GROUNDWATER HYDROLOGY

The groundwater hydrology of the site has been logically divided into five phases of monitoring, analysis, and investigation as outlined below:

Sample Station Locations
Correlation of Aquifers
Physical and Chemical Analysis of Groundwater
Data Dye Study of Aquifer Interconnections
Summary of Impact Assessment of Groundwater

1. Sample Station Locations and Descriptions

Four groundwater monitoring wells were constructed as true piezometers to serve as monitoring points. Each well was sampled weekly to determine and measure the following:

static water level
specific conductance
field pH
laboratory pH
alkalinity (mg/l - 4.5 pH)
acidity (mg/l - 8.2 pH)
sulphates (mg/l)
total iron (mg/l)
ferrous iron (mg/l)

The locations of each well are shown on the following sheets: Sheets 2, 3, and 8.

The four monitoring well sampling stations are described below:

Station 9	-	Monitoring Well R1-B (Hamilton Standard Deep Mine Pool)
Station 10	-	Monitoring Well R2 (Flow System B2)
Station 11	-	Monitoring Well R3 (Flow System B3)
Station 12	-	Monitoring Well C1 (Flow System B6)

When reviewing the analyses on the following pages, refer to the following sheets which show the data plotted on a time relationship basis for the period of monitoring:

Sheet 28 - Sample Zone 9 (Monitoring Well R1-B)
Sheet 29 - Sample Zone 10 (Monitoring Well R2)
Sheet 30 - Sample Zone 11 (Monitoring Well R3)
Sheet 31 - Sample Zone 12 (Monitoring Well C1)

2. Correlation of Aquifers

The four monitor wells constructed as true piezometers were developed to monitor selected flow systems, previously described and shown on Sheet 8:

Monitoring Well R1-B (Sample Station 9)

This well monitors flow system A2, which includes the Hamilton-Standard deep mine complex in the Brookville coal. The monitoring well was developed specifically to:

a. Observe fluctuations in the static elevation of the mine reservoir.

b. Allow chemical sampling at mine reservoir in lowest (structural) mined area.

c. Serve as a dye injection point for aquifer interconnection study.

Monitoring Well R2 (Sample Station 10)

This well was developed to monitor flow system B2. This flow system was excluded from study at the artesian well due to casing/ grouting constraints.

Monitoring Well R3 (Sample Station 11)

This well was developed to monitor flow system B3. This flow system is the upper most system studied at the artesian well and has been subsequently identified as the lowest "degraded" aquifer in the study area. This degradation was most prominent at the flowing artesian well, less prominent at this station.

Monitoring Well C1 (Sample Station 12)

This well was developed to monitor flow system B6. This flow system is the lowest system studied at the artesian well. This well was cored prior to casing and grouting and serves as the lithologic marker hole for correlation purposes for Wells R2 and R3 which were just adjacent to this monitoring well.

The reviewer is directed to reexamine sheets 5 and 6 of the plans which show the geophysical and stratigraphic conditions at each piezometer.

3. Physical/Chemical Analysis of Groundwater Data

The physical/chemical analysis of the groundwater sampling points will rely heavily on the use of three statistical measures:

a. Regression analysis - this statistical procedure will be the principle method in which we will describe relationships between parameters and infer trends for each given parameter of concern. A principle measure of importance will be the multiple correlation coefficient which will be used to gauge the strength of the relationship (or trend).

b. Standard deviation - this statistical measure quantifies the variance. Remember that the standard deviation given on the analysis sheets in the appendices represents the magnitude of one standard deviation. As previously discussed, we will model the field of variation as two standard deviations (approximately 95% level of significance).

c. Analysis of variance - this procedure was used by the author to evaluate the regression analysis results and select that analysis which statistically is the most significant, by utilizing the F-test procedure when appropriate.

The relationships we will examine for groundwater sampling points are:

Specific Conductance vs. pH
Specific Conductance vs. Alkalinity
Specific Conductance vs. Acidity Specific
Conductance vs. Total Iron Specific
Conductance vs. Ferrous Iron Specific
Conductance vs. Ferric Iron

A graph accompanies each chemical specie relationship to allow the reviewer to visually assess the relationship. Additionally, sheets 28, 29, 30, and 31 show the data plotted on a time relationship basis for the monitoring period.

Due to the extensive amount of data and analyses (approximately 20 sheets per sample station), the physical and chemical analyses will be presented as appendices 9, 10, 11, and 12 (corresponding to the sample number) contained in the back of the report.

The summary of this section of the report will be divided into three phases of examination:

Pre-closure analysis (background)
Closure analysis
Post-closure analysis

4. DYE STUDY OF AQUIFERS

A dye injection and routing study was undertaken to' determine the interconnection and the degree of interconnection between the flow systems. Additionally, a time of travel assessment could be made.

The principle objective was to inject a large slug of dye into the Hamilton-Standard underground mine pool. As the dyed water moved out of the mine, we would be able to trace its occurrence. We utilized 50 pounds (18.925 liters) of 20% Rotamine WT fluorescent dye. Several possible paths existed for the migrating dye. To determine where the dye went, the following monitoring points were monitored:

Surface Water Sample Station

3 - Slippery Rock Creek (north of mine)
4 - Flowing artesian well (west of mine)
5 - Surface mine discharge (south of mine)

Groundwater Sample Stations (R2, R3, CI)

10 - Flow Zone B2
11 - Flow Zone B3
12 - Flow Zone B6

Flowing Artesian Well Sample Stations

13 - Flow Zone B3
14 - Flow Zone B3
15 - Flow Zone B4
16 - Flow Zone B4
17 - Flow Zone B5
18 - Flow Zone B5
19 - Flow Zone B6
20 - Flow Zone B6

Domestic Well Sample Stations

W1 - Flow Zone A3
W2 - Flow Zone BI
W3 - Flow Zone BI
W4 - Flow Zone B6
W5 - Flow Zone A2
W6 - Flow Zone BI -

*These monitoring points located in and near Hilliards, PA and shown on sheets 2 and 3 of plans.

1. DYE INJECTION PROCEDURE

The dye injection into the mine reservoir was accomplished by utilizing monitoring well RI-B. However, this meant that further sampling of RI-B would have to be terminated to prevent contamination of the well sampling device. For this reason, the dye injection was scheduled after completion of the background sampling and closure phases of the groundwater/artesian well programs.

On 6/12/83, dye was injected into RI-B. The amount of dye used is discussed below:

A. Dye Injection Calculations

I. Background fluoresence was measured prior to injection. The typical values were in the range of 0.00 - 0.15 parts/ billion (ppb).

2. The mine pool which existed at the time of injection was estimated to extend approximately 23 acres. Assuming a 4' nominal depth and correcting for decreases in depth near the edge of the pool; the pool volume was estimated to be 26 million gallons.

3. The dye was 20% (weight) Rotanine 'T. Five (5) gallons of dye were injected into the mine. The calculated concentration of dye in the mine pool after injection was:

GIVEN:

238,000 mg/l	20% weight
5 gal x 3.785 L/gal =	18.925L

THEN

$$\frac{(18.925L)(238{,}000\ mg/l)}{(26{,}000{,}000g)(3.785\ l/g)} = .045769\ mg/1 \quad 45\ ppb$$

4. Generally, a five-fold (5x) increase in background fluoresence is sufficient to positively correlate the presence of dye. Smaller increases can still indicate the occurrence of dye. Since our background generally was .15 ppb., then .75 ppb concentration would be adequate to show occurrence of migrated dye.

5. The factor of safety for this dye injection study can be calculated as follows:

Concentration of uniformly dyed reservoir = Safety factor minimum concentration to show occurrence

or

$$\frac{45\ ppb\ (reservoir)}{.75\ ppb\ (required)} = 60\ (Safety\ Factor)$$

6. The safety factor of 60 allows considerable dilution to occur as the dye moves outward from the reservoir. This was necessary since the author believed the dye would migrate significantly in both the horizontal and vertical directions.

B. Dye Injection Results

The results of the dye testing are shown on the following sheets:

Sheet 19 - Sample 20
Sheet 20 - Sample 19
Sheet 21 - Sample 18
Sheet 22 - Sample 17
Sheet 23 Sample 16
Sheet 24 - Sample 15
Sheet 25 - Sample 14
Sheet 26 - Sample 13
Sheet 27 - Sample 4
Sheet 28 - Sample 9
Sheet 29 - Sample 10
Sheet 30 - Sample 11
Sheet 31 - Sample 12

The first occurrence of dye was noted at Sample Station 10 (Monitoring Well R2) as shown on Sheet 29. The dye reached this point rather quickly (18 days) and peaked within 40 days following injection.

The dye showed up at monitoring wells R3 and CI (sample Station 11 and 12) as shown on sheets 30 and 31. The time to first occurrence (28 days) and time to estimated peak (45 days) were longer than observed at R2. Four important conclusions could be made at this point:

I. The dye concentration (fluoresence) measured at R3 and CI was significantly less than that at R2 monitoring well.

2. The concentrations, occurrence time, time to peak and duration were almost identical for R3 and CI wells.

3. The additional five days between time to estimated peak at Station 10 (40 days) and time to estimated peak at Stations 11 and 12 (45 days) is presumed to be due to the <u>vertical</u> migration component since all three wells are approximately the same horizontal distance from the injection well.

4. Estimated gross velocities (uncorrected for differential horizontal and vertical velocity components) are estimated below:

Sample Station 10

Linear distance = 2950 ft. = ,051 ft' _2.55 x 10-2 an Tim to peak
57600 min. min.
sec.

Sample Station 11

Linear distance = 3050 ft._ _ , 047 f t' _2.35 x 10-2 am Time to peak 64800 min. min. sec.

Sample Station 12

Linear distance _ 3500 ft. = .054 f t 2.70 x 10-2 an
Tim to peak 64800min. min. sec.

The dye appeared in the artesian well approximately 45-60 days after injection. The dye concentrations were markedly reduced compared to the concentrations observed at the monitoring wells.

The results of the dye study for each sample station monitored in Bertha are shown on the appropriate sample station sheets (Sheet 19 to Sheet 26 inclusive).

I. Dye appeared first in the upper zones of the well, specifically at sample stations 13 and 14. The first occurrence was approximately 45 days after injection with peaks occurring after approximately 70-80 days. The concentration of dye at the well was reduced somewhat compared to that observed in the same flow system at monitoring well R3. This is probably due to dispersion of the dye plume or front coupled with dilution as the dye encounters greater volumes of water the further the dye moves away from the injection point.

2. Dye subsequently was found in the lower zones of the artesian well)sample stations 14 - 20 inclusive). The first occurrence was approximately 50 days after injection with peaks occurring after approximately 70r80 days. The concentration of dye at the well was reduced substantially compared to the levels observed at Well CI.

3. Estimated gross velocities (uncorrected for differential horizontal and vertical velocity components) are estimated below for the following:

Sample Stations 13 and 14

Linear distance = 4150 ft. =.041 f t 2.05 x 10-2 cm
time to peak 100800 min. min. sec.

Sample Stations 15 through 20

$$\frac{\text{Linear distance}}{\text{Time to peak}} = \frac{4500 \text{ ft}}{100800 \text{ min.}} = .044 \; {}^{f}t \; 2.20 \times 10^{-2} \text{ minsec.}$$

No dye was found at any of the six locations sampled at Hbilliards (WI W6), indication a preferential movement of groundwater towards the artesian dell.

Dye was also <u>not observed</u> at sample station 5 (strip pit reservoir discharge). The author feels that the discharge is hydrologically upgradient from the underground mine pool.

Dye was certainly present at sample station 3 (since the flowing artesian well discharges into Slippery Rock Creek above sample station 3); however the concentration was masked by excessive dilution and could not be distinguished from background levels.

Several notes with regard to dye studies should be interjected at this point:

1. The samples collected for dye studies are usually 20 ml vials. Proper sampling requires several (typically 2 or 3) vials to be taken at each site. This is to provide replicates and to prevent erroneous readings from previously contaminated vials (that is, vials with high background fluoresence due to inadequate cleaning procedures).

2. The fluoresence is measured on a flurometer, generally at the office. however, the flurometer is portable and can be utilized for field (flow through) studies.

3. No <u>hard-copy</u> analyses are generated by the flurometer, rather the range and scale. are set and read from a meter.

5. ADJACENT WATER WELL RECONNAISSANCE

A cursory reconnaissance (6/7/83) and dye monitoring study was conducted in the hilliards area to assess the (potential) occurrence of dye (due to interconnection of aquifers being studied at the site). Six locations were initially sampled for chemical parameters and background fluoresence. The owner, well characteristics, and correlation to zones sampled for this report are listed below, and a copy of the chemical analyses are shown on the following page.

Well	Owner	Well Characteristics	Zone
W1	Merle Cook	8' deep - hand dug - 3' to water	A-3
W2	Joe Graham	44' deep - drilled - 6' to water	B-1
W3	Mertz Graham (also serves A. Douglas)	25' deep - hand dug - 8-10' to water	B-1
W4	Hilliards Methodist Church	200' deep - drilled - depth unknown.	B-6
W5	Florence Walker (also serves 6 other residences)	Spring - 3' catchment	A-2
W6	Paul Montgomery	205' deep - drilled - 55' to water	B-1

Bi-weekly samples of fluoresence values (p.p.b.) were taken at the following points to check for dye occurrence:

Date	W-5 (Zone A-2)	W-1 (Zone A-3)	W-3 (Zone B-1)
6/07/83*	.10	.10	.08
6/16/83	.08	.14	.10
6/29/83	.12	.06	.12
7/10/83	.06	.08	.08
7/26/83	.08	.10	.06
8/06/83	.12	.10	.10
8/21/83	.08	.12	.12
9/22/83	.06	.08	.08

*NOTE: This sample served as background value for comparison

'epartment of Environmental Resources
awk Run Treatment Plant
. O. Box 209
awk Run, PA 16840
(…-342-4221)

MINE DRAINAGE ANALYSES

Indicate mailing address for results:

Gwin, Dobson & Foreman, Inc.
2900 Fairway Drive
Altoona, PA 16603

Consultant ____ & In

Sampled by Mining Department

Date Collected 6-7-83

mple mber	Source	Receiving Stream	Project Number	Lab No.	pH	Acid	Alk.	Fe total	Fe^{+2}	SO_4	Extra
11	Well	Slippery Rock Creek	SL-110-7 101.5	4014	5.99	1	26	59.0	5.35	465	
12	"	"	"	4015	6.94	0	66	43.0	35.0	411	
W-1	"	"	"	4016	6.09	0	58	0.2	0.1	74	
W-2	"	"	"	4017	6.60	0	84	1.7	1.5	21	
W-3	"	"	"	4018	5.31	3	9	0.9	0.3	60	
W-4	"	"	"	4019	6.71	0	114	0.4	0	29	
W-5	"	"	"	4020	5.98	3	10	0.2	0	25	
W-6	"	"	"	4021	5.91	0	16	13.8	0.5	33	
	"	"	"								
	"	"	"								

RES. MGMT. D.E.R. JUN 23 1983 EBENSBURG, PA

Comments Rec'd 6/9/83

GROUNDWATER HYDROLOGY SUMMARY

Several aquifers were determined to exist in the subsurface below the deep mine/surface reprocessing operation. Examination of the aquifers revealed the following results:

Pre-Closure Analysis

I. All of the flow systems below the mines examined were sufficiently confined to exhibit artesian tendencies at the flowing artesian well as determines by multiple tracer flow determinations.

2. Each flow system contributed a unique yield (recharge) to the artesian well, governed by the effective permeability of the strata.

3. The artesian well (following construction) exhibited steady state discharge conditions and each flow system also maintained stable recharge conditions. The well was totally unaffected by precipitation events. Grouting the upper flow systems (BI and B2) virtually assured that the remaining aquifers would be deep-seated, extensive regional entities.

4. Monitoring of the piezometers indicated that the upper flow systems had a higher head (potential) than did the lower flow systems.

5. Each flow system exhibited a unique chemical identity. The fol lowing similarities and generalizations can be made:

   a. The upper flow systems had groundwater with significant duration. These systems generally exhibited acidic, high sulphate, high iron waters.

   b. The lower flow systems had groundwater which was highly alkaline, with little or no acidity, and moderate to low sulphate and iron concentrations.

Closure Analysis

1. Closure at the artesian well caused significant increases in static Hater levels simultaneously and to similar degrees (magnitude of increase) indicating that all the subsurface flow systems are interconnected.

2. Physically, closure of the flowing artesian well removed a discharge point for all of the aquifers defined in this study. This allowed the aquifers to pressurize. The following chart shows the increases in static water elevation (due to pressurization) and increased head (in parenthesis) for each well during the study period (relative to value at closure), allowing an assessment of the maximum rise in head for these aquifers.

Date	R1-B	R-2	R-3	C-1
5/04/83	1229.0(begin)	1241.5(begin)	1226.5(begin)	1226.5(begin)
5/11/83	1235.5 (6.5')	1245.5 (4.0')	1234.5 (8.0')	1234.5 (8.0')
5/19/83	1237.0 (8.0')	1244.0 (2.5')	1234.5 (8.0')	1234.5 (8.0')
5/25/83	1239.0(10.0')	1245.5 (4.0')	1233.0 (6.5')	1233.0 (6.5')
6/01/83	1239.0(10.0')	1245.5 (4.0')	1233.0 (6.5')	1233.0 (6.5')
6/07/83	1240.5(11.5')	1245.0 (3.5')	1234.0 (7.5')	1234.0 (7.5')
6/12/83	1239.0(10.0')	1244.0 (2.5')	1232.0 (5.5')	1232.0 (5.5')
6/16/83*	1239.0(10.0')	1243.5 (2.0')	1231.5 (5.0')	1231.5 (5.0')

*NOTE: Gate valve reopened at flowing artesian well.

3. Closure did not appear to introduce or cause any significant chemical changes at the piezometers (Sample Stations 10-12); however, at the artesian well" localized" effects were noticed during sampling immediately after reopening the gate valve in the same flow systems. The increased mine pool level (sample 9) appeared to introduce "stability" of sampled concentrations which fluctuated significantly during pre-closure.

4. Closure did not cause an increase in the mine pool level to the extent that a discharge was evident nor did closure affect the surface mining operation.

5. Closure levels in the mine pool and the monitoring wells could be elevationally correlated very well with the calculated elevation at the artesian well (due to the observed pressure head). Additionally, the response characteristics at closure, during closure, and 'immediately after reopening indicate an interconnection of flow systems

Post Closure Analysis

1. Dye injection studies indicate that all the subsurface flow systems examined are interconnected to some degree as the dye could be reliably identified in each flow system.

2. No chemical changes were observed in the piezometers that could be directly attributed to post closure conditions.

3. Same decrease was noted in all the monitoring wells static water elevations followed by a stability in elevations.

Interpretation of the above results leads to an apparent paradox:

> How can flow systems which appear to be physically and chemically unique and which exhibit stable, constant tendencies be interconnected?

The answer lies' in understanding the properties of a classic hydrologic entity, the leaky aquifer.

A leaky aquifer is formed by semi confining (partially permeable) beds which allow some inflow from, and outflow to adjacent (overlying/underlying) aquifers yet the majority of the water in the aquifer occurs as a result of horizontal flow in the aquifer from the recharge area.

At this site, the upper flow systems (B1 - B3) are sufficiently permeable (leaky) such that they have been degraded while the amount of inflow to the lower flow system is not significant enough to overcame the normal chemical tendencies of the flow system and they remain undegraded.

The cutoff between degraded and unaffected flow systems has been determined to be at the base of the flow system B-3 and the top of flow system 4.