water samples were collected in polyethylene bottles after one rinse with well water. The water samples were then capped and stored on ice until returned to the laboratory. Trace elements were collected in a similar fashion except unused polyethylene bottles that had been acid leached for several days were used to hold the samples. Trace element samples were also acid fixed to under pH 2. Water quality samples were refrigerated at 10° Celsius from the time of sampling until analysis.

Wells having adequate head conditions were bailed on a monthly basis to insure a turnover of the groundwater flowing into them. Bailing of the wells was done by removing most of the water (all but 6 inches) above the bottom of the piezometer tube.

Correlation Analysis

Statistical correlations were performed using the Statistical Analysis System language to detect possible relationships between the monthly water quality parameters for a specific piezometer and relationships between rainfall, time, and water depth between all piezometers (Barr, Goodnight, Sall, and Helwig, 1976). These correlations are presented in Appendix E. The correlation data are presented in three parameters: r , p , and n . The correlation coefficient (r) gives an estimate of the degree of relationship of two parameters. Correlation coefficient values (r) approaching 1.0 indicate a high degree of estimated relationship, while values near 0.0 indicate little or no estimated relationship. The second parameter (p) is used to ascertain the significance of the correlation coefficient (r). Only p values less than one were considered meaningful. The percent significance level is computed by subtracting the p value from 1.0 and multiplying this result by 100. The parameter n is the number of data pairs used to arrive at the listed correlation coefficient.

PREMINING WATER FLOW

Premining Surface Water Flow

The premining surface (Figure 10) as seen in Figure 11 was drained by a series of dendritic water ways or small basins. Figure 11 shows that four small basins are responsible for the majority of surface water drainage from the premining ICP#1 site to Coal Creek. An area near the previous Iowa Coal Company mine north of ICP#1 was mined as an extension of ICP#1. This area was drained by parts of five small drainage basins prior to mining. Three of these basins drain to North Coal Creek on the east and north, while two of the basins drain to the southeast across the initial ICP#1 site. These last two drainages have been modified by road ditches that have been cut across them.

Premining Groundwater Flow

Groundwater flow occurs between particles and in the joints or fissures of the geologic material in the ICP#1 area on both a regional and local scale. Figure 12 illustrates the relationship between local and regional flow for the ICP#1 area. The Des Moines River acts as the regional groundwater sink or discharge point while Coal Creek and North Coal Creek are local discharge points.

Figure 10. Premining topography

Figure 11. Small basins controlling premining surface water drainage of the ICP#1 site

Figure 12. Comparison of local and regional groundwater flow

An in depth study of the regional groundwater impact of the ICP#1 surface mine is beyond the scope of this research. However, it is believed that regional impact from ICP#1 mining would be slight because of the low permeability of underlying sediments and the small area of regional groundwater recharge represented by the mine.

Study of the local shallow flow regime of the mine area was chosen as the major concern. The local groundwater flow regime of the study site can be partitioned into flow through surficial deposits and the consolidated bedrock materials. The surficial materials generally have greater permeabilities than do the consolidated materials of the area (with the exception of bedrock coal strata), and likewise transmit the largest portion of local groundwater flow. Coals are assumed to contribute little groundwater flow because they are almost completely confined by siltstones, claystones and shales.

Surficial deposits

The unconsolidated surficial materials as previously mentioned consist of glacial and alluvial deposits as well as weathered bedrock debris and eolian loess. The water flow through the loess occurs primarily only after rainfall and snowmelt because the loess is situated well above the water table. Flow in this material is usually in an unsaturated condition. Occasional saturated flow may occur if water is

held up on the loess-till interface due to a high permeability contrast. The primary routes for water movement in the loess are large desiccation cracks that appear in the material during drying periods. These cracks open to widths of one to one and one half inch, and reach depths of several feet. During periods of high rainfall these may be closed by sedimentation, swelling, or slumping. As the desiccation cracks close interparticle flow becomes relatively more important than does the previously mentioned "fissure" flow. Interparticle flow occurs between the silt grains and clay particles through connected pores. Pore flowage is also important at depths where drying cracks do not develop.

Most water flowing through the glacial till which lies below much of the loess is credited to fissure or joint flow as in the loess. The joints or cracks in the till probably occur as "fossil" desiccation cracks. The joints were most likely developed just after glacial deposition. In plan view the joints of the till form irregular three to six sided polygons ranging in size from four inches to two feet. Some of the cracks also appear to be dead end, i.e., they do not intersect other cracks. In plan view the central opening of the joints is not apparent, but an orange colored band from one to four inches wide marks their sinuous distribution. The color band may be an oxidation zone around the fracture or a fracture filling of oxidized material. In crossection the

joints appear to be an eighth of an inch wide or less. The wider joints are usually filled with a fine white sand, while the smaller openings have iron coatings on each side. In cross section the joints are roughly vertical and very wavy. Water may also flow through the pores in the till, but because of their small size and poor connection the flow is very slow. As a result of the small pore flow it is likely that most of the till flow characteristics are controlled by jointing.

Other glacial materials at ICP#1 that contribute to groundwater flow are the glacial sands and gravels which underlie till at the northwest corner of the site (Figure 4). The water flow through the sands and gravels is mostly between large interparticle pores. No joints are found as such in the sand and gravel deposits, but cross bedding foreset beds may have a similar effect. In the sand body, areas of higher matrix porosity and permeability may occur where coarse sands and gravels are mixed with finer sands at the base of planer and trough cross beds. Iron banding parallel to the trough cross beds is another evidence in favor of high matrix porosity in the sands. Several iron bands are often seen branching out from a common bedding plane and interfingering the coarser laminations of trough cross beds. Near the top and bottom of the sand unit are areas of well cemented ferruginous sandstone. This may or may not indicate a once preferred zone of water movement, but surely imposes a barrier at present. The

undulating conglomeritic and limonitic layer in the sands also would appear to retard vertical flow and may represent the premining water table. No apparent seepage was ever observed from the sands although they were very moist just under the surface below the conglomeritic zone.

The alluvium, and glacial sands compose the greatest water flow regime of the site. The saturated alluvium along Coal Creek consists of a series of very local and complex point bar, back swamp, clay plug, and low level terrace deposits. In upland areas, alluvium may be less than one foot thick while on the flood plain of Coal Creek it is commonly over 30 feet thick. The permeability of the saturated alluvium is relatively high due to the interconnection of point bar sand and gravel deposits, and the depth to water varies between ten and fifteen feet. Unsaturated portions of the alluvium near Coal Creek consist mostly of overbank silt and clay deposits. Unsaturated flow through the shallow parts of the alluvium is often by a combination of fissure flow and by flow between clay and silt particles. In the saturated zone most flow is through the coarser deposits such as sand and gravel which underlie the southeast side of the ICP#1 site (Figure 3).

A material with transitional groundwater flow properties between the unconsolidated and consolidated deposits is the weathered bedrock surface. In this material the natural

bedding planes have been enlarged by erosion or chemical breakdown. Often the bedrock surface is weathered and reworked by gravity to form a colluvial deposit. This type of deposit is commonly found at the flood plain-upland transition. The water flowing through these deposits is largely moving in fractures or bedding planes enlarged by weathering, and to a small extent through the pores of the more consolidated blocks or fragments of the weathered rock.

Consolidated bedrock

The flow of groundwater through the consolidated bedrock is in general much less than that of the unconsolidated deposits. This is due to the low permeability typical of shales, siltstones, and claystones making up the majority of the shallow consolidated bedrock of the area. The flow through these rocks is very slow with the largest part of the flow along numerous bedding planes, cross beds, and vertical joints. In the shales the bedding planes are separated by at most a few inches. Joints are commonly observed to be between one and three feet long and randomly intersect several bedding planes. The joints also appeared to have a major and a minor trend. These trends are approximately north 60° west and north 60° east for the major and minor sets, respectively. In addition to these joints there are several normal faults in the shales. These fractures show six to eight inches of displacement and dip between 45 and 55 degrees to the east.

These fractures may also be present in the other bedrock lithologies, but surface weathering and slumping prevented inspection of them. The pores of shales, claystones, and siltstones are very small and poorly connected causing their low water flow rates.

An exception to the low permeability of the bedrock is the coal that is found among the shales and other tight materials. The coals may be the most permeable of all geologic materials at the mine site. Although the coals have relatively high permeabilities it is believed that they contribute little to local groundwater flow because of near total confinement by much less permeable siltstones, claystones, shales and surficial clays.

The premining water table for the ICP#1 site (observed in the initial 15 auger holes and eight piezometers placed in August, 1975) is as in Figure 13. From this figure it is apparent that the water table is a subdued version of the sites topography. The groundwater flow direction of the site approximates that of the surface drainage. This flow direction is roughly from the northwest to the southeast or generally perpendicular to the water table elevation contours shown in Figure 13. The average gradient of the water table also appears to be near seven feet of head drop per 100 feet of horizontal movement.

Figure 13. Premining water table

Figure 14. Postmining water table, summer 1977

WATER FLOW DURING MINING

Surface Water Flow

During mining at ICP#1 surface water was diverted to either side of mining area to avoid frequent accumulations of precipitation runoff in the mine cuts. Diversion trenches were often cut just above the high walls to accomplish this task. A drain tube was used to move excess water from the mine cuts to the sediment pond after heavy rainfall.

Groundwater Flow

Coal surface mines as well, as other quarrying operations, assume characteristics of a large diameter well when extending below the groundwater table or into aquifers. As these "wells" or mining cuts breach water bearing strata the water will begin to move into the open excavation. The rate of this water movement is determined by the amount of water "standing" above the water level in the excavation (recharge head), the level of water standing in the excavation (discharge head), the permeability of the material releasing the water and the distance between the recharge and discharge heads. With time for a stationary mine cut an equilibrium flow rate will establish a cone of depression around the mine. Once mining increases the cut size the potential for an even larger cone of depression occurs. In this way mines potentially influence water storage

and flow in larger and larger areas. As to whether or not a mine actually effects its potential area of influence depends again on the permeabilities of the surrounding geologic materials and their head and gradient conditions. At ICP#1 most of the materials around the mining cuts are of types characterized by very low permeability. Because of these low permeabilities it is unlikely that the water systems of these materials will be significantly disturbed outside the mined areas. For the "tight" materials it is most likely that the mining process moves more rapidly into the upgradient strata than does an advancing cone of depression caused by free drainage. An exception to this rule lies in the highly permeable coal seams. This exception will be discussed in a later section.

The initiation of mining at ICP#1 upset the flow of groundwater across the ICP#1 site. Temporary water table reductions of as much as 50 feet from the premining condition are estimated (Figures 13 and 14). The causes of the groundwater flow disruption are the seepage and evaporation of water from highwalls, mine cut floors, and the spoiled material as mining cuts truncate groundwater flow paths. Figure 15 schematically represents this evaporation water loss and the accompanied water table drop at ICP#1.

As mentioned earlier the geologic materials making up the highwalls and mine cut floors are mostly low permeability

Figure 15. Schematic of groundwater loss induced by mining at ICP#1

rock types such as shales, claystones and siltstones. The coal seams are the only significant variation from this rule. The coals have relatively large permeabilities in comparison. These large coal permeabilities may be of little significance if coals are confined by shales, siltstones and claystones before mining. After mining opens a coal seam its large permeability would cause the majority of initial flow from the coal to be of water held in storage in the coal itself. Flow would decline from the initial rate until the flow out of the coal seam reaches equilibrium with recharge from its surroundings. Where the recharge is from siltstones and shales the area of equilibrium recharge would be very large.

Calculation of maximum seepage from evaporation data

The mining cuts at ICP#1 never accumulated a significant amount of water due to groundwater seepage. This indicates that the loss of groundwater to seepage from saturated portions of the mining cuts is less or at most equal to the average groundwater evaporation from the saturated areas. Following this premise a maximum groundwater seepage loss for the site can be generated with knowledge of the average saturated area of the mine exposed to evaporation, the average evaporation rate and the time over which the evaporation occurs. The area of the mine cuts can be estimated from Figure 16. Figure 16 shows the progression of the mining cuts

Figure 16. ICP#1 mining plan

as well as the location of spoil stock piles and the sediment retention pond. Table 4 lists the duration of the ICP#1 mining cuts, while Table 5 lists the estimated saturated area for mine cut floors and highwalls. From these tables it is found that the highwalls and mine cut floors compose 18 and 82 per cent of the saturated mine areas respectively. The saturated highwall

Table 4. Duration of ICP#1 mining cuts

Bottom seam cut	Opened	Closed	Duration (days)
1	9/1/75	12/15/75	106
2	12/15/75	5/15/76	152
3	5/15/76	8/2/76	79
4	8/2/76	2/15/77	197(225) ^a
5	2/15/77	6/15/77	120
Top seam cut			
1	7/15/76	8/15/76	31
2	8/2/76	1/15/77	166 ^b
3	8/15/76	2/15/77	184 ^b
4	2/15/77	4/15/77	59

^aOne half the highwall length of mine cut 4 was open simultaneously with cut 5 for the period 2/15/77 to 3/15/77.

^bCuts 2 and 3 of the top seam were open simultaneously for the period 8/15/76 to 2/15/77.

Table 5. Estimated saturated mine cut surfaces

Mine cut	Highwall length (ft)	Average highwall saturated height (ft)	Saturated ^{ab} highwall area (ft ²)	Saturated ^a mine floor area (ft ²)
<u>Bottom seam</u>				
1 ^c	1345	11	15000	--
1 ^d	1200	23	28000	200000
2	1520	26	40000	240000
3	1075	37	40000	150000
4	1025	44	45000	140000
4 ^e	500	45	23000	40000
5	500	45	23000	48000
<u>Top seam</u>				
1	550	15	8000	43000
2	800	15	12000	56000
3	650	15	10000	73000
4	525	15	8000	67000

^aHighwalls are assumed to be vertical.

^bRounded to nearest 1000 square feet.

^cBottom highwall of cut 1.

^dTop highwall of cut 1.

^eCorrection for over lap of mine cuts 4 and 5 of the bottom seam.

height was calculated from the premining water table configuration as in Figure 13, and Figure 17 which shows the estimated base of the mine spoil fill or the base of the highwalls in the mine cut areas. From Tables 4 and 5 an

Figure 17. Base of spoil fill and other disturbed areas

estimate of the average saturated surface area of mine cuts can be generated. This estimate is derived by multiplying the sum of saturated highwall and floor area times their duration in days, and then summing across all mine cuts and dividing by 667 (the estimated length of time in days that mining cuts were open to groundwater seepage and evaporation at ICP#1). The average saturated surface area open to evaporation per day of mining a ICP#1 is then 245,000 square feet.

Next, an average evaporation value must be derived. Kohler, Nordenson and Baker (1959) find south-central Iowa to have an average annual class A pan evaporation of 50 inches with a standard deviation of 5 inches. This value then yields an average daily evaporation of 0.137 inches or 0.0114 feet. From the average daily evaporation and the average daily mining cut size the "maximum" average daily seepage and evaporation from the mine is calculated to be near 2800 ft³ of water per day or 1,863,000 ft³ for the entire 667 days of mining at ICP#1. These values in gallons are 21,000 and 11,972,000 gallons for daily and total mining periods respectively.

The previous seepage and evaporation illustration was calculated following the assumption that reclaimed spoil faces of the mining cuts contributed a negligible amount of water to evaporation because of their undersaturated condition.

Gregory (1977) shows that the shale spoil on the site was at

less than one half water saturation. This fact is demonstrated by Gregory's volume moisture content data from before and after a series of infiltration tests. These data show a preinfiltration moisture content range of about 10 to 16 percent, while the moisture content after a steady state runoff occurred (assuming this implies saturation) was in a range of 36 to 41 percent by volume.

The evaporation illustration does not account for the seasonal variation of evaporation. The ICP#1 mine was open for approximately two fall, winter, and spring seasons and only one summer. This would indicate that the "maximum" seepage and evaporation estimate would be a little high. A more accurate average estimate would be .0099 inches per day based on seasonal evaporation data for central Iowa (Ames) as listed in U.S. Department of Commerce (1950).

The season weighted evaporation rate would then reduce the previous estimated maximum seepage and evaporation by about 15 percent to 2400 ft³ per day and 1,618,000 ft³ for 667 days of mining.

A season-mining area weighted seepage and evaporation rate may also be needed to determine the interaction of both changing mine cut areas and changing seasonal evaporation. This weighted average system will be introduced in the following refinement of groundwater seepage and evaporation. Monthly and daily adjusted evaporation estimates for ICP#1 are as listed in Table 6.

Table 6. Estimated monthly and daily evaporation (from U.S. Dept. Commerce 1950; Kohler et al., 1959)

Month	A ^a	B ^b	Month	A	B	Month	A	B
Jan. ^c	0.74	0.024	May ^d	6.32	0.204	Sept. ^d	5.67	0.189
Feb. ^c	0.97	0.035	Jun. ^d	7.45	0.248	Oct. ^d	3.80	0.123
Mar. ^c	1.94	0.063	Jul. ^d	8.73	0.282	Nov. ^c	1.31	0.044
Apr. ^d	5.10	0.170	Aug. ^d	7.23	0.233	Dec. ^c	0.74	0.024

^aMonthly amount in inches.

^bDaily amount in inches.

^cWeighted values by comparison to Lakeside Missouri values of November through March.

^dAverage for Ames, Clarinda, and Iowa City, seven month record.

Combining data of Tables 4, 5, 6, and 7 the "maximum" seasonal-area adjusted seepage and evaporation for the ICP#1 site is 1,536,000 ft³ for the 667 days of mining or an average of 2300 ft³ per day. The seasonal adjusted evaporation amounts used in the previous calculation are listed in Table 7 as follows:

Table 7. Seasonal adjusted evaporation

Bottom seam cut	Evaporation inches/day	Top seam cut	Evaporation inches/day
1	.0105	1	.0258
2	.0080	2	.0114
3	.0251	3	.0089
4	.0099	4	.0084
4a	.0050		
5	.0146		

Calculation of maximum seepage from permeability and gradient estimates

Groundwater seepage from the mine cuts has been approached from an evaporation limit standpoint. It is also of interest to obtain a perspective of seepage as controlled by the permeabilities and groundwater flow gradients at the ICP#1 mine, but first some timely observations must be reviewed.

As previously pointed out the majority of saturated bed-rock materials at ICP#1 are characterized by low permeability. Because of these low permeabilities evaporation prevents the accumulation of any moisture on their surfaces. Coals provide a striking exception to the low permeability rule. While coal accounts for less than ten percent of the thickness of deposits it probably has the greatest influence on groundwater flow

during mining. This influence is due to the high permeabilities characterizing the coal seams. Most of the bedrock materials at the ICP#1 site are siltstones, claystones and shales which commonly have hydraulic conductivity values between 0.01 and 0.00001 ft/day (Morris and Johnson, 1967). On the other hand coal commonly has a conductivity range between 0.1 and 500 ft/day (Taber, Fulton, Dabbous, and Reznik, 1974).

Numerous coal seams occurred in the strata at ICP#1, but only three of these coals developed significant seepages. Two of these coals were mined, while the third was not. The two mined seams occurred at elevations between 697 to 715 and 745 to 760 with respective average thicknesses of about two and one-half and five feet. The third coal was located near elevation 730 at the west side of the mine and had a thickness of about one and one-half foot. Of these three coals only the upper coal was positioned so that an estimated flow rate could be obtained. The visible seepage rate was initially estimated at about ten gallons per hour from a one by fifty foot seepage face in August 1976. At the same time two other seepages occurred at the east and west end of the upper seam, but the combined flow of these two was only about half that of the first. Near the end of mining the visible seepage from the upper mined coal seam was significantly reduced to less than one gallon per hour at the west side of the upper coal seam.

A small pool of water (about ten square feet in surface area) was maintained by a seepage below piezometer Q also.

From the initial seepage of ten gallons per hour an estimate can be made of the hydraulic conductivity of the coal from the Darcy flow equation:

$$Q = KiA \quad (1)$$

where:

Q = volume of flow

K = hydraulic conductivity

i = flow gradient

A = cross sectional flow area.

By rearranging Equation 1 we get:

$$K = Q/iA. \quad (2)$$

Assuming the coal seam flow gradient equals the average water table slope and the seepage face is fifty square feet, the value of K will equal about 69 gallons/ft²/day (9.2 ft/day) if Q is ten gallons per hour. This indicates that the coal seams are from one thousand to one million times as "permeable" as the other bedrock materials at ICP. From this example it can be seen that where coal seams outcrop from very low permeability rocks the coal will provide an under drain effect and significantly increase the effective seepage face of the surrounding low permeability strata.

To understand the extent of the influence of drainage from coals opened by mining it is important to understand the flow gradients and head conditions that may prevail in the coal seam before and after it is opened by mining. Prior to mining the water flow system of the coal seam will be in equilibrium with the surrounding siltstones, claystones, and shales. The initial head conditions of the coal seam would then be equal to the average head of the overlying saturated material. At ICP#1 the bottom coal would then have an approximate head of 740 msl. This premise follows from the assumption that the piezometric head in the siltstones, claystones, and shales can be approximated by the water table surface.

As the mining operation opens the coal the head conditions in the coal would rapidly adjust to the level of the mine cut at about 700 msl. Water would drain quickly from the coal relative to the low permeability overlying rocks. Rocks above the coal would not be able to supply waters to the coal as rapidly as it would be capable of draining them. This could mean that a large area of coal would have a greatly decreased head from the premining condition. The area of head decrease would be determined by the permeability and flow gradient across the low permeability rock-coal contact relative to the coal's permeability and flow gradient to its seepage face at the mine cut. The relationship between the coals and the overlying low permeability rock at ICP#1 is shown in Figure 18.

Figure 18. Relationship of ICP#1 coals to surrounding low permeability strata

In the case of both coals it should be noted that shales are the overlying strata.

Two models exist for the drainage of water from the coal seams at ICP#1. These two possibilities depend upon the topography of the coal seams. The first model as in Figure 19 occurs when the unmined coal behind a highwall is at the same, or a higher elevation than the coal outcrop in the mine cut (down dip seepage). In this case the vast majority of initial seepage would be of water stored in the coal itself. The amount of seepage would then decrease until a recharge equilibrium had been set up with the overlying shale. The second model as in Figure 20 occurs where the coals behind the highwalls are at a lower elevation than those at the mine cut outcrop (up dip seepage). In this instance the coal contributes little of the water stored in it, but passes water only in response to the head drop between the overlying shales and the coal outcrop at the mine cut. The rocks below the mining cuts and coal seams probably contribute only the water that has been stored due to compression from the overlying premining head. This amount of water would be very little since the water would not have been significantly compressed by the premining head. A maximum of 60 feet of premining head would compress water only about 0.008 percent for water with a bulk modulus of 310,000 (Shortley and Williams, 1971).

Figure 19. Up dip coal seepage

Figure 20. Down dip coal seepage

The up and down dip seepage models represent a rather complex situation when applied to the ICP#1 coal seams. The bottom and top seams as shown in Figures 21 and 22 form very irregular surfaces. Each seam undulates as much as 20 feet in the mining area. The upper coal may dip steeply west of ICP#1. It has also been described as forming a split from the lower coal. The juncture of this split was found in a mine cut at the Star Coal Company west of ICP#1 (personal communication Lyle Sendlein and John Lemish ICP#1).

The structure of the upper coal seam indicates that water would flow from its crest to the north and south into mining cuts operated by ICP#1. The upper coal would contribute down dip seepage to active mining cuts. The lower ICP#1 coal presents a more complex picture. From the exposed coal and its elevation in various core and auger holes it would appear to contribute only up dip seepage to the mine area. The observation that the bottom coal is mined at Star Coal Company 1500 feet to the west at approximately the same elevation would indicate that the coal seam tends to undulate in a narrow elevation range. Assuming that this is true it is possible to tabulate possible maximum gradients that could occur in the lower coal as it is opened to mining. These gradients are listed in Table 8. These gradients were calculated under the assumption that the coal seams undulate no more than 20 feet above or below the seepage outcrop, and that

Figure 21. Bottom seam structure contour

Figure 22. Top seam structure contour

Table 8. Maximum and minimum slopes (ft/ft) of ICP#1 coal seams and associated water flow gradients

Distance range (feet)	Maximum and minimum coal seam slope ^a	Maximum unconfined water flow gradient ^a
0	--	∞
1-10	$\pm 0.059^b$	0.331
10-100	$\pm 0.059^b$	0.086
100-1000	$\pm 0.059^b$	0.062
1000-2000	± 0.014	0.015

^aAverage over range.

^bHighest observed slope on the lower ICP#1 coal seam.

the flow gradients (in coal seams opened by mining) are controlled by their structure.

Table 8 gives the gradients for the water in coal seams, but gradients are still needed for the shales and siltstones surrounding the coals. The average saturated thickness of shale over the lower coal seam at ICP#1 is about 40 feet. It was also noted that joints from one to three feet long were common in the shales. If it is assumed that the majority of vertical head loss in the shale is due to joint flow, the gradient would be equal to the head drop across the shale-coal interface divided by the average joint length. If the average head drop is taken to be 40, and the average distance over

which the head drops is 2 (the average joint length), the gradient would be 20.

The hydraulic conductivity of the shale bedrock around piezometer 5a was measured by a bailing test. The results are tabulated in Appendix F. The results show that the shale has an average conductivity of .001 ft/day. This value is two orders of magnitude greater than the average computed by Morris and Johnson (1967). This high conductivity may also reflect the shales proximity to siltstones below. This point is given support by ICP#1 core hole data given by Sendlein (1975) for geologic strata below the lower coal.

The distribution of the coal seams is also of interest in calculating mining seepage. The lower coal is known to exist in the Star mine 1500 feet west of ICP#1 and also below the ICO mine site. If it is assumed that elevation 720 of the ICP#1 area locates the lower coal seam it would have an area of about 130 acres. This area is only the area that would contribute seepage to ICP#1. The western boundary used to calculate the coal area would be about 750 feet west of ICP#1. This is due to the fact that the lower coal was not mined at Star until one of the latest cuts was opened near Star coal company's western border (Personal communication with Jim Huyser, Star Coal Co.). It is assumed that drainage will be approximately divided equally between the Star Company's mine cuts and those of ICP#1. East of the divide line between

ICP#1 and Star the lower coal should be drained "only by ICP#1 mining. At ICP#1 about 18 acres of the bottom seam has been mined. This would leave at a maximum, the remaining coal (having recharge effects on ICP#1) to have an area of 112 acres. The initial extent of the upper seam was about 40 acres in recharge areas effecting ICP#1. Of this seam a maximum of 15 acres remains to the north and northwest of ICP#1.

Table 9 summarizes the geohydrologic parameters discussed which lend to an evaluation of seepage during mining at ICP#1.

Table 9. Hydrogeologic summary

hydraulic conductivities (ft/day) -
coal: 10
shale: 0.001 (to 0.00001)
average evaporation rate: .0114 ft/day
hydraulic gradients -
coal: .331 to .015
shale: 20
coal seepage face: 1 foot
average highwall length: 1500 feet
average mine cut floor area: 201,000 ft ²
average height of saturated highwall: 41 ft

From Table 9 a maximum average daily flow from the lower coal seam (removable by evaporation) was calculated. This flow is about 2300 ft^3 as seen earlier. This flow is equivalent to about 1.5 ft^3 of water flow from one cubic foot of coal seepage face. For the bottom coal which has a conductivity of 10 ft/day this would give a flow gradient through the coal of about 0.15 ft/ft.

At ICP#1 the flow from coals in the highwall was never uniform. Seepages were usually located near the depressions in the coal surface. The entire floor of the mine was never saturated after most of the coal had been removed. At most about one third of the mine pit floor was saturated. This fact suggests that the flow into the mine pit was at most about $765 \text{ ft}^3/\text{day}$. This would suggest a gradient flow of about .05. This is approximately equal to the gradient of the premining water table.

If we assume .07 to be the average gradient for all the materials in the highwall at ICP#1 the average daily flows from the highwall would be as in Table 10.

Table 10 illustrates the apparent lack of water seepage from any highwall materials except the coal. The flow from the highwalls is also equal to about 38 percent of the maximum evaporation from the mine cuts.

In addition to seepage from the highwalls there is the possibility of seepage up through the mine floors. Seepage

Table 10. Average highwall daily seepage (flow gradient = .07)

Rock type	Hydraulic conductivity (ft/day)	Thickness	Flow/day ^a (ft ³)
Coal	10	1.0 ^b	1050
Shale ^c	.001	15	1.6
Shale ^d	.00001	15	0.02
Siltstone and claystone ^d	.001	10	1.0
Overburden ^e	.001	10	1.0

^aFlow for 1500 foot average highwall length.

^bCoal seepage face (average coal thickness for upper and lower seam combined was 3.5 feet) time weighted.

^cShale with conductivity as tested at ICP#1.

^dShale with conductivity after Morris and Johnson (1967).

^eOxidized shale and till.

up through the mine cut floor is probably very low because there can be only a very limited amount of head transfer through a level coal seam open to the mining cut. Any pressure or head added to the coal seam from the overlying shales would push water through the coal seam to the seepage face before it could transfer the head to the low permeability siltstones and shales below the coals. As will be discussed in the next section the upper coal was dewatered north of

ICP#1 by mining from 100 to 300 feet away. From this fact, for seepage to move up from the mine floor it must have a "near by" source of head. At ICP#1 the source of head is usually water saturated shale overlying a coal bed. As seen at the mine the coal bed can be drained at least 100 feet from the mine cut. This means that head transfer from the shale overlying the coal, to a shale or siltstone underlying the coal, must occur beyond 100 feet from the coal seepage face. Thus, if 20 feet of head is exerted across the coal into the underlying siltstones or shale to cause seepage 100 hundred feet away the flow gradient would be 0.2. This would give a maximum flow of 0.0002 cubic feet per square foot of the mine floor just in front of the highwall. Assuming that flow would be parallel to the width of the mine cut (135 ft) the average gradient across a mine cut would be 0.12. This would give a maximum flow of 0.00012 cubic feet per square foot of mine floor (with 0.001 ft/day hydraulic conductivity). The total seepage from an average size mine cut floor at ICP#1 (201,000 ft²) would only be about 24 cubic feet per day. This flow is about 100 times less than the flow that must occur to give an excess surface accumulation of seepage water relative to average evaporation. This mine floor seepage is also less than 2 percent of the previously calculated seepage flow from the highwalls.

The water that moved through the ICP#1 mining cuts during 667 days of mining can be better understood by dividing it into five classes. These classes include:

1. Surface runoff (primarily from areas upslope from mining cuts)
2. Groundwater flow through the mine floor and mine highwalls
3. Precipitation intercepted by the mining cuts
4. Evaporation from the mine floor and highwalls
5. Drainage from the mine cut to the sediment pond.

The surface runoff that moved into the mine cuts is estimated at 505,600 cubic feet. This value was derived by summing all precipitation falling on areas that drained to the mining cuts, and multiplying by 0.18. The multiplication factor was derived from data given by Walton (1970) for glaciated drainage basins in Illinois. The factor is the average runoff divided by the total precipitation.

The groundwater flow into the mine cuts has already been estimated. It includes: 700,400 cubic feet of flow through the coal seams, 2,400 cubic feet of flow through the siltstones and shales overlying the coal, and 16,000 cubic feet of seepage up through the mine floor for a total of 718,800 cubic feet.

The precipitation intercepted by the mining cuts was calculated by summing the products of mine cut areas and the rainfall that occurred while they were open. The derived estimate is

864,700 cubic feet of water.

The evaporation from the mine cuts was previously estimated at a maximum (potential) value of 1,536,000 cubic feet. A more realistic value may be attained again from Walton (1970). Walton's data indicates that approximately 65 percent of rainfall on glacial drainage basins of Illinois is lost to evaporation. Assuming this estimate holds for southern Iowa, the evaporation from water flowing into the ICP#1 mine cuts can be calculated. The amount of evaporation can then be broken down as follows: 562,100 cubic feet from rainfall and 457,200 cubic feet from groundwater flow. It is also possible that as much as 328,600 cubic feet of additional evaporation may have occurred from surface runoff moving through the mine cuts. The total estimated evaporation is then 1,019,300 cubic feet if the surface runoff is ignored or 1,347,900 cubic feet including the evaporation from surface runoff into the mining cuts.

Estimates of drainage from the mine cuts to the sediment pond can be made from the previous four classes. Water inflow into the mine cuts is estimated to be 2,089,100 cubic feet from rainfall interception, surface runoff and groundwater. Since the mining cuts did not accumulate significant amounts of water the outflow must equal the water inflow. Evaporation and drainage constitute the major outflows, thus the subtraction of evaporation from inflows (due to rainfall, surface runoff, and groundwater flow) will yield an estimate of 1,069,800 ft³.

Dynamic piezometric effects of mining at ICP#1

The extent of dewatering of the geologic strata at ICP#1 was observed in three piezometers above the north highwall of the mine. These piezometers are 4a, M, and Q as located in Figures 4 and 5. Piezometer 4a has a surface elevation of about 800 feet and extends to a depth of 43 feet. 4a is open to sample from the upper coal between depths of 39 and 43 feet. Piezometer M has a surface elevation of about 772 and was drilled to a depth of 17 feet. M is open to sample water from a silty sand and gravel alluvial deposit. The third piezometer, Q, has a surface elevation of 769 feet and has a maximum depth of 40 feet. Piezometer Q is open to collect groundwater from its bottom 35 feet. Q's 35 foot sampling depth contains shales, siltstones, claystones, the upper coal, and the silty sands and gravels sampled in M.

The strata monitored by these piezometers were not significantly disturbed by mining until May and June of 1976, however no significant changes were observed until late in July 1976. At this time the upper coal seam was opened for mining at a distance of about 300 feet from piezometer 4a (mine cut 1 of the top coal seam in Figure 16). As the coal was removed the water level dropped eight tenths of one foot and leveled off at this head (759.8) until the end of September 1976 (Figure 23). This leveling perhaps indicates a temporary recharge was received from the overlying sands and gravels.

Figure 23. Dynamic piezometric effects of surface mining at ICP#1

The leveling may have also been due to a new equilibrium set up as a result of mining. A similar but less obvious trend was also observed in piezometer Q.

Late in September 1976 a north-south cut was excavated into the upper coal seam at the northwest corner of the site (mine cut 2 of the top coal seam in Figure 16). This allowed a second seepage face to form on the upper coal at a distance from piezometer 4a of again about 300. This activity was followed by the complete loss of water in piezometer 4a as shown in Figure 23. A small amount of water, however remained seeping from the coal outcrop in cut 2. This was possibly due to flow from recharge areas to the northwest.

Declining water levels in M and Q were also noticed at this time (September--November 1976). The water level in Q dropped from an elevation of 760.4 to about 750 feet (Figure 23). The water level in M dropped also, but only about three feet. The water level in M leveled off at this time and never went significantly lower. Q, on the other hand, continued to lose head. From early November 1976 until mid-February of 1977 Q lost an additional four feet due to mining as close as ten feet away. From mid-February until the fall of 1977 Q regained about seven feet of head due to closure of the mining cuts during reclamation of the upper coal seam bench. The logs of the hole in which Q was placed show that the upper coal was located at a depth of 18.5 to 24.5 feet. The water

level depth record as shown in Figure 23 indicates that the coal was dewatered through four and one half to five feet of its six feet thickness (assuming that the coal seam is the only significant charge to Q).

Piezometers 4a and M remained unchanged through the summer of 1977. It appears that the shales, sands and gravels near M and Q are recharging the coal seam. This is not the case near 4a. Apparently in the case of 4a, a larger dewatering impact was felt in this area due to mine cut 2 which substantially constricted an already narrow recharge path from the northwest through the upper coal.

From June 1976 until February 1977 the water levels correlate significantly (+.88). This is higher than their correlation before and after mining (+.65). These piezometers also correlate with rainfall more strongly during mining than at other times. The correlations for M for the entire study period and for the mining period are .51 (August 1975--August 1977) and .73 (June 1976--March 1977) respectively. This variation may be explained by the loss of water storage in enclosing sediments during mining. With less water held in storage the addition of precipitation infiltration will change water levels by a larger relative extent. Infiltration water would be more quickly drained also.

The results of water level monitoring north of ICP#1 indicate that the coal seams are the only strata significantly

disturbed by mining in upgradient areas, although some water loss must occur from all the strata.

Another condition exists that may affect the piezometric head at the north of ICP#1. This is the drainage of the south ICO mining cut (Figure 24). Approximately three feet of water was drained from the ICO mining cut at the end of September 1976. During this drainage the water surface in the ICO cut was reduced from 753.5 to 750.5. No significant drainage occurred after this until the fall of 1977. The ICO cut is located 130 and 170 feet from piezometers Q and M respectively. The upper coal seam at the ICO cut is near the same elevation as at piezometer Q. The top of the coal at piezometer Q is at 750.5 so that the drainage at the ICO cut to this elevation would not have produced the loss of five feet of head below this level. The drainage of the ICO pit could reduce the recharge of water to the top coal at Q and thus allow a seepage face at ICP#1 to drain the coal more effectively. It appears possible then that the affects of mining on the water in the coal at Q are related to both ICP#1 mining and drainage from the ICO mine cut. This is supported by the fact that Q regained only seven of the fourteen feet of "mining head loss" after reclamation.

The "large" loss of water from the upper coal seam north of the mine is largely due to the fact that they dip or slope into the mining area. Well 2a (Figures 5, 6 and 7) is located

Figure 24. ICO site before and after reclamation

RECLAMATION
GRADE ORIGINAL SPOIL
TOPOGRAPHY

in a portion of what appears to be the lower coal seam. The coal at this location appears to be dipping or sloping away from the mined area in Figure 21. The water depths in well 2a have a correlation of -0.51 with time over the period June 1976 to August 1977. This would indicate that the piezometric head decreased on the average with time for this area also. The piezometric head in 2a dropped at most three and one half feet during mining, but the coal never came close to being drained. The equilibrium piezometric head fluctuated between 13.5 and 17 feet above the coal seam for the period June 1976 to August 1977.

POST MINING WATER FLOW

Surface Water Flow

The post mining surface topography of the ICP#1 site is shown in Figure 25. The surface consists of four flat terraces separated by four relatively steep backslopes. The premining drainage ways have been eliminated in favor of a tile drainage system located at the foot of each terrace backslope. Surface water is gravity drained from the terraces to tile inlets as shown by arrows in Figure 25. After reaching the tiles the water is drained to South Coal Creek by an underdrain system as shown in Figure 25.

Groundwater Flow

Spoil character and water flow

The groundwater flow after mining at ICP#1 will be governed by the unsaturated spoil replaced into the mining cuts. Until the spoil material is saturated the groundwater flow through the site may be retarded. Groundwater flow through the ICP#1 site after mining will be rather chaotic in the areas filled with spoil. The spoil fill consists of several materials. They are pulverized and blocky shales and siltstones, sands and gravel, and some oxidized clays.

The permeability of the replaced spoil will be governed by the trade-offs between increased porosity after mining and

Figure 25. ICP#1 post mining topography

the premining fracture and joint flow. The spoil would perhaps tend to have a larger permeability than the original shale because of the increase of the fracture system through the material. The "secondary" fracture system of the spoil could also be significantly closed by very fine particles associated with the coarser fragments of bedrock and by compaction during reclamation. Areas of higher porosity would also include portions of the mine cuts filled with glacial sands and gravels as well as the base of the spoil where coarse accumulations of waste coal are located. The bedrock just below the coal may also have developed a larger porosity due to cracking after the shales were unloaded by overburden removal. Another case for the increase of porosity in the bedrock below the spoil would follow from the use of explosives to dislodge and break up the coal during mining.

Spoil undersaturation

As mentioned previously Gregory (1977) showed that the spoil at ICP#1 was from 60-75 percent undersaturated. The undersaturated condition is derived partially from evaporation and partially from the swell of the overburden materials as they are pulverized by the surface mining process.

Gregory (1977) shows that the shale spoil of the ICP#1 site has an effective porosity of about 40 percent. Part of this porosity is due to that of the original shale and part

has been added by swell. For an average swell at ICP#1 between 10 and 15 percent (personal communication with Marty Briggs, Agricultural Engineering, Iowa State University) the original effective porosities would be 31 and 27 percent respectively. From these porosity values estimates can be derived for the average amount of water lost from the spoil during handling and the volume of water needed to resaturate the fill.

Gregory (1977) reported the moisture content of the stockpiled shale at ICP#1 to range from about 10 to 16 percent by volume. The difference between the moisture content of the spoil and the effective porosity of the original shale would then give an estimate of the water lost due to evaporation through the mining process. The moisture content of the spoils should be corrected for swell. The corrected spoil moisture contents would then range from 11 to 19 percent by volume. The differences between the estimated original shale's effective porosity and the corrected spoil moisture range from eight to twenty percent. This range is then the unit loss of moisture due to mining.

If the previous moisture lost can be assumed over all the initially saturated spoils we can calculate the volume of water lost due to spoiling of the overburden. From Table 5 the total saturated bedrock at ICP#1 that has been spoiled is about 2,749,000 cubic feet (approximately one million cubic yards). This spoiled bedrock volume gives a water loss of 2,300,000 to

5,750,000 cubic feet of water. This water loss is 1.5 to 3.75 times the maximum possible seepage-evaporation rate of all the CP#1 mine cuts combined.

It is also of interest to calculate the volume of water needed to resaturate the spoil fill. For this calculation it will be assumed that the equilibrium water table across the reclaimed spoil is the same as across the original sediments. It will also be assumed that the shale spoil is representative for all spoils backfilled into the mining cuts.

The water needed to resaturate the spoil material would equal the difference between the total effective water porosity and the spoils present moisture content times the volume of spoil to be resaturated. The net moisture needed for resaturation would be between 24 and 30 percent by volume, given an effective porosity of 40 percent and a moisture content range of 10 to 16 percent. Using the same saturated volume as previously ($28,749,000 \text{ ft}^3$) the water needed would be between $6,900,000 \text{ ft}^3$ and $8,265,000 \text{ ft}^3$.

The previous examples show that the porosity of the shale spoil may be as much as 29 to 50 percent higher allowing for a much greater water storage potential. This storage potential has been given credit for recharging domestic and municipal water supplies as well as low flow augmentation of rivers (Agnew, 1966; Cederstrom, 1971; Deane, 1966; and Traux, 1965).

Recharge rates

As seen in the previous section the reclaimed spoil will need a large quantity of water for resaturation. This water will come from surface infiltration and from flow through the bedrock below. The recharge contribution of the bedrock will be determined by the magnitude of difference between the saturated bedrock permeabilities and the unsaturated spoil permeabilities. Assuming the spoil permeabilities are greater than or equal to the bedrock's we can estimate a recharge. Previously it was concluded that a quantity of 1050 ft^3 of water would flow into the mine daily from a 1500 foot highwall, for a combined upper and lower coal seepage face of about two feet. The ICP#1 mine cut has approximately 2000 and 1300 feet of highwall for the bottom and top coal respectively. If one foot seepage faces are initially present on coals in the present highwalls, the flows would be approximately the same. At a rate of 1050 ft^3 per day it would take a minimum of about 6 years to resaturate the volume of unsaturated spoil present at ICP#1. This assumes little contribution from the mine floor. Groundwater recharge would probably be more controlled by the permeability of the spoil fill. If this is the case a much slower recharge rate would occur.

Surface infiltration would also contribute a recharge to ICP#1 spoils. Walton (1970) lists groundwater recharge rates for basins of central Illinois. These basins are characterized

by glacial deposits and gentle to rugged topography as indicated by stream gradients from 3.9 to 16.6 feet per mile. The Coal Creek basin has a gradient of 10 feet per mile and is covered by glacial sediments also. Using these facts it appears that the ICP#1 mine's groundwater recharge contribution could be estimated with Walton's data. Walton (1970) lists a range of recharge values from about 4 inches per year to 10 inches per year. For the average spoil thickness of 40 feet at ICP#1 there is between 9.6 and 12 cubic feet of unsaturated spoil for every square foot of surface area. This indicates then that if favorable spoil permeability exists, the spoil would be resaturated in 12 to 36 years.

Recharge to the mine area of ICP#1 has been observed in six piezometers: 5a, 5b, 5c, 7a, 7b (Figure 5). Piezometer nest 5 indicates very little recharge to the spoil in this area. The base of the spoil fill near 5a and 5b is at 700 feet, while at 5c it is at 695. The spoil fill was replaced near 5a and 5b in January 1976. The fill near 5c was not replaced until June 1976. The dates of fill replacement should give an approximate date for the beginning of recharge assuming that it will essentially stop evaporation losses. From the time of spoil refill until August 1977 the spoil has recovered at most 2.75 and about 1.6 feet in 5a and 5c respectively. The water level in 5b is still 3.5 feet below the bottom of the fill. These slow water level increases may

indicate that the water table in these areas have always been low or that recharge to the down gradient side of the mine is very slow. Piezometer 5a does not directly sample the head of the spoil material, but that of the bedrock below. The head increase in this well may indicate recharge to the bedrock below the spoils or possibly a water table adjustment to reloading the area with spoil after mining. The small rise may also be only a seasonal trend. Piezometer 5b indicates that evaporation may remove a considerable amount of water from the mine floor sediments. The low water level at 5b may also demonstrate the water flow toward lower piezometric head areas near 5c where the water level is about two feet below that found at 5b.

At piezometer nest 7 only one of the three piezometers shows any head increase above the base of the shale. 7c showed this increase in about one foot of water level rise above the base of the spoil by July 1977. The spoil was replaced at 7c during May 1976. 7a and 7b as of July 1977 were 1 foot and 1.5 feet below the base of the shale fill. The spoil around 7a and 7b was replaced in October of 1975.

The recharge at nests 5 and 7 may be slow because they are at the down gradient side of the mine, or because of drainage to even lower areas of unsaturated fill.

Recharge areas

The recharge areas of ICP#1 can be broken into two categories. The first is the area which will contribute significant recharge to ICP#1 through surficial infiltration of rainfall. The second is the area that will contribute recharge to ICP#1 by groundwater flow through the bedrock and surficial geologic deposits.

The recharge area for rainfall infiltration at ICP#1 would be primarily the terraces over the 25 acres of mine spoil at ICP#1 (Figure 25). Areas outside the terraces may contribute infiltration recharge also but groundwater flow would be an intermediate step.

The flat terraces should provide the maximum opportunity for surface infiltration. At ICP#1 the terraces appear to be saturated in several places indicating their effectiveness to hold water. The water saturating the terraces may be backing up from a permeability drop between the oxidized overburden and the shale spoil below it. Another possibility would be the accumulation of water at the bottom depth of surface drying cracks in the oxidized overburden. Assuming that the cracks do not penetrate the oxidized overburden they could also cause a permeability contrast between material containing drying cracks and that not containing cracks.

If recharge does significantly recharge spoil beneath the oxidized overburden it may be possible to get springs forming

at the backslopes of the terraces. This condition is apparent when comparing the post mining surface with the premining water table as in Figure 26.

Groundwater recharge to the mine appears to be less significant than surface infiltration in terms of volume of flow. The primary contributors of groundwater flow to the ICP#1 mine spoil are the unmined portions of the coal seams. These strata can conduct large amounts of flow unless they are limited by very low permeability confining materials. The lower coal seam is unmined in its extent to the north and northeast of ICP#1. To the west it is unmined until the west side of the Star Coal Company mine. To the northwest the lower coal is unmined north of the Star mine. The maximum areal extent of portions of the lower coal seam that could contribute to groundwater flow at ICP#1 is 112 acres. As discussed earlier this includes about one-half of the coal between ICP#1 and Star and all of the coal to the north and northeast. The coal to the northwest of ICP#1 would probably drain away from ICP#1 due to its westerly slope (Figure 21). The possible extent of the lower coal seam is shown by the heavy black line and heavy black dotted line in Figure 27.

The recharge area covered by the upper coal seam mined at ICP#1 has an extent of only about 15 acres maximum as displayed by the solid black portion of Figure 27. The upper coal seam to the northwest of ICP#1 appears to have been

Figure 26. Comparison of post and premining surfaces

Figure 27. ICP#1 groundwater recharge areas

removed by glacial or preglacial erosion at piezometer location 10a (Figure 5). The upper coal also extends along the roads where it has not been removed by mining, and also occurs in a five acre area between ICP#1 and its continuation lease near the abandoned ICO mine. A portion of this five acre area is also eroded away as evidenced by an exploration core hole.

The glacial drift sands at the northwest corner of ICP#1 are another possible recharge source. The sands are distributed in the same areas as the upper coal (Figure 27). The sands are believed to be periodically saturated and could then contribute recharge to ICP#1. Figure 28 shows the position of the sands relative to the deposits at ICP#1. In some areas the shale between the upper coal and the sand has been eroded away so that water may easily move from the sand to the coal. Figure 28 shows the possibility of a seepage face developing at the back of the top terrace if significant recharge to the sand and coal can occur. The need for a drainage tube in the depression on the ICO site is also obvious from the cross-section in Figure 28. If water were allowed to accumulate in the depression it could also add to a seepage face at the back of the top ICP#1 terrace.

Other significant materials conducting flow to the unsaturated spoil at ICP#1 are the claystones, siltstones and shales. These materials are important because they confine the coals and control the waters moving through the coals.

Figure 28. ICO - ICP#1 cross section

figure 29 illustrates the distribution of these materials (from ICP#1 core hole logs) at the base of the mining cuts. As previously discussed these materials have contributed very little recharge to the down gradient side of the mine.

The last significant material to help recharge the ICP#1 spoils is the cast and scraper mining spoil of the Star and ICO mining sites. These areas are denoted by the diagonal shading in Figure 27. The spoil below the tipple at the Star Coal Company, 200 feet west of ICP#1, was saturated only six feet below the surface. This indicates an area of abundant recharge water, except that it occurs too low on the topography (elevation 730) to contribute to recharge through the upper coal. The water is also apparently separated from the lower coal by shales.

The maximum bedrock and surficial deposit recharge to ICP#1 is limited by natural and man made gradients in and near ICP#1. Figure 30 shows the maximum recharge area if flow from the perimeter of the ICP#1 spoils allow an equilibrium gradient to be set up. This would represent the cone of depression formed by opposing gradients of .07 ft/ft.

Figure 29. Distribution of low permeability bedrock and coals in the ICP#1 mine

Figure 30. Maximum recharge area for opposing natural and ICP#1 induced gradients of .07

WATER QUALITY DURING MINING AND RECLAMATION AT ICP#1

Sources of Water Quality Alteration

The primary purpose of monitoring the water quality of ICP#1 is to detect possible groundwater quality changes that could be correlated to surface mining and reclamation. Of special interest is the quality of groundwater near surface charges of acidic waters. The unreclaimed mine cuts, acidic spoil storage areas and runoff and sediment basins would be the most likely of the acid charge locations.

Changes in water quality will be judged by differences between yearly means and correlation to a time scale estimating the days of mining previous to a given sampling. Reference will also be made to water quality from sample sites out side the ICP#1 area.

The first location of mining impact on groundwater quality to be reviewed will be around the ICP#1 sediment retention pond. But before this is studied in detail it is necessary to review the sources of acid mine waters occurring at ICP#1. Before mining the water chemistry of the site was controlled by equilibriums between carbon dioxide, water, carbonic acid, hydrogen ion and bicarbonate as in Figure 31. The source of carbon dioxide is the atmosphere and bacterial action in soils (Sawyer and McCarty, 1967). With dissociation of carbonic

Figure 31. Dominant premining equilibrium

Figure 32. Equilibrium shift due to mining

acid the hydrogen ion will establish an equilibrium with carbonates in the surface soil and bedrock (Sawyer and McCarty, 1967). These two reactions give a water with calcium and bicarbonate as the primary dissolved species.

Mining exposes materials often rich in iron sulfides. These materials react strongly with atmospheric oxygen as in Figure 32 to give an acidic sulfate water. The acid conditions change the favored side of the carbon dioxide--bicarbonate equilibrium and carbon dioxide is given up from the system. The dominant species in water that is effected by mining are then calcium, iron and sulfate.

Spoil runoff

At ICP#1 the spoiled bedrock materials as well the high-walls and floor of mining cuts serve as reaction sites for the oxidation of pyrite as in Figure 32. The oxidation of pyritic bedrock materials at ICP#1 caused a large degradation of surface waters of the ICP#1 site. Most of the surface water from the mine cuts and spoil storage areas was drained to the sediment pond as seen in Figure 16.

The greatest impact to surface water quality at ICP#1 was caused by drainage from a shale storage pile located just to the north of the sediment pond. Analysis of water samples collected by Gregory (1977) during artificial rainfall on the shale pile illustrate the poor quality of the effluent (see

Appendix D6). Selected components of the effluent have been plotted against time in Figure 33. The data show very high initial concentrations of dissolved species, especially calcium, magnesium and sulfate. For rainfall of 3.4 inches per hour intensity the concentration of dissolved species decay rather rapidly after runoff begins. The rainfall intensity used by Gregory was nearly ten times the mean of the median class for rainfall measured at ICP#1 as listed in Table 11 (personal communications with Mary Briggs and Steve Colvin, Agricultural Engineering, Iowa State University).

From Figure 33 it took about 3.5 minutes for runoff to occur from the shale under a rainfall intensity of 3.4 inches/hour. If a rainstorm of intensity .93 inches/hour (the average intensity by percent total rainfall) fell on the shale pile it would take about 3.7 times as long as in Gregory's study to reach the average runoff threshold time. This time would be about 13 minutes. From this it is apparent that for the average intensity of rainfall experienced at ICP#1 the runoff would be at a rate about 3.7 times lower than Gregory's data show. This also means that the high concentration of dissolved species in the natural runoff from the shale pile would decay at a slower rate, perhaps 3.7 times slower. At any rate for a "long" term rainstorm the total amounts of dissolved species removed from the pile would be about the same, assuming the concentrations of dissolved species had reached

Figure 33. Shale storage pile effluent with time for simulated rainfall of intensity 3.4 in/hr

Table 11. ICP#1 rainfall intensity distribution from August 1975 to July 1977. (From personal communication with Marty Briggs and Steve Colvin, Agricultural Engineering, Iowa State University.)

Rainfall intensity class (in/hr)	Percent of total rainfall	Rainfall intensity class (in/hr)	Percent of total rainfall
.00- .01	18	1.50-2.00	4
.10- .25	24	2.00-2.50	5
.25- .50	15 ^a	2.50-3.50	5
.50-1.00	13 ^b	3.50-5.00	3
1.00-1.50	12	5.00-7.00	2

^aMedian class.

^bClass containing average intensity (weighted by percent total rainfall).

its lower limits by the end of the rainfall period. In other words the total dissolved material load for a one hour storm of 3.4 inches per hour intensity should roughly equal total dissolved material load for a 3.7 hour storm of .93 inches per hour intensity. If this model holds, the time taken to reach the decay limit for runoff at a rainfall intensity of .93 inches per hour would be about an hour and fifty minutes. This was computed by multiplying the 30 minutes needed for Gregory's runoff (to approach its bottom dissolved constituent limit) by 3.7. From the average rainfall intensity and from

the total rainfall recorded from the period August 1, 1975 through July 31, 1977; the total hours of rainfall at ICP#1 for that period can be calculated. From Appendix C the total rainfall for the two year period of study is found to be 58.82 inches. This indicates that about 63 hours of rainfall occurred at ICP#1 over two years. One hundred and fifteen rainfall events occurred at ICP#1 between August 1975 and August 1977 so the average rainfall period would be one-half hour. Also the time needed for runoff (from average intensity rainfall at ICP#1) to reach the lower dissolved constituent limit is one hour and fifty minutes. From these last two observations the runoff water from the shale pile would then appear to be significantly more concentrated than the lower dissolved constituent limit.

Sediment pond water quality

The sediment pond is located at the southeast corner of the mining site (Figure 16). It is located in this position to best intercept the surface water flow across the site. The pond is situated on relatively high permeability alluvial sediments mantled by a silt and a clay layer. Depths to water near the sediment pond ranged from 10 to 15 feet before its initial filling in the fall of 1975. As water accumulated in the pond the groundwater piezometric surface rose a maximum of ten feet creating a groundwater mound. This mound developed

artesian conditions in Piezometer G at the east-central side of the pond. This condition was related to the very good interconnection between the pond and the sediments around G. The interconnection was due to a soil disturbance in that area caused by placing a tile or pipe from the pond to a stock hydrant near G.

The water quality of the pond remained fairly constant from September 1975 and April 1976 (personal communication with Lavene Payne, Botany, Iowa State University). Typical pH values ranged between 7 and 8. Other parameters that were studied also remained fairly constant for this period. Alkalinity was low, typically between five and ten milligrams per liter as CaCO_3 . Sulfate and total hardness were below 100 mg/l. Specific conductance was measured at about 100 as ppm NaCl, with total iron and chloride concentrations at .3 and 2 mg/l respectively. In late April 1976 after about eight months of mining the sediment pond began to show the effects of acid drainage from the previously referenced shale storage pile to the north. It is estimated that between one-half and one-third of the shale pile area of about $75,000 \text{ ft}^3$ would drain into the sediment pond. Drainage from oxidized overburden piles also drained into the sediment pond but their initial effluent was about 6 to 60 times less mineralized than shale spoil runoff as evidenced by water quality data from the Gregory (1977) study (see Appendix D6).

From late April until late September and early October of 1976 the pond was overcome by acid drainage from the shale storage area. Data from Table 12 indicated this change.

Table 12. Sediment pond water quality change

Sample date	5/01/76	9/17/76
pH	6.1	<4.1
Specific conductance	210	1500
Sulfate	160	1100
Total iron	0.5	20
Total hardness	210	1045

The very acid conditions of the pond caused the corrosion of the pond drainage pipe and complete drainage of the sediment pond in July 1976. Attempts were made to reduce the acidity of the pond with lime treatments with significant success. The lime treatments also effected the iron concentration of the sediment pond water. The total iron content of the pond dropped from an initial concentration of 20 mg/l to 6 mg/l for the first lime treatment and from 6 mg/l to 2.5 mg/l after the second. One month after the treatments the total iron content was back up to 5 mg/l. The total iron never exceeded 5.5 mg/l according to monthly determinations after

lime treatment. The pond contained a high manganese concentration of about 10 mg/l just prior to its drainage in April 1977.

Groundwater Quality

The effects of mining on the groundwater surrounding the sediment pond are not nearly as blatant as those observed for the surface water in the pond. This is probably due to the precipitation and adsorption of the chemical pollutants at the bottom of the sediment pond. Williams and Steinbergs (1962) found that sulfate could be adsorbed by clays with maximum absorption occurring at pH values between two and four.

The causes of groundwater alteration from the sediment pond are a combination of at least two phenomena. The first is the infiltration of acid mine waters containing large concentrations of acidity, sulfate, hardness and iron. The second process is the formation of soil reducing conditions as infiltrating water filled and forced air from the pores of the sediments near the sediment pond. The reducing conditions then should follow from the groundwater mound generated by the sediment pond. Hesse (1971) states that water logged soils may cause formation of sulfides from sulfates and thus reduce sulfate contents. Hesse (1971) also states that the water logging of soils can increase divalent manganese concentrations. Van Breeman and Brinkman (1976) add that flooding can cause pH

drops in alkaline soils as well as increased ferrous iron nitrite, and alkalinity. The reactions which Van Breeman and Brinkman (1976) use to illustrate the formation of alkalinity following flooding are as follows:

Effects similar to those previously discussed appear to have occurred from observation of yearly water quality averages as listed in Table 13.

Groundwater quality near the sediment pond

As suggested before, the changes in the groundwater quality below the sediment pond are not as obvious as those observed for the surface water of the pond. Piezometers C1, C2, E and G sample from depths of 33, 22, 21 and 24 feet respectively. All of these piezometers show significant positive correlations between specific conductance and time. The respective coefficients for C1, C2, E and G are 0.84, 0.90,

Table 13. Selected yearly water quality averages.

Piezometer	C1		C2		E		G	
Year	1 ^a	2 ^b	1	2	1	2	1	2
Specific conductance	183-278		162-207		175-213		175-219	
pH	7.6-7.6		7.5-7.1		7.3-7.1		7.1-6.6	
Chloride	5-4.7		3-4.3		2.9-4.2		4.1-4.9	
Alkalinity	197-250		185-202		184-187		128-116	
sulfate	20- 48		4.6-3.4		11 ^c - 19		68- 73	
Total iron	3.6-6.6		2.1-7.6		5.1-9.7		4.8-6.7	
Total hardness	160-216		147-153		173-158		134-130	
Calcium hardness	109-135		107-104		130-110		98-100	
Magnesium hardness	51- 81		40- 49		43- 48		37- 31	

^aAverage for year 8/75 to 7/76.

^bAverage for year 8/76 to 7/77

^cData not included from 8/8/75.

0.61 and 0.74. These indicate a possible increase in dissolved mineral species with time. The ranges for these increases are from 52 percent in piezometer C1 to 22 percent in piezometer E. Alkalinities show increases in piezometers C1 and C2, while G has a decrease and E remains nearly constant. The total iron concentration of all the piezometers show some increase in iron. All wells but C1 show significant positive correlations with time for total iron concentration.

The pH values of all the piezometers but C1 show decreases. These decreases of pH were accompanied by significant negative correlation coefficients of $-.65$, $-.49$ and $-.62$ for C2, E and G respectively. The wells all showed some increase in chloride after the sediment pond became acidic. This was also about the time that the chloride concentration of the pond dropped to zero. The chloride drop may be due to the complexing of the chloride with iron.

The sulfate behavior of the piezometers around the sediment pond vary widely. Piezometers C1 and E show initial declines in sulfate. At about the same time as the sediment pond became acid the sulfates in C1 and E began to increase and level off at constant levels. Piezometer G showed no trend in sulfate concentration while C2 shows a small decline.

Trace element runs were conducted near the beginning of mining (November 1975) and at the end of mining (June 1977). The trace element analysis of wells around the sediment pond show large relative decreases in nearly all constituents measured except for the common groundwater ions of calcium and magnesium, and the less common manganese and cobalt. Manganese concentrations show increases of 72, 58 and 30 percent in wells C2, E and G respectively. Manganese concentrations around the pond after mining range from 1.23 to .49 mg/l.

In summary the piezometers around the pond have all been effected by increased specific conductance, total iron, and

chloride. Specific conductance increases in piezometers C1 and C2 are explained by increasing hardness and alkalinity. piezometers E and G show no relationships between their increased specific conductances and their other water quality parameters. Piezometer G is the only well near the pond which does not have alkalinity values greater than its hardness. This may indicate a neutralization of bicarbonate by acid mine water. Piezometer E may also be affected by acid drainage from the pond in this way.

From hydrogeologic information gathered during the placement of piezometers some interesting light can be shed on the chemistry observed in the groundwater around the mine. From Figure 3 it can be seen that piezometer C1 penetrates to relatively low permeability gray clayey sands and the bedrock surface, while piezometer C2 penetrates to slightly more permeable gray sands and gray clays. At the east side of the sediment pond wells E and G penetrate very permeable sands and a gravel layer. The inferred relative permeabilities for the sediments sampled by sediment pond piezometers would then be $C1 < C2 < E < G$. This would imply a faster infiltration rate for sediments sampled at the east side of the sediment pond in wells E and G. With these data in mind plus evidence listed in Tables 13 and 14 the chemistry of the groundwater in this area become more clear.

Table 14. Ferrous-total iron relationship for ICP#1 (averaged data from spring and summer of 1977)

piezometer	Location	Fe++ average % of Total Fe	Maximum sampling depth elevation
C ₁	Flood plain	17	670
C ₂	Flood plain	82	681
E	Flood plain	82	680
G	Flood plain	69	676
S ₂	Flood plain	59	691
9a	Flood plain	92	687
T	Flood plain ^a	4	674
1a	Transitional	7	694
1b	Transitional ^b	42	689
1c	Transitional	4	699
1d	Transitional	8	697
2a	Transitional	10	701
2b	Transitional	7	688
2c	Transitional	14	701
2d	Transitional	21	711
3a	Transitional	7	713
0	Transitional	2	702
K	Upland	1	709
ICP#1 dug well	Upland	5	712
M	Upland	11	755
Q	Upland	3	729
7a	Reclaimed fill	81	700
7c	Reclaimed fill	85	702
5a	Bedrock	35	690

^aPiezometer is partially plugged.

^bPiezometer is partially into bedrock.

As seen from Tables 13 and 14, and as previously mentioned, wells C1 and C2 exhibit increasing specific conductivity, alkalinity, and hardness, while experiencing a decreasing pH. C2 has a high ferrous iron content while C1 does not. (The low ferrous iron content of C1 is not believed representative of the sediments it samples. Water moves so slowly into this well that it would be easily oxidized.) These suggest that C1 and C2 are sampling from groundwaters becoming more reduced.

Piezometers E and G show decreasing pH values, with increased iron. Sulfate, hardness, and alkalinity show nearly constant or reduced values as seen in Table 13. Table 14 suggests that E and G have high ferrous to ferric ratios indicating reducing conditions as in C2. This suggests that while piezometers C1 and C2 are subjected mostly to a reducing environment, piezometers E and G are subjected to a reducing environment with some influence caused by infiltrating acidic sediment pond water. The degree of effect by infiltrating acid pond water appears to be correlated with the permeability of the sediments sampled by the piezometers. Piezometer G appears to be effected the most because of a decreasing alkalinity, slightly increased sulfate, and low pH. The low pH of G as well as the reduced alkalinity suggest that acidity related to infiltrating mine water is present in the sample. The presence of acidity in piezometer E may also be reflected

by the increase in specific conductance while alkalinity and hardness show stable and decreased concentrations respectively.

Groundwater quality in the reclaimed fill

Another major area of groundwater quality interest is the spoil-fill areas of the reclaimed mine cuts. At ICP#1 the fill water quality is being monitored at the present time by six piezometers. Unfortunately only three of the wells have yielded enough water for analysis, and one of the wells is actually a bedrock background well. The piezometers monitoring the fill areas include nests 5 and 7. Wells 5b, 5c, 7a, 7b and 7c are open to the base of the shale fill. Well 5a is open in the bedrock just below the bedrock-shale fill contact.

The water found at the base of the fill is highly mineralized in comparison to other areas of the mine site. Piezometers 7a and 7c were placed into this mineralized water in the first mine cut at ICP#1. The groundwater below the fill is much less mineralized than the fill water. Piezometer 5a penetrates into the bedrock to sample ground water from an elevation about 10 feet below the fill water sampled by 7a and 7c. Table 15 shows periodic averages for water quality parameters from piezometers 7a and 5a as well as the variation of water quality in the lower coal mine cuts.

Piezometers 5a and 7a have very different water qualities except for alkalinity. Piezometer 7a appears to be much more

Table 15. Water quality comparisons for piezometers 7a and 5a and lower ICP#1 mine cuts

Sample location	Piezometer 5a		Piezometer 7a		Lower mine cut low-high
	1 ^a	2 ^b	1 ^c	2 ^d	
pH	7.3-7.3		6.6-6.5 ^e		4.0- 9.1
Chloride	7.4-5.4		6.3-3.7 ^e		0.5-22.5
Alkalinity	435-481		473-437 ^e		0.0-140
Sulfate	103- 84		1220-1380 ^f		310-1700
Nitrate-Nitrogen	0.29-0.26		0.66-0.55 ^e		0.88-19.0
Total iron	0.4-1.2		2.3-3.9 ^e		0.1-11.8
Total hardness	216-204		1818-1618 ^f		240-1480
Specific conductance	452-536		1859-1588 ^e		410-1600

^aInitial six month's average.

^bFinal six month's average.

^cInitial four to five month's average.

^dFinal four to five month's average.

^eFour month average.

^fFive month average.

similar to the highly mineralized mine cut waters from ranges given in Table 15. Specific conductances for 7a appear to be three to four times those found on the average in 5a, while hardness and sulfate are twelve to sixteen and seven to nine times higher respectively. This is contrasted by alkalinities

of similar ranges. The water in 7a appears to be remnant acid water from the mine cut floor area that has been nearly neutralized by the alkalinity of recharging waters from the consolidated bedrock below. It is also possible that recharging waters from the bedrock have dissolved pyrite oxidation products from formerly dry spoil. Another possibility is that the mineralized water is effluent from a broken drainage tube used to drain an acid puddle on the surface of the reclaimed spoil. The location of this drainage tube is shown in Figure 34. The remnant acid model appears to be the better because the water drained by the drainage tube was acid for at most only about three months prior to the first sampling of piezometer 7a. This would only allow a short period of time for water to flow about 200 feet in the tight shale spoil to piezometer 7a.

The last major area of water quality alteration is the area of dewatering up gradient from the mine. The major dewatering of sediments north of the mine occurred in the upper coal seam and possibly in the sand body which was above the coal. Three piezometers 4a, M, and Q with respective depths of 42, 17 and 40 feet were used to study this dewatering. The water quality data for piezometer Q and M fluctuate rather radically. These fluctuations appear to be related to precipitation as shown by significant negative correlations with precipitation. The parameters showing these variations are

Figure 34. Potential enclave development at ICP#1

alkalinity, sulfate, calcium hardness and total hardness. The cause for the emphasized relationship between rainfall and water quality parameters as well as depth to water can be seen from examining its topographic setting. M and Q are located at the base of a semi-circular drainage. This waterway is also blocked by a road just to the north of M that may slow the surface drainage enough to increase infiltration. These piezometer's sensitivity to water level fluctuations cause them to be good indicators of drainage by the mining occurring near them. Table 16 summarizes the increased concentrations observed as mining progressed.

Piezometer Q is open to about 35 feet of siltstones, shale, the upper coal seam, and silty alluvial sands and gravels. The silty sands and gravels, and the coal seam are probably the major water contributors in this section prior to mining. As previously mentioned the coal is the most permeable of the strata supplying water to Q. This would indicate that before the coal was dewatered by mining it should contribute the largest portion of water to Q. As the coal is dewatered more rapidly (by mining) than the silty sands and gravels, piezometer Q would take on the water quality characteristics of the water at piezometer M. The reduction of head at Q could also draw effluent from the southern ICO mining cut through the coal.

Table 16. Periodic averages for water quality parameters in piezometers M and Q

piezometer	M		Q	
	1 ^a	2 ^b	1 ^c	2 ^d
Specific conductance	283-353		200-449	
pH	7.3-3.0		7.3-7.4	
Chloride	5 -5.5		5.2-4.7	
Alkalinity	146-185		123-219	
Sulfate	167-167		84-194	
Total iron	0.63-1.31		0.75-0.35	
Total hardness	320-377		222-415	
Calcium hardness	210-255		147-339	

^aAverage for year August 1975 to July 1976.

^bAverage for year August 1976 to July 1977.

^cAverage for monthly samples between May 1976 and November 1976.

^dAverage for monthly sample between January 1977 and July 1977.

The head in well Q should also reflect the piezometer head of the coal seam better than any of the other strata because of the low permeability of materials below the upper coal, the lower permeability of the sands and gravels, and the tendency for the coal to drain any water higher than its base as long as it is open to mining.

The previous set of conditions were very well illustrated by the water quality data contributed by Q. When the upper seam was opened by mining the water quality of Q was significantly different from that observed after mining started. This difference can be seen between the averages listed in Table 16. The silty sands and gravels probably contribute most of the water to Q and the coal because at M, the silty sands and gravels lie directly over the coal.

A different sequence of events was observed in piezometer 4a. This well (open to the upper coal and some shale above it) was placed into the coal at a time after mining effects had begun. The water initially tested was more similar to the mineralized water of the sands and gravels. Just prior to the drying up of the well the water quality became noticeably better. This may have been due to a slower movement of the water allowing the coal to better "treat" or remove impurities from the water. These changes are summarized in Table 17.

A final point can be made about the northeast side of the site of spoil cored terraces built above the water table. The purpose of monitoring these terraces is to detect water quality changes due to infiltration of waters that may pick up oxidation products of pyrite abundant in some of the spoil under the terraces. Monitoring was also to detect water table configuration changes due to an altered infiltration pattern caused by the terraces. No significant water quality or flow

Table 17. Selected data from piezometer #4a

	7/16/76	8/11/76	9/12/76
Specific conductance	420	233	225
Chloride	8	7	5
Alkalinity	316	269	135
Total hardness	380	300	155
Calcium hardness	265	215	60
Noncarbonate hardness	64	31	20
Water depth	39.6	40.3	42.1
Sulfate	115	69	82

changes that could be attributed to mining were observed. The shale cores of the terraces remained unsaturated after one year of placement as proven during piezometer placement drilling in March of 1977. A significant impact of another sort was detected. This was caused by the situation of a farm barnyard on the site previous to mining. High concentrations of chloride, nitrate, and manganese were observed at various wells in this location that are attributable to the barnyard environment.

Enclave development

It appears that the only areas of possible contamination plume development are areas where seepage can move out from the reclaimed mine cuts and from the base of the sediment pond. To date there appears to be only a limited resaturation in the first mine cut, and thus no significant amounts of highly mineralized water are moving out from this area.

Three potential mineralized water seepages from the first mine cut to the alluvial sediments of Coal Creek are possible. These seepages are labeled 1, 2, and 4 in Figure 34. Two of these seepages (1 and 2) are located in premining waterways. The third (4) is located along a ruptured drainage tube that had been used to remove water from the mine cuts.

The sediment pond is currently the origin of a slightly acidic plume as discussed previously. This contamination plume may be extensively increased after burial of wet sediments deposited in the sediment retention pond. This is because of the significant quantities of iron sulfates and hydroxides that characterize the sediments of the sediment pond. After burial of these deposits with organic rich topsoil, reducing conditions may begin in the very wet sediments. The reducing conditions could cause remobilization of the iron in the sediments and reduce the iron sulfates to iron sulfides. After the sediments dry, oxidation of the iron sulfides may again occur and release sulfuric acid. This cycle could be

further complicated by frequent flooding of the flood plain sediments in the location of the sediment pond.

Comparison of ICP#1 Groundwaters
to Others of the Area

Several sites outside the ICP#1 mine that were sampled during the summer of 1977 (except Garden samples which were taken in the fall of 1975) are shown in Figure 35. These wells were sampled to check the variability of groundwater quality outside the mine. Six deep wells (200+ feet in depth) and five shallow wells (25 feet in depth) were sampled. The deeper wells were characterized by very mineralized waters. Their hardness ranged from 550 to 1480 mg/l as CaCO_3 . Alkalinities ranged from 240 to 355 mg/l as CaCO_3 , while sulfates and specific conductances ranged from 300 to 2700 and 1400 mg/l to 2800 as ppm NaCl respectively. In comparison to ICP#1 the deep wells were similar to the mineralized water from the reclaimed mine cuts except for much higher chlorides in the range of 173 to 233 mg/l.

The shallow wells compared more closely with the ICP#1 piezometers outside the fill areas. For these wells specific conductances ranged from 590 to 235 as ppm NaCl. Alkalinities ranged from 110 to 320 mg/l as CaCO_3 , sulfates and hardness range from 18 to 220 mg/l and 117 to 490 mg/l as CaCO_3 respectively.

Figure 35. Locations of groundwater sampling outside the ICP#1 site

SUMMARY AND CONCLUSIONS

The groundwater effects of surface mining at ICP#1 can be classified primarily as water quality and water quantity effects.

The water quantity effects of ICP#1 surface mining are:

- 1) The loss of groundwater saturation in spoil materials that were initially removed from over the coal and later replaced;
- 2) The dewatering of high permeability geologic strata up gradient of mining area;
- 3) The increase in porosity and possibly permeability in refilled spoil materials;
- 4) The change in groundwater gradients in mined areas and near the sediment pond.

The water quality effects of ICP#1 surface mining and reclamation are:

- 1) The generation of slightly mineralized enclaves near the sediment pond and spoil accumulations;
- 2) The generation of thin zones of highly mineralized water near the base of reclaimed spoil probably due mostly to remnant acid mine water;
- 3) Reduction of water quality in coal seams as a result of dewatering at the time of mining and subsequent oxidation of their pyrite content.

Most effects of water quantity loss in and around the mine are not permanent. Recharge of geologic strata outside the ICP#1 site has begun as indicated in piezometer Q. Unfortunately this recharge is being pirated from shallower strata, but the shallow strata are more directly susceptible to infiltration from surface waters. The recharge of the reclaimed mine area and surrounding geologic strata will come from areas near the mine that have not been disturbed to a major extent by surface mining. Coal spoil materials to the west of ICP#1 may also contribute valuable recharge. The primary recharge to groundwater at ICP#1 may be due to surface infiltration. Major groundwater recharge areas around the ICP#1 site include the undisturbed hills to the northwest, north, and northeast of the mine cut area. The major groundwater recharge conduits are the unmined portions of the coal seams and the sands and gravels of the undisturbed surrounding hillsides. Secondary recharge sources appear to be the bedrock in and below the highwalls of the reclaimed portion of the mine cuts.

Water quality disturbances of the fringe areas of reclaimed mine areas will be very slow in attenuating because of the slow groundwater flow through these materials. Areas of thicker spoil and larger potential water level increases are believed to have better water quality because of dilution as larger quantities of water will return to these areas.

Adulterated groundwaters in high permeability areas such as the flood plain alluvium will be more quickly attenuated than those in the mine spoil areas, but these enclaves also have the potential to effect much larger areas due to more rapid groundwater movement. At ICP#1 a slightly mineralized enclave exists in the flood plain groundwaters to the south-east and south of the sediment pond. The source of the enclave is water infiltrating from the acid sediment retention pond.

Reduced pH and alkalinity were observed in a very restricted area near the east side of the sediment pond. While large increases in alkalinity and hardness were observed to the south, it is very doubtful that the enclave produced by the sediment pond will have a significant effect on the groundwater environment because of the low level of mineralization. The mineralized areas of the mine pits, on the other hand, may be sources of groundwater alteration on a larger scale if the contaminants can move through the shale bedrock or get flushed into flood plain sediments.

RECOMMENDATIONS FOR FURTHER STUDY

Continued study is needed to establish attenuation rates and the shape of mineralized water enclaves introduced by acid water from the ICP#1 sediment pond. Similar work is also needed to study the mineralization and the recharge of the groundwater in the spoil reclamation areas. These further studies are needed to confirm the capabilities of rainfall infiltration and groundwater flow to provide recharge water to reclaimed fill. Mathematical modeling of groundwater and surface infiltration would also give a much closer approximation of rates of water return to the mine spoils.

Work should also be done to determine saturated and unsaturated permeabilities of the spoil fill as well as the geologic materials surrounding the fill. These studies would help to plan possible mining in other areas.

More complete chemical analyses may also be needed to confirm the elevated acidity of groundwater in the sediment pond area as well as possible remobilization of iron sulfates and hydroxides deposited by the sediment pond.

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**APPENDIX A: WELL DEVELOPMENT
AND SURFACE ELEVATIONS**

Table A1. Well development and surface elevations

Well	3" auger hole	1.5" PVC casing	7" auger hole	2" PVC casing	3' slotted screen	2' slotted screen	3' drilled screen	5' drilled screen	3' gravel pack	5' gravel pack	Bentonite backfill	4" core hole	30" bored well	Completion depth	Surface elevation
C1	XX	XX					XX		XX		XX			33	702.6
C2	XX	XX					XX		XX		XX			22	702.5
E	XX	XX					XX		XX		XX			21	700.9
G	XX	XX					XX		XX		XX			24	700.3
K	XX	XX					XX		XX		XX			34	742.9
Dug well													XX	25	737.4
M	XX	XX					XX		XX		XX			17	771.8
Q				XX				XX			XX	XX		40	769.4
S2	XX	XX			XX				XX		XX			20	710.8
T	XX	XX					XX		XX		XX			33	707.2
1a			XX	XX				XX		XX	XX			20	714.4
1b			XX	XX	XX					XX	XX			25	714.0
1c			XX	XX	XX					XX	XX			15	714.0
1d			XX	XX	XX					XX	XX			29	726.0
2a			XX	XX				XX		XX	XX			35	735.5
2b			XX	XX	XX					XX	XX			35	725.8
2c			XX	XX	XX					XX	XX			25	725.7
2d			XX	XX	XX					XX	XX			25	735.8
3a			XX	XX				XX		XX	XX			23	736.4
4a			XX	XX				XX		XX	XX			43	800.1
5a			XX	XX				XX		XX	XX			43	733.0
5b			XX	XX	XX					XX	XX			40	738.7
5c			XX	XX	XX					XX	XX			43	739.6
7a			XX	XX				XX		XX	XX			34	734.4
7b			XX	XX	XX					XX	XX			30	733.5
7c			XX	XX	XX					XX	XX			34	736.4
8a	XX	XX				XX			XX		XX			25	726.9
9a	XX	XX				XX			XX		XX			25	711.6
10a			XX	XX	XX					XX	XX			48	806.6

APPENDIX B: WELL AND BORE HOLE LOGS

Table B1. Well logs

Well no.	Date placed	Description of material	Depth (feet)
C1	8-6-75	Yellow-brown silt	0-5
		Gray clayey silty	5-10
		Yellow-gray sandy clay (9' water table)	10-15
		Gray sand	15-20
		Gray sandy silt	20-25
		Gray sand	25-33
C2	8-7-75	Yellow-brown silt (9' water table)	0-10
		Fine yellow clayey sand	10-14
		Gray sand gradually changes to gray clay	14-22
E	8-8-75	Yellow-brown silt	0-5
		Brown sandy clay	5-10
		Brown clayey sand (13' water table)	10-15
		Olive sand	15-18
		Gravel	18-19
		Olive sand	19-20
		Gray clay and shale	20-20.5
G	8-7-75	Yellow-brown silt	0-5
		Sandy clay (11' water table)	5-20
		Olive sand and gravel	20-24
		Shale	24
K	8-14-75	Clay fill (added February 1976)	0-10
		Yellow-brown gravel and sand	10-15
		Red-brown sand (27' water table)	15-30
		Yellow-brown sand	30-35
		Gray shale	35
M	8-13-75	Brown silt	0-3
		Yellow-brown silt and gravel	3-5
		Red-brown sand and some gravel (10' water table)	5-15
		Dark brown sand	15
		Dark gray sandy clay	15-17
		Gray shale	17
Q	3-3-76	Brown silty clay	0-2.5
		Sand and gravelly clay	2.5-8.5
		Gray and brown mottled clay	8.5-13
		Gray hard silty clay	13-14.4

Table B1 (Continued)

Well no.	Date placed	Description of material	Depth (feet)
Q	3-3-76 (Continued)	Black hard shale	14.4-17.9
		Black to light gray sandy banded siltstone	17.9-18.5
		Coal	18.5-24.5
		Light gray siltstone	24.5-33.4
		Light gray to buff claystone	33.4-40.9
S ₂	4-9-77	Black to dark brown silty clay	0-4
		Brown silt with siltstone fragments	4-9
		Medium brown silty clay	9-12
		Olive clay (15' water table)	12-15
		Olive clay with fine sand	15-25
		Gray fine sandy clay with red weathered shale (well placed to 20')	25-30
T	8-12-75	Yellow-brown silt	0-10
		Brown clay (14' water table)	10-15
		Gray sandy clay	15-25
		Gray sand	25-33
1a	6-7-76	Black silty clay	0-1
		Medium brown silty clay	1-5
		Gray-brown silty clay (moist at 8')	5-8
		Medium brown sandy clay (15' water table)	8-18
		Medium brown sand with gravel	18-20
1b	2-28-77	Black silty clay	0-1
		Medium brown silty clay	1-9
		Gray-brown silty clay	9-14
		Medium brown sandy clay (little auger return and 22' water table)	14-24
		Gray shale	24-25
1c	2-28-77	Black silty clay	0-1
		Medium brown clay (some black shale mixed in)	1-5
		Medium brown silty clay	5-10
		Medium brown sandy clay	10-14.5

Table B1 (Continued)

Well no.	Date placed	Description of material	Depth (feet)
2a	6-8-76	Medium brown clay and black topsoil	0-5
		Medium brown silty clay	5-10
		Light gray shale of siltstone	10-12
		Medium brown silty clay	12-17
		Light brown loess clayey silts (dry)	17-19
		Light gray shale (dry) (siltstone?)	19-24
		Red shale or siltstone	24-25
		Gray and red shale of siltstone	25-28.5
		Gray calcareous shale or siltstone (Hard drilling)	28.5-29.5
		Red shale or siltstone	29.5-35
		Light to medium gray shale or siltstone (coal blossom on bit when retrieved)	34-35
2b	2-28-77	Medium brown silty clay and black silty clay (mixed)	0-5
		Medium brown sandy clay	5-10
		Gray siltstone	10-15
		Red siltstone	15-20
		Red and gray siltstone	20-25
		Gray siltstone	25-30
		Gray siltstone (wet at 34')	30-34
		Dark gray shale	34-35
2c	2-28-77	Medium brown clay and black silty clay topsoil mixed	0-5
		Medium brown sandy clay	5-8
		Medium brown clay	8-13
		Red siltstone	13-21
		Light gray siltstone (dry)	21-25
2d	2-28-77	Medium brown clay and black silty clay topsoil mixed	0-5
		Medium brown silty clay	5-10
		Medium brown clay	10-15
		Medium brown sandy clay (moist?)	15-20
		Medium brown silty clay	20-23
		Gray siltstone	23-24
		Red siltstone (dry)	24-25

Table B1 (Continued)

Well no.	Date placed	Description of material	Depth (feet)
3a	6-7-77	Medium brown sandy clay	0-9
		Light gray to buff sandy clay	9-11
		Light gray clay (18' water table)	11-18
		Red-brown and buff sands	18-22
		Dark gray shale	22-22.5
4a	6-8-76	Brown silty clay	0-30
		Brown medium sands and some gravels	30-35
		Hard cemented sands and gravel	35-39
		Coal	39-42.5
5a	6-9-76	Light brown silty clay	0-8
		Gray shale	8-13
		Gray-black shale	13-17
		Light brown silty clay	17-19
		Dark gray shale	19-37.5
		Dark gray shale (original material) (dry)	37.5-42.5
5b	3-1-77	Medium brown silty clay	0-7
		Gray-black shale (dry)	17-40
5c	3-1-77	Yellow-brown silty clay	0-10
		Dark gray-brown silty clay	10-13
		Yellow-brown silty clay at 23' turning into dark gray shale at 28'	23-28
		Dark gray shale (hit concretion at 34')	28-34
		Dark gray shale and pieces of concretion hit at 34'	34-39
		Gray-black shale (original material)	39-43
7a	6-9-76	Red-brown sandy clay	0-8
		Dark gray shale (moist?)	8-14
		Dark gray-black shale (dry) (Hit concretion - limestone returned 22-23 feet, Black limestone)	14-32
		Hard dark gray-black shale (original material)	32-34
7b	3-1-77	Brown sandy clay	0-10
		Gray-black shale	10-30

Table B1 (Continued)

Well no.	Date placed	Description of material	Depth (feet)
7c	3-1-77	Yellow-brown silty clay	0-1
		Gray-black shale	4-8
		Yellow-brown silty clay	8-9
		Gray-black shale	9-14
		Light gray siltstone	14-21
		Black shale and brown silty clay	21-24
		Gray-black shale	24-27
		Gray-black shale and brown silty clay	27-32
		Gray shale	32-34
8a	4-9-77	Black silty clay	0-3
		Yellow-brown silty clay	3-8
		Yellow-brown clay	8-10
		Yellow-brown clay with sand (16' water table)	10-20
		Dark brown clay	20-25
9a	4-9-77	Black silty clay	0-5
		Dark brown silty clay	5-8
		Medium brown clay	8-10
		Yellow-brown clay (12' water table)	10-13
		Yellow clay with black shale fragments	13-15
		Gray clay	15-20
10	3-1-76	Gray clay with reddish-gray sand	20-25
		Yellow-brown silty clay	0-11
		Yellow-brown loess	11-14
		Red and yellow-brown clay (till)	14-35
		Red-brown sand and some gravel	35-49
		Silty dark gray sand with weathered coal and shale (well placed to 47.5 due to cave in)	49-53

Table B2. Auger hole logs

Auger hole	Date placed	Description of material	Depth (feet)
A	8-6-75	Brown silty clay	0-5
		Brown silt with clay	5-11
		Sandy clay	11-14
		Yellow-brown fine sand (15' water table)	14-22
		Gray clay	22-36
B	8-6-75	Yellow-brown silt	0-5
		Gray-brown silt	5-7.5
		Gray silt with clay	7.5-10
		Gray sandy clay (14' water table)	10-14
		Yellow-brown sand	14-20
		Gray sand	20-27
		Shale	27
D	8-7-75	Gray-brown silt	0-1.5
		Brown silt	1.5-5
		Red sand	5-9
		Red-brown clay (12' water table)	9-15
		Olive sand	15-20
		Dark olive sand	20-25
		Gray clay with pyrite	25-27.5
F	8-8-75	Yellow-brown silt	0-5
		Brown sandy clay	5-10
		Fine olive to gray-brown sand (11' water table)	10-18
		Gravel and olive sand	18-18.5
		Olive sand	18.5-22
		Black shale	22
L	8-13-75	Light brown silt	0-5
		Red-brown sandy clay	5-7
		Black sandy silt	7-8
		Coal	8
		Black shale (9' water table)	8-10
N	8-13-75	Light brown silt	0-2
		Yellow-brown sandy clay	2-10
		Red-brown sandy clay	10-12
		Red-brown sand	12-17
		Gray pyritic shale	17

Table B2 (Continued)

Auger hole	Date placed	Description of material	Depth (feet)
R	8-12-75	Yellow-brown silt	0-5
		Yellow-brown clay	5-10
		Yellow-brown sandy clay	10-11
		Red-brown sandy clay (15' water table)	11-15
		Yellow coarse sand with clay	15-20
		Light gray clay	20-25
		Gray clay	25-34
S	8-12-75	Yellow-brown silt	0-10
		Yellow-brown mottled clay (14' water table)	10-15
		Gray and yellow-brown clay	15-20
		Yellow clay	20-25
		Gray clay	25-30
		Fine gray sand	30-35
		Gray shale	35

Table B3. Core hole logs^a

Core hole	Surface elev.	Dominant lithology	Depth	
			From	To
1	784.5	Oxidized overburden	0	17.5
		Shale	17.5	31.0
		Siltstone	31.0	32.4
		Shale	32.4	35.5
		Coal	35.5	41.1
		Siltstone and claystone	41.1	50.1
1A	739	Oxidized overburden	0	22
		Shale	22	31
		Siltstone	31	34.5
		Shale	34.5	41
		Coal	41	50
		Siltstone	50	51
1B	727	Oxidized overburden	0	11.8
		Shale	11.8	12.2
		Siltstone	12.2	16.4
		Shale	16.4	24.6
		Coal	24.6	29.2
		Shale	29.2	31.5
1C	717	Siltstone	31.5	34
		Oxidized overburden	0	12.5
		Shale	12.5	21.3
		Coal	21.3	21.6
2	745.5	Siltstone	21.6	23
		Oxidized overburden	0	20.8
		Shale	20.8	34.6
		Coal	34.6	37.3
2A	723	Siltstone	37.3	45.0
		Oxidized overburden	0	13.1
		Shale	13.1	15.8
		Coal	15.8	19.5
2B	715	Shale	19.5	20
		Oxidized overburden	0	15
		Siltstone	15	20
		Shale	20	24.9
		Siltstone	24.9	35

^aModified after Sendlein 1975.

Table B3 (Continued)

Core hole	Surface elev.	Dominant lithology	Depth	
			From	To
3	755.5	Oxidized overburden	0	13.3
		Shale	13.3	22.4
		Coal	22.4	23.5
		Interbedded siltstones, claystones and sandstones	23.5	35.6
		Shale	35.6	47.1
		Coal	47.1	50.2
		Siltstone	50.2	50.8
		Shale	50.8	56.4
3A	725	Oxidized overburden	0	16.2
		Siltstone	16.2	20
4	757.5	Oxidized overburden	0	20
		Shale	20	29.3
		Coal	29.3	31.2
		Siltstone	31.2	34.8
		Coal	34.8	36
		Siltstone	36	36.5
		Sandstone	36.5	40.3
		Coal	40.3	41
		Shale	41	56.1
		Coal	56.1	58.8
		Siltstone	58.8	62.8
4A	725	Oxidized overburden	0	14
		Siltstone	14	25
4B	734	Oxidized overburden	0	15.3
		Shale	15.3	21
		Coal	21	24.5
		Shale	24.5	27
5	771.5	Oxidized overburden	0	10
		Shale	10	18
		Coal	18	22.8
		Siltstone and claystone (with minor coal)	22.8	49.1
		Shale	49.1	68.8
		Coal	68.8	72
		Shale	72	74.8
5A	755	Oxidized overburden	0	7.5
		Siltstone	7.5	20

Table B3 (Continued)

Core hole	Surface elev.	Dominant lithology	Depth	
			From	To
6	769	Oxidized overburden	0	14.4
		Shale	14.4	17.9
		Siltstone	17.9	18.5
		Coal	18.5	24.5
		Siltstone	24.5	33.4
		Claystone	33.4	44.0
		Limestone	44.0	45.1
		Shale	45.1	62.8
		Coal	62.8	66.8
		Siltstone	66.8	76.9
6A	771	Oxidized overburden	0	15.7
		Coal	15.7	20
		Siltstone	20	25
6B	765	Oxidized overburden	0	11.3
		Siltstone	11.3	16.9
		Shale	16.9	25
7	728	Oxidized overburden	0	8
		Shale	8	13.2
		Coal	13.2	16.3
		Shale	16.3	19.5
		Siltstone	19.5	20
7A	759	Oxidized overburden	0	6.5
		Coal	6.5	7
		Siltstone	7	8
8	730.5	Oxidized overburden	0	14
		Limestone	14	16.3
		Siltstone	16.3	30.7
		Claystone	30.7	31.2
8A	722	Oxidized overburden	0	17.4
		Limestone	17.4	19
		Siltstone	19	23
		Shale	23	32.1
		Siltstone	32.1	33.4
		Shale	33.4	38.2
		Siltstone	38.2	39.5
		Shale	39.5	40

Table B3 (Continued)

Core hole	Surface elev.	Dominant lithology	Depth	
			From	To
8B	739	Oxidized overburden	0	9.6
		Coal	9.6	10.8
		Shale	10.8	18.2
		Siltstone	18.2	20.2
		Sandstone	20.0	21.8
		Siltstone	21.8	27.4
		Shale	27.4	39
		Coal	39	39.2
		Siltstone	39.2	43
		Shale	43	45
9A	730	Oxidized overburden	0	13.2
		Shale	13.2	22.8
		Siltstone	22.8	26
		Limestone	26	27
		Siltstone	27	30
		Coal	30	31
		Shale	31	33
		Coal	33	33.8
		Shale	33.8	34.6
10A	736	Siltstone	34.6	40
		Oxidized overburden	0	18.5
		Siltstone	18.5	30.5
		Shale	30.5	43
		Siltstone	43	45.5
		Coal	45.5	47
11A	736.1	Shale	47	50
		Oxidized overburden	0	9.5
		Siltstone	9.5	13.5
		Shale	13.5	30
		Siltstone	30	35.5
		Shale	35.5	39.5
		Coal	39.5	43
		Shale	43	50

Table B3 (Continued)

Core hole	Surface elev.	Dominant lithology	Depth	
			From	To
12A	746.4	Oxidized overburden	0	11.5
		Shale	11.5	20
		Coal	20	20.5
		Siltstone	20.5	25.5
		Shale	25.5	41
		Shale with black limestone concretions	41	46
		Coal	46	49
		Shale	49	54
		Siltstone	54	60

APPENDIX C: SAMPLING DATES AND PRECIPITATION

Table Cl. Cumulative precipitation between samplings and sampling "day" and date

sampling date	Day	Precipitation
8/08/75	0	
8/30/75	22	
10/02/75	55	2.82
11/04/75	88	0.60
12/07/75	121	3.81
1/10/76	155	0.53
2/07/76	183	0.00
3/04/76	208	1.32
4/03/76	239	3.48
5/01/76	267	6.24
6/03/76	300	4.87
7/16/76	343	9.74
8/17/76	375	5.11
9/12/76	401	0.72
10/02/76	420	
10/10/76	429	2.89
11/23/76	473	0.64
1/16/77	527	0.00
2/11/77	553	0.00
3/26/77	596	4.07
4/15/77	616	
4/17/77	618	1.89
5/24/77	655	2.15
6/19/77	681	0.31
7/08/77	700	0.31
8/18/77	740	7.32

APPENDIX D: CHEMICAL ANALYSIS AND WATER LEVEL DATA

symbols used in Tables D1, D2, D3, and D4 are defined as follows:

Sp Cond	Specific Conductance as ppm NaCl
pH	-log of Hydrogen ion concentration
Cl-	mg/l Chloride ion
Alk	Alkalinity as mg/l CaCO ₃
SO ₄ =	mg/l Sulfate ion
NO ₃ -	mg/l Nitrate-Nitrogen
Tot Hard	Total Hardness as mg/l CaCO ₃
Ca++	Calcium Hardness as mg/l CaCO ₃
Mg++	Magnesium Hardness as mg/l CaCO ₃
HCO ₃ -	mg/l Bicarbonate ion
Tot Fe	Total Iron as mg/l Fe
Fe++	mg/l Ferrous Iron ion
COD	Chemical Oxygen Demand mg/l O ₂
H ₂ O Depth	Water Depth measured at time of sampling
C Depth	Water Depth corrected for effect of bailing previous to sampling
Ex Alk	Alk minus Tot Hard where Alk is greater than Tot Hard as mg/l CaCO ₃
NCH	Noncarbonate Hardness as mg/l CaCO ₃
T	Temperature in degrees Celsius
Mn++	mg/l Manganese ion
$\frac{SO_4=}{HCO_3-}$	Sulfate to Bicarbonate ratio
$\frac{Ca++}{Mg++}$	Calcium Hardness to Magnesium Hardness ratio
Day	Day of study
Ppt	Precipitation since last sampling

Table D1. Chemical analysis and water level data

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
<u>Well Cl</u>																
0	110	8.9	6.0	90	30.5	-	21.0	135.0	100	60	40	9.00	17.0	9.00	-	-
22	125	8.5	7.0	160	17.0	-	0.4	-	120	90	30	14.00	15.0	14.00	-	-
55	215	7.0	5.0	220	65.0	-	0.5	-	220	140	80	14.50	16.0	14.50	-	-
88	- ^a	-	-	-	-	-	-	-	-	-	-	14.00	14.0	14.00	-	-
121	-	-	-	-	-	-	-	-	-	-	-	-	11.0	15.50	-	-
155	190	7.3	3.0	200	25.0	0.50	1.0	-	160	110	50	13.00	10.0	13.00	-	-
183	210	7.5	2.5	210	1.0	0.50	1.6	13.1	175	120	55	12.00	11.0	12.00	-	-
208	175	7.6	3.0	220	2.0	0.60	1.1	13.5	150	100	50	12.80	9.0	12.83	-	-
239	160	7.6	3.8	170	7.0	-	2.0	13.7	150	100	50	13.00	11.0	13.00	-	-
267	140	7.2	7.5	190	10.0	0.11	2.5	9.3	150	100	50	12.80	12.0	12.83	-	-
300	200	7.1	5.0	216	9.5	0.59	5.5	42.7	173	122	51	8.50	11.0	8.50	-	-
343	305	7.4	7.0	291	32.5	0.50	0.3	-	200	144	56	6.00	12.0	6.00	-	-
375	210	7.6	8.0	248	41.0	0.24	18.0	26.4	240	155	85	9.80	13.0	9.67	-	-
401	250	-	5.0	205	44.0	2.10	-	-	150	70	80	15.75	11.0	13.40	-	-
429	245	7.2	5.0	220	62.0	1.70	10.0	15.0	260	90	170	15.00	14.0	15.00	-	-
473	275	7.4	5.0	225	56.0	1.15	6.0	-	230	140	90	14.80	12.0	14.75	-	-
527	330	7.8	5.0	250	47.0	0.40	1.2	-	230	160	70	14.00	8.0	14.00	-	-
553	250	7.6	5.0	275	85.0	0.65	5.0	-	200	150	50	15.30	10.0	15.29	-	-
596	265	8.5	4.0	240	42.0	0.70	1.5	-	215	150	65	14.40	11.0	14.50	-	0.00
618	290	7.5	3.8	250	32.0	0.90	4.0	46.8	195	140	55	10.40	10.0	10.42	-	0.00
655	310	7.6	2.0	265	37.0	0.85	1.0	-	215	140	75	12.83	10.0	12.83	0.10	0.00
681	-	-	-	-	39.0	-	13.3	-	228	153	75	14.33	-	14.33	-	2.14
700	350	7.0	3.8	320	44.0	0.40	5.5	-	215	140	75	14.54	13.0	14.55	1.25	0.60
740	290	7.5	-	-	-	-	10.0	-	-	-	-	14.20	12.5	14.20	-	-
Mean																
364	233	7.5	4.8	223	24.7	0.74	5.3	35.1	189	123	67	12.82	12.0	12.84	0.68	0.55
SD																
233	68	0.5	1.7	50	22.1	0.52	6.0	39.9	42	29	28	2.48	2.2	2.42	0.81	0.93
Max																
740	350	8.9	8.0	320	85.0	2.10	21.0	135.0	260	160	170	15.75	17.0	15.50	1.25	2.14
Min																
0	110	7.0	2.0	90	1.0	0.11	0.3	9.3	100	60	30	6.00	8.0	6.00	0.10	0.00

Well C2

0	110	8.7	2.5	135	12.6	-	5.00	353.0	100	60	40	10.00	16.0	10.00	-	-
22	70	9.0	2.5	100	7.0	-	0.30	-	140	90	50	9.00	15.0	9.00	-	-
55	115	7.6	3.0	160	9.0	-	0.10	62.6	170	110	60	9.00	16.0	9.00	-	-
88	175	7.3	7.5	195	14.0	-	0.60	20.6	170	140	30	7.00	14.0	7.00	-	0.40
121	175	7.1	1.5	200	4.0	1.30	1.60	15.0	175	140	35	6.00	11.0	6.00	-	-
155	170	7.5	1.5	210	1.0	0.68	1.50	7.5	165	130	35	6.00	9.0	6.00	-	-
183	170	7.5	1.5	200	1.0	0.90	2.75	19.0	152	110	42	7.30	7.0	7.33	-	-
208	165	7.2	2.0	215	1.0	0.35	0.75	23.3	150	110	40	6.00	8.0	6.00	-	-
239	170	7.2	1.9	210	3.0	-	1.90	26.2	155	115	40	5.00	12.0	5.00	-	-
267	190	7.1	2.5	230	0.0	0.22	3.30	22.7	155	110	45	2.30	12.0	2.30	-	-
300	200	7.1	4.5	222	1.5	0.59	5.50	30.6	77	63	14	2.30	11.0	2.33	-	-
343	230	7.0	5.0	156	1.0	0.63	1.44	-	145	102	43	4.20	12.0	4.17	-	-
375	135	7.2	6.0	208	3.0	0.12	14.00	18.6	160	111	49	6.80	14.0	6.08	-	-
401	200	-	5.0	205	3.0	0.95	-	15.0	130	100	30	7.90	14.0	7.92	-	-
429	175	7.1	5.0	200	1.0	1.25	6.00	15.0	160	100	60	7.80	14.0	7.75	-	-
473	200	7.1	5.0	210	2.0	0.90	4.00	-	150	100	50	7.00	12.0	7.00	-	-
527	240	7.2	5.0	210	3.0	-	3.00	-	180	110	70	7.30	8.0	7.33	-	-
553	190	6.8	5.0	205	5.0	0.70	3.50	-	150	95	55	7.50	10.0	7.50	-	-
596	215	7.1	4.0	200	6.0	1.00	6.00	-	150	110	40	11.00	10.0	5.75	-	0.40
618	220	7.0	2.5	200	3.0	1.20	6.00	20.6	150	105	45	8.00	8.0	5.25	-	0.50
655	230	7.1	3.1	215	2.0	1.25	4.50	-	155	105	50	7.29	10.0	7.29	4.5	0.70
681	-	-	-	-	6.0	-	13.40	-	143	95	48	-	-	8.75	-	0.71
700	260	7.0	2.5	170	3.0	0.20	16.00	-	157	110	47	9.33	13.0	9.33	10.0	0.90
740	220	7.0	-	-	-	-	16.00	-	-	-	-	9.25	13.0	8.87	-	-
Mean	364	184	7.3	3.6	193	4.0	0.77	5.09	46.4	150	105	7.10	12.0	6.79	7.3	
SD	233	45	0.5	1.7	31	3.7	0.39	4.96	89.1	34	19	2.19	3.0	2.02	3.9	
Max	740	260	9.0	7.5	230	14.0	1.30	16.00	353.0	180	140	11.00	16.0	10.00	10.0	
Min	0	70	6.8	1.5	100	0.0	0.12	2.10	7.5	77	60	2.30	7.0	2.30	4.5	

^aAnalysis not performed.

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
<u>Well E</u>																
0	190	8.6	2.0	140	123.0	-	2.00	68.5	260	180	80	13.00	15.0	13.00	-	-
22	190	8.1	1.5	180	55.0	-	--	-	200	150	50	10.00	16.0	10.00	-	-
55	110	7.1	3.0	210	9.0	-	0.10	7.2	180	140	40	6.00	17.0	6.00	-	-
88	175	7.2	7.5	195	13.0	-	0.10	19.7	170	140	30	7.00	15.0	7.00	-	0.80
121	170	7.1	1.5	195	7.0	1.30	1.10	15.0	165	135	30	6.00	11.0	6.00	-	-
155	175	7.2	1.3	185	5.0	0.45	4.00	5.7	165	140	25	6.00	10.0	6.00	-	-
188	180	7.2	1.0	190	3.0	0.50	3.00	2.0	155	113	42	8.50	10.0	8.42	-	-
208	155	6.8	2.0	180	2.0	0.44	7.00	22.2	150	110	40	6.20	9.0	6.17	-	-
239	160	7.2	1.9	175	5.0	-	13.00	45.8	155	110	45	5.80	9.0	5.75	-	-
267	155	7.1	3.5	190	6.0	0.22	11.30	15.7	150	115	35	3.60	11.0	3.60	-	-
300	200	7.1	5.0	184	8.0	0.18	8.50	16.6	168	115	53	3.40	12.0	3.50	-	-
343	235	7.0	4.5	183	8.5	0.34	5.70	-	155	114	41	4.50	13.0	4.50	-	-
375	140	7.5	5.0	193	10.8	0.16	14.00	12.6	167	100	67	7.20	16.0	7.21	-	-
401	200	-	5.0	190	12.0	0.60	-	19.6	150	100	50	7.40	-	7.38	-	-
429	185	7.0	5.0	180	12.0	0.90	5.00	19.8	145	110	35	7.30	15.0	7.33	-	-
473	200	7.1	5.0	180	12.0	0.65	2.50	-	150	110	40	7.20	13.0	7.17	-	-
527	245	7.0	5.0	180	19.0	0.23	18.00	-	160	105	55	7.30	10.0	9.25	-	-
553	235	7.1	5.0	230	21.0	0.35	6.00	-	165	115	50	6.80	9.0	6.83	-	-
596	215	7.1	3.5	200	20.0	0.60	5.00	-	175	130	45	5.80	8.0	5.83	-	0.60
618	220	7.0	2.5	165	21.0	0.70	8.00	19.9	154	102	52	8.50	8.0	6.58	-	0.90
655	245	7.0	3.1	175	31.0	0.75	5.00	-	165	118	47	9.79	10.0	9.79	4.5	1.00
681	-	-	-	-	29.0	-	15.60	-	146	103	43	-	-	10.13	-	1.23
700	240	7.2	2.5	180	24.0	0.30	18.00	-	160	118	42	10.67	13.0	10.67	12.9	1.60
740	175	7.0	-	-	-	-	18.00	-	-	-	-	10.00	14.0	10.00	-	-
Mean																
364	191	7.2	3.5	185	19.8	.51	7.80	20.7	166	121	45	7.3	12.0	7.42	8.7	
SD																
233	36	.4	1.7	17	25.4	.30	6.0	17.1	24	19	12	2.29	3.0	2.33	5.9	
Max																
740	245	8.6	7.5	230	123.0	1.3	18.0	68.5	260	180	80	3.4	17.0	13.00	12.9	
Min																
0	110	6.8	1.0	140	2.0	.16	.1	2.0	145	100	25	13.0	8.0	3.50	4.5	

Well G

0	170	8.5	5.0	120	81.0	-	15.10	465.0	160	100	60	14.00	15	14.00	-	-
22	150	8.0	5.0	170	70.0	-	0.60	-	140	120	20	5.00	17	15.00	-	-
55	190	8.1	1.5	150	90.0	-	0.10	11.3	120	110	20	-1.00	21	-1.00	-	-
88	175	7.2	10.0	140	73.0	-	0.10	9.1	170	100	70	-0.70	22	-0.67	-	0.34
121	170	6.8	3.5	140	70.0	1.00	0.10	13.0	150	100	50	-3.00	0	-3.00	-	-
155	-	-	-	-	-	-	-	-	-	-	-	-3.00	0	-1.25	-	-
188	170	6.7	2.5	150	65.0	0.10	1.30	55.0	140	100	40	0.60	0	0.50	-	-
208	170	6.2	3.0	100	55.0	0.22	7.50	10.0	120	90	30	-1.00	2	-1.00	-	-
239	150	6.6	3.8	100	70.0	-	8.00	21.0	120	90	30	-1.00	12	-1.00	-	-
267	140	6.1	3.5	130	65.0	0.10	7.50	8.2	120	90	30	-1.00	12	-1.00	-	-
300	200	6.8	6.0	114	56.0	0.20	7.50	10.0	120	93	27	-1.20	12	-1.25	-	-
343	235	6.6	6.0	122	57.5	0.18	4.60	-	118	84	34	-2.10	12	-2.08	-	-
375	140	6.5	6.0	121	61.0	0.14	10.00	17.4	131	100	31	1.30	18	1.33	-	-
401	175	-	5.0	125	72.0	0.45	-	15.0	125	90	35	1.60	-	1.58	-	-
429	215	6.8	5.0	140	70.0	0.35	3.00	12.2	120	100	20	1.00	16	1.00	-	-
473	235	6.9	5.0	110	75.0	0.40	2.00	-	125	100	25	1.10	10	1.08	-	-
527	255	6.7	7.5	110	75.0	0.40	2.50	-	130	95	35	1.60	7	1.58	-	-
553	200	6.3	5.0	105	82.0	0.60	1.50	-	135	100	35	1.40	7	1.42	-	-
596	225	6.5	5.0	120	84.0	0.50	4.00	-	145	110	35	-0.70	10	-0.50	-	0.00
618	220	6.3	3.1	100	72.0	0.35	12.00	15.6	130	100	30	2.00	8	2.00	-	0.40
655	245	6.4	3.8	110	71.0	0.70	5.00	-	132	110	32	2.91	12	2.92	5.0	0.20
681	-	-	-	-	80.0	-	12.70	-	128	95	33	-	-	4.29	-	0.50
700	275	6.6	3.1	115	66.0	0.25	14.00	-	135	105	30	5.25	15	5.25	5.5	0.70
740	230	6.7	-	-	-	-	20.00	-	-	-	-	5.75	17	5.33	-	-
Mean																
364	197	6.8	4.7	123	71.0	0.37	6.40	51.0	132	97	35	1.25	11	1.86	5.3	0.36
SD																
233	39	0.6	1.9	19	9.0	0.24	5.60	125.0	14	9	15	3.68	7	4.46	0.4	0.24
Max																
740	275	8.5	10.0	170	90.0	1.0	20.00	465.0	170	120	90	14.00	22	15.00	5.5	0.70
Min																
0	140	6.1	1.5	100	55.0	0.1	0.10	8.2	118	80	20	-3.00	0	-3.00	5.0	0.00

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
Well K																
0	-	-	-	-	157	-	2.00	-	-	-	-	15.00	17.0	27.00	-	-
22	165	8.1	5.0	120	140	-	0.60	-	246	194	52	15.00	17.0	25.00	-	-
55	300	7.7	12.0	200	190	-	0.50	41.8	340	250	90	12.00	18.0	22.00	-	-
88	-	7.5	-	-	-	-	-	32.0	-	-	-	14.50	15.0	24.50	-	-
121	-	-	-	-	-	-	-	-	-	-	-	15.00	12.0	25.00	-	-
155	280	7.9	2.0	210	190	0.20	0.30	4.5	300	230	70	15.00	10.0	26.00	-	-
183	-	-	-	-	-	-	-	-	-	-	-	14.50	11.0	27.00	-	-
208	270	8.3	4.0	230	70	0.20	0.25	35.7	260	185	75	16.00	9.0	26.00	-	-
239	-	8.0	9.4	255	35	-	1.80	-	290	190	100	16.00	14.0	-	-	-
267	-	-	40.0	160	42	-	-	-	190	130	60	16.00	12.0	-	-	-
343	-	-	-	-	-	-	-	-	-	-	-	28.20	-	-	-	-
375	252	-	8.0	140	180	0.12	-	-	366	250	116	28.20	16.0	28.17	-	-
429	415	4.3	5.0	0	380	0.20	1.00	48.8	367	258	109	26.00	15.0	26.00	-	-
473	350	6.9	5.0	110	190	0.20	8.00	-	330	230	100	26.70	12.0	26.67	-	-
527	370	6.8	6.0	180	155	0.35	2.00	-	310	230	80	25.70	10.0	25.67	-	-
553	325	7.1	5.0	180	162	0.35	4.50	-	320	230	90	27.40	10.0	27.42	-	-
596	365	7.0	5.0	175	165	0.35	3.50	-	315	240	75	26.80	13.0	26.75	-	2.20
618	350	7.0	7.5	45	220	0.30	2.00	41.1	360	250	110	26.70	-	26.67	-	1.40
655	380	7.0	5.0	170	145	0.15	2.50	-	350	250	100	26.83	13.0	26.83	0.00	1.50
681	-	-	-	-	130	-	3.40	-	313	230	83	-	-	27.58	-	2.79
700	425	7.0	6.2	140	168	0.40	0.10	-	375	218	157	27.38	13.0	27.38	0.01	2.30
740	400	6.6	-	-	-	-	6.00	-	-	-	-	26.60	14.0	26.60	-	-
Mean																
365	332	7.1	8.3	154	160	0.26	2.40	34.0	315	223	92	21.21	13.0	26.22	-	2.04
SD																
243	72	1.0	9.1	67	77	0.10	2.23	15.6	50	33	25	6.24	3.0	1.40	-	0.58
Max																
740	425	8.3	40.0	255	380	0.40	8.00	48.8	375	248	157	28.20	18.0	28.17	0.01	2.79
Min																
0	165	4.3	2.0	0	35	0.12	0.10	4.5	190	130	52	12.00	9.0	22.00	.00	1.40

ICP Dug Well

267	515	7.8	27.5	175	200	11.0	0.05	-	460	315	145	-	-	-	-	-
300	450	7.1	25.5	236	230	-	-	-	420	271	149	18.80	10.0	18.80	-	-
428	595	-	30.0	290	225	-	-	-	400	365	35	-	-	-	-	-
473	-	-	-	-	280	6.6	-	-	-	-	-	-	-	-	-	-
527	490	7.5	22.5	120	190	5.4	0.00	-	540	370	170	16.60	10.0	16.60	-	-
553	520	7.5	20.0	240	250	4.0	0.10	-	500	355	145	-	-	-	-	-
596	550	7.1	20.0	260	220	5.1	0.10	4.6	575	400	175	21.10	10.0	21.10	-	0.00
618	610	7.0	22.0	255	190	6.1	0.10	-	565	375	190	17.30	-	17.30	-	0.20
655	580	7.0	25.0	270	220	6.0	0.00	-	545	390	155	16.83	13.0	16.83	0.00	0.50
681	-	-	-	-	240	-	0.10	-	440	330	110	16.50	-	16.50	-	0.68
700	540	7.0	23.0	277	200	4.1	0.10	-	572	400	172	16.20	13.0	16.20	0.00	0.30
740	510	7.0	-	-	-	-	0.15	-	-	-	-	18.80	15.0	18.80	-	-
Mean																
545	536	7.2	23.9	236	222	6.0	0.08	4.6	502	357	145	17.77	12.0	17.77	0.00	0.34
SD																
153	49	0.3	3.4	55	28	2.2	0.05	0	67	41	44	1.68	2.0	1.68	0.00	0.26
Max																
740	610	7.8	30.0	290	280	11.0	0.15	4.6	575	400	190	21.10	15.0	21.10	0.00	0.68
Min																
267	450	7.0	20.0	120	190	4.1	0.00	4.6	400	271	35	16.20	10.0	16.20	0.00	0.00

Well M

0	250	8.7	5.0	80	190	-	1.00	425.0	280	200	80	10.00	17.0	10.00	-	-
22	205	8.6	6.0	85	175	-	0.10	-	266	184	82	9.00	17.0	9.00	-	-
55	110	7.2	6.0	126	190	-	-	13.6	280	190	90	9.50	16.0	9.50	-	-
88	325	7.3	10.0	175	190	-	0.40	5.7	320	250	70	9.50	14.0	9.50	-	0.70
121	330	6.9	3.0	195	190	4.70	0.25	7.0	320	230	90	9.00	11.0	9.00	-	-
155	325	7.2	2.3	185	190	3.00	0.75	3.1	375	260	115	10.00	9.0	10.00	-	-
183	350	7.0	2.0	200	200	2.00	1.40	6.0	350	295	55	10.20	10.0	10.17	-	-
208	350	6.5	2.0	190	190	2.25	0.25	28.4	390	270	120	10.30	9.0	10.33	-	-
239	325	7.0	3.8	200	160	-	0.20	30.2	390	250	140	9.80	12.0	9.75	-	-
267	200	7.0	6.3	115	100	2.20	1.30	10.0	212	135	77	6.50	11.0	6.50	-	-
300	275	7.1	8.5	79	86	0.75	0.60	17.9	313	135	178	8.50	12.0	8.50	-	-

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
343	350	7.3	5.5	126	145	2.10	0.68	-	340	220	120	8.30	14.0	8.33	-	-
375	225	7.0	7.0	169	128	1.76	1.50	19.0	336	232	104	9.10	15.0	9.13	-	-
401	325	-	5.0	175	180	2.50	-	15.0	340	170	170	9.80	-	9.83	-	-
429	390	7.2	5.0	200	165	2.25	0.15	19.8	380	250	130	10.80	17.0	10.83	-	-
473	345	7.2	10.0	160	165	2.00	1.00	-	350	240	110	11.40	14.0	11.42	-	-
527	430	7.3	6.7	230	170	0.30	0.45	-	430	305	125	12.00	8.0	12.00	-	-
553	375	7.0	5.0	200	190	1.70	0.25	-	410	290	120	12.60	10.0	12.58	-	-
596	375	6.7	4.0	130	180	1.75	2.50	-	345	260	85	12.30	10.0	12.25	-	0.00
618	350	7.0	3.8	133	155	2.10	2.50	28.6	340	230	110	12.30	10.0	12.25	-	0.10
655	290	6.8	3.1	200	170	1.80	0.75	-	418	270	148	12.33	12.0	12.33	0.1	0.40
681	-	-	-	-	170	-	2.50	-	365	265	100	-	-	12.21	-	0.81
700	425	7.2	3.1	250	164	1.00	1.50	-	430	300	130	12.13	13.0	12.13	0.1	0.20
740	490	7.0	-	-	-	-	3.10	-	-	-	-	12.00	15.0	12.00	-	-
Mean																
364	322	7.2	5.1	164	167	2.01	1.05	45.0	347	236	111	10.32	13.0	10.40	0.1	0.37
SD																
233	84	0.5	2.3	48	29	0.95	0.89	109.7	55	48	31	1.60	3.0	1.61	0.0	0.33
Max																
740	490	8.7	10.0	250	200	4.7	3.10	425.0	430	305	178	12.60	17.0	12.58	0.1	0.81
Min																
0	110	6.5	2.0	79	86	0.3	0.10	3.1	212	135	55	6.5	8.0	6.50	0.1	0.00
Well Q																
267	150	6.7	3.5	55	70	1.10	2.00	8.4	155	100	55	10.10	11.0	10.08	-	-
300	175	7.1	5.0	88	78	0.23	0.15	9.4	184	120	64	11.50	11.0	11.50	-	-
343	230	7.2	5.0	79	74	0.31	0.32	-	174	122	52	5.40	14.0	5.42	-	-
375	175	7.5	8.0	136	87	0.26	0.90	10.3	209	154	55	8.60	16.0	8.58	-	-
401	125	-	5.0	130	28	0.50	-	16.0	200	140	60	17.40	-	10.50	-	-
429	315	7.6	5.0	190	125	0.75	0.10	5.1	285	195	90	8.80	16.0	8.83	-	-
473	235	7.5	5.0	180	125	0.65	1.00	-	350	195	155	11.40	14.0	21.50	-	-
527	420	7.5	7.5	200	160	0.45	0.10	-	320	255	65	22.80	9.0	22.83	-	-
553	300	7.7	7.5	300	135	0.55	0.10	-	320	250	70	25.30	9.0	22.83	-	-

596	400	7.5	4.0	250	170	0.40	0.50	-	370	260	110	26.30	13.0	20.92	-	0.00
618	575	7.3	3.1	162	260	0.90	0.70	14.9	582	420	162	19.80	-	17.00	-	0.80
655	525	7.0	3.1	210	220	0.70	0.50	-	477	355	122	16.50	13.0	16.50	0.00	0.70
681	-	-	-	-	220	-	0.30	-	358	270	88	-	-	16.17	-	0.08
700	475	7.5	3.1	223	190	0.50	0.25	-	477	353	124	9.79	14.0	16.79	0.01	0.20
740	535	7.6	-	-	-	-	0.20	-	-	-	-	15.90	17.0	15.90	-	-
Mean																
511	331	7.4	5.0	169	139	0.56	0.51	10.7	319	228	91	14.97	13.0	15.02	-	0.36
SD																
153	156	0.3	1.7	71	68	0.25	0.52	4.1	129	99	38	6.65	3.0	5.60	-	0.37
Max																
740	575	7.7	8.0	300	260	1.10	2.00	16.0	582	420	162	26.30	17.0	22.83	0.01	0.80
Min																
267	125	6.7	3.1	55	28	0.23	0.10	5.1	155	100	52	5.40	9.0	5.42	0.00	0.00

Well T

0	180	8.6	4.0	100	100	-	-	246.0	200	100	100	14.00	17.0	14.00	-	-
22	170	7.6	3.0	170	39	-	0.50	-	160	100	60	13.00	17.0	13.00	-	-
55	245	7.6	5.0	265	39	-	0.50	74.7	220	140	80	12.00	15.0	12.00	-	-
88	225	7.5	9.5	270	14	-	0.15	21.6	370	130	240	14.00	14.0	14.00	-	0.40
121	250	8.3	3.5	230	15	1.00	0.15	21.0	200	125	75	15.00	11.0	15.00	-	-
155	270	8.3	2.5	245	5	0.20	1.50	14.4	280	135	145	13.00	10.0	13.00	-	-
183	310	8.2	3.0	220	20	0.50	2.35	-	160	100	60	17.60	11.0	17.67	-	-
208	250	8.1	3.0	260	13	0.13	1.00	-	270	135	135	17.80	10.0	17.83	-	-
239	250	8.5	1.9	300	5	-	1.30	-	230	150	80	17.50	15.0	17.50	-	-
267	260	8.2	7.5	270	9	0.11	0.62	-	210	100	110	18.40	15.0	18.40	-	-
300	240	7.6	6.5	282	5	0.54	0.70	-	205	134	71	18.50	11.0	18.50	-	-
655	-	-	-	-	-	-	-	-	-	-	-	-	-	18.08	-	-
700	280	8.5	3.8	277	20	1.00	1.25	-	205	125	80	18.96	14.0	18.96	0.05	0.20
681	-	-	-	-	19	-	5.80	-	173	110	63	17.79	-	17.79	-	0.10
740	325	8.5	-	-	-	-	8.00	-	-	-	-	20.80	13.0	20.80	-	-
Mean																
294	250	8.1	4.4	241	23	0.50	1.83	75.5	222	122	100	16.31	13.0	16.43	0.05	0.23
SD																
264	43	0.4	2.3	56	26	0.38	2.37	98.3	57	18	50	2.72	2.0	2.67	0.00	0.15
Max																
740	325	8.6	9.5	300	100	1.00	8.00	246.0	150	150	240	20.80	17.0	20.80	0.05	0.40

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
Min																
0	170	7.5	1.9	100	5	0.11	0.15	14.4	100	100	60	12.00	10.0	12.00	0.05	0.10
<u>Well S2</u>																
616	325	7.2	5.0	230	70	0.40	-	-	280	190	90	10.83	11.0	10.83	-	0.50
618	350	7.1	5.0	290	90	0.25	4.0	48.8	330	210	120	11.20	-	10.80	-	0.60
655	340	7.2	2.5	305	48	0.70	3.0	-	280	177	103	11.33	11.0	11.33	2.00	0.50
681	-	-	-	-	37	-	2.1	-	233	158	75	12.40	-	12.40	-	0.74
700	325	7.5	4.0	298	30	0.35	2.0	-	368	162	206	13.33	13.0	13.33	1.00	0.60
740	360	7.3	-	-	-	-	1.8	-	-	-	-	13.30	12.0	12.90	-	-
Mean																
668	340	7.3	4.1	281	55	0.43	2.6	48.8	298	179	119	12.07	12.0	11.93	1.50	0.59
SD																
48	15	0.2	1.2	34	25	0.19	0.9	0	52	21	51	1.10	1.0	1.09	0.70	0.10
Max																
740	360	7.5	5.0	305	90	0.70	4.0	48.8	368	210	206	13.33	13.0	13.33	2.00	0.74
Min																
616	325	7.1	2.5	230	30	0.25	1.8	48.8	233	158	75	10.83	11.0	10.80	1.00	0.50
<u>Well 1a</u>																
343	230	7.2	6.0	140	34	0.37	0.40	7.41	160	114	46	3.30	13.0	3.25	-	-
375	120	7.1	7.5	130	34	1.59	0.50	7.00	257	103	154	3.20	18.0	3.17	-	-
401	200	7.1	6.0	130	46	1.60	-	7.60	90	65	25	4.50	-	4.42	-	-
429	215	7.1	6.0	135	49	3.40	1.00	-	180	120	60	4.00	17.0	4.00	-	-
473	225	7.2	6.0	130	74	3.35	0.10	-	170	105	65	5.70	14.0	5.67	-	-
527	270	7.1	6.0	150	47	3.40	0.20	-	210	140	70	7.30	8.0	7.33	-	-
553	220	7.0	6.0	150	54	3.45	0.30	-	205	125	80	7.30	10.0	7.33	-	-
596	190	6.6	7.5	100	49	3.60	1.80	-	160	100	60	3.80	9.0	3.83	-	0.00
618	240	6.6	4.4	110	42	4.10	0.70	10.20	162	100	62	3.80	-	3.83	-	0.00
655	220	6.8	4.4	115	49	4.60	1.00	-	170	110	60	4.88	12.0	4.88	0.10	0.30
681	-	-	-	-	43	-	0.20	-	140	93	58	-	-	6.00	-	0.02
700	250	6.6	5.0	120	46	4.00	0.25	-	175	110	65	7.25	14.0	7.25	0.01	0.00
740	200	6.8	-	-	-	-	0.35	-	-	-	-	7.20	16.0	7.20	-	-

Mean	545	215	6.9	5.4	128	47	3.04	0.57	8.05	173	107	67	5.19	13.0	5.24	0.06	0.063
SD	132	37	0.2	1.1	16	10	1.29	0.49	1.45	40	18	30	1.67	3.0	1.63	0.06	0.132
Max	740	70	7.2	7.5	150	74	4.60	1.80	10.20	257	140	154	7.30	18.0	7.33	0.10	0.300
Min	343	120	6.6	4.4	100	34	.37	0.10	7.00	90	65	25	3.2	8.0	3.17	0.01	0.000

Well 1b

596	190	6.6	10.0	160	40	0.3	2.0	-	165	110	55	22.10	13.0	10.00	-	0.20
618	250	-	3.1	155	34	0.2	-	-	165	110	55	22.00	-	12.40	-	0.00
655	220	7.0	2.5	210	11	0.2	1.0	-	178	112	66	17.13	11.0	11.00	0.1	1.20
681	-	-	-	-	9	-	0.3	-	160	105	55	10.70	-	10.70	-	0.73
700	240	7.0	3.1	220	10	0.2	4.8	-	180	115	65	14.38	12.0	14.38	3.5	1.90
740	240	7.0	-	-	-	-	6.1	-	-	-	-	18.60	13.0	11.79	-	-

Mean	665	228	6.9	4.7	186	21	0.2	2.8	-	170	110	59	17.49	12.0	11.71	1.8	0.81
SD	53	24	0.2	3.6	34	15	0.5	2.5	-	9	4	6	4.44	1.0	1.55	2.4	0.77
Max	740	250	7.0	10.0	220	40	0.3	6.1	-	180	115	66	22.10	13.0	14.38	3.5	1.90
Min	596	190	6.6	2.5	155	9	0.2	0.3	-	160	105	55	10.70	11.0	10.00	0.1	0

Well 1c

596	340	7.0	6.0	180	150	2.2	0.30	-	320	220	100	3.60	8.0	3.60	-	0.20
618	300	7.0	3.1	172	62	3.2	1.00	13.6	235	145	90	3.80	-	3.80	-	0.00
655	260	7.4	2.5	175	53	3.6	0.10	-	220	150	70	4.54	12.0	4.54	0.10	0.30
681	-	-	-	-	52	-	0.20	-	203	133	70	5.70	-	5.70	-	0.13
700	300	7.3	3.1	185	47	3.0	0.25	-	240	165	75	7.00	15.0	7.00	0.01	0.00
740	290	7.1	-	-	-	-	0.16	-	-	-	-	6.90	17.0	6.10	-	-

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
Mean																
665	298	7.2	3.7	178	73	3.0	0.34	13.6	244	163	81	5.26	13.0	5.12	0.06	0.13
SD																
53	29	0.2	1.6	6	43	0.6	0.33	0	45	34	13	1.50	4.0	1.36	0.06	0.13
Max																
740	340	7.3	6.0	185	150	3.6	1.00	13.6	320	220	100	7.00	17.0	7.00	0.10	0.20
Min																
596	260	7.0	2.5	172	47	2.2	0.10	13.6	203	133	70	3.60	8.0	3.60	0.01	0.00
Well 1d																
596	210	7.0	5.0	165	89	1.00	0.30	-	315	220	95	14.40	11.0	14.40	-	1.30
618	250	6.6	3.8	173	43	1.30	0.70	14.0	200	140	60	13.80	-	13.80	-	0.70
655	250	7.3	3.1	210	43	0.90	1.00	-	230	165	65	14.42	11.0	14.42	0.10	0.10
681	-	-	-	-	40	-	0.20	-	215	150	65	16.40	-	16.40	-	0.16
700	290	7.1	3.8	213	37	0.95	0.20	-	245	165	80	17.58	13.0	17.58	0.01	0.50
740	285	6.8	-	-	-	-	0.21	-	-	-	-	16.90	13.0	16.90	-	-
Mean																
665	257	7.0	3.9	190	50	1.04	0.44	14.0	241	168	73	15.58	12.0	15.58	0.06	0.55
SD																
53	32	0.3	0.8	25	22	0.18	0.34	0.0	45	31	14	1.57	1.0	1.57	0.06	0.49
Max																
740	290	7.3	5.0	213	89	1.30	1.00	14.0	315	220	95	17.58	13.0	17.58	0.10	1.30
Min																
596	210	6.6	3.1	165	37	0.90	0.21	14.0	200	140	60	13.80	11.0	13.80	0.01	0.10
Well 2a																
343	330	8.3	9.0	236	92	0.22	2.40	-	285	208	77	18.70	11.0	18.67	-	-
375	243	7.5	6.5	302	72	0.11	1.00	9.15	341	260	91	20.60	12.0	20.58	-	-
401	225	7.5	5.0	320	45	0.65	-	11.00	270	150	120	19.70	-	19.58	-	-
429	375	7.5	7.5	335	85	0.55	0.30	6.30	290	265	25	18.80	14.0	18.83	-	-
473	375	7.4	5.0	290	94	0.40	0.10	-	320	215	105	19.90	13.0	19.92	-	-
527	405	7.6	5.0	360	103	0.45	0.15	-	370	285	85	20.80	10.0	20.83	-	-

553	390	7.3	5.0	400	96	0.40	0.25	-	380	285	95	21.30	9.0	21.33	-	-
596	400	7.5	5.0	330	86	0.40	0.30	-	340	300	40	23.30	12.0	21.17	-	0.00
618	380	7.5	2.5	325	78	0.50	0.50	8.50	385	265	120	22.00	-	20.00	-	0.00
655	425	7.3	2.5	223	86	0.50	0.50	-	295	175	120	20.50	12.0	20.50	0.10	0.20
681	-	-	-	-	77	-	0.20	-	330	245	85	-	-	20.50	-	0.02
700	425	7.5	1.3	360	77	0.30	1.50	-	340	242	98	20.96	12.5	20.96	0.01	0.10
740	450	7.3	-	-	-	-	0.10	-	-	-	-	21.10	13.0	20.79	-	-

Mean

545	369	7.5	4.9	316	83	0.41	0.61	8.74	329	241	88	20.64	11.9	20.28	0.06	0.06
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SD

132	70	0.3	2.3	52	15	0.15	0.70	1.94	38	46	30	1.29	1.5	0.84	0.06	0.09
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Max

740	450	8.3	9.0	400	103	0.65	2.40	11.00	385	300	120	23.30	14.0	21.33	0.10	0.20
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Min

343	225	7.3	1.3	223	45	0.11	0.10	6.30	270	150	25	18.70	9.0	18.67	0.01	0.00
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Well 2b

596	400	8.5	5.0	190	210	0.30	0.60	-	360	280	80	31.00	12.0	15.8	-	1.20
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618	420	8.0	10.0	170	195	0.20	1.00	32.00	390	250	140	31.50	-	20.8	-	-
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655	475	7.9	7.0	280	150	0.50	1.00	-	345	220	125	27.42	12.0	19.0	0.10	0.20
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681	-	-	-	-	150	-	0.30	-	305	223	83	18.80	-	18.8	-	0.03
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700	525	7.6	6.3	255	130	0.45	0.30	-	310	239	71	24.50	13.0	24.5	0.01	0.20
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740	440	7.7	-	-	-	-	0.10	-	-	-	-	25.50	13.0	19.0	-	-
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Mean

665	452	7.9	7.1	224	167	0.36	0.55	32.70	342	242	100	26.45	13.0	19.7	0.06	0.41
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SD

53	49	0.4	2.1	51	34	0.14	0.38	0.00	35	24	31	4.70	1.0	2.9	0.06	0.53
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Max

740	525	8.5	10.0	280	210	0.50	1.00	32.70	390	280	140	31.50	13.0	24.5	0.10	1.20
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Min

596	400	7.6	5.0	170	130	0.20	0.10	32.70	305	220	71	18.80	12.0	15.8	0.01	0.03
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Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
<u>Well 2c</u>																
596	340	7.3	6.0	230	105	1.00	0.20	-	320	230	90	11.00	11.0	11.00	-	0.70
618	290	7.4	5.6	245	55	1.25	0.20	21.8	285	190	95	9.80	-	9.80	-	0.20
655	310	7.3	4.4	257	48	1.20	0.50	-	275	200	75	10.67	11.0	10.67	-	0.50
681	-	-	-	-	50	-	0.30	-	245	180	65	11.10	-	11.10	-	0.21
700	320	7.3	5.0	320	35	1.20	0.15	-	257	195	62	12.17	13.0	12.17	-	0.10
740	290	7.3	-	-	-	-	0.10	-	-	-	-	11.70	15.0	11.70	-	-
Mean																
665	310	7.3	5.3	263	59	1.16	0.24	21.8	276	199	77	11.07	13.0	11.07	-	0.34
SD																
53	21	0.0	0.7	40	27	0.11	0.14	0	29	19	15	0.82	2.0	0.82	-	0.25
Max																
740	340	7.4	6.0	320	105	1.25	0.50	21.8	320	230	95	12.17	15.0	12.17	-	0.70
Min																
596	290	7.3	4.4	230	35	1.00	0.10	21.0	245	180	62	9.80	11.0	9.80	-	0.10
<u>Well 2d</u>																
596	370	7.4	7.5	220	155	0.40	1.00	-	350	265	85	19.00	11.0	19.00	-	0.40
618	340	7.6	3.8	195	100	0.30	0.70	695.0	319	210	109	18.50	-	18.50	-	0.25
655	320	7.6	4.4	253	68	0.70	0.50	-	288	202	86	18.67	12.0	18.67	-	0.10
681	-	-	-	-	73	-	0.40	-	248	173	75	20.50	-	20.50	-	0.09
700	370	7.8	3.8	270	69	0.25	0.55	-	300	228	72	19.33	12.0	19.33	-	0.80
740	350	7.6	-	-	-	-	0.30	-	-	-	-	18.80	13.0	18.80	-	-
Mean																
665	350	7.6	4.9	235	93	0.41	0.58	695.0	301	216	85	19.13	12.0	19.13	-	0.29
SD																
53	21	0.1	1.8	34	37	0.20	0.25	0.0	38	34	15	0.73	1.0	0.73	-	0.33
Max																
740	370	7.8	7.5	270	155	0.70	1.00	695.0	350	265	109	20.50	13.0	20.50	-	0.80
Min																
596	320	7.4	3.8	195	68	0.25	0.30	695.0	248	173	72	18.50	11.0	18.50	-	0.09

Well 3a

343	325	7.2	5.5	152	105	0.19	0.15	-	212	143	69	9.40	12.0	9.42	-	-
375	140	6.7	6.0	154	54	0.18	2.00	7.09	152	96	56	7.80	16.0	7.75	-	-
401	265	6.8	5.0	90	110	0.60	-	6.00	195	120	75	9.90	-	9.92	-	-
429	225	6.8	5.0	160	48	0.50	0.20	5.40	150	100	50	9.60	15.0	9.58	-	-
473	215	6.9	5.0	155	53	0.25	0.10	-	210	100	110	10.90	13.0	10.92	-	-
527	250	6.8	6.0	150	51	0.05	0.20	-	160	105	55	11.80	8.0	11.83	-	-
553	210	6.8	5.0	155	62	0.55	0.45	-	160	110	50	11.60	10.0	11.58	-	-
596	215	6.6	4.0	150	78	0.30	0.20	-	180	105	75	9.50	9.0	9.50	-	0.00
618	270	6.6	3.1	145	82	0.30	1.00	11.40	190	120	50	10.50	-	10.50	-	0.20
655	225	6.7	3.1	158	47	0.20	1.00	-	165	103	62	11.25	11.0	11.25	0.10	0.10
681	-	-	-	-	45	-	0.92	-	148	93	55	-	-	11.59	-	0.29
700	260	6.5	3.8	163	41	0.20	0.27	-	160	100	60	11.87	14.0	11.88	0.01	0.20
740	250	6.6	-	-	-	-	0.25	-	-	-	-	11.00	15.0	11.00	-	-
Mean																
545	238	6.8	4.7	148	65	0.30	0.56	7.47	174	108	66	10.43	12.0	10.52	0.06	0.16
SD																
132	45	0.2	1.0	20	24	0.17	0.57	2.71	23	14	17	1.22	3.0	1.22	0.06	0.11
Max																
740	325	7.2	6.0	163	110	0.60	2.00	11.40	212	143	110	11.87	16.0	11.88	0.10	0.29
Min																
343	140	6.5	3.1	90	41	0.05	0.10	5.40	148	93	50	7.80	8.0	7.75	0.01	0.00

Well 4a

343	420	-	8.0	316	115	0.90	0.75	-	380	265	115	39.60	-	39.60	-	-
375	233	7.3	7.0	269	69	0.98	-	13.60	300	215	85	40.30	12.0	40.30	-	-
401	225	-	5.0	135	82	1.00	-	-	155	60	95	-	-	-	-	-
Mean																
373	293	7.3	6.7	240	89	0.96	0.75	13.60	278	180	98	40.00	12.0	40.00	-	-
SD																
29	110	0.0	1.5	94	24	0.05	0.00	0.00	114	106	15	0.50	0.0	0.50	-	-
Max																
401	420	7.3	8.0	316	115	1.00	0.75	13.60	380	265	115	40.30	12.0	40.30	-	-
Min																
343	225	7.3	5.0	135	69	0.90	0.75	13.60	155	60	85	39.60	12.0	39.60	-	-

Table D1 (Continued)

Day	SP Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
<u>Well 5a</u>																
343	465	-	7.5	371	120	0.60	0.05	-	264	202	62	33.50	9.0	33.50	-	-
375	345	7.1	7.0	452	91	0.11	1.00	41.7	282	195	87	33.10	8.0	33.08	-	-
401	525	7.1	7.5	385	125	0.50	-	13.0	125	65	60	34.50	11.0	34.50	-	-
429	415	7.3	7.5	450	95	0.10	0.10	41.4	235	158	77	32.50	-	32.50	-	-
473	450	7.2	7.5	470	100	0.20	0.20	-	200	140	60	32.80	13.0	32.83	-	-
527	510	7.6	7.5	480	86	0.20	0.35	-	190	145	45	32.20	8.0	32.17	-	-
553	525	7.2	12.5	500	94	0.03	0.45	-	210	145	65	31.80	8.0	31.83	-	-
596	425	7.6	2.5	430	78	0.20	0.50	-	180	130	50	30.80	9.0	30.75	-	0.50
618	540	7.5	1.9	480	60	0.50	1.50	59.4	210	140	70	35.00	9.0	30.83	-	0.70
655	575	7.2	1.3	480	84	0.20	0.25	-	224	160	64	31.42	9.0	30.40	0.10	0.50
681	-	-	-	-	90	-	0.40	-	178	120	58	-	-	30.83	-	0.46
700	550	7.0	6.2	517	96	0.20	0.50	-	225	160	65	31.13	11.0	31.13	0.15	0.50
740	600	7.1	-	-	-	-	4.00	-	-	-	-	31.50	10.0	31.50	-	-
Mean																
545	494	7.3	6.3	456	93	0.28	0.78	38.9	210	147	64	32.52	10.0	31.99	0.13	0.53
SD																
132	75	0.2	3.2	45	17	0.17	1.09	19.2	41	35	11	1.32	2.0	1.24	0.04	0.10
Max																
740	600	7.6	12.5	517	125	0.60	4.00	59.4	282	202	87	35.00	13.0	34.50	0.15	0.70
Min																
343	345	7.0	1.3	371	60	0.10	0.05	13.0	125	65	45	30.80	8.0	30.40	0.10	0.46
<u>Well 5b</u>																
700	-	-	44.0	417	36	0.20	1.40	-	330	240		40.75	-	40.75	-	2.40

Well 7a

421	2100	6.6	5.0	430	500	-	-	-	1650	1200	450	31.50	8.0	31.50	-	-
429	1700	6.7	7.5	470	1350	0.20	2.10	22.6	1600	1160	440	31.50	-	31.50	-	-
473	2000	6.6	5.0	490	950	0.18	-	-	1860	1310	550	31.80	13.0	31.83	-	-
527	1635	6.6	7.5	500	1200	0.70	2.50	-	2130	1460	670	31.50	8.0	31.50	-	-
553	1800	6.7	5.0	450	2100	1.55	0.70	-	1850	1400	450	32.60	8.0	32.58	-	-
596	1500	6.5	3.5	490	1200	0.30	4.00	-	1850	1300	550	31.30	12.0	31.33	-	5.80
618	1500	6.5	4.4	290	1400	0.15	3.50	65.0	1700	1170	530	31.80	13.0	31.75	-	6.75
655	1550	6.3	2.0	517	1100	0.20	8.00	-	1390	1360	30	32.04	12.0	32.04	6.5	6.40
681	-	-	-	-	1100	-	0.03	-	1310	1180	130	-	-	32.58	-	5.40

Mean

550	1723	6.5	5.0	454	1211	0.47	2.98	43.8	1704	1282	422	31.76	11.0	31.86	6.5	6.09
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SD

95	228	0.1	1.9	72	425	0.51	2.63	30.0	254	110	208	0.41	2.0	0.47	0.0	0.60
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Max

681	2100	6.7	7.5	517	2100	1.55	8.00	65.0	2130	1460	670	32.60	13.0	32.58	6.5	6.75
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Min

421	1500	6.3	2.0	290	500	0.15	0.03	22.6	1310	1160	30	31.30	8.0	31.33	6.5	5.40
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Well 7c

618	1800	6.6	1.3	550	1400	1.20 ^b	2.5	423	1940	1430	510	33.40	16.0	33.40	-	3.70
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655	1800	6.5	2.0	590	1200	0.20 ^b	3.0	-	1480	1320	160	32.75	15.0	32.75	2.5	3.50
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681	-	-	-	-	1350	-	0.3	-	3198	1255	143	32.80	-	32.80	-	7.68
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700	2200	6.5	2.5	565	1300	0.15	3.6	-	1420	1340	80	33.00	16.0	33.00	3.1	6.70
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740	2250	6.4	-	-	-	-	2.6	-	-	-	-	31.20	15.0	31.20	-	-
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Mean

679	2013	6.5	1.9	568	1313	0.52	2.4	423	1560	1336	223	32.63	16.0	32.63	2.8	5.40
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SD

46	246	0.1	0.6	20	85	0.59	1.3	0	256	72	194	0.84	1.0	0.84	0.4	2.11
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Max

740	2250	6.6	2.5	590	1400	1.20	3.6	423	1940	1430	510	33.40	16.0	33.40	3.1	7.68
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Min

618	1800	6.4	1.3	550	1200	0.15	0.3	423	1398	1255	80	31.20	15.0	31.20	2.5	3.50
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^bTurbidity interference.

Day	SP Cond	pH	Cl-	Alk	SO4--	NO3-	Tot Fe	COD	Tot Hard	Ca++	Mg++	H2O Depth	T	C	Fe++	Mn+
<u>Well 8a</u>																
616	250	6.7	3.8	165	75	0.95	-	-	210	140	70	10.83	10.0	10.83	-	0.20
618	550	6.8	3.8	155	310	0.90	3.00	80.5	550	390	160	18.50	-	10.80	-	1.20
655	575	7.2	2.0	205	60	0.30	0.25	-	210	135	75	9.20	9.0	9.20	0.0	1.25
681	-	-	-	-	43	-	1.10	-	150	98	53	18.50	-	18.50	-	0.64
700	275	6.8	2.5	145	44	0.40	0.45	-	140	100	40	12.04	12.0	12.04	0.0	0.80
740	250	6.8	-	-	-	-	2.50	-	-	-	-	9.40	14.0	9.40	-	-
Mean																
668	380	6.9	3.0	168	106	0.64	1.46	80.5	252	173	80	13.08	11.0	11.80	0.0	0.81
SD																
48	167	0.2	0.9	26	115	0.35	1.23	0	170	123	47	4.32	2.0	3.45	0.0	0.43
Max																
740	575	7.2	3.8	205	310	0.95	3.00	80.5	550	390	160	18.50	14.0	18.50	0.0	1.25
Min																
616	250	6.7	2.0	145	43	0.30	0.25	80.5	140	98	40	9.20	9.0	9.20	0.0	0.20
<u>Well 9a</u>																
616	320	6.9	20	220	67	0.10	-	-	280	210	70	9.00	10.0	9.00	-	0.25
618	290	6.8	19	245	29	0.10	0.7	105	260	180	80	11.90	-	9.00	-	0.20
655	325	6.8	19	260	28	0.20	4.5	-	275	200	75	8.42	11.0	8.42	4.0	0.80
681	-	-	-	-	27	-	8.4	-	155	193	63	9.20	-	9.20	-	0.45
700	325	7.0	20	245	27	0.15	4.7	-	260	200	60	9.96	13.0	9.96	4.4	0.30
740	300	6.7	-	-	-	-	6.0	-	-	-	-	10.00	15.0	10.00	-	-
Mean																
668	312	6.8	20	243	36	0.14	4.9	105	246	197	70	9.75	12.0	9.26	4.2	0.40
SD																
48	16	0.1	1	17	18	0.05	2.8	0	52	11	8	1.21	2.0	0.61	0.3	0.24
Max																
740	325	6.7	20	260	67	0.20	8.4	105	280	210	80	12.00	15.0	10.00	4.4	0.80
Min																
616	290	7.0	19	220	27	0.10	0.7	105	155	180	60	8.00	10.0	8.00	4.0	0.20

Table D2. ICP surface water

Day	Sp Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	Tot Hard	Ca++	Mg++	T	Fe++	Mn++
<u>ICP Sediment Pond</u>													
88	-	-	-	-	-	-	1.55	25	11	14	-	-	0.012
208	110	7.6	2.0	10	85	0.50	0.30	90	60	30	-	-	-
239	-	7.5	1.9	15	90	-	0.35	110	70	40	-	-	-
267	210	6.1	2.0	0	160	0.50	0.50	210	140	70	17	-	-
300	410	5.7	5.0	0	180	0.69	-	270	182	88	27	-	-
343	590	4.3	4.5	0	340	0.89	4.60	455	315	140	28	-	-
375	665	4.2	0.0	0	740	4.65	18.00	800	520	280	23	-	-
401	1500	4.1	0.0	0	1100	4.90	-	1045	625	420	-	-	-
429	1600	<4.0	0.0	0	1100	3.70	6.00	900	600	300	16	-	-
473	-	-	-	-	-	-	2.50	-	-	-	-	-	-
527	1500	<4.0	0.0	0	1650	0.50 ^b	5.00	1950	1240	710	0	-	-
553	1300	4.2	- ^a	-	1800	1.55	3.80	1125	800	325	2	-	-
596	850	<4.0	6.0	0	725	0.50 ^b	5.50	900	625	275	12	-	9.600
740	700	4.8	-	-	-	-	5.00	-	-	-	25	-	-
Mean													
396	858	-	2.1	3	725	1.84	4.43	657	432	224	17	-	4.806
SD													
173	537	-	2.3	5	622	1.83	4.77	571	370	205	10	-	6.800
Max													
740	1600	7.6	6.0	15	1800	4.90	18.00	1950	1240	710	0	-	9.600
Min													
88	110	<4.0	0.0	0	85	0.5	0.30	25	11	14	28	-	0.012
<u>Coal Creek</u>													
88	-	-	-	-	-	-	0.65	390	116	174	-	-	1.780
239	360	8.5	30.0	150	270	-	-	420	335	85	-	-	-
267	710	7.6	20.0	120	250	5.40	0.65	450	300	150	18	-	-
300	280	8.0	17.0	151	400	0.48	0.06	344	206	138	26	-	-
343	290	7.2	9.5	51	130	0.82	0.80	250	188	62	25	-	-
375	775	-	12.0	80	237	0.42	-	410	295	115	-	-	-
401	725	-	10.0	75	800	0.60	-	1080	670	410	-	-	-
429	2500	8.5	7.5	140	450	0.18	-	625	455	170	15	-	-

527	2500	6.8	10.0	320	110	0.20	2.50	410	260	150	0	-	-
553	900	8.0	20.0	230	800	0.80	1.50	1050	800	250	2	-	-
596	670	8.5	57.0	170	375	0.40	2.50	625	475	150	10	-	1.20
618	600	9.0	58.0	170	220	0.45	0.70	495	340	155	-	-	0.50
655	670	9.0	50.0	190	350	0.40	1.00	580	445	135	26	-	1.10
681	-	-	-	-	470	-	0.65	515	405	110	-	-	5.90
740	160	7.4	-	-	-	-	12.00	-	-	-	20	-	-
Mean													
454	720	8.0	25.1	154	374	0.92	2.09	560	378	161	16	0.1	2.10
SD													
188	600	0.7	19.2	73	219	1.50	3.38	244	186	84	10	-	2.17
Max													
740	2500	9.0	58.0	320	800	5.40	12.00	1080	800	410	26	0.1	0.50
Min													
88	160	7.2	7.5	51	110	0.18	0.06	250	116	62	0	0.1	5.90
ICP Top Seam Mining Cuts													
401	300	-	5.0	70	880	0.30	-	950	650	300	-	-	-
428	775	5.3	5.0	15	780	0.40	-	880	600	280	16	-	-
596	735	9.1	9.0	14	475	0.40	0.20	800	600	200	16	-	1.0
618	1700	9.1	5.0	130	990	0.40 ^b	0.20	1410	1080	330	29	-	1.8
655	1800	4.0	0.0	0	1600	2.70 ^b	20.00	2200	1480	720	25	20.0	28.0
428	525	8.0	5.0	100	300	0.15	5.00	500	360	140	21	-	-
401	225	-	5.0	110	110	0.10 ^b	-	200 ^c	125	75	-	-	-
655	2600	4.0	0.0	0	3000	7.30 ^b	4.00	1500 ^c	700	800	28	4.0	12.0
								1050 ^c	550	500	16	-	-

^aBlue interference.

^bLavender interference.

^cEnd point interference.

Table D2 (Continued)

Day	Sp Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	Tot Hard	Ca++	Mg++	T	Fe++	Mn++
Mean													
523	1083	6.6	4.3	55	1017	1.48	5.88	1055	699	356	23	12.0	10.7
SD													
118	851	2.4	3.0	54	924	2.50	8.19	630	418	264	6	11.3	12.6
Max													
655	2600	9.1	9.0	130	3000	19.00	20.00	2200	1480	800	29	20.0	28.0
Min													
401	225	4.0	0.0	0	110	0.10	0.20	200	125	75	16	4.0	1.0
ICP Bottom Seam Mining Cuts													
428	-	-	0.0	0	1700	19.00	-	395	350	45	-	-	-
239	-	8.5	1.9	25	310	-	0.10	1480	980	500	-	-	-
267	1100	8.1	17.8	15	1000	0.88	0.80	372	288	84	31	-	-
300	600	9.0	14.0	84	280	2.80	0.35	610	452	158	29	-	-
343	660	-	2.5	0	425	0.32	4.50	900	600	300	22	-	-
428	-	-	0.0	0	750	0.90	-	800	600	200	18	-	1.2
596	1300	9.1	22.5	140	940	2.45	0.20	430	300	130	-	-	10.0
267	410	4.7	5.0	0	335	3.30	0.60	240	116	124	27	-	-
300	750	6.8	12.5	0	600	5.00	0.90	1080	335	745	24	-	-
343	1600	4.6	9.0	0	700	2.40	11.80	950	600	350	16	-	-
428	-	-	-	-	900	-	-	1080	720	360	28	-	6.7
618	1250	4.0	0.5	0	870	2.40 ^b	9.00						
Mean													
380	959	6.9	7.8	24	734	3.95	3.14	782	490	291	23	-	6.0
SD													
125	413	2.1	7.9	46	399	5.46	4.38	375	233	210	6	-	4.4
Max													
618	1600	9.1	22.5	140	1700	19.00	11.80	1480	980	745	31	-	10.0
Min													
239	410	4.0	0.0	0	280	0.88	0.10	240	116	45	16	-	1.2
ICP Standpipe (on fill)													
343	750	7.6	2.0	0	1105	2.15	15.00	552	312	240	29	-	-

Table D3. ICO surface water quality

Day	Sp Cond	pH	Cl-	Alk	SO4=	NO3-	Tot Fe	Tot Hard	Ca++	Mg++	T	Fe++	Mn++
<u>North ICO Mining Cut and Sediment Pond</u>													
343	1900	7.6	5.5	54	1200	0.20	1.10	1848	1420	428	29	-	-
401	1700	-	5.0	150	1450	0.15	-	2150	1545	605	-	-	-
428	1900	-	5.0	125	1450	0.20	-	1875	1350	527	16	-	-
343	790	8.3	3.5	56	675	0.19	0.20	966	784	182	26	-	-
401	1400	-	5.0	110	1100	0.40	-	1475	1250	225	-	-	-
618	1250	9.0	3.1	105	1000	0.35	0.50	1800	1280	520	28	-	0.10
681	-	-	-	-	1100	-	0.05	1443	1303	140	-	-	0.18
700	2000	8.9	4.4	155	1400	0.30	1.00	2210	1482	728	29	0.0	1.50
740	925	8.5	-	-	-	-	0.30	-	-	-	26	-	-
Mean													
517	1483	8.5	4.5	108	1172	0.26	0.53	1721	1302	419	26	0.0	0.59
SD													
164	465	0.6	0.9	41	266	0.09	0.43	410	233	215	5	-	0.79
Max													
740	2000	9.0	5.5	155	1450	0.40	1.10	2210	1545	728	29	0.0	1.50
Min													
343	790	7.6	3.1	54	675	0.15	0.20	966	784	140	16	0.0	0.10
<u>South ICO Mining Cut</u>													
343	2000	4.3	5.5	0	1350	0.28	0.85	1970 ^b	1284	686	26	-	-
401	1800	-	5.0	0	1900	0.40	-	2350 ^b	1350	1000	-	-	-
428	2300	-	5.0	0	1850	0.40	-	2275	1500	775	-	-	-
527	1400	<4.0	5.0	0	2450	-	3.00	1710	5101	200	0	-	-
553	850	6.6	4.0	35	1750	0.35	0.50	1125	950	175	1	-	-
596	1500	<4.0	3.5	0	1400	0.45	10.00	1600	950	650	13	-	38.5
618	1600	<4.0	2.5	0	1400	0.35	4.00	1680	1160	520	28	-	25.2
655	1600	<4.0	0.0	0	1700	0.90 ^a	3.50	2100	1300	700	25	1.5	35.0
681	-	-	-	-	2200	-	10.80	1543	1375	168	-	-	95.9

700	2750	<4.0	0.0	0	2100	1.60 ^a	13.00	2880 ^b	1640	1240	28	2.0	8.4
740	2200	<4.0	-	-	-	-	60.00	-	-	-	27	-	-
Mean													
567	1800	-	3.4	4	1810	0.59	11.74	1923	1302	611	19	1.8	40.6
SD													
131	536	-	2.1	12	368	0.45	18.65	500	229	358	12	0.4	33.0
Max													
740	2750	6.6	5.0	35	2450	1.60	60.00	2880	1640	1240	28	2.0	95.9
Min													
343	850	4.0	0.0	0	1350	0.28	0.50	1125	950	168	0	1.5	8.4

^aLavender interference.

^bEnd point interference.

Table D4. Farm well water quality near ICP#1

	Day	Sp Cond	pH	Cl-	Alk
Dust Suppression Well	703	560	7.6	2.5	320
Abandoned Farm Well	703	500	7.2	3.8	280
Denburger Farm Well	703	270	6.6	6.9	110
Blizzard Farm Well	703	2700	7.7	173.0	335
Scott Farm Well	703	2700	7.9	173.0	275
Childers Farm Well	703	2700	8.0	190.0	270
Childers Farm Well	703	235	6.8	20.0	110
Voss Farm Well	703	590	8.0	12.0	340
Garden Farm Well (sampled at house)	22	2800	7.4	233.0	240
Garden Farm Well (sampled at hydrant)	22	2800	8.6	233.0	240
Garden Farm Well	22	1200	8.0	245.0	290
Garden Farm Pond	22	385	9.2	65.0	260
Garden Farm Pond	22	400	9.2	68.0	245

^aAnalysis not performed.

SO4=	NO3-	Tot Fe	Fe++	Tot Hard	Ca++	Mg++	T	H2O Depth	Mn++
180	1.00	4.00	1.00	490	360	130	16	25	2.4
160	1.35	2.60	0.50	460	325	135	12	25	0.2
49	3.50	0.15	0.00	150	118	32	24	25	0.1
1250	0.40	1.00	0.50	810	610	200	14	200	0.4
1100	0.35	3.60	2.80	845	550	295	15	200	0.0
1400	0.20	2.20	1.00	1075	720	355	17	200	0.2
18	1.50	0.35	0.15	117	75	42	28	25	0.5
130	0.25	1.60	0.00	230	155	75	20	220	0.0
350	7	0.1	- ^a	1480	1140	340	-	200	-
300	11	0.1	-	1430	1130	300	-	200	-
200	150	0.1	-	800	460	340	-	25	-
180	5	0.1	-	240	130	110	-	1	-
140	7	0.2	-	230	160	70	-	5	-

Table D5. Trace element analysis

Surface sample location		Al	As	B	Ba	Be	Ca	Co	G	Cu	Fe	Hg
ICP Sediment Pond	A ^a	1.52	.062	.045	.097	.000	10.4	.011	.003	.006	1.55	.018
Coal Creek	A	.101	.178	.312	.091	.000	155	.055	.027	.007	.823	.126
	B ^b	.060	.036	.184	.059	ND	162	.008	.002	.002	.649	-
ICO Sediment Pond	B	.040	.049	.386	.033	.00002	521	.0005	.005	ND	.046	-
ICO South Mine Cut	B	75.6	1.22	.264	.018	.021	550	.869	.065	.072	10.8	-
Well Location												
C1	B	6.12	.169	.233	.267	.0006	61	.114	.015	.005	13.3	-
C2	A	1.32	.252	.132	.438	.000	40.7	.063	.006	.016	18.1	.193
	B	.041	.029	.093	.218	ND ^c	38	.102	.001	.0003	13.4	- ^d

^aAnalysis of samples from 11/4/75 (Dr. Fassel group Ames Lab).

^bAnalysis of samples from 6/19/77 (Dr. Kniseley group Ames Lab).

^cNot determinable.

^dAnalysis not performed.

Table D5 (Continued)

Surface sample location		Mg	Mn	Ni	Pb	Sb	Se	Sn	Sr	V	Y	Zn
ICP Sediment Pond	A ^a	4.42	.011	.013	.011	.011	-- ^e	.009	.068	.003	.002	.009
Coal Creek	A	46.6	1.78	.122	.046	.026	.091	-	.663	.011	.002	.053
	B ^b	44	5.88	.014	.021	.019	.019	-	.174	.004	-	.008
ICO Sediment Pond	B	56	.172	.028	.050	.042	.031	-	.390	.004	-	.008
ICO South Mine Cut	B	67	95.9	1.87	.261	.228	.257	-	.604	.036	-	2.24
Well Location												
C1	B	30	2.14	.025	.051	.030	.045	-	.086	.023	-	.052
C2	A	12.4	.410	.031	.322	.098	-	-	.203	.008	.017	.068
	B	19	.706	.001	.029	.009	.014	-	.051	.0009	-	.017

^eNegative detection range.

Table D5 (Continued)

Surface sample location		Al	As	B	Ba	Be	Ca	Co	Cr	Cu	Fe	Hg
E	A	2.65	.224	.153	.564	.0003	46.6	.092	.015	.029	24.8	.259
	B	.094	.028	.087	.379	ND	41	.118	.002	.0001	15.6	-
G	A	1.21	.125	.155	.202	-	40.13	.003	.009	.020	7.04	.097
	B	.176	.055	.164	.070	ND	38	.099	.002	.001	12.7	-
K	B	.546	.035	.143	.084	.0002	92	.041	.003	.002	3.39	-
ICP Dug Well	B	.006	.036	.064	.060	ND	132	ND	.002	.003	.114	-
M	A	1.87	.217	.074	.159	.0003	81.9	.055	.017	.040	11.2	.165
	B	.334	.042	.045	.058	ND	106	.023	.003	.0004	2.45	-
Q	B	.092	.027	.103	.081	ND	108	ND	.002	.0004	.310	-
T	A	6.84	.415	.207	.414	.0008	57.0	.088	.018	.035	21.8	.246
	B	.858	.049	.152	.378	.0006	44	.048	.003	.0005	5.78	-
S2	B	.278	.039	.115	.080	ND	63	.016	.002	.0009	2.09	-

Table D5 (Continued)

Surface sample location		Mg	Mn	Ni	Pb	Sb	Se	Sn	Sr	V	Y	Zn
E	A	11.5	.780	.046	.266	.058	-	-	.235	.016	.022	.122
	B	17	1.23	.006	.018	.010	.018	-	.054	.002	-	.017
G	A	9.22	.346	.035	.150	.027	-	-	.197	.007	.002	.102
	B	13	.496	.004	.026	.010	.012	-	.053	.001	-	.021
K	B	33	2.79	.042	.028	.016	.013	-	.111	.004	-	.070
ICP Dug Well	B	44	.676	.010	.018	.014	.021	-	.108	.001	-	.272
M	A	27.6	.737	.077	.480	.043	.024	-	.230	.013	.027	.167
	B	40	.810	.013	.032	.014	.017	-	.079	.003	-	.034
Q	B	35	.083	.007	.030	.012	.010	-	.273	.0008	-	.016
T	A	24.4	.408	.067	.401	.086	.0006	-	.276	.030	.012	.132
	B	25	.102	.014	.034	.009	.014	-	.084	.005	-	.020
S2	B	30	.743	.006	.023	.009	.013	-	.057	.002	-	.024

Table D5 (Continued)

Surface sample location		Al	As	B	Ba	Be	Ca	Co	Cr	Cu	Fe	Hg
1a	B	.060	.016	.041	.109	ND	37	ND	.0009	ND	.182	-
1b	B	.083	.023	.101	.189	ND	42	ND	.0009	ND	.309	-
1c	B	.114	.021	.020	.069	ND	53	ND	.001	ND	.202	-
1d	B	.100	.025	.023	.089	ND	60	ND	.001	ND	.207	-
2a	B	.140	.035	.192	.082	ND	98	ND	.001	ND	.216	-
2b	B	.176	.032	.536	.080	ND	89	ND	.002	ND	.291	-
2c	B	.122	.027	.049	.072	ND	72	ND	.001	ND	.255	-
2d	B	.182	.029	.027	.080	ND	69	ND	.001	ND	.372	-

Table D5 (Continued)

Surface sample location		Mg	Mn	Ni	Pb	Sb	Se	Sn	Sr	V	Y	Zn
1a	B	23	.015	.002	.009	.002	.007	-	.034	ND	-	.010
1b	B	22	.729	.001	.019	.003	.006	-	.051	.0002	-	.010
1c	B	28	.125	.005	.012	.005	.009	-	.044	.0005	-	.013
1d	B	26	.159	.005	.011	.005	.007	-	.049	.0004	-	.010
2a	B	34	.020	.003	.018	.010	.012	-	.183	.001	-	.007
2b	B	33	.026	.004	.015	.009	.009	-	.131	.0008	-	.008
2c	B	26	.205	.005	.019	.005	.013	-	.074	.0007	-	.013
2d	B	30	.085	.003	.030	.007	.009	-	.061	.0007	-	.011

Table D5 (Continued)

Surface sample location		Al	As	B	Ba	Be	Ca	Co	Cr	Cu	Fe	Hg
3a	B	.095	.020	.040	.066	ND	37	.013	.0008	ND	.916	-
5a	B	.177	.042	.906	.073	ND	48	ND	.001	ND	.371	-
7a	B	.074	.080	.492	.014	ND	471	.012	.004	ND	.028	-
7c	B	.129	.102	1.01	.031	ND	503	.022	.005	.0003	.290	-
8a	B	.301	.026	.048	.056	ND	39	.010	.001	.0005	1.07	-
9a	B	.131	.033	.084	.120	ND	77	.068	.001	ND	8.42	-
Rinse ^f H2O	B	<.0005	ND	ND	ND	ND	.013	ND	ND	ND	.0009	-

^f Deionized rinse water used to cleanse bottles.

Table D3 (Continued)

Surface sample location		Mg	Mn	Ni	Pb	Sb	Se	Sn	Sr	V	Y	Zn
3a	B	22	.288	.003	.009	.004	.008	-	.047	.0009	-	.012
5a	B	23	.455	.004	.016	.004	.022	-	.166	.0003	-	.009
7a	B	51	5.41	.079	.041	.035	.041	-	.469	.005	-	.055
7c	B	57	7.68	.041	.083	.043	.043	-	.646	.006	-	.024
8a	B	21	.639	.003	.020	.004	.007	-	.033	.0007	-	.015
9a	B	25	.449	.003	.018	.009	.015	-	.081	.0009	-	.013
Rinse ^f H2O	B	.003	ND ^c	ND	ND	ND	ND	-	ND	ND	-	.003

Table D6. Analysis of artificial runoff from James Gregory study, August 1976

Sample	Time ^a	Cl-	Alk	SO4=	NO3-	Tot Hard	Ca++	Mg++	Sp Cond
<u>Shale Runoff</u>									
S1	w ^b	2.5	20	80	0.10	20.0	15.0	5.0	24
	0	0.0	0	1080	13.00	1400.0	600.0	800.0	1300
	10	0.0	0	420	1.90	325.0	200.0	125.0	650
	15	0.0	0	380	1.15	225.0	150.0	75.0	630
	20	0.5	0	230	1.25	180.0	150.0	30.0	480
	25	2.0	0	160	0.60	110.0	90.0	20.0	300
	30	2.0	0	120	0.40	110.0	60.0	50.0	260
	40	2.0	0	120	0.40	130.0	55.0	75.0	270
S2	w	2.5	20	0	0.40	15.0	10.0	5.0	18
	0	0.0	0	640	3.50	400.0	250.0	150.0	825
	10	0.0	0	330	2.00	200.0	150.0	50.0	625
	15	0.5	0	230	1.70	145.0	90.0	55.0	480
	20	2.0	0	190	1.50	120.0	90.0	30.0	410
	25	2.0	0	170	1.30	100.0	80.0	20.0	410
	30	2.0	0	140	0.65	70.0	70.0	0.0	280
	40	2.5	0	90	0.60	80.0	60.0	20.0	280
	50	3.0	0	64	0.20	60.0	40.0	20.0	195
	60	2.5	0	77	0.50	70.0	50.0	20.0	180
S3	70	2.5	0	69	0.50	60.0	40.0	20.0	190
	w	2.0	20	7	0.70	25.0	15.0	10.0	21
	0	0.0	0	540	6.60	300.0	200.0	100.0	880
	10	0.0	0	420	4.00	250.0	150.0	100.0	790
	15	0.0	0	240	2.60	150.0	110.0	40.0	630
	20	2.0	0	200	1.50	100.0	75.0	25.0	460
	25	2.0	0	150	1.10	112.5	75.0	37.5	375
	30	2.0	0	160	1.10	75.0	62.5	12.5	380
	40	1.5	0	150	0.95	100.0	70.0	30.0	360
	50	2.0	0	130	1.10	85.0	60.0	25.0	380
	60	2.0	0	62	0.90	35.0	15.0	20.0	280

Topsoil Runoff

TS1	w	3.0	35	0	0.15	40.00	20.00	20.00	28
	0	2.5	20	6	0.30	15.00	8.75	6.25	23
	10	3.0	17	0	0.30	12.50	7.50	5.00	23
	15	2.5	20	-	-	-	-	-	-
	20	2.0	17	0	0.25	12.50	7.50	5.00	18
	25	2.5	25	0	0.25	17.50	8.75	8.75	22
	30	3.0	25	1	0.20	15.00	7.50	7.50	25
	40	2.0	20	0	0.15	10.00	7.50	2.50	13
	0	3.5	22	0	0.25	13.75	8.75	5.00	22
	15	3.0	25	7	0.35	17.50	10.00	7.50	28
TS2	20	2.5	25	1	0.25	13.75	7.50	6.25	19
	25	2.5	20	1	0.25	12.50	7.50	5.00	18
	30	2.5	25	0	0.10	17.50	12.50	5.00	21
	40	2.0	20	0	0.25	12.50	7.50	5.00	16
	50	2.0	15	3	0.30	10.00	5.00	5.00	13
	60	2.0	30	0	0.20	20.00	12.50	7.50	27
	80	1.5	22	7	0.40	17.50	10.00	7.50	18
	w	2.0	35	2	0.15	25.00	15.00	10.00	34
	0	2.0	25	9	0.30	17.50	10.00	7.50	27
	10	1.0	25	2	0.20	12.50	7.50	5.00	23
TS3	15	1.0	25	0	0.20	12.50	7.50	5.00	21
	20	2.0	30	3	0.20	17.50	10.00	7.50	25
	25	1.0	25	0	0.20	12.50	7.50	5.00	22
	30	2.5	25	3	0.20	12.50	7.50	5.00	21
	40	2.0	25	0	0.30	15.00	7.50	7.50	23
	50	2.0	25	1	0.30	12.50	7.50	5.00	21
	60	2.0	15	3	0.20	10.00	5.00	5.00	12

^aTime in minutes for duration of artificial precipitation.

^bAnalysis of water before infiltration and runoff.

Table D6 (Continued)

Sample	Time ^a	Cl-	Alk	SO4=	NO3-	Tot Hard	Ca++	Mg++	Sp Cond
<u>Tilled Topsoil Runoff</u>									
TTS2	w	2.0	25	4	0.30	17.5	10.00	7.50	15
	0	2.0	10	13	0.90	20.0	10.00	10.00	31
	35	2.5	10	18	1.00	15.0	10.00	5.00	27
	40	3.5	10	20	1.30	20.0	12.50	7.50	40
	45	4.0	10	21	13.0	17.5	8.75	8.75	35
	50	3.5	10	17	0.90	17.5	8.75	8.75	32
TTS3	w	2.0	18	0	0.20	10.0	5.00	5.00	10
	0	3.0	15	15	0.90	17.5	8.75	8.75	30
	50	4.0	15	16	0.90	17.5	8.75	8.75	28
	60	4.0	12	11	1.00	17.5	8.75	8.75	28
	70	4.0	15	13	0.90	15.0	7.50	7.50	28
	80	3.5	15	8	0.70	15.0	7.50	7.50	25
	90	2.5	12	4	0.60	12.5	7.50	5.00	22
	100	2.5	15	9	0.70	15.0	7.50	7.50	24
	120	2.5	15	1	0.55	15.0	7.50	7.50	19
	w	3.0	15	5	0.10	7.5	5.00	2.50	11
TTS4	0	5.0	10	3	0.20	10.0	5.00	5.00	13
	70	2.5	10	0	0.20	10.0	5.00	5.00	10
	80	12.5	10	2	0.20	10.0	5.00	5.00	22
	90	5.0	10	0	0.30	5.0	2.50	2.50	12
	100	2.5	10	0	0.20	5.0	2.50	2.50	14
	110	5.0	10	1	0.30	5.0	2.50	2.50	16
	120	2.5	10	1	0.30	5.0	2.50	2.50	9

Subsoil Runoff

SS1	w	<2.5	25	0	0.15	25.0	15.00	5.00	25
	0	<2.5	25	17	0.35	35.0	20.00	15.00	44
	5	<2.5	20	6	0.90	3.0	12.50	17.50	36
	10	<2.5	20	4	0.50	25.0	12.50	12.50	27
	15	<2.5	20	3	0.95	25.0	13.75	11.25	25
	20	<2.5	20	2	0.60	25.0	12.50	12.50	22
	25	<2.5	20	2	0.70	20.0	12.50	7.50	20
	30	<2.5	20	2	0.30	20.0	13.75	6.25	24
	40	<2.5	20	1	0.35	20.0	13.75	6.25	21
	50	<2.5	25	7	0.25	20.0	13.75	6.25	23
SS2	60	<2.5	25	3	0.25	20.0	13.75	6.25	19
	w	<2.5	30	2	0.45	20.0	13.75	6.25	24
	0	<2.5	20	7	0.40	30.0	20.00	10.00	26
	5	<2.5	23	3	0.45	20.0	12.50	7.50	23
	10	<2.5	20	2	0.80	15.0	8.75	6.25	18
	15	<2.5	20	4	0.35	20.0	10.00	10.00	21
	20	<2.5	20	7	0.70	15.0	10.00	5.00	19
	25	<2.5	20	8	0.40	15.0	10.00	5.00	19
	30	<2.5	20	4	0.80	20.0	12.50	7.50	21
	0	<2.5	20	4	0.65	20.0	12.50	7.50	19
SS3	10	<2.5	20	2	0.35	15.0	8.75	6.25	14
	15	<2.5	25	1	0.60	20.0	10.00	10.00	21
	20	<2.5	30	2	0.75	23.0	11.25	11.75	20
	25	<2.5	20	3	0.40	15.0	7.50	7.50	14
	30	<2.5	20	2	0.90	20.0	11.25	8.75	23

Table D6 (Continued)

Sample	Time ^a	Cl-	Alk	SO4=	NO3-	Tot Hard	Ca++	Mg++	Sp Cond
<u>Grass Covered Topsoil Runoff</u>									
G2	w	3.0	25	3	0.25	15.0	10.00	5.00	23.5
	0	15.0	60	6	0.65	50.0	45.00	5.00	66.0
	10	7.5	30	1	1.10	30.0	20.00	10.00	43.5
	15	7.5	40	3	0.65	30.0	15.00	15.00	35.0
	20	6.0	30	2	0.70	30.0	20.00	10.00	32.5
	25	4.0	20	2	0.75	20.0	13.0	7.00	26.5
	30	5.0	30	1	0.65	25.0	15.00	10.00	29.0
	40	3.0	30	2	0.65	20.0	15.00	5.00	23.0
	50	3.0	30	1	0.55	18.0	13.00	5.00	22.0
	60	3.0	30	3	0.60	20.0	15.00	5.00	29.0
G3	w	2.0	25	2	0.20	10.0	10.00	0.00	14.0
	0	3.0	30	2	0.45	30.0	23.00	7.00	34.0
	5	3.0	35	3	0.55	30.0	20.00	10.00	29.0
	10	3.0	30	3	0.45	25.0	15.00	10.00	28.0
	15	3.0	30	1	0.35	20.0	15.00	5.00	26.0
	20	2.5	25	2	0.40	20.0	14.00	6.00	20.5
	24	2.5	25	0	0.40	20.0	15.00	5.00	20.0
	30	2.5	25	6	0.50	20.0	10.00	10.00	19.0
	40	2.5	30	2	0.55	15.0	15.00	0.00	22.0
	60	2.0	25	1	0.30	20.0	15.00	5.00	18.5

Reclaimed Fill Runoff

RC1	w	5.0	20	3	0.25	10.0	5.00	5.00	17.0
	0	7.5	30	150	0.40	130.0	100.00	30.00	195.0
	10	5.0	30	100	0.55	110.0	90.00	20.00	170.0
	15	4.0	25	104	0.35	110.0	100.00	10.00	190.0
	25	4.0	20	-	-	90.0	70.00	20.00	135.0
	30	4.0	20	48	0.25	75.0	65.00	10.00	105.0
	40	3.0	30	68	0.40	100.0	100.00	0.00	125.0
	50	5.0	30	47	0.40	80.0	70.00	10.00	115.0
	60	4.0	30	33	0.25	70.0	60.00	10.00	90.0
	w	4.0	20	0	0.20	15.0	10.00	5.00	17.0
RC2	0	7.5	25	150	0.80	170.0	160.00	10.00	230.0
	5	5.0	20	120	0.70	120.0	105.00	15.00	170.0
	10	4.0	20	51	0.40	80.0	80.00	0.00	115.0
	15	5.0	25	59	0.45	60.0	50.00	10.00	120.0
	25	-	-	83	0.25	-	-	-	-
	w	6.0	20	1	0.40	15.0	10.00	5.00	21.0
	0	6.0	25	280	0.90	410.0	365.00	45.00	410.0
RC3	5	5.0	20	186	0.60	260.0	250.00	10.00	310.0
	10	5.0	30	160	0.40	220.0	210.00	10.00	280.0
	15	5.0	20	140	0.40	175.0	155.00	20.00	235.0
	20	5.0	20	130	0.40	130.0	130.00	0.00	205.0
	25	5.0	30	120	0.35	170.0	170.00	0.00	220.0
	30	5.0	20	135	0.40	130.0	130.00	0.00	220.0

APPENDIX E: STATISTICAL CORRELATIONS

Symbols used in Tables E1, E2, E3, and E4 are defined as follows:

Sp Cond	Specific Conductance as ppm NaCl
pH	-log of Hydrogen ion concentration
Cl-A	mg/l Chloride ion
Alk	Alkalinity as mg/l CaCO ₃
SO ₄ =	mg/l Sulfate ion
NO ₃ -	mg/l Nitrate-Nitrogen
Tot Hard	Total Hardness as mg/l CaCO ₃
Ca++	Calcium Hardness as mg/l CaCO ₃
Mg++	Magnesium Hardness as mg/l CaCO ₃
HCO ₃ -	mg/l Bicarbonate ion
Tot Fe	Total Iron as mg/l Fe
Fe++	mg/l Ferrous Iron ion
COD	Chemical Oxygen Demand mg/l O ₂
H ₂ O Depth	Water Depth measured at time of sampling
C Depth	Water Depth corrected for effect of bailing previous to sampling
Ex Alk	Alk minus Tot Hard where Alk is greater than Tot Hard as mg/l CaCO ₃
NCH	Noncarbonate Hardness as mg/l CaCO ₃
T	Temperature in degrees Celsius
Mn++	mg/l Manganese ion
$\frac{SO_4=}{HCO_3-}$	Sulfate to Bicarbonate ratio
$\frac{Ca++}{Mg++}$	Calcium Hardness to Magnesium Hardness ratio
Day	Day of study
Ppt	Precipitation since last sampling

Table E1. ICP groundwater correlations

Well Cl		Sp Cond	Alk	Tot Hard	Ca++	T	SO4=			
Day	r	.84	.77	.66	.62	-.44	.42			
	p	.00	.00	.00	.00	.03	.06			
	n	21	20	21	21	23	21			
Sp Cond	r	.86	.84	.73	.68	.49	-.40	.38	.38	
	p	.00	.00	.00	.00	.03	.08	.10	.10	
	n	20	21	20	20	20	21	20	20	
pH	r	.85	-.54	-.47						
	p	.00	.02	.04						
	n	9	19	19						
Cl-	r	.63	.48	.41						
	p	.00	.03	.08						
	n	18	20	19						
Alk	r	.96	.86	.78	.77	.72	-.70	.58	-.54	-.44
	p	.04	.00	.00	.00	.00	.04	.01	.02	.05
	n	4	20	20	20	20	9	20	19	20

Table E1 (Continued)

		Tot Hard	Mg++	Sp Cond	H2O Depth	Day	C Depth	Alk	Ca++
SO4=	r	.61	.51	.49	.42	.42	.42	.40	.38
	p	.00	.02	.03	.05	.06	.06	.08	
	n	21	21	20	21	21	21	20	21
		Mn++	<u>Ca</u> Mg	Mg++	Ca++	NCH	H2O Depth		
NO3-	r	-.93	-.70	.59	-.55	.52	.43		
	p	.07	.00	.02	.03	.04	.09		
	n	4	16	16	16	16	16		
		Mn++	COD	Ta	Ex Alk	<u>Ca</u> Mg	Cl-		
Tot	r	.97	.70	.50	-.45	-.44	.41		
Fe	p	.01	.04	.02	.05	.05	.08		
	n	5	9	20	20	20	19		
		pH	Tot Fe	Alk	T	H2O Depth	C Depth		
COD	r	.85	.70	-.70	.69	-.65	-.64		
	p	.00	.04	.04	.04	.06	.06		
	n	9	9	9	9	9	9		
		Ca++	Sp Cond	Mg++	Alk	Day	SO4=	pH	
Tot	r	.74	.73	.72	.72	.66	.61	-.47	
Hard	p	.00	.00	.00	.00	.00	.00	.04	
	n	21	20	21	20	21	21	19	

Table E1 (Continued)

		Alk	Tot Hard	Sp Cond	Day	NO3-	Ca++ Mg++	SO4=	T	
Ca++	r	.78	.74	.68	.62	-.55	.43	.38	-.38	
	p	.00	.00	.00	.00	.03	.05	.09	.10	
	n	20	21	20	21	16	21	21	20	
		NCH	Ca++ Mg++	Tot Hard	NO3-	SO4=	Sp Cond			
Mg++	r	.79	-.74	.72	.59	.51	.38			
	p	.00	.00	.00	.02	.02	.10			
	n	20	21	21	16	21	20			
		C Depth	COD	Ppt	NO3-	SO4=				
H2O Depth	r	.98	-.64	-.61	.43	.42				
	p	.00	.06	.00	.09	.05				
	n	23	9	21	16	21				
		Mn++	COD	Tot Fe	Cl-	Day	Alk	Sp Cond	Ex Alk	Ca++
T	r	.94	.69	.50	.48	-.44	-.44	-.40	-.39	-.38
	p	.06	.04	.02	.03	.03	.05	.08	.09	.10
	n	4	9	20	20	23	20	21	20	20
		Tot Fe	Alk	T	NO3-					
Mn++	r	.97	.96	.94	-.93					
	p	.01	.04	.06	.07					
	n	5	4	4	4					

Table E1 (Continued)

Ppt		Cl-	H2O Depth	C Depth			
Ppt	r	.63	-.61	-.55			
	p	.00	.00	.01			
	n	18	21	22			
NCH		Mg++	Ca++ Mg++	NO3-	Ex Alk		
NCH	r	.79	-.63	.52	-.40		
	p	.00	.00	.04	.08		
	n	20	20	16	20		
Ex Alk		Alk	Tot Fe	NCH	Ca++ Mg++	T	Sp Cond
Ex Alk	r	.58	-.45	-.40	.40	-.39	.38
	p	.01	.05	.08	.07	.09	.10
	n	20	20	20	21	20	20
Ca++ Mg++		Mg++	NO3-	NCH	Tot Fe	Ca++	Ex Alk
Ca++ Mg++	r	-.74	-.70	-.63	-.44	.43	.40
	p	.00	.00	.00	.05	.05	.07
	n	21	16	20	20	21	21

Table E1 (Continued)

Well C₂

		Sp Cond	Tot Fe	pH	COD	Alk	NCH	SO4=		
Day	r	.80	.69	-.65	-.46	.40	-.38	-.36		
	p	.00	.00	.00	.10	.07	.08	.09		
	n	23	23	22	14	22	23	23		
		Mn++	Day	pH	NCH	COD	Alk	T	SO4=	Tot Fe
Sp Cond	r	.87	.80	-.78	-.62	-.60	.53	-.48	-.46	.37
	p	.06	.00	.00	.00	.02	.01	.02	.03	.09
	n	5	23	22	23	14	22	23	22	22
		COD	Sp Cond	Alk	NCH	Day	SO4=	C Depth	Temp	Ca++
pH	r	.92	-.78	-.78	-.72	-.65	.52	.46	.45	-.37
	p	.00	.00	.00	.00	.00	.02	.03	.03	.10
	n	13	22	21	22	22	21	22	22	21
		COD	pH	NCH	Ex Alk	C Depth	T	SO4=	Sp Cond	H2O Depth
Alk	r	-.81	-.78	-.72	.67	-.58	-.56	-.53	.53	-.49
	p	.00	.00	.00	.00	.00	.01	.01	.01	.02
	n	14	21	22	22	22	22	22	22	22
		Day	Ca++ Mg++							
Alk	r	.40	.36							
	p	.07	.10							
	n	22	22							

Table E1 (Continued)

		COD	T	Alk	C Depth	H2O Depth	pH	Sp Cond	Ex Alk	Day
SO4=	r	.59	.55	-.53	.52	.52	.52	-.46	-.43	-.36
	p	.03	.01	.01	.01	.01	.02	.03	.04	.09
	n	14	22	22	23	22	21	22	23	23
		Mn++	Day	Sp Cond						
Tot Fe	r	.81	.69	.37						
	p	.05	.00	.09						
	n	6	23	22						
		pH	Alk	Ca++	Sp Cond	SO4=	C Depth	Tot Hard	H2O Depth	Day
COD	r	.92	-.81	-.61	-.60	.59	.51	-.50	.46	-.46
	p	.00	.00	.02	.02	.03	.07	.07	.09	.10
	n	13	14	14	14	14	14	14	14	14
		Ca++	Mg++	Ex Alk	COD					
Tot Hard	r	.86	.57	-.55	-.50					
	p	.00	.00	.01	.07					
	n	23	23	23	14					
		Tot Hard	COD	Ca++ Mg++	pH					
Ca++	r	.86	-.61	.38	-.37					
	p	.00	.02	.07	.10					
	n	23	14	23	21					

Table E1 (Continued)

		<u>Ca++</u> Mg++	Mn++	Tot Hard	Ex Alk	C Depth	H2O Depth		
Mg++	r	-.84	.74	.57	-.54	.44	.38		
	p	.00	.10	.00	.01	.03	.08		
	n	23	6	23	23	23	22		
		C Depth	Ex Alk	SO4-	Alk	COD	<u>Ca++</u> Mg++	Mg++	
H2O Depth	r	.84	-.54	.52	-.49	.46	-.43	.38	
	p	.00	.01	.01	.02	.09	.04	.08	
	n	23	22	22	22	14	22	22	
		Alk	SO4-	Sp Cond	pH	C Depth	HCH		
T	r	-.56	.55	-.48	.45	.40	.36		
	p	.01	.01	.02	.03	.06	.10		
	n	22	22	23	22	23	23		
		Sp Cond	C Depth	Tot Fe	Mg++				
Mn++	r	.87	.83	.81	.74				
	p	.06	.04	.05	.10				
	n	5	6	6	6				

Table E1 (Continued)

Ppt	r	C Depth							
	p	-.50							
	n	.02							
		22							
		pH	Alk	Sp Cond	Ex Alk	Day	T		
NCH	r	.72	-.72	-.62	-.40	-.38	.36		
	p	.00	.00	.00	.06	.08	.10		
	n	22	22	23	22	23	23		
		Alk	C Depth	Tot Hard	Mg++	H2O Depth	SO4=	Ca++ Mg++	HCH
Ex	r	.67	-.63	-.55	-.54	-.54	-.43	.41	-.40
Alk	p	.00	.00	.01	.01	.01	.04	.05	.06
	n	22	23	23	23	22	23	23	22
		Mg++	C Depth	H2O Depth	Ex Alk	Ca++	Alk		
Ca++	r	-.84	-.48	-.43	.41	.38	.36		
Mg++	p	.00	.02	.04	.05	.07	.10		
	n	23	23	22	23	23	22		

Table E1 (Continued)

Well E

		Ca++	Tot Fe	Sp Cond	pH	Tot Hard	Ca++ Mg++	NCH			
Day	r	-.65	.62	.61	-.49	-.49	-.46	-.38			
	p	.00	.00	.00	.02	.02	.03	.07			
	n	23	22	23	22	23	23	23			
		Day	T								
Sp Cond	r	.61	-.40								
	p	.00	.07								
	n	23	22								
		Tot Hard	SO4=	NCH	Ca++	COD	Mg++	H2O Depth	C Depth		
pH	r	.90	.87	.86	.74	.71	.62	.58	.57		
	p	.00	.00	.00	.00	.01	.00	.00	.01		
	n	21	21	22	21	13	21	22	22		
		Ex Alk	Day	T	Alk						
pH	r	-.53	-.49	.46	-.46						
	p	.01	.02	.03	.04						
	n	21	22	22	21						
		COD	Ex Alk	NCH	SO4=	H2O Depth	C Depth	pH	Mg++	Tot Hard	
Alk	r	-.81	.77	-.61	-.58	-.51	-.47	-.46	-.40	-.40	
	p	.00	.00	.00	.01	.02	.03	.04	.06	.07	
	n	14	22	22	22	22	22	21	22	22	

Table E1 (Continued)

		NCH	Tot Hard	pH	COD	H2O Depth	C Depth	Ca++	Mg++	Alk	Ex Alk
SO4=	r	.94	.88	.87	.80	.75	.74	.68	.68	-.58	-.54
	p	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01
	n	22	23	21	14	22	23	23	23	22	23
		Tot Fe	Mg++								
NO3-	r	-.65	-.46								
	p	.01	.06								
	n	16	17								
		Mn++	NO3-	Day	Ca++	Ca++ Mg++					
Tot	r	.86	-.65	.62	-.58	-.51					
Fe	p	.03	.01	.00	.01	.02					
	n	6	16	22	21	21					
		Alk	NCH	SO4=	pH	Tot Hard	Ex Alk	Mg++	C Depth	H2O Depth	Ca++
COD	r	-.81	.80	.80	.71	.68	-.63	.60	.58	.56	.46
	p	.00	.00	.00	.01	.01	.02	.02	.03	.04	.09
	n	14	14	14	13	14	14	14	14	14	14
		NCH	pH	SO4=	Ca++	COD	Mg++	H2O Depth	C Depth	Day	
Tot	r	.91	.90	.88	.87	.68	.60	.58	.51	-.49	
Hard	p	.00	.00	.00	.00	.01	.00	.00	.01	.02	
	n	22	21	23	23	14	23	22	23	23	

Table E1 (Continued)

		Ex Alk	Alk	T							
Tot	r	-.43	-.40	.40							
Hard	p	.04	.07	.07							
	n	23	22	21							
		Tot Hard	pH	NCH	SO4=	Day	Tot Fe	COD	Ca++ Mg++	H2O Depth	T
Ca++	r	.87	.74	.73	.68	-.65	-.58	.46	.46	.41	.41
	p	.00	.00	.00	.00	.00	.01	.09	.03	.06	.07
	n	23	21	22	23	23	21	14	23	22	21
		Ca++ Mg++	SO4=	NCH	pH	Tot Hard	COD	H2O Depth	C Depth	NO3-	Alk
Mg++	r	-.77	.68	.64	.62	.60	.60	.49	.47	-.46	-.40
Hard	p	.00	.00	.00	.00	.00	.02	.02	.02	.06	.06
	n	23	23	22	21	23	14	22	23	17	22
		C Depth	Mn++	SO4=	NCH	pH	Tot Hard	COD	Alk	Mg++	
H2O	r	.97	.89	.75	.58	.58	.58	.56	-.51	.49	
Depth	p	.00	.04	.00	.00	.00	.00	.04	.02	.02	
	n	23	5	22	23	22	22	14	22	22	

Table E1 (Continued)

		Ex Alk	Ca++	Ppt	
H2O	r	-.48	.41	-.40	
	p	.03	.06	.08	
	n	22	22	21	
		pH	Ca++	Tot Hard	Sp Cond
T	r	.46	.40	.40	-.40
	p	.03	.07	.07	.07
	n	22	21	21	22
		H2O Depth	C Depth	Tot Fe	
Mn++	r	.89	.88	.86	
	p	.04	.02	.03	
	n	5	6	6	
		C Depth	H2O Depth		
Ppt	r	-.45	-.39		
	p	.03	.08		
	n	22	21		

Table E1 (Continued)

		SO4=	Tot Hard	pH	COD	Ca++	Mg++	Alk	H2O Depth	C Depth
NCH	r	.94	.91	.86	.80	.73	.64	-.61	.58	.58
	p	.00	.00	.00	.00	.00	.00	.00	.00	.00
	n	22	22	22	14	22	22	22	23	23
		Ex Alk	Day							
NCH	r	-.46	-.38							
	p	.03	.07							
	n	22	23							
		Alk	COD	SO4=	pH	C Depth	H2O Depth	NCH	Tot Hard	
Ex	r	.77	-.63	-.54	-.53	-.50	-.48	-.46	-.43	
Alk	p	.00	.02	.01	.01	.02	.03	.03	.04	
	n	22	14	23	21	23	22	22	23	
		Mg++	Tot Fe	Ca++	Day					
Ca++	r	-.77	-.51	.46	-.46					
Mg++	p	.00	.02	.03	.03					
	n	23	21	23	23					

Table E1 (Continued)

Well G

		Sp Cond	pH	Alk	Ex Alk	Tot Fe					
Day	r	.74	-.62	-.60	-.45	.43					
	p	.00	.00	.00	.04	.04					
	n	22	21	21	22	22					
		Day									
Sp Cond	r	.74									
	p	.00									
	n	22									
		COD	Day	C Depth	Alk	H2O Depth	Ex Alk	T	SO4=	Tot Hard	Ca++
pH	r	.69	-.62	.61	.55	.52	.51	.47	.46	.40	.39
	p	.01	.00	.00	.01	.02	.02	.03	.04	.08	.08
	n	12	21	21	20	21	20	21	20	20	20
		Mg++	Ca++	Tot Hard	Ca++ Mg++						
Cl-	r	.56	-.43	.40	-.40						
	p	.01	.05	.07	.07						
	n	21	21	21	21						
		Ex Alk	Day	NCH	pH	Tot Fe	Ca++				
Alk	r	.77	-.60	-.57	.55	-.52	.39				
	p	.00	.00	.00	.01	.02	.08				
	n	21	21	21	20	20	21				

Table E1 (Continued)

		NO3-	pH	Ca++	Ppt				
SO4=	r	.57	.46	.42	-.41				
	p	.02	.04	.05	.07				
	n	16	20	22	20				
		Tot Hard	SO4=	Mg++					
NO3-	r	.59	.57	.51					
	p	.02	.02	.04					
	n	16	16	16					
		H2O Depth	COD	Alk	Ex Alk	Day			
Tot	r	.57	.55	-.52	-.43	.43			
Fe	p	.01	.06	.02	.05	.04			
	n	21	12	20	21	22			
		H2O Depth	C Depth	pH	NCH	Tot Fe	Tot Hard		
COD	r	.95	.94	.69	.57	.55	.49		
	p	.00	.00	.01	.04	.06	.09		
	n	13	13	12	13	12	13		
		Mg++	NO3-	NCH	Ca++ Mg++	COD	Cl-	pH	H2O Depth
Tot	r	.83	.59	.54	-.50	.49	.40	.40	.39
Hard	p	.00	.02	.01	.02	.09	.07	.08	.08
	n	22	16	21	22	13	21	20	21

Table E1 (Continued)

		Ca++ Mg++	Ex Alk	C Depth	Mg++	Cl-	SO4=	pH	Alk
Ca++	r	.69	.54	.51	-.47	-.43	.42	.39	.39
	p	.00	.01	.01	.03	.05	.05	.08	.08
	n	22	22	22	22	21	22	20	21
		Tot Hard	Ca++ Mg++	Cl-	NO3-	NCH	Ca++	Ex Alk	
Mg++	r	.83	-.80	.56	.51	.50	-.47	-.40	
	p	.00	.00	.00	.04	.02	.03	.07	
	n	22	22	21	16	21	22	22	
		COD	C Depth	Fe Tot	pH	Tot Hard	NCH		
H2O Depth	r	.95	.89	.57	.52	.39	.39		
	p	.00	.00	.01	.02	.08	.07		
	n	13	23	21	21	21	23		
		pH	Ex Alk						
T	r	.47	.38						
	p	.03	.10						
	n	21	20						
		Ppt	C Depth						
Mn++	r	-.88	.76						
	p	.02	.08						
	n	6	6						

Table E1 (Continued)

		Mn++	NCH	SO4=						
Ppt	r	-.88	-.42	-.41						
	p	.02	.06	.07						
	n	6	21	20						
		Ex			Tot		Ca++		H2O	
		Alk	Alk	COD	Hard	Mg++	Mg++	Ppt	Depth	
NCH	r	-.59	-.57	.57	.54	.50	-.48	-.42	.39	
	p	.00	.01	.04	.01	.02	.03	.06	.07	
	n	21	21	13	21	21	21	21	23	
		Alk	Ca++		Ca			Tot		
			Mg++	NCH	Hard	pH	Day	Fe	Mg++	T
Ex Alk	r	.77	.77	-.59	.54	.51	-.45	-.43	-.40	.38
	p	.00	.00	.00	.01	.02	.04	.05	.07	.10
	n	21	22	21	22	20	22	21	22	20
		Mg++	Ex		Tot					
			Alk	Ca++	Hard	NCH	Cl-			
Ca++ Mg++	r	-.80	.77	.69	-.50	-.48	-.40			
	p	.00	.00	.00	.02	.03	.07			
	n	22	22	22	22	21	21			

Table E1 (Continued)

Well K

		H2O Depth	Sp Cond	C Depth	NO3-	Mg++	Tot Hard	pH	NCH	Tot Fe
Day	r	.88	.81	.57	.55	.53	.53	-.50	.49	.47
	p	.00	.00	.01	.08	.03	.03	.06	.03	.07
	n	21	14	19	11	16	16	15	21	16
		Day	pH	Tot Hard	H2O Depth	Mg++	Ca++ Mg++	Ca++		
Sp Cond	r	.81	-.71	.69	.64	.64	-.59	.50		
	p	.00	.01	.01	.01	.02	.03	.08		
	n	14	13	13	14	13	13	13		
		SO4=	Alk	Sp Cond	Tot Hard	Ca++	NCH	H2O Depth	Day	
pH	r	-.85	.76	-.71	-.67	-.66	-.66	-.63	-.50	
	p	.00	.00	.01	.01	.01	.01	.01	.06	
	n	13	13	13	13	13	15	15	15	
		Ca++	Ppt	Tot Hard	C Depth					
Cl-	r	-.69	.66	-.59	-.48					
	p	.00	.01	.02	.10					
	n	15	14	15	13					
		NCH	SO4=	pH	H2O Depth					
Alk	r	-.88	-.77	.76	-.49					
	p	.00	.00	.00	.06					
	n	15	15	13	4					

Table E1 (Continued)

		pH	NCH	Alk	Ca++	Tot Hard
SO4=	r	-.85	.81	-.77	.74	.68
	p	.00	.00	.00	.00	.00
	n	13	16	15	16	16
		Day				
NO3-	r	.55				
	p	.08				
	n	11				
		H2O Depth	Day			
Tot	r	.53	.47			
Fe	p	.04	.07			
	n	15	16			
		Ca++ Mg++	Ppt			
COD	r	-.88	.79			
	p	.05	.06			
	n	5	6			

Table E1 (Continued)

		Ca++	Mg++	NCH	Sp Cond	SO4=	pH	H2O Depth	Cl-	Day	
Tot Hard	r	.89	.80	.79	.69	.67	-.67	.65	-.59	.53	
	p	.00	.00	.00	.01	.00	.01	.01	.02	.03	
	n	16	16	15	13	16	13	15	15	16	
		Tot Hard	SO4=	NCH	Cl-	pH	H2O Depth	Sp Cond	Mg++		
Ca++	r	.89	.74	.71	-.69	-.66	.54	.50	.44		
	p	.00	.00	.00	.00	.01	.04	.08	.09		
	n	16	16	15	15	13	15	13	16		
		Tot Hard	Ca++ Mg++	Sp Cond	NCH	H2O Depth	Day	Ca++			
Mg++	r	.80	-.78	.54	.62	.58	.53	.44			
	p	.00	.00	.02	.01	.02	.03	.09			
	n	16	16	13	15	15	16	16			
		Day	Tot Hard	C Depth	Sp Cond	pH	Mg++	NCH	Ca++	Tot Fe	Alk
H2O Depth	r	.88	.55	.64	.64	-.63	.58	.56	.54	.53	-.49
	p	.00	.01	.00	.01	.01	.02	.01	.04	.04	.06
	n	21	15	18	14	15	15	21	15	15	15

Table E1 (Continued)

T	r p n	Ppt							
		.44							
		.08							
Mn++	r p n	17							
		C							
		Depth							
Ppt	r p n	.83							
		.08							
		5							
Ppt	r p n	COD	Cl-	T					
		.79	.66	.44					
		.06	.01	.08					
NCH	r p n	6	14	17					
		Alk	SO4=	Tot Hard	Ca++	pH	Mg++	H2O Depth	Day
		-.88	.81	.79	.71	-.66	.62	.56	.49
Ca++ Mg++	r p n	.00	.00	.00	.00	.01	.01	.01	.03
		15	16	15	15	15	15	21	21
		COD	Mg++	Sp Cond					
Ca++ Mg++	r p n	-.88	-.78	-.59					
		.05	.00	.03					
		5	16	13					

Table E1 (Continued)

ICP Dug well

		NO3-	T	Ca++	pH	Tot Hard	Cl-		
Day	r	-.85	.77	.73	-.65	.63	-.60		
	p	.01	.07	.02	.06	.05	.09		
	n	8	6	10	9	10	9		
		Ca++	Alk						
Sp Cond	r	.67	.58						
	p	.05	.10						
	n	9	9						
		Alk	Day						
pH	r	-.76	-.65						
	p	.03	.06						
	n	8	9						
		Mn++	NO3-	Tot Hard	Mg++	Ca++	NCH	Day	
Cl-	r	1.0	.82	-.76	-.75	.66	-.64	-.60	
	p	.00	.02	.02	.02	.06	.06	.10	
	n	4	7	9	9	9	9	9	
		pH	NCH	Sp Cond					
Alk	r	-.76	-.63	.58					
	p	.03	.07	.10					
	n	8	9	9					

Table E1 (Continued)

		NCH							
SO4=	r	-	.81						
	p		.00						
	n		10						
		Day	Cl-	Ca++	Tot Hard				
NO3-	r	-	.85	.82	-.76	-.67			
	p		.01	.02	.05	.09			
	n		8	7	7	7			
		NCH							
Tot Fe	r	-	.66						
	p		.07						
	n		8						
		Mn++	Mg++	NCH	Ca++	Cl-	NO3-	Day	
Tot Hard	r	-	.83	.80	.78	.76	-.76	-.68	.63
	p		.08	.01	.01	.01	.02	.09	.05
	n		5	10	9	10	9	7	10
		NO3-	Tot Hard	Day	Sp Cond				
Ca++	r	-	.76	.76	.73	.67			
	p		.05	.01	.02	.05			
	n		7	10	10	9			
		Ca++ Mg++	Mn++	Tot Hard	NCH	Cl-			
Mg++	r	-	.90	-.85	.80	.79	-.75		
	p		.00	.07	.01	.01	.02		
	n		10	5	10	9	9		

Table E1 (Continued)

		C Depth																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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Table E1 (Continued)

Well M		C Depth	H2O Depth	Sp Cond	Tot Hard	Tot Fe	NO3-	pH	Alk	Ca++	Mg++
Day	r	.73	.70	.65	.61	.60	-.57	-.47	.43	.43	.41
	p	.00	.00	.00	.00	.00	.02	.03	.05	.04	.05
	n	24	23	23	23	22	17	22	22	23	23
		Tot Hard	Ca++	Day	Alk	C Depth	H2O Depth				
Sp Cond	r	.76	.70	.65	.64	.63	.63				
	p	.00	.00	.00	.00	.00	.00				
	n	22	22	23	22	23	23				
		COD	T	Alk	Day	Tot Hard					
pH	r	.90	.60	-.50	-.47	-.41					
	p	.00	.00	.02	.03	.06					
	n	13	22	21	22	21					
		SO4=	T	Ca++	Alk						
Cl-	r	-.40	.40	-.39	-.36						
	p	.06	.07	.07	.10						
	n	22	21	22	22						
		Tot Hard	Ca++	Sp Cond	Ppt	COD	pH	C Depth	H2O Depth	Day	T
Alk	r	.81	.79	.64	-.62	-.52	-.50	.50	.49	.43	-.41
	p	.00	.00	.00	.00	.06	.02	.02	.02	.05	.07
	n	22	22	22	20	14	21	22	22	22	21
		SO4=	Cl-								
Alk	r	.38	-.36								
	p	.09	.10								
	n	22	22								

Table E1 (Continued)

		Ppt	Ca++	Ca++ Mg++	H2O Depth	C Depth	Cl-	Alk	Mg++
SO4=	r	-.61	.57	.55	.45	.44	-.40	.38	-.36
	p	.00	.00	.01	.03	.03	.06	.09	.09
	n	21	23	23	22	23	22	22	23
		Day	NCH						
NO3-	r	-.57	-.51						
	p	.02	.04						
	n	17	17						
		Day	NCH	C Depth					
Tot	r	.60	-.42	.39					
Fe	p	.00	.06	.07					
	n	22	21	22					
		pH	Alk						
COD	r	.90	-.52						
	p	.00	.06						
	n	13	14						
		Ca++	Alk	Sp Cond	H2O Depth	C Depth	Day	NCH	
Tot	r	.83	.81	.76	.75	.74	.61	.51	
Hard	p	.00	.00	.00	.00	.00	.00	.02	
	n	23	22	22	22	23	23	22	
		Ppt	Mg++	T	pH				
Tot	r	-.51	.47	-.42	-.41				
Hard	p	.02	.02	.06	.06				
	n	21	23	21	21				

Table E1 (Continued)

		Tot Hard	Alk	C Depth	H2O Depth	Sp Cond	SO4=	Ppt	Ca++ Mg++	
Ca++	r	.83	.79	.73	.73	.70	.57	-.56	.55	
	p	.00	.00	.00	.00	.00	.00	.01	.01	
	n	23	22	23	22	22	23	21	23	
		Day	T	Cl-						
Ca++	r	.43	-.41	-.39						
	p	.04	.06	.07						
	n	23	21	22						
		Ca++ Mg++	NCH	Tot Hard	Day	SO4=				
Mg++	r	-.76	.53	.47	.41	-.36				
	p	.00	.01	.02	.05	.09				
	n	23	22	23	23	23				
		C Depth	Mn++	Tot Hard	Ca++	Day	Sp Cond	Alk	Ppt	SO4-
H2O	r	1.00	-.84	.75	.73	.70	.63	.49	-.48	.45
Depth	p	.00	.07	.00	.00	.00	.00	.02	.03	.03
	n	23	5	22	22	23	23	22	21	22
		Mn++	pH	Tot Hard	Ca++	Alk	Cl-	Ppt		
T	r	.85	.60	-.42	-.41	-.41	.40	.39		
	p	.07	.00	.06	.06	.07	.07	.09		
	n	5	22	21	21	21	21	20		

Table E1 (Continued)

		T	H2O Depth					
Mn++	r	.85	-.84					
	p	.07	.07					
	n	5	5					
		Alk	SO4=	Ca++	Tot Hard	C Depth	H2O Depth	T
Ppt	r	-.62	-.61	.56	-.51	-.50	-.48	.39
	p	.00	.00	.00	.02	.02	.03	.09
	n	20	21	21	21	22	21	20
		Mg++	NO3-	Tot Hard	Tot Fe			
NCH	r	.53	-.51	.51	-.42			
	p	.01	.04	.02	.06			
	n	22	17	22	21			
		Mg++	Ca++	SO4=				
Ca++	r	-.76	.55	.55				
Mg++	p	.00	.01	.01				
	n	23	23	23				

Table E1 (Continued)

Well Q		Ca++	Sp Cond	SO4=	Tot Hard	Alk	Mg++	C Depth	Ca++ Mg++	H2O Depth
Day	r	.91	.90	.88	.88	.80	.63	.61	.51	.48
	p	.00	.00	.00	.00	.00	.01	.02	.06	.08
	n	14	14	14	14	13	14	15	14	14
		SO4=	Mn++	Ca++	Tot Hard	Day	Mg++	Alk	NCH	C Depth
Sp Cond	r	.97	.96	.96	.93	.90	.68	.57	.55	.50
	p	.00	.04	.00	.00	.00	.01	.04	.04	.07
	n	13	4	13	13	14	13	13	14	14
		Alk	Tot Fe	Cl-						
pH	r	.72	-.62	.52						
	p	.01	.02	.08						
	n	12	13	12						
		NCH	Mg++	pH	NO3-					
Cl-	r	-.65	-.55	.52	-.50					
	p	.02	.05	.08	.08					
	n	13	13	12	13					
		Day	C Depth	pH	Ppt	H2O Depth	Ca++	Tot Hard	SO4=	Sp Cond
Alk	r	.80	.77	.72	-.69	.67	.63	.60	.57	.57
	p	.00	.00	.01	.01	.01	.02	.03	.04	.04
	n	13	13	12	13	13	13	13	13	13

Table E1 (Continued)

		Ca++ Mg++	Tot Fe							
Alk	r	.54	-.51							
	p	.06	.09							
	n	13	12							
		Sp Cond	Ca++	Tot Hard	Day	NCH	Mg++	Alk	C Depth	Ppt
SO4=	r	.97	.93	.92	.88	.81	.71	.57	.56	-.46
	p	.00	.00	.00	.00	.00	.00	.04	.04	.10
	n	13	14	14	14	13	14	13	14	14
		Mn++	Tot Fe	Cl-						
NO3-	r	.96	.59	-.50						
	p	.04	.05	.08						
	n	4	12	13						
		pH	NO3-	Alk	Ca++ Mg++					
Tot	r	-.62	.59	-.51	-.51					
Fe	p	.02	.05	.09	.08					
	n	13	12	12	13					
		H2O Depth								
COD	r	.88								
	p	.02								
	n	6								

Table E1 (Continued)

		Ca++	Sp Cond	SO4=	Day	Mn++	Mg++	NCH	Alk	C Depth	Ppt
Tot Hard	r	.98	.93	.92	.88	.87	.86	.85	.60	.59	-.55
	p	.00	.00	.00	.00	.06	.00	.00	.03	.03	.04
	n	14	13	14	14	5	14	13	13	14	14
		Tot Hard	Sp Cond	SO4=	Day	Mn++	NCH	Mg++	Alk	C Depth	Ppt
Ca++	r	.98	.96	.93	.91	.88	.81	.74	.63	.58	-.56
	p	.00	.00	.00	.00	.05	.00	.00	.02	.03	.03
	n	14	13	14	14	5	13	14	13	14	14
		Tot Hard	NCH	Ca++	SO4=	Sp Cond	Day	Cl-	C Depth		
Mg++	r	.86	.81	.74	.71	.68	.63	-.55	.50		
	p	.00	.00	.00	.00	.01	.01	.05	.07		
	n	14	13	14	14	13	14	13	14		
		COD	C Depth	Alk	T	Ca++ Mg++	Ppt	Day			
H2O Depth	r	.88	.77	.67	-.53	.52	-.49	.48			
	p	.02	.00	.01	.08	.07	.08	.08			
	n	6	14	13	12	13	14	14			
		H2O Depth									
T	r	-.52									
	p	.08									
	n	12									

Table E1 (Continued)

		NO3-	Sp Cond	Ca++	Tot Hard		
Mn++	r	.96	.96	.88	.87		
	p	.04	.04	.05	.06		
	n	4	4	5	5		
		Alk	C Depth	Ca++	Tot Hard	H2O Depth	SO4=
Ppt	r	-.68	-.64	-.56	-.55	-.49	-.46
	p	.01	.01	.04	.04	.08	.10
	n	13	15	14	14	14	14
		Tot Hard	SO4=	Mg++	Ca++	Cl-	Sp Cond
NCH	r	.85	.81	.81	.81	-.65	.55
	p	.00	.00	.00	.00	.02	.04
	n	13	13	13	13	13	14
		HCO3-	Alk	H2O Depth	Day	Tot Fe	
Ca++ Mg++	r	.54	.54	.53	.51	-.51	
	p	.06	.06	.07	.06	.08	
	n	13	13	13	14	13	

Table E1 (Continued)

Well T										
		COD	H2O Depth	C Depth	Tot Fe	Sp Cond	Alk			
Day	r	-.89	.78	.78	.77	.70	.54			
	p	.05	.00	.00	.00	.01	.07			
	n	5	14	15	13	13	12			
		COD	Day	Tot Fe	C Depth	H2O Depth	SO4=	Alk	T	Ex Alk
Sp Cond	r	-.88	.70	.69	.64	.64	-.62	.60	-.57	.51
	p	.05	.01	.01	.02	.02	.03	.04	.04	.09
	n	5	13	12	13	13	12	12	13	12
pH		Cl-								
	r	-.54								
	p	.07								
	n	12								
Cl-		Mg++	Tot Fe	pH						
	r	.57	-.55	-.54						
	p	.05	.08	.07						
	n	12	11	12						
Alk		COD	SO4=	Ca++	Sp Cond	Day	Ex Alk			
	r	-.92	-.87	.69	.60	.54	.53			
	p	.03	.00	.01	.04	.07	.07			
	n	5	12	12	12	12	12			

Table E1 (Continued)

		COD	Alk	Sp Cond	T	NCH	
SO4=	r	1.00	-.87	-.62	.61	.52	
	p	.00	.00	.03	.04	.08	
	n	5	12	12	12	12	
		<u>Ca++</u> Mg++	Mg++				
NO3-	r	.75	-.70				
	p	.05	.08				
	n	7	7				
		Day	Sp Cond	H2O Depth	C Depth	Cl-	
Tot	r	.77	.69	.55	.55	-.55	
Fe	p	.00	.01	.05	.05	.08	
	n	13	12	13	13	11	
		SO4=	Alk	Day	Sp Cond	Ca++	T
COD	r	1.00	-.92	-.89	-.88	-.84	.81
	p	.00	.03	.05	.05	.07	.10
	n	5	5	5	5	5	5
		Mg++	<u>Ca++</u> Mg++	NCH	Ca++		
Tot	r	.95	-.71	.58	.53		
Hard	p	.00	.01	.05	.06		
	n	13	13	12	13		

Table E1 (Continued)

		COD	Alk	Tot Hard		
Ca++	r	-.84	.69	.53		
	p	.07	.01	.06		
	n	5	12	13		
		Tot Hard	Ca++ Mg++	NO3-	NCH	Cl-
Mg++	r	.95	-.86	-.70	.70	.57
	p	.00	.00	.08	.01	.05
	n	13	13	7	12	12
		C Depth	Day	Sp Cond	Tot Fe	Ex Alk
H2O Depth	r	1.00	.78	.64	.55	.54
	p	.00	.00	.02	.05	.05
	n	14	14	13	13	13
		COD	SO4=	Sp Cond		
T	r	.81	.61	-.57		
	p	.10	.04	.04		
	n	5	12	13		

Table E1 (Continued)

		<u>Ca++</u> Mg++	Mg++	Ex Alk	Tot Hard	SO4=		
NCH	r	-.71	.70	-.64	.58	.52		
	p	.01	.01	.03	.05	.08		
	n	12	12	12	12	12		
		NCH	<u>Ca++</u> Mg++	H2O Depth	C Depth	Alk	Sp Cond	
Ex Alk	r	-.64	.55	.54	.54	.53	.51	
	p	.03	.05	.05	.05	.07	.09	
	n	12	13	13	13	12	12	
		Mg++	NO3-	Tot Hard	NCH	Ex Alk		
<u>Ca++</u> Mg++	r	-.86	.75	-.71	-.71	.55		
	p	.00	.05	.01	.01	.05		
	n	13	7	13	12	13		

Table E1 (Continued)

Well S2

		H2O Depth	SO4=	Tot Fe	C Depth	Ca++
Day	r	.94	-.94	-.93	.91	-.91
	p	.01	.02	.02	.01	.03
	n	6	5	5	6	5

		T	C Depth
pH	r	.98	.91
	p	.02	.03
	n	4	5

		Ex Alk
Cl-	r	-.92
	p	.08
	n	4

		Ca++	Tot Fe	Day	C Depth
SO4=	r	.98	.97	-.94	-.88
	p	.00	.03	.02	.05
	n	5	4	5	5

		Ex Alk
NO3-	r	.95
	p	.05
	n	4

Table E1 (Continued)

		Ca++	SO4=	C Depth	Day	H2O Depth
Tot	r	.98	.97	-.94	-.93	-.90
Fe	p	.02	.03	.02	.02	.04
	n	4	4	5	5	5

		T	Mg++	<u>Ca++</u> <u>Mg++</u>
Tot	r	1.00	.92	-.86
Hard	p	.00	.03	.06
	n	3	5	5

		Tot Fe	SO4=	Day	C Depth
Ca++	r	.98	.98	-.91	-.84
	p	.02	.00	.03	.07
	n	4	5	5	5

		T	<u>Ca++</u> <u>Mg++</u>	Tot Hard
Mg++	r	.99	-.93	.92
	p	.07	.00	.03
	n	3	5	5

		C Depth	Day	Tot Fe	pH
H2O	r	.98	.94	-.90	.83
Depth	p	.00	.01	.04	.08
	n	6	6	5	5

Table E1 (Continued)

		Tot Hard	Mn++	Mg++	pH	C Depth
T	r	1.00	1.00	.99	.98	.94
	p	.00	.00	.07	.02	.06
	n	3	3	3	4	4
		T				
Mn++	r	1.00				
	p	.00				
	n	3				
		Ex Alk				
NCH	r	-.91				
	p	.09				
	n	4				
		NO3-	Cl-	NCH		
Ex	r	.95	-.92	-.91		
Alk	p	.05	.08	.09		
	n	4	4	4		
		Mg++	Tot Hard			
Ca++	r	-.98	-.86			
Mg++	p	.00	.06			
	n	5	5			

Table El (Continued)

Well 1a

		COD	NO3-	pH	C Depth	H2O Depth
Day	r	.98	.87	-.81	.60	.58
	p	.02	.00	.00	.03	.05
	n	4	11	12	13	12
		Cl-	Mg++	<u>Ca++</u> Mg++	C Depth	H2O Depth
Sp Cond	r	-.72	-.63	.55	.50	.50
	p	.01	.04	.08	.10	.10
	n	11	11	11	12	12
		Mn++	COD	Day	Alk	NO3-
pH	r	1.00	-.99	-.81	.78	-.64
	p	.00	.02	.00	.00	.03
	n	4	4	12	11	11
		Sp Cond	Ppt			
Cl-	r	-.72	.56			
	p	.01	.07			
	n	11	11			
		COD	pH	Tot Fe		
Alk	r	-.94	.78	.69		
	p	.06	.00	.03		
	n	4	11	10		

Table E1 (Continued)

SO4=	r p n	Ppt		
NO3-	r p n	Day	Ppt	pH
Tot Fe	r p n	Alk	C Depth	H2O ² Depth
COD	r p n	pH	Day	Alk

Table E1. (Continued)

		NCH	Mg++	<u>Ca++</u> <u>Mg++</u>	Ca++	Ex Alk
Tot	r	.89	.89	-.73	.68	-.65
Hard	p	.00	.00	.01	.01	.02
	n	11	12	12	12	12
		Ex Alk	Tot Hard			
Ca++	r	-.72	.68			
	p	.01	.01			
	n	12	12			
		NCH	<u>Ca++</u> <u>Mg++</u>	Tot Hard	Sp Cond	
Mg++	r	.95	-.89	.89	-.63	
	p	.00	.00	.00	.04	
	n	11	12	12	11	
		C Depth	Day	Tot Fe	Sp Cond	
H2O	r	1.00	.58	-.55	.50	
Depth	p	.00	.05	.08	.10	
	n	12	12	11	12	

Table E1 (Continued)

		pH	<u>Ca++</u> Mg++				
Mn++	r	1.00	.90				
	p	.00	.04				
	n	4	5				
		NO3-	Cl-	SO4=			
Ppt	r	-.67	.56	-.54			
	p	.02	.07	.07			
	n	11	11	12			
		Mg++	<u>Ca++</u> Mg++	Tot Hard	Ex Alk		
NCH	r	.95	-.93	.89	-.55		
	p	.00	.00	.00	.08		
	n	11	11	11	11		
		Ca++	Tot Hard	NCH	<u>Ca++</u> Mg++		
Ex Alk	r	-.72	-.65	-.55	.53		
	p	.01	.02	.08	.08		
	n	12	12	11	12		
		NCH	Mn++	Mg++	Tot Hard	Sp Cond	Ex Alk
<u>Ca++</u> <u>Mg++</u>	r	-.93	.90	-.89	-.73	.55	.53
	p	.00	.04	.00	.01	.08	.08
	n	11	5	12	12	11	12

Table E1 (Continued)

Well 1b

		SO4=	Alk	Mn++
Day	r	-.94	.92	.85
	p	.02	.08	.07
	n	5	4	5

		pH
Sp Cond	r	.92
	p	.08
	n	4

		NCH	NO3-	SO4-	Cl-	Mg++	Tot Hard	Alk	Sp Cond
pH	r	-1.00	-1.00	-1.00	-1.00	1.00	.99	.99	.92
	p	.00	.00	.02	.05	.05	.08	.10	.08
	n	4	3	3	3	3	3	3	4

		pH	NO3-
Cl-	r	-1.00	1.00
	p	.05	.00
	n	3	4

		Tot Hard	Ex Alk	pH	H2O Depth	Mg++	Mn++	SO4-	Ca++ Mg++
Alk	r	1.00	1.00	.99	-.98	.98	.98	-.97	-.95
	p	.00	.00	.10	.02	.02	.02	.03	.05
	n	4	4	3	4	4	4	4	4

		Day	NCH	Ca++
Alk	r	.92	-.92	.91
	p	.08	.08	.09
	n	4	4	4

Table E1 (Continued)

				H2O				
		pH	Alk	Day	Depth			
SO4-	r	-1.00	-.97	-.94	.90			
	p	.02	.03	.02	.04			
	n	3	4	5	5			
		pH	Cl-					
NO3-	r	-1.00	1.00					
	p	.00	.00					
	n	3	4					
		Alk	pH	Ex Alk	Mg++	Ca++	NCH	Ca++ Mg++
Tot Hard	r	1.00	.99	.97	.96	.90	-.90	-.84
	p	.00	.08	.01	.01	.03	.10	.08
	n	4	3	5	5	5	4	5
		Alk	Tot Hard	Ex Alk				
Ca++	r	.91	.90	.81				
	p	.09	.03	.10				
	n	4	5	5				
		pH	Alk	Ex Alk	Tot Hard	Ca++ Mg++	NCH	Mn++
Mg++	r	1.00	.98	.98	.96	-.95	-.90	.86
	p	.05	.02	.00	.01	.01	.10	.06
	n	3	4	5	5	5	4	5

Table E1 (Continued)

		Alk	SO4=	NCH				
H2O	r	-.98	.90	.81				
Depth	p	.02	.04	.10				
	n	4	5	5				
		Alk	Ex Alk	Ca++ Mg++	Mg++	Day		
Mn++	r	.98	.92	-.86	.86	.85		
	p	.02	.03	.06	.06	.07		
	n	4	5	5	5	5		
		pH	Alk	Mg++	Tot Hard			
NCH	r	-1.00	-.92	-.90	-.90			
	p	.00	.08	.10	.10			
	n	4	4	4	4			
		Alk	Mg++	Tot Hard	Mn++	Ca++ Mg++	Ca++	
Ex	r	1.00	.98	.97	.92	-.91	.81	
Alk	p	.00	.00	.01	.03	.03	.10	
	n	4	5	5	5	5	5	
		SO4= HCO3-	HCO3-	Mg++	Alk	Ex Alk	Mn++	Tot Hard
Ca++	r	.97	-.95	-.95	-.95	-.91	-.86	-.84
Mg++	p	.03	.05	.01	.05	.03	.06	.08
	n	4	4	5	4	5	5	5

Table E1 (Continued)

<u>Well 1c</u>			H2O	C		
		T	Depth	Depth	Mg++	NCH
Day	r	1.00	.95	.89	-.87	-.85
	p	.00	.00	.02	.06	.07
	n	4	6	6	5	5
		NO3-	Tot Hard	Cl-		
Sp Cond	r	-.97	.91	.91		
	p	.03	.09	.09		
	n	4	4	4		
		Mg++				
pH	r	-.95				
	p	.05				
	n	4				
		Tot Hard	NCH	SO4=	Ca++	NO3- Sp Cond
Cl-	r	1.00	1.00	.98	.97	-.96 .91
	p	.00	.00	.02	.03	.04 .09
	n	4	4	4	4	4 4
		NCH	Cl-	Tot Hard	Ca++	Mg++
SO4=	r	.99	.98	.94	.91	.84
	p	.01	.02	.02	.03	.07
	n	4	4	5	5	5

Table E1 (Continued)

		Sp Cond	Tot Hard	Cl-	NCH	Ca++		
NO3-	r	-.97	-.97	-.96	-.94	-.94		
	p	.03	.03	.04	.06	.06		
	n	4	4	4	4	4		
		<u>Ca++</u> <u>Mg++</u>						
Tot	r	-.83						
Fe	p	.08						
	n	5						
		Cl-	NCH	Ca++	NO3-	SO4=	Sp Cond	Mg++
Tot	r	1.00	.99	.98	-.97	.94	.91	.87
Hard	p	.00	.01	.00	.03	.02	.09	.06
	n	4	4	5	4	5	4	5
		Tot Hard	Cl-	NCH	NO3-	SO4=		
Ca++	r	.98	.97	.95	-.94	.91		
	p	.00	.03	.05	.06	.03		
	n	5	4	4	4	5		
		pH	Day	Tot Hard	SO4=			
Mg++	r	-.95	-.87	.87	.84			
	p	.05	.06	.06	.07			
	n	4	5	5	5			

Table E1 (Continued)

		C Depth	Day	T				
H2O	r	.98	.95	.95				
Depth	p	.00	.00	.05				
	n	6	6	4				
		Day	H2O Depth	NCH				
T	r	1.00	.95	-.92				
	p	.00	.05	.08				
	n	4	4	4				
		Cl-	Tot Hard	SO4= HCO3-	Ca++	NO3-	T	Day
NCH	r	1.00	.99	.99	.95	-.94	-.92	-.85
	p	.00	.01	.01	.05	.06	.08	.07
	n	4	4	4	4	4	4	5
		Tot Fe						
Ca++	r	-.83						
Mg++	p	.08						
	n	5						

Table E1 (Continued)

Well 1d

		Alk	Sp Cond	C Depth	H2O Depth
Day	r	.93	.91	.86	.86
	p	.07	.03	.03	.03
	n	4	5	6	6

		Day	NCH	H2O Depth	C Depth
Sp Cond	r	.91	-.82	.82	.82
	p	.03	.09	.09	.09
	n	5	5	5	5

		NO3-
pH	r	-.98
	p	.02
	n	4

		Mn++	NCH
Cl-	r	.98	.94
	p	.02	.06
	n	4	4

Table El (Continued)

		Day				
Alk	r	.93				
	p	.07				
	n	4				
		NCH	Ca++	Tot Hard	Mn++	
SO4=	r	.98	.92	.89	.85	
	p	.02	.03	.04	.07	
	n	4	5	5	5	
		pH				
NO3-	r	-.98				
	p	.02				
	n	4				
		Ca++	Mg++	NCH	SO4=	
Tot Hard	r	.99	.97	.93	.89	
	p	.00	.01	.07	.04	
	n	5	5	4	5	
		Tot Hard	NCH	Mg++	SO4=	
Ca++	r	.99	.93	.93	.92	
	p	.00	.07	.02	.03	
	n	5	4	5	5	

Table E1 (Continued)

Mg++	r	Tot Hard	Ca++			
	p	.97	.93			
	n	.01	.02			
		5	5			
H2O Depth	r	C Depth	T	Day	Sp Cond	
	p	1.00	.99	.86	.82	
	n	.00	.01	.03	.04	
		6	4	6	5	
T	r	H2O Depth	C Depth			
	p	.99	.99			
	n	.01	.01			
		4	4			
Mn++	r	Cl-	SO4=			
	p	.98	.85			
	n	.02	.07			
		4	5			
NCH	r	SO4=	Cl-	Ca++	Tot Hard	Sp Cond
	p	.98	.94	.93	.93	-.82
	n	.02	.06	.07	.07	.09
		4	4	4	4	5

Table E1 (Continued)

Well 2a

		Cl-	Sp Cond	C Depth	H2O Depth	pH			
Day	r	-.81	.80	.64	.62	-.56			
	p	.00	.00	.02	.03	.06			
	n	11	12	13	12	12			
		Day	SO4=						
Sp Cond	r	.80	.70						
	p	.00	.02						
	n	12	11						
		Tot Fe	Cl-	C Depth	Ppt	Day			
pH	r	.81	.61	-.61	.57	-.56			
	p	.00	.04	.04	.05	.06			
	n	11	11	12	12	12			
		Day	Ppt	pH	C Depth	Mg++	H2O Depth		
Cl-	r	-.89	.67	.61	-.59	-.58	-.55		
	p	.00	.02	.04	.05	.06	.08		
	n	11	11	11	11	11	11		

Table E1 (Continued)

		NCH	Ca++	Tot Hard	Ppt
Alk	r	-.78	.63	.62	-.61
	p	.00	.04	.04	.05
	n	11	11	11	11
		COD	Sp Cond	Ca++	Ex Alk
SO4=	r	-.93	.70	.53	-.53
	p	.07	.02	.08	.08
	n	4	11	12	12
		Tot Fe	Ex Alk	Ppt	
NO3-	r	-.66	.56	-.55	
	p	.04	.08	.08	
	n	10	11	11	
		pH	NO3-	Ppt	
Tot Fe	r	.81	-.66	.53	
	p	.00	.04	.07	
	n	11	10	12	
		SO4=			
COD	r	-.93			
	p	.07			
	n	4			

Table E1 (Continued)

		Ca++	H2O Depth	C Depth	T	Alk		
Tot	r	.76	.69	.68	-.65	.62		
Hard	p	.00	.02	.02	.06	.04		
	n	12	111	12	9	11		
		Mn++	Tot Hard	Alk	Mg++	H2O Depth	Ca++ Mg++	SO4=
Ca++	r	-.91	.76	.63	-.57	.55	.54	.53
	p	.03	.00	.04	.05	.08	.07	.08
	n	5	12	11	12	11	12	12
		Ca++ Mg++	Cl-	Ca++ Mg++				
Mg++	r	-.93	-.58	-.57				
	p	.00	.06	.05				
	n	12	11	12				
		C Depth	Tot Hard	Day	Ca++	Cl-		
H2O	r	.80	.69	.62	.55	-.55		
	p	.00	.02	.03	.08	.08		
	n	12	11	12	11	11		
		Tot Hard						
T	r	-.65						
	p	.06						
	n	9						

Table E1 (Continued)

		Ca++				
Mn++	r	-.91				
	p	.03				
	n	5				
		Cl-	Alk	pH	NO3-	Tot Fe
Ppt	r	.67	-.61	.57	-.55	.53
	p	.02	.05	.05	.08	.07
	n	11	11	12	11	12
		Ex Alk				
NCH	r	-.78	-.65			
	p	.00	.03			
	n	11	11			
		NCH	NO3-	SO4=		
Ex Alk	r	-.65	.56	-.53		
	p	.03	.08	.08		
	n	11	11	12		
		Mg++	Ca++			
Ca++ Mg++	r	.93	.54			
	p	.00	.07			
	n	12	12			

Table E1 (Continued)

Well 2b

		SO4=	Mn++	NCH	pH	Tot Hard	Tot Fe
Day	r	-.97	-.91	-.90	-.86	-.86	-.74
	p	.00	.09	.04	.06	.06	.09
	n	5	4	5	5	5	6

		SO4=	C Depth	H2O Depth
Sp	r	-.99	.81	-.81
Cond	p	.01	.09	.10
	n	4	5	5

		SO4=	Day	H2O Depth
pH	r	.90	-.86	.83
	p	.10	.06	.08
	n	4	5	5

		NO3-	NCH
Alk	r	.99	-.97
	p	.01	.04
	n	4	4

		Sp Cond	Day	Mn++	pH	Ca++	Tot Hard
SO4=	r	-.99	-.97	.93	.90	.81	.81
	p	.01	.01	.07	.10	.10	.10
	n	4	5	4	4	5	5

Table E1 (Continued)

		Alk	NCH			
NO3-	r	.99	-.98			
	p	.01	.02			
	n	4	4			
		Mg++	Tot Hard	Day		
Tot Fe	r	.93	.83	-.74		
	p	.02	.08	.09		
	n	5	5	6		
		NCH	H2O Depth	Day	Tot Fe	SO4=
Tot Hard	r	.91	.91	-.86	.83	.81
	p	.09	.03	.06	.08	.10
	n	4	5	5	5	5
		Mn++	SO4=			
Ca++	r	.96	.81			
	p	.04	.10			
	n	4	5			

Table E1 (Continued)

		Ca++ Mg++	Tot Fe				
Mg++	r	-.93	.93				
	p	.02	.02				
	n	5	5				
		NCH	Tot Hard	pH	Sp Cond		
H2O	r	.93	.91	.83	-.81		
Depth	p	.02	.03	.08	.10		
	n	5	5	5	5		
		NCH	Ca++	SO4=	Day		
Mn++	r	1.00	.96	.53	-.91		
	p	.05	.04	.07	.09		
	n	3	4	4	4		
		Mn++	NO3-	Alk	H2O Depth	Tot Hard	Day
NCH	r	1.00	-.98	-.97	.93	.91	-.90
	p	.05	.02	.04	.02	.09	.04
	n	3	4	4	5	4	5
		Mg++					
Ca++	r	-.93					
Mg++	p	.02					
	n	5					

Table E1 (Continued)

Well 2c

		Alk	Mg++	Tot Hard	T	NCH	SO4=
Day	r	.96	-.95	-.92	.91	-.88	-.84
	p	.04	.01	.03	.09	.05	.08
	n	4	5	5	4	5	5

		NO3-
Sp	r	-.90
Cond	p	.10
	n	4

		Ex Alk	Day
Alk	r	.96	.96
	p	.04	.04
	n	4	4

		NCH	Tot Hard	Ca++	Day	Mn++
SO4=	r	.98	.88	.85	-.84	.83
	p	.02	.05	.07	.08	.08
	n	4	5	5	5	5

Table E1 (Continued)

		Ca++	Sp Cond			
NO3-	r	-.99	-.90			
	p	.01	.10			
	n	4	4			
		NCH	Day	Ca++	SO4=	Mg++
Tot	r	1.00	-.92	.89	.88	.82
Hard	p	.00	.03	.04	.05	.09
	n	4	5	5	5	5
		NO3-	Tot Hard	Mn++	SO4=	
Ca++	r	-.99	.89	.85	.85	
	p	.01	.04	.07	.07	
	n	4	5	5	5	
		Day	Ca++ Mg++	Tot Hard		
Mg++	r	-.95	-.90	.82		
	p	.01	.04	.09		
	n	5	5	5		
		C Depth	Ca++ Mg++			
H2O	r	1.00	.96			
Depth	p	.00	.01			
	n	6	5			

Table E1 (Continued)

		Ex Alk	Day	
T	r	1.00	.91	
	p	.00	.09	
	n	3	4	
		Ca++	SO4=	
Mn++	r	.85	.83	
	p	.07	.08	
	n	5	5	
		Tot Hard	SO4=	Day
NCH	r	1.00	.98	-.88
	p	.00	.02	.05
	n	4	4	5
		T	Alk	
Ex Alk	r	1.00	.96	
	p	.00	.04	
	n	3	4	
		C Depth	H2O Depth	Mg++
<u>Ca++</u> <u>Mg++</u>	r	.96	.96	-.89
	p	.01	.01	.04
	n	5	5	5

Table E1 (Continued)

Well 2d

		T	NCH	Tot Fe	SO4=
Day	r	.95	-.94	-.89	-.86
	p	.05	.02	.02	.06
	n	4	5	6	5

		T
Cl-	r	-.99
	p	.10
	n	3

		NCH
Alk	r	-.92
	p	.08
	n	4

		T	Tot Fe	Day	Tot Hard
SO4=	r	-1.00	.96	-.86	.82
	p	.01	.01	.06	.09
	n	3	5	5	5

		T	SO4=	Tot Hard	NCH	Ca++	Day
Tot Fe	r	-.97	.96	.95	.91	.90	-.89
	p	.03	.01	.02	.03	.04	.02
	n	4	5	5	5	5	6

Table E1 (Continued)

		Tot Fe	Ca++	SO4=
Tot	r	.95	.92	.82
Hard	p	.02	.03	.09
	n	5	5	5

		Tot Hard	Tot Fe
Ca++	r	.92	.90
	p	.03	.04
	n	5	5

		C Depth
H2O	r	1.00
Depth	p	.00
	n	6

		SO4=	Cl-	Tot Fe	Day	NCH
T	r	-1.00	-.99	-.97	.95	-.94
	p	.01	.10	.03	.05	.06
	n	3	3	4	4	4

		T	Day	Alk	Tot Fe
NCH	r	-.94	-.94	-.92	.91
	p	.06	.02	.08	.03
	n	4	5	4	5

Table E1 (Continued)

Well 3a

		Cl-	pH	C Depth	H2O Depth	SO4=
Day	r	-.78	-.75	.68	.66	-.50
	p	.00	.01	.01	.02	.10
	n	11	12	13	12	12

		Mn++	Ca++	Tot Fe	Tot Hard	SO4=
Sp Cond	r	.95	.80	-.59	.56	.55
	p	.05	.00	.06	.07	.08
	n	4	11	11	11	11

		COD	Day	Ca++	Cl-	Tot Hard
pH	r	-.96	-.75	.63	.57	.53
	p	.04	.01	.04	.07	.10
	n	4	12	11	11	11

		Day	pH
Cl-	r	-.78	.57
	p	.00	.07
	n	11	11

Table E1 (Continued)

		NCH	SO4=	T			
Alk	r	-.81	-.72	.61			
	p	.00	.01	.08			
	n	11	11	9			
		Ca++	NCH	Alk	Tot Hard	Sp Cond	Day
SO4=	r	.86	.84	-.72	.71	.55	-.50
	p	.00	.00	.01	.01	.08	.10
	n	12	11	11	12	11	12
		Sp Cond					
Tot Fe	r	-.59					
	p	.06					
	n	11					
		pH					
COD	r	-.96					
	p	.04					
	n	4					
		NCH	Mg++	SO4=	Ca++	Sp Cond	pH
Tot Hard	r	.84	.80	.71	.70	.56	.53
	p	.00	.00	.01	.01	.07	.09
	n	11	12	12	12	11	11

Table E1 (Continued)

		SO4=	Sp Cond	Tot Hard	pH	NCH	Ppt
Ca++	r	.86	.80	.70	.63	.62	.58
	p	.00	.00	.01	.04	.04	.05
	n	12	11	12	11	11	12
		<u>Ca++</u> <u>Mg++</u>	Tot Hard	NCH			
Mg++	r	-.84	.80	.62			
	p	.00	.00	.04			
	n	12	12	11			
		C Depth	Day	Ppt			
H2O	r	1.00	.66	-.55			
Depth	p	.00	.02	.06			
	n	12	12	12			
		Mn++	Alk	Ex Alk			
T	r	.99	.61	.61			
	p	.07	.08	.08			
	n	3	9	9			

Table E1 (Continued)

		T	Sp Cond	Ppt	Ca++ Mg++		
Mn++	r	.99	.95	-.92	.84		
	p	.07	.05	.03	.08		
	n	3	4	5	5		
		Mn++	Ca++	C Depth	H2O Depth		
Ppt	r	-.92	.58	-.58	-.55		
	p	.03	.05	.04	.06		
	n	4	12	13	12		
		SO4=	Tot Hard	Alk	Ca++	Mg++	
NCH	r	.84	.84	-.81	.62	.62	
	p	.00	.00	.00	.04	.04	
	n	11	11	11	11	11	
		T					
Ex Alk	r	.61					
	p	.08					
	n	9					
		Mg++	Mn++				
Ca++ Mg++	r	-.84	.84				
	p	.00	.08				
	n	12	5				

Table E1 (Continued)

Well 4a

		NO3-			
Sp Cond	r	-.99			
	p	.10			
	n	3			
		Tot			
		Hard	Alk	Ca++	
Cl-	r	1.00	1.00	1.00	
	p	.02	.05	.06	
	n	3	3	3	
		HCO3-			
Alk	r	1.00	1.00	1.00	.99
	p	.00	.01	.05	.07
	n	3	3	3	3
		Mg++			
SO4=	r	1.00			
	p	.04			
	n	3			

Table E1 (Continued)

		NCH	Sp Cond		
NO3-	r	-1.00	-.99		
	p	.03	.10		
	n	3	3		
		Cl-	Alk	Ca++	
Tot Hard	r	1.00	.99	.99	
	p	.02	.07	.08	
	n	3	3	3	
		Alk	Cl-	Tot Hard	
Ca++	r	1.00	1.00	.99	
	p	.01	.06	.08	
	n	3	3	3	
		SO4=			
Mg++	r	1.00			
	p	.04			
	n	3			
		NO3-			
NCH	r	-1.00			
	p	.03			
	n				

Table E1 (Continued)

Well 5a

		C Depth	Alk	Sp Cond	SO4=	H2O Depth			
Day	r	-.85	.74	.71	-.61	-.54			
	p	.00	.01	.01	.04	.07			
	n	13	11	12	12	12			
		Day	Ex Alk						
Sp Cond	r	.71	.57						
	p	.01	.07						
	n	12	11						
		SO4=							
pH	r	-.63							
	p	.05							
	n	10							
		C Depth	SO4=						
Cl-	r	.58	.55						
	p	.06	.08						
	n	11	11						
		COD	Day	Ex Alk	Ppt	C Depth	SO4=	NO3-	
Alk	r	.99	.74	.69	-.67	-.67	-.61	-.55	
	p	.01	.01	.02	.02	.03	.04	.08	
	n	4	11	11	11	11	11	11	

Table E1 (Continued)

		COD	Mn++	C Depth	Tot Fe	pH	Alk	Day	Cl-
SO4=	r	-.98	-.88	.80	-.74	-.63	-.61	-.61	.55
	p	.02	.05	.00	.01	.05	.04	.04	.08
	n	4	5	12	11	10	11	12	11
		Mn++	H2O Depth	Alk					
NO3-	r	1.00	.66	-.55					
	p	.00	.03	.08					
	n	4	11	11					
		Mn++	SO4=						
Tot Fe	r	.96	-.74						
	p	.01	.01						
	n	5	11						
		Alk	SO4=	C Depth					
COD	r	.99	-.98	-.97					
	p	.01	.02	.03					
	n	4	4	4					
		Ca++	Mg++	Ppt	Ca++ Mg++				
Tot Hard	r	.97	.64	.61	.50				
	p	.00	.02	.04	.10				
	n	12	12	12	12				
		Tot Hard	Ca++ Mg++	Ppt					
Ca++	r	.97	.69	.63					
	p	.00	.01	.03					
	n	12	12	12					

Table El. (Continued)

		Tot Hard			
Mg++	r	.64			
	p	.02			
	n	12			
		Mn++	NO3-	C Depth	Day
H2O Depth	r	.99	.66	.56	-.54
	p	.01	.03	.06	.07
	n	4	11	12	12
		NO3-	H2O Depth	Tot Fe	SO4=
Mn++	r	1.00	.99	.96	-.88
	p	.00	.01	.01	.05
	n	4	4	5	5
		Alk	Ca++	Tot Hard	
Ppt	r	-.67	.63	.61	
	p	.02	.03	.04	
	n	11	12	12	
		Alk	Sp Cond		
Ex Alk	r	.69	.57		
	p	.02	.07		
	n	11	11		
		Ca++	SO4= HCO3-	Tot Hard	
Ca++ Mg++	r	.69	-.56	.50	
	p	.01	.07	.10	
	n	12	11	12	

Table E1 (Continued)

Well 7a

		Sp Cond	pE	Cl-		
Day	r	-.78	-.75	-.69		
	p	.02	.03	.06		
	n	8	8	8		
		Day				
Sp Cond	r	-.78				
	p	.02				
	n	8				
		Tot Fe	<u>Ca++</u> Mg++	Cl-	Day	Mg++
pH	r	-.96	-.81	.80	-.75	.64
	p	.00	.02	.02	.03	.09
	n	6	8	8	8	8
		pH	Tot Fe	Day	<u>Ca++</u> Mg++	Mg++
Cl-	r	.80	-.74	-.69	-.65	.65
	p	.02	.09	.06	.08	.03
	n	8	6	8	8	8
		NO3-	H2O Depth			
SO4=	r	.85	.66			
	p	.02	.07			
	n	7	8			

Table E1 (Continued)

		Mn++	T	SO4=	C Depth	H2O Depth
NO3-	r	-1.00	-.86	.85	.67	.67
	p	.03	.03	.02	.10	.10
	n	3	6	7	7	7
		pH	<u>Ca++</u> Mg++	Cl-		
Tot Fe	r	-.96	.77	-.74		
	p	.00	.04	.09		
	n	6	7	6		
		NCH	Mg++	Ca++		
Tot Hard	r	.95	.90	.59		
	p	.00	.00	.09		
	n	8	9	9		
		Tot Hard				
Ca++	r	.59				
	p	.09				
	n	9				
		NCH	Tot Hard	<u>Ca++</u> Mg++	Cl-	pH
Mg++	r	.92	.90	-.80	.65	.64
	p	.00	.00	.01	.08	.09
	n	8	9	9	8	8
		C Depth	NO3-	SO4=		
H2O Depth	r	1.00	.67	.66		
	p	.00	.10	.07		
	n	8	7	8		

Table E1 (Continued)

		NO3-				
T	r		-.86			
	p		.03			
	n		6			
		NO3-				
Mn++	r		-1.00			
	p		.03			
	n		3			
		C Depth				
Ppt	r		-.63			
	p		.10			
	n		8			
		Tot Hard	Mg++	<u>Ca++</u> <u>Mg++</u>		
NCH	r	.95	.92	-.77		
	p	.00	.00	.03		
	n	8	8	8		
		pH	Mg++	Tot Fe	NCH	Cl-
<u>Ca++</u> <u>Mg++</u>	r	-.81	-.80	.77	-.77	-.65
	p	.02	.01	.04	.03	.08
	n	8	9	7	8	8

Table E1 (Continued)

Well 7c

		Cl-	pH	NCH	Sp Cond	Ca++ Mg++	Mg++	Tot Hard	H2O Depth	C Depth
Day	r	.99	-.94	-.93	.93	.93	-.93	-.90	-.84	-.84
	p	.10	.06	.07	.07	.07	.07	.10	.08	.08
	n	3	4	4	4	4	4	4	5	5
		Mn++	Day							
Sp Cond	r	1.00	.93							
	p	.04	.07							
	n	3	4							
		NO3-	Tot Hard	NCH	Day	C Depth	H2O Depth			
pH	r	1.00	.99	.98	-.94	.93	.93			
	p	.03	.07	.02	.06	.07	.07			
	n	3	3	4	4	4	4			
		Tot Fe	Day							
Cl-	r	.99	.99							
	p	.10	.10							
	n	3	3							
		SO4=								
Alk	r	-.99								
	p	.09								
	n	3								

Table E1 (Continued)

		Alk						
SO4=	r	-.99						
	p	.09						
	n	3						
		NCH	pH	Tot Hard	Mg++			
NO3-	r	1.00	1.00	1.00	.99			
	p	.01	.03	.04	.09			
	n	3	3	3	3			
		Cl-						
Tot Fe	r	.99						
	p	.09						
	n	3						
		NCH	NO3-	pH	Mg++	C Depth	H2O Depth	Day
Tot Hard	r	1.00	1.00	.99	.99	.90	.90	-.90
	p	.03	.04	.07	.01	.10	.10	.10
	n	3	3	3	4	4	4	4
		H2O Depth	C Depth					
Ca++	r	.90	.90					
	p	.10	.10					
	n	4	4					

Table E1 (Continued)

		NCH	NO3-	Tot Hard				
Mg++	r	.99	.99	.99				
	p	.07	.09	.01				
	n	3	3	4				
		C Depth	NCH	pH	Ca++	Tot Hard	Day	
H2O Depth	r	1.00	.98	.93	.90	.90	-.84	
	p	.00	.02	.07	.10	.10	.08	
	n	5	4	4	4	4	5	
		Sp Cond						
Mn++	r	1.00						
	p	.04						
	n	3						
		NO3-	Tot Hard	Mg++	pH	C Depth	H2O Depth	Day
NCH	r	1.00	1.00	.99	.98	.98	.98	-.93
	p	.01	.03	.07	.02	.02	.02	.07
	n	3	3	3	4	4	4	4
		Day						
Ca++ Mg++	r	.93						
	p	.07						
	n	4						

Table E1 (Continued)

Well 8a

		NO3-
Cl-	r	.99
	p	.01
	n	4

		C	Ca++
		Depth	Mg++
Alk	r	-.96	-.90
	p	.04	.10
	n	4	4

		NCH	Ca++	Tot Hard	Mg++	Tot Fe
SO4=	r	1.00	1.00	.99	.98	.94
	p	.00	.00	.00	.00	.06
	n	4	5	5	5	4

		Tot Fe	Cl-
NO3-	r	1.00	.99
	p	.06	.01
	n	3	4

Table E1 (Continued)

		NO3-	SO4=	Ca++	Tot Hard	
Tot	r	1.00	.94	.93	.92	
Fe	p	.06	.06	.07	.08	
	n	3	4	4	4	
		Ca++	SO4=	Mg++	NCH	Fe
Tot	r	1.00	.99	.99	.99	Tot
Hard	p	.00	.00	.00	.01	
	n	5	5	5	4	4
		Tot Hard	SO4=	NCH	Mg++	Tot Fe
Ca++	r	1.00	1.00	1.00	.99	.93
	p	.00	.00	.01	.00	.07
	n	5	5	4	5	4
		Tot Hard	Ca++	SO4=	NCH	
Mg++	r	.99	.99	.98	.96	
	p	.00	.00	.00	.04	
	n	5	5	5	4	

Table E1 (Continued)

		NCH				
H2O	r		.95			
Depth	p		.01			
	n		5			
		<u>Ca++</u> <u>Mg++</u>				
T	r		1.00			
	p		.03			
	n		3			
		SO4=	Ca++	Tot Hard	Mg++	H2O Depth
NCH	r	1.00	1.00	.99	.96	.95
	p	.00	.01	.01	.04	.01
	n	4	4	4	4	5
		Alk	C Depth	<u>Ca++</u> <u>Mg++</u>		
HCO3-	r	1.00	-.97	-.91		
	p	.00	.03	.09		
	n	4	4	4		
		T	Alk			
Ca++	r	1.00	-.90			
Mg++	p	.03	.10			
	n	3	4			

Table E1 (Continued)

Well 9a

		T	Mg++	C Depth
Day	r	.99	-.81	.76
	p	.01	.09	.08
	n	4	5	6

		H2O Depth
Sp Cond	r	-.83
	p	.08
	n	5

		Mg++	Ca++ Mg++	Cl ₂
pH	r	-.97	.92	.90
	p	.03	.08	.10
	n	4	4	4

		pH
Cl-	r	.90
	p	.10
	n	4

		NCH	SO4=
Alk	r	-.90	-.90
	p	.10	.10
	n	4	4

Table E1 (Continued)

		NCH	Alk		
SO4=	r	1.00	-.90		
	p	.00	.10		
	n	4	4		
		Mn++			
NO3-	r	.92			
	p	.07			
	n	4			
		T			
Tot Hard	r	-1.00			
	p	.06			
	n	3			
		pH	<u>Ca++</u> Mg++	Day	
Mg++	r	-.97	-.96	-.81	
	p	.03	.01	.10	
	n	4	5	5	
		Sp Cond			
H2O Depth	r	-.83			
	p	.08			
	n	5			

Table E1 (Continued)

		Tot Hard	Day
T	r	-1.00	.99
	p	.06	.01
	n	3	4
		NO3-	
Mn++	r	.92	
	p	.08	
	n	4	
		SO4=	Alk
NCH	r	1.00	-.90
	p	.00	.10
	n	4	4
		Mg++	pH
Ca++ Mg++	r	-.96	.92
	p	.01	.08
	n	5	4

Table E2. ICP surface water correlations

Coal Creek

		Cl-	Alk	Ca++	Ca++ Mg++			
Day	r	.61	.53	.51	.50			
	p	.04	.08	.06	.07			
	n	12	12	12	14			
		Mn++	Alk	T	Ppt			
Sp Cond	r	.99	.83	-.69	-.66			
	p	.08	.00	.04	.02			
	n	3	11	9	12			
		Cl-						
pH	r	.74						
	p	.02						
	n	10						
		pH	Day					
Cl-	r	.74	.61					
	p	.02	.04					
	n	10	12					
		Sp Cond	T	Ppt	Tot Fe	Day		
Alk	r	.83	-.75	-.68	.62	.53		
	p	.00	.03	.02	.10	.08		
	n	11	8	12	8	12		

Table E2 (Continued)

		NCH	Tot Hard	Ca++	Mg++	Ppt	
SO4=	r	.93	.91	.89	.80	-.52	
	p	.00	.00	.00	.00	.07	
	n	12	13	13	13	13	
		Mn++					
NO3-	r	-.99					
	p	.08					
	n	3					
		Alk					
Tot Fe	r	.52					
	p	.10					
	n	8					
		NCH	Ca++	SO4=	Mg++	Ppt	
Tot Hard	r	.96	.95	.91	.86	-.54	
	p	.00	.00	.00	.00	.05	
	n	12	14	13	14	14	
		Tot Hard	NCH	SO4=	Mg++	Day	
Ca++	r	.95	.92	.89	.67	.51	
	p	.00	.00	.00	.01	.06	
	n	14	12	13	14	14	
		NCH	Tot Hard	SO4=	Ca++	T	Ppt
Mg++	r	.88	.86	.80	.67	-.66	-.51
	p	.00	.00	.00	.01	.08	.07
	n	12	14	13	14	8	14

Table E2 (Continued)

		Alk	Sp Cond	Ppt	Mg++			
T	r	-.75	-.69	.69	-.66			
	p	.03	.04	.04	.08			
	n	8	9	9	8			
		Sp Ccnd	NO3-					
Mn++	r	.99	-.99					
	p	.08	.08					
	n	3	3					
		T	Alk	Sp Cond	NCH	Tot Hard	SO4=	Mg++
Ppt	r	.69	-.68	-.66	-.54	-.54	-.52	-.51
	p	.04	.02	.02	.05	.05	.07	.07
	n	9	12	12	13	14	13	14
		Tot Hard	SO4=	Ca++	Mg++	Ppt		
NCH	r	.96	.93	.92	.88	-.54		
	p	.00	.00	.00	.00	.06		
	n	12	12	12	12	13		
		Day						
Ca++	r	.50						
Mg++	p	.07						
	n	14						

Table E2 (Continued)

Sediment Pond

		Ca++	Tot Hard	SO4=	Mg++	pH	Ca++ Mg++	Alk		
Day	r	.86	.83	.82	.76	-.67	.61	-.59		
	p	.00	.00	.00	.00	.02	.04	.08		
	n	12	12	11	12	12	12	10		
		SO4=	Tot Hard	Ca++	Mg++	NCH	pH	T	Ppt	
Sp Cond	r	.88	.84	.84	.83	.79	-.78	-.69	-.55	
	p	.00	.00	.00	.00	.01	.00	.04	.08	
	n	10	10	10	10	10	11	9	11	
		Alk	Sp Cond	Ca++	Tot Hard	SO4=	Mg++	NCH	Day	Tot Fe
pH	r	.84	-.78	-.78	-.77	-.73	-.73	-.68	-.67	-.59
	p	.00	.00	.00	.01	.01	.01	.02	.02	.07
	n	10	11	11	11	11	11	11	12	10
		Ca++ Mg++	NO3-							
Cl-	r	.78	-.64							
	p	.01	.06							
	n	10	9							
		pH	Day							
Alk	r	.84	-.59							
	p	.00	.08							
	n	10	10							

Table E2 (Continued)

		NCH	Ca++	Tot Hard	Sp Cond	Mg++	T	Day	pH	Ppt
SO4=	r	.97	.93	.91	.88	.87	-.86	.82	-.73	-.62
	p	.00	.00	.00	.00	.00	.01	.00	.01	.04
	n	10	11	11	10	11	8	11	11	11

		Tot Fe	Cl-
NO3-	r	.81	-.64
	p	.01	.06
	n	8	9

		NO3-	pH
Tot Fe	r	.81	-.59
	p	.01	.07
	n	8	10

		NCH	Ca++	Mg++	SO4=	Sp Cond	Day	T	pH
Tot Hard	r	1.00	1.00	.99	.91	.84	.83	-.82	-.77
	p	.00	.00	.00	.00	.00	.00	.01	.01
	n	10	12	12	11	10	12	8	11

		NCH	Tot Hard	Mg++	SO4=	Day	T	Sp Cond	pH
Ca++	r	1.00	1.00	.97	.93	.86	-.84	.84	-.78
	p	.00	.00	.00	.00	.00	.01	.00	.00
	n	10	12	12	11	12	8	10	11

Table E2 (Continued)

		NCH	Tot Hard	Ca++	SO4=	Sp Cond	T	Day	pH
Mg++	r	.99	.99	.97	.87	.83	-.77	.76	-.73
	p	.00	.00	.00	.00	.00	.03	.00	.01
	n	10	12	12	11	10	8	12	11
		Ppt	SO4=	NCH	Ca++	Tot Hard	Mg++	Sp Cond	
T	r	.88	-.86	-.85	-.84	-.82	-.77	-.69	
	p	.00	.01	.01	.01	.01	.03	.04	
	n	9	8	8	8	8	8	9	
		T	SO4=	Sp Cond					
Ppt	r	.88	-.62	-.55					
	p	.00	.04	.08					
	n	9	11	11					
		Tot Hard	Ca++	Mg++	SO4=	T	Sp Cond	pH	
NCH	r	1.00	1.00	.99	.97	-.85	.79	-.68	
	p	.00	.00	.00	.00	.01	.01	.02	
	n	10	10	10	10	8	10	11	
		Cl-	Day						
Ca++ Mg++	r	.78	.61						
	p	.01	.04						
	n	10	12						

Table E2 (Continued)

ICP Top Mine Pits

		Sp Cond	NCH	Tot Hard	Mg++	Ca++	SO4=			
Day	r	.87	.79	.79	.74	.73	.68			
	p	.00	.02	.02	.04	.04	.07			
	n	8	8	8	8	8	8			
		SO4=	Mg++	Day	NO3-	T	NCH	Tot Hard	Cl-	Ca++
Sp	r	.90	.89	.87	.84	.83	.79	.79	-.71	.64
Cond	p	.00	.00	.00	.01	.04	.02	.02	.05	.09
	n	8	8	8	8	6	8	8	8	8
		Ca++ Mg++	Cl-	Mg++						
pH	r	.88	.85	-.81						
	p	.02	.03	.05						
	n	6	6	6						
		pH	Mg++	SO4=	NO3-	Sp Cond	Tot Hard	NCH	Ca++ Mg++	
Cl-	r	.85	-.85	-.78	-.76	-.71	-.69	-.68	.68	
	p	.03	.01	.02	.03	.05	.06	.06	.06	
	n	6	8	8	8	8	8	8	8	
		Mg++								
Alk	r	-.63								
	p	.09								
	n	8								

Table E2 (Continued)

		NO3-	Mg++	Sp Cond	Cl-	NCH	Tot Hard	Day	
SO4=	r	.96	.94	.90	-.78	.73	.71	.68	
	p	.00	.00	.00	.02	.04	.05	.07	
	n	8	8	8	8	8	8	8	
		SO4=	Mg++	Sp Cond	Cl-	Ca++ Mg++			
NO3-	r	.96	.87	.84	-.76	-.72			
	p	.00	.00	.01	.03	.04			
	n	8	8	8	8	8			
		Mn++							
Tot Fe	r	.98							
	p	.02							
	n	4							
		NCH	Ca++	Mn++	Mg++	Sp Cond	Day	SO4=	Cl-
Tot Hard	r	1.00	.95	.91	.88	.79	.79	.71	-.69
	p	.00	.00	.09	.00	.02	.02	.05	.06
	n	8	8	4	8	8	8	8	8
		Tot Hard	NCH	Day	Mg++	Sp Cond			
Ca++	r	.95	.94	.73	.69	.64			
	p	.00	.00	.04	.06	.09			
	n	8	8	8	8	8			

Table E2 (Continued)

		SO4=	NCH	Sp Cond	Tot Hard	NO3-	Cl-	pH	Day	Ca++	Alk
Mg++	r	.94	.89	.89	.88	.87	-.85	-.81	.74	.69	-.63
	p	.00	.00	.00	.00	.00	.01	.05	.04	.06	.09
	n	8	8	8	8	8	8	6	8	8	8
			Ppt	Sp Cond							
T	r	-.97	.83								
	p	.03	.04								
	n	4	6								
		Tot Fe	NCH	Tot Hard							
Mn++	r	.98	.95	.91							
	p	.02	.05	.09							
	n	4	4	4							
		T									
Ppt	r	-.97									
	p	.03									
	n	4									
		Tot Hard	Mn++	Ca++	Mg++	Sp Cond	Day	SO4=	Cl-		
NCH	r	1.00	.95	.94	.89	.79	.79	.73	-.68		
	p	.00	.05	.00	.00	.02	.02	.04	.06		
	n	8	4	8	8	8	8	8	8		
		pH	NO3-	Cl-							
Ca++	r	.88	-.72	.68							
Mg++	p	.02	.04	.06							
	n	6	8	8							

Table E2 (Continued)

ICP Bottom Mine Pits

		Mg++	SO4=	Tot Hard	NCH	Tot Fe	
Sp	r	.82	.78	.72	.69	.64	
Cond	p	.01	.02	.04	.06	.09	
	n	8	8	8	8	8	
		Tot Fe	Alk	Cl-			
pH	r	-.74	.72	.63			
	p	.04	.04	.09			
	n	8	8	8			
		Alk	pH				
Cl-	r	.71	.63				
	p	.01	.09				
	n	11	8				
		pH	Cl-				
Alk	r	.72	.71				
	p	.04	.01				
	n	8	11				
		T	Sp Cond	NO3-	Tot Hard	NCH	Mg++
SO4=	r	-.79	.78	.74	.68	.67	.62
	p	.01	.02	.02	.01	.02	.03
	n	9	8	10	12	11	12

Table E2 (Continued)

		SO4=					
NO3-	r	.74					
	p	.02					
	n	10					
		Mg++	pH	Sp Cond			
Tot Fe	r	.74	-.74	.64			
	p	.02	.04	.09			
	n	9	3	8			
		NCH	Ca++	Mg++	Sp Cond	SO4=	
Tot Hard	r	.99	.86	.83	.72	.68	
	p	.00	.00	.00	.04	.01	
	n	11	12	12	8	12	
		Tot Hard	NCH	SO4=			
Ca++	r	.86	.83	.54			
	p	.00	.00	.07			
	n	12	11	12			
		NCH	Tot Hard	Sp Cond	Tot Fe	Ca++ Mg++	SO4=
Mg++	r	.84	.83	.81	.74	-.62	.62
	p	.00	.00	.01	.02	.03	.03
	n	11	12	8	9	12	12

Table E2 (Continued)

T	r p n	SO4=				
		-.79				
		.019				
NCH	r p n	Tot Hard	Mg++	Ca++	Sp Cond	SO4=
		.99	.84	.83	.69	.67
		.00	.00	.00	.06	.02
		11	11	11	8	11
<u>Ca++</u> <u>Mg++</u>	r p n	Mg++				
		-.62				
		.03				
		12				

Table E3. ICO north mining pits and sediment pond

ICC North Mining Pits and Sediment Pond

		Tot Fe	SO4=	Ca++	Tot Hard	NCH	Mg++	Cl-
Sp	r	.99	.92	.88	.86	.82	.74	.71
Cond	p	.00	.00	.01	.01	.01	.06	.07
	n	5	7	7	7	8	7	7

		Ppt
pH	r	-.85
	p	.07
	n	5

		Cl-
	r	.71
	p	.07
	n	7

		Ppt	SO4=	Mg++	Tot ³ Hard	NCH
Alk	r	-.92	.75	.73	.73	.68
	p	.01	.05	.06	.06	.10
	n	6	7	7	7	7

		Sp Cond	Ca++	Tot Hard	NCH	Alk	Mg++
SO4=	r	.92	.90	.89	.88	.75	.72
	p	.00	.00	.00	.01	.05	.05
	n	7	8	8	7	7	8

Table E3 (Continued)

Tot Fe	r p n	Sp Cond	T					
		.99	.94					
		.00 5	.02 5					
Tot Hard	r p n	NCH	Ca++	Mg++	SO4=	Sp Cond	Alk	
		1.00	.92	.91	.89	.86	.73	
		.00 7	.00 8	.00 8	.00 8	.01 7	.06 7	
Ca++	r p n	Mn++	NCH	Tot Hard	SO4=	Sp Cond	Mg++	
		1.00	.96	.92	.90	.88	.68	
		.94 5	.00 7	.00 8	.00 8	.01 7	.06 8	
Mg++	r p n	NCH	Tot Hard	Ca++ Mg++	Sp Cond	Alk	SO4=	Ca++
		.92	.91	-.83	.74	.73	.72	.68
		.00 7	.00 8	.01 8	.06 7	.06 7	.05 8	.06 8

Table E3 (Continued)

T	r p n	Tot Fe						
		.94						
		.02 5						
Mn++	r p n	Ca++						
		1.00						
		.03 3						
Ppt	r p n	Alk	pH					
		-.92	-.85					
		.01 6	.07 5					
NCH	r p n	Tot Hard	Ca++	Mg++	SO4=	Sp Cond	Ca++ Mg++	Alk
		1.00	.96	.93	.88	.82	-.76	.68
		.00 7	.00 7	.00 7	.01 7	.01 8	.05 7	.10 7
Ca++ Mg++	r p n	Mg++	NCH					
		-.83	-.76					
		.01 8	.05 7					

Table E3 (Continued)

ICO South Mining Pit

		Cl-						
Day	r	-.88						
	p	.00						
	n	9						
		Mn++	Tot Hard	Mg++	Ca++	T	Alk	Ca++ Mg++
Sp Cond	r	-.93	.92	.85	.75	.75	-.62	-.60
	p	.07	.00	.00	.02	.03	.08	.09
	n	4	9	9	9	8	9	9
		Alk						
pH	r	.99						
	p	.00						
	n	7						
		Day						
Cl-	r	-.88						
	p	.00						
	n	9						
		pH	NCH	Sp Cond	Tot Hard			
Alk	r	.99	-.63	-.62	-.62			
	p	.00	.07	.08	.08			
	n	7	9	9	9			

Table E3 (Continued)

		Ppt	Ca++	Ca++ Mg++				
SO4=	r	-.69	.66	.64				
	p	.04	.04	.05				
	n	9	10	10				
Tot	r	-.68						
Fe	p	.06						
	n	8						
		NCH	Sp Cond	Mg++	Ca++	T	Alk	Ca++ Mg++
Tot	r	1.00	.92	.91	.75	.67	-.62	-.59
Hard	p	.00	.00	.00	.01	.10	.08	.07
	n	9	9	10	10	7	9	10
		NCH	Sp Cond	Tot Hard	SO4=			
Ca++	r	.81	.75	.75	.66			
	p	.01	.02	.01	.04			
	n	9	9	10	10			
		NCH	Tot Hard	Mn++	Sp Cond	Ca++ Mg++	T	
Mg++	r	.91	.91	-.86	.85	-.84	.78	
	p	.00	.00	.06	.00	.00	.04	
	n	9	10	5	9	10	7	

Table E3 (Continued)

		<u>Ca++</u> Mg++	Mg++	Sp Cond	Tot Hard		
T	r	-.86	.78	.75	.67		
	p	.01	.04	.03	.10		
	n	7	7	8	7		
		<u>Ca++</u> Mg++	Sp Cond	Mg++			
Mn++	r	.94	-.93	-.86			
	p	.02	.07	.06			
	n	5	4	5			
		SO4=					
Ppt	r	-.69					
	p	.04					
	n	9					
		Tot Hard	Mg++	Ca++	Tot Fe	Alk	
NCH	r	1.00	.91	.81	-.68	-.63	
	p	.00	.00	.01	.06	.07	
	n	9	9	9	8	9	
		Mn++	T	Mg++	SO4=	Sp Cond	Tot Hard
Ca++	r	.94	-.86	-.84	.64	-.60	-.59
Mg++	p	.02	.01	.00	.05	.09	.07
	n	5	7	10	10	9	10

Table E4. Well depth correlation (through August, 1977)

		7b	7c	Q	3a	C1	1a	M	C2	E				
Ppt	r	-.95	.80	.69	.61	.59	.53	.51	.50	.47				
	p	.05	.06	.00	.02	.00	.04	.01	.01	.02				
	n	4	6	18	15	24	15	24	24	24				
		S2	5b	4a	5a	9a	T	7c	M	3a	2a	Q	2b	K
Day	r	-.89	-.89	-.88	.84	-.80	-.78	.77	-.75	-.60	-.57	-.57	-.55	-.52
	p	.01	.05	.00	.00	.03	.00	.04	.00	.00	.01	.00	.10	.01
	n	7	5	8	20	7	15	7	32	20	21	24	10	24
		5b	5a	7c	Day	K								
T	r	1.00	.96	-.91	-.78	.70								
	p	.00	.04	.09	.00	.01								
	n	4	4	4	15	12								
		2c	S2	Q	Ppt	3a	1a	7a	K	2a	M	C2		
C1	r	.78	.77	.66	.59	.57	.55	-.55	-.44	.43	.43	.40		
	p	.02	.07	.00	.00	.01	.02	.07	.03	.07	.02	.03		
	n	8	6	21	24	18	18	12	23	18	29	29		
		1c	S2	1d	E	2c	9a	1a	G	3a	Ppt	M	C1	
C2	r	.96	.95	.94	.83	.77	.72	.68	.64	.56	.50	.47	.40	
	p	.00	.00	.00	.00	.01	.07	.00	.00	.01	.01	.01	.03	
	n	9	7	9	31	9	7	20	30	20	24	31	29	
		C2	G	1c	1d	4a	1a	3a	2b	M	5a	Ppt	Q	
E	r	.83	.79	.77	.67	.67	.65	.64	.63	.48	-.48	.47	.37	
	p	.00	.00	.01	.05	.10	.00	.00	.07	.01	.04	.02	.08	
	n	31	30	9	9	7	20	20	9	31	18	24	23	

Table E4 (Continued)

		S2	1c	9a	E	1d	4a	2b	1b	C2	1a	3a	5a	
G	r	.96	.87	.82	.79	.77	.70	.68	.65	.64	.56	.54	-.47	
	p	.00	.00	.02	.00	.01	.08	.05	.06	.00	.01	.01	.05	
	n	7	9	7	30	9	7	9	9	30	20	20	18	
		4a	T	2d	7a	Q	Day	3a	C1					
K	r	-.79	.70	.69	.65	-.53	-.52	-.46	-.44					
	p	.02	.01	.09	.03	.04	.01	.08	.03					
	n	8	12	7	11	16	24	15	23					
		4a	5b	5a	Day	Q	7c	7a	3a	2a	Ppt	E	C2	C1
M	r	.97	-.95	-.80	-.75	.75	.73	.66	.64	.56	.51	.48	.47	.43
	p	.00	.01	.00	.00	.00	.06	.01	.00	.01	.01	.01	.01	.02
	n	8	5	19	32	24	7	13	20	20	24	31	31	29
		7b	4a	M	2a	Ppt	C1	3a	2b	1c	Day	5a	K	E
Q	r	-.85	.78	.75	.74	.69	.66	.65	-.65	-.62	-.57	-.55	-.53	.37
	p	.07	.02	.00	.00	.00	.00	.00	.06	.08	.00	.02	.04	.08
	n	5	8	24	20	18	21	20	9	9	24	19	16	23
		1c	S2	1d	2c	9a	3a	C2	1b	E	2a			
la	r	1.00	.99	.96	.86	.86	.84	.68	.67	.65	.64			
	p	.00	.00	.00	.00	.01	.00	.00	.03	.00	.00			
	n		7	10	10	7	20	20	10	20	21			
		2d	G	C1	Ppt									
la	r	.60	.56	.55	.53									
	p	.07	.01	.01	.04									
	n	10	20	18	15									

Table E4 (Continued)

		S2	2c	9a	Q	1a	1d	Day	M	5a	3a	Cl
2a	r	.95	.83	.80	.74	.64	.64	-.58	.56	-.49	.46	.43
	p	.00	.00	.03	.00	.00	.05	.01	.01	.04	.04	.07
	n	7	10	7	20	21	10	21	20	18	20	18
		1c	1a	S2	2b	1d	4a	Q	1b	M		
3a	r	.85	.84	.80	.73	.71	.68	.65	.65	.64		
	p	.00	.00	.03	.03	.03	.09	.00	.06	.00		
	n	9	20	7	9	9	7	20	9	20		
		E	Ppt	Day	Cl	C2	G	5a	2a	K		
3a	r	.64	.61	-.60	5.7	.56	.54	-.47	.46	-.46		
	p	.00	.02	.00	.01	.01	.01	.05	.04	.08		
	n	20	15	20	18	20	20	18	20	15		
		M	7a	Day	5a	K	Q	G	3a	E		
4a	r	.97	-.95	-.88	-.88	-.79	.78	.70	.68	.67		
	p	.00	.05	.00	.00	.02	.02	.08	.09	.10		
	n	8	4	8	8	8	8	7	7	7		
		T	5b	4a	Day	M	7c	Q	2a	E	G	3a
5a	r	.96	.93	-.88	.84	-.80	-.70	.55	-.49	-.48	-.47	-.47
	p	.04	.02	.00	.00	.00	.08	.02	.04	.04	.05	.05
	n	4	5	8	20	19	7	19	18	18	18	18
		S2	4a	1c	M	K	Cl					
7a	r	.98	-.95	.93	-.66	.65	-.55					
	p	.02	.05	.02	.01	.03	.07					
	n	4	4	5	13	11	12					

Table E4 (Continued)

		1c	2b	1a	3a	G	1d							
1b	r	.71	.68	.67	.65	.65	.60							
	p	.02	.03	.03	.06	.06	.06							
	n	10	10	10	9	9	10							
		1a	S2	1d	C2	7a	G	9a	2c	3a	E	1b	G	2d
1c	r	1.00	.99	.97	.96	.93	.87	.87	.87	.85	.77	.71	-.62	.59
	p	.00	.00	.00	.00	.02	.00	.01	.00	.00	.01	.02	.08	.07
	n	10	7	10	9	5	9	7	10	9	9	10	9	10
		S2	1c	1a	C2	2c	9a	G	3a	E	2d	2a	1b	
1d	r	.99	.97	.96	.94	.92	.84	.77	.71	.67	.64	.64	.60	
	p	.00	.00	.00	.00	.00	.02	.01	.03	.05	.05	.05	.05	
	n	7	10	10	9	10	7	9	9	9	10	10	10	
		8a	3a	1b	G	Q	E	Day						
2b	r	.83	.73	.68	.68	-.65	.63	-.55						
	p	.08	.03	.03	.05	.06	.07	.10						
	n	5	9	10	9	9	9	10						
		K	1d	1a	1c	2c								
2d	r	.69	.64	.60	.59	.59								
	p	.09	.05	.07	.07	.07								
	n	7	10	10	10	10								
		T	M	5a	Day	7b	7c							
5b	r	1.00	-.95	.93	-.89	.38	-.87							
	p	.00	.01	.02	.05	.05	.05							
	n	4	5	5	5	5	5							

Table E4 (Continued)

		S2	ld	lc	la	2a	9a	C1	C2	2d			
2c	r	.98	.92	.87	.86	.83	.82	.78	.77	.59			
	p	.00	.00	.00	.00	.00	.02	.02	.01	.07			
	n	7	10	10	10	10	7	8	9	10			
		7c	Ppt	5b	Q								
7b	r	-.99	-.95	.88	-.85								
	p	.00	.05	.05	.07								
	n	5	4	5	5								
		7b	T	5b	Ppt	Day	M	5a					
7c	r	-.99	-.91	-.87	.80	.77	.73	-.70					
	p	.00	.09	.05	.06	.04	.06	.08					
	n	5	4	5	6	7	7	7					
		S2	lc	la	ld	G	2c	2a	Day	C2			
9a	r	.89	.87	.86	.84	.82	.82	.80	-.80	.72			
	p	.01	.01	.01	.02	.02	.02	.03	.03	.07			
	n	7	7	7	7	7	7	7	7	7			
		lc	la	ld	7a	2c	G	C2	2a	9a	Day	3a	C1
S2	r	.99	.99	.99	.98	.98	.96	.95	.95	.89	-.89	.80	.77
	p	.00	.00	.00	.02	.00	.00	.00	.00	.01	.01	.03	.07
	n	7	7	7	4	7	7	7	7	7	7	7	6
		2b											
8a	r	.83											
	p	.08											
	n	5											

APPENDIX F: WELL 5a PUMP TEST

Table F1. Well 5a pump test

Time (days/hrs/min)	Depth to water (feet)	Water flow volume, Q. (in. ³)	K (10 ⁻³ ft/day)
---	31.13	---	
0:00:00	37.83	6.28	1.63
0:00:15	37.67	21.99	2.74
0:00:48	37.08	0.00 ^a	---
0:01:17	37.08	6.28	0.44
0:02:19	36.92	15.71	0.96
0:03:26	36.50	17.28	1.8
0:04:22	36.04	20.42	0.64
0:07:17	35.50	25.13	0.24
0:18:47	34.83	9.43	0.19
1:00:47	34.58	20.42	0.44
1:06:57	34.04	51.84	0.25
2:10:28	32.67		

$= Q/iA$; $A = 2\pi r l + \pi r^2$; $r = 4"$, $l = 60"$, $A = 1558 \text{ in.}^2$.

$=$ initial depth to water minus the average depth to water
for water flow volume interval) all divided by r .