GEOLOGY

Since the time of the first Pennsylvania Geologic Survey, 1836 to 1858, geologic investigations concerned with surface geology, stratigraphy, structure, sedimentation, glaciation, hydrology, coal resources, and mine drainage have been carried out in Western Pennsylvania and the Slippery Rock Creek Watershed. Results of these investigations are detailed in the excellent geologic reports on the area. Due to the extensive number of these available reports, it would be redundant to explicitly detail the geologic investigations and interpretations contained in each report. Therefore, we will present the general geologic setting of the project site for reference purposes and move directly into site-specific data collected for this report.

Geologic Setting

The strata present at this site which are important in regard to coal extraction are of Pennsylvanian age, specifically the Pottsville and Allegheny groups of formations. The most important coal seam from a historical standpoint is the Brookville coal which has been extensively mined in the study area. The Brookville coal is extremely variable in structural continuity with numerous rolls and minor structural features. The Middle Kittanning coal is the second most important coal seam from a historical standpoint; although it is principally extracted as a surface mining operation. This coal is also highly persistent and extremely uniform in structural aspects.

The strata present at this site which are important in regard to gas and oil extraction are of Mississipian age, specifically the Burgoon sandstone (locally called "Mountain sandstone"). The depth of the abandoned flowing artesian well known locally as "Big Bertha" was measured at 300'. This places the well approximately 320'± below the Brookville coal. This correlates with the Burgoon sandstone by interval and stratigraphically fits well.

A regional hydrogeologic features map is included (Sheet 10). This was adapted from PA Geological Survey data which this author considers to be excellent, and is further described below.

Regional Hydrogeologic Features

A map showing the important regional hydrogeologic features has been developed from information and mapping supplied by the Pennsylvania Geologic Survey and others.

The map shows the watershed boundary making up the project area for this study. The deep mines developed in the Brookville coal seam are shaded. The locations and extent of the deep mines were supplied by the Pennsylvania Geologic Survey from mine maps and tracings obtained from operators, consultants, and other sources.

The location of the outcrop (contact) of the Brookville coal seam is also shown. The Brookville coal forms a conspicuous marker bed throughout the area. The author has classified the flow systems or aquifers in the study area (see Sheet 8 of plans). The Brookville coal seam then marks the position of the base of flow system A2.

Review of the location of the Brookville coal seam outcrop indicates that nearly all strata situated below the Brookville outcrop are not exposed as a surface outcrop, rather these lower strata are deep-seated. Based on these physiographic and stratigraphic observations, this author caned the flow systems at the site into two classes:

A - all flow systems occurring at or <u>above</u> the regional drainage (Brookville coal seam horizon) are coded with a capital "A" excluding the horizon immediately below the Brookville coal which makes up the flood plains and is probably alluvium (coded as."A3".)

B -all flow systems occurring <u>below</u> the regional drainage (Brookville coal seam horizon) are coded with a capital "B".

The regional groundwater flow direction is controlled by the attitude of the strata at the project site. Structural contours developed by the Pennsylvania Geologic Survey (on the Middle Kittanning horizon) indicate regional flow directed south to 30° west of south, as shown on sheet 10.

<u>Geophysical Logging Methods</u>

Geophysical logging involves lowering sensing devices into a borehole and recording a physical parameter that may be interpret <u>d</u> in terms of formation type and characteristics, groundwater quality, groundwater quantity and movement, and borehole structure.

Two types of logs are commonly used when evaluating geologic and hydrologic parameters:

(1) Physical Logs
(2) Radiation Logs

The physical logs we utilized at this site are:

(1) Caliper - this provides a record of the average diameter of a borehole.

(2) Temperature - this measures and provides a record of the thermal gradient in the well when water is present. If a stand (no flow) exists, a definite increase in temperature with depth will be noticeable. If flowing (artesian) conditions are present, then no gradient will exist in the producing zones and the temperature log will appear vertical.

(3) Fluid Resistance - this measures the electrical resistance in the well when water is present. The resistance properties of water are related to the amount of dissolved solids and the temperature, so this is useful in determining mineral rich waters, saline zones, dilution tendencies, etc.

(4) Self-Potential - this measures the natural electric potentials in the earth. These are useful in determining permeable zones (in a relative fashion); and in estimating specific conductance of groundwater.

(5) Single-Point - this is a resistance log which measures the lithology (in a relative fashion) and can be, used to determine and distinguish fresh and saline waters in surrounding rock.

The radiation logs we utilized at the site are:

(1) (Natural) Gamma - this measures the natural gamma radiation which all rocks emit. The natural tendency of clay and shale formations to snit <u>significantly more</u> gamma radiation than quartz sandstones and carbonates make this log ideally suited for determinations of lithologies.

(2) Gamma/Gamma - this measures the "reflectance" properties of the strata and hence the gamma-gamma log is very useful for lithologic determinations. Additionally, certain rocks 'nave unusual gamma reflectance properties and they "stand out" as anomalously high readings in a gamma-gamma log (for example: coal and carbonaceous shales give large magnitude readings).

(3) Neutron - this measures the moisture content (or porosity) by measuring and correlating the hydrogen content associated with the water in the strata.

<u>Interpretations of Geologic and Geophysical Logs at R1-B</u>

Sheet 5 shows the geophysical logs made at R1-B and the conventional geologic logs compiled by the author from drill chips at the site.

The caliper log shows a relatively uniform hole with a minor broken zone at 50' and a major broken zone at 85'. Both zones are shale/sandstone contacts where this might be expected to occur.

The gamma ray logs indicate lithologies, and there is good agreement with this log and the conventional geologic log. Note that shale sequences are on the right while sandstones tend to the left. Both the gamma-gamma log and the single point show no significant trends or anomalies.

<u>Interpretation of Geologic and Geophysical Logs at R2, R3, and C1</u>

Sheet 6 shows the geophysical logs made at R2, R3, and C1 and the conventional geologic logs compiled by the author and Mr. Cliff Dodge (PA G.S.) from core hole data.

The reviewer should note that the principle difference between the geologic logs of the author and Mr. Dodge is centered on nomenclature. The designation of shales (by the author) and claystones (by Mr. Dodge) are interchangeable between logs.

The caliper log (below 60' surface casing) shows a relatively uniform hole.

The gamma ray log indicates lithologies which very closely correspond with the conventional logs. Note the prominent sandstone representations at 70'-90' and 210'-270' which are conspicuously left justified as expected.

The gamma-gamma ray log shows four spikes which are to the right of the center (at 55', 95', 125', and 180') indicating the coal seams and a spike at 65'-70' indicating sandstone.

The single point log also shows zone at high conductance (highly mineralized) from 210'-270' which corresponds well with the sandstone shown on the conventional log.

It should be noted that true piezometers were constructed at each of these wells such that water cannot flow interchangeably between zones. Therefore, we will not discuss the water temperature logs in detail for these wells.

<u>Interpretations of Geologic and Geophysical Logs at Big Bertha</u>

Sheet 7 shows the geophysical logs made at the artesian well site and the interpretation of the litholgies present based on stratigraphic data from other drilling at the site, structural projections, and the geophysical logs.

The caliper log shows casing to 58 feet, and also indicates the deformation of the casing at the bottom which occurred during placement. The casing was subsequently extended to 72' approximately. Three broken zones are extremely evident. The first is a sharp small zone at 62'. The second is extremely large in diameter extending from 72' to 77' approximately. The third zone occurs between 120' and 130'. All three zones occur where lithologic changes are occurring and where water was later determined to be moving strongly.

The fluid resistivity log shows only one anomaly of interest; a sharp decrease in resistivity occurs at 180' indicating an increase in the specific conductance of the water may occur below that depth. Subsequent investigations determined that conductance does sharply increase at the anomaly area.

The temperature log shows three anomalies of importance. First, at 180' there is an increase in temperature and the beginning of a partial thermal gradient below this zone. This indicates very slowly flowing water. This has been subsequently confirmed by dye investigations of the artesian well recharge systems. This 180' anomaly also corresponds very well with the observed fluid resistance change. Second, a marked decrease in temperature was observed at 110' indicating the influx of colder (shorter residence) water into the well. Third, at approximately 72' another change in water temperature occurs indicating the occurrence of another water source being introduced above this zone. This also correlates well with the broken zone shown on the caliper log.

The gamma ray log indicates the lithologies present and is generally in good agreement with those presented by the author. The sandy/silty sequences which occur above 60' are represented well. The shale/clay sequences which occur between 60' and 120' also are well correlated (as they are right justified on the log.). The prominent sandstones which occur between 120'-210' (Connoquenessing) and 225'-285' (Burgoon) are very evident in the log. The shales which separate these sandstone bodies also show up prominently on the log (210'-225'), where they are right justified.

The gamma-gamma log yields no new or significant information. The reviewer will notice that three significant peaks occur to the right (at 62', 72'-77'; and 125') and one significant peak occurs to the left (at 58'). The reviewer is now referred to the previous discussion of the caliper log and note the near exact correspondence between the gamma-gamma peaks and those portions of the drill hole where broken (large diameter) zones occur. Since the gamma-gamma log measures reflectance from a downhole source, the wider the hole the less the reflectance. These peaks in the gamma-gamma log are pseudo-peaks caused by hole diameter variance.

The single point log dramatically shows the difference in conductance at the water below 180'. Two less prominent increases are shown at beginning at 80', and beginning at 125'. The anomaly at 58' is deemed as casing effects (close proximity bias).

The neutron log indicates zones above 120' as having more moisture content thus significantly more porosity than lower zones (which are right hand justified). A notable high moisture content zone also occurs between 200' and 220' which corresponds somewhat with the shale zone present.

The self potential confirms earlier logs such that zones below 180' are more mineralized (higher conductance) and that significant permeability changes occur at 180', 120', 90', 72', and 62' (which also corresponds well with previous logs).

Stratigraphic Correlations

a. Geologic Cross-Sections

Utilizing the data available from the drilling program, the geophysical investigations, physical reconnaissance of the site, survey information, and structural information obtained from mine maps, a geologic cross-section was developed. The section line is shown on Sheet 3.

The cross-section is on two sheets contained in the plan:

Sheet 8
Sheet 9

The cross-section is supplemented by the inclusion of geologic and hydrologic data as presented on Sheet 8:

Geologic series
Geologic group of formations
Significant geologic memoirs, beds,
markers Hydrologic zones
(1) A zones - perched aquifers
(2) B zones - regional aquifers which are artesian in nature
(3) Lower zones - regional aquifers Which are not coded due to insufficient data.
Samples zones corresponding to monitoring points
Baseflow yield/zone (each zone) Cumulative yield/zone (progression up well column) Description of Aquifer indicating:
Type of Aquifer
Confining Member(s)
Conducting Member(s)
Yield information
Location of Monitor wells, artesian well
Lithologies
Mine Workings

HYDROLOGIC MONITORING CONSIDERATIONS

Two general areas of concern must be considered when developing a monitoring program. They are:

1. Selection of Monitoring Points

   This includes considerations of the purpose of the monitoring point, the selection of the physical location, and device(s) to be used at that location.

2. Methods of Data Analysis

   This involves a decision as to what method or group of methods will be used to analyze the monitoring data collected. The decision is contingent to a considerable degree on the desired goals of interpretation and the format chosen to display the interpretations of the author.

The author will present a general description of the monitoring points and methods of analysis; both are supplemented by narratives pertaining to the specific monitoring location and data contained in the appropriate appendices.

1. SELECTION OF MONITORING POINTS

The monitoring at the site is divided into four phases of work:

Precipitation Monitoring

The precipitation at the site was recorded hourly and compiled into daily values for comparison of volumes of precipitation and subsequent increases in. discharges.

a. A continuous recording rain gauge was installed at the site. This device recorded on an hourly interval the rainfall which occurred at the site. The charts were divided into .01 inch intervals and were changed weekly.

b. The rainfall records of the water treatment plant north of Butler, PA were collected for comparison.

c. The gauge was installed in an open area adjacent to the artesian well. This allowed use of the storage box at the well for protecting the chart recorder from rain and vandals.

Surface Water Hydrology Monitoring Points

The normal procedure for monitoring a discharge and gauging its effect on a stream would involve a monitoring point in the stream above the discharge (for background up gradient assessment); a monitoring point at the discharge proper; and a monitoring point below the discharge (for assessment of the impact of the discharge by comparing parameters to the background upgradient point).

At this site, however, a special case exists where several discharges enter an artificially created duck pond constructed for wildlife management purposes. Therefore, we were unable to develop a unique upgradient/downgradient monitoring point for each discharge source. Instead, we developed a "systems" approach where several sources enter between the upgradient and downgradient monitoring points .

The systems approach allows for an assessment of the contribution of a group of sources to the stream. Consideration of any individual source should be made by comparison with the, downgradient monitoring point.

For the purposes of this report, two surface flow systems were established and monitored, as further described in the surface water hydrology section.

The locations of the surface monitoring points are shown on Sheet 2 - General Location Map, designated as sample stations 1 through 8. The physical devices used to collect the data are described below:

1. One continuous discharge recorder - a Sigma Motor bubbler - was established at a location along Slippery Rock Creek, sample station 3.

2. One staff gauge was established to record the relative level of the stream where the continuous flow recording device (bubbler) tube was measuring.

3. The purpose of these device. is to provide a measurement of stream stage at each location. A continuous graph reads % of maximum stage and allows determination of continuous flow records.

4. Eight weirs to measure surface water flow, with staff gauges for calibration of stages.

   a. Five were 6' x 18" rectangular weirs capable of measuring up to 35 cf., at sample stations 2, 3, 6, and 7.
   b. One was a 12" v-notch weir capable of measuring up to 2.4 cfs., at sample station 5.
   c. Two were 6" v-notch weirs capable of measuring up to 0.4 cfs, at sample stations 4 and 8.
   d. Eight staff gauges were established to record the level of the weir pool, one guage to a weir.

5. One staff gauge was established to record the level of the surface mine pool.

Artesian Well Hydrology Monitoring Points

The artesian well was examined using multiple dye tracer tests to determine flow directions, yield for each zone tested, and cumulative yield (progressive) from the bottom of the well to the top. Zones were then further defined by lithologies determined to be present from stratigraphic correlation. and geologic/geophysical data available.

At this point, the well could be divided into 7 zones, all of which had some potential to act as an independent chemical system. These are shown on Sheet 8.

However, several zones had the same approximate yield (effective permeability) indicating that the zones may be similar in characteristics or have similar pressure heads (due to possible interconnection).

The strategy of the artesian well monitoring program was to sample each zone possible as outlined below:

Zone B1 -	unable to sample due to casing and grouting con struction.
Zone B2 -	unable to sample due to casing and grouting con struction.
Zone B3 -	sampled near top of zone (Sample 13) sampled near base of zone (Sample 14)
Zone B4 -	sampled near top of zone (Sample 15) sampled near base of zone (Sample 16)
Zone B5 -	sampled near top of zone (Sample 17) sampled near base of zone (Sample 18)
Zone B6 -	sampled near top of zone (Sample 19) sampled near base of zone (Sample 20)

This sampling scheme allows the reviewer to assess the chemical conditions as flow progresses from one zone to the next. Generally, samples near the base of each zone represent water from the lower zone combined with water from the zone of interest which are not fully mixed (reacted), while samples near the top of each zone represent waters after they are fully mixed and shows the impact of water added from that zone, when compared to water from the top of the lower zone. Note: Zone B7 is a "combination" of all possible zones below 210' which cannot be sampled due to a packer which is wedged at that depth.

The physical devices used to collect the data are described below:

1. Continuous discharge measurement recorders. One continuous discharge recorder - an ISCO bubbler - was established at the artesian well weir, sample station 4.

2. Gate Valve/Pressure Gage Assembly. These are shown on Sheet 4. The purpose of this assembly was to allow the author to close off the flow at the artesian well and observe any subsequent increased head (pressurization) in the flow systems present.

3. Each zone (Sample 13 through Sample 20) was sampled using a discrete interval well sampling device which allows water representative of the well at that depth to be isolated and recovered unmixed.

Groundwater Hydrology Monitoring Points

The groundwater hydrology of the area is really a combination of the data developed from the 4 monitoring wells and the artesian well data. However, since we have already discussed the development of the artesian well sampling points, the discussion here will be limited to the development of groundwater monitoring well sample points.

Previous authors (Complex Ground-water and Mine-Drainage Problems from a Bituminous Coal Mine in astern Pennsylvania, D.R. Thompson,, Bull. of Assoc. of Eng. Geologists, Vol. IX, No. 4, 1972) have equated the groundwater problems which show up at the artesian well to a combination of deep mine (Hamilton-Standard) and surface mine (Lucas Coal Co.) sources which are hydrologically connected with water moving from the deep mine to the artesian well. A principle irethod of determining the accuracy of the previous examination is to place monitoring wells at the following locations:

1. Monitoring Well R1-B

This well is placed in the deep mine at the lowest (structural) point to observe fluctuations in the deep mine reservoir pool and serve as a dye injection point.

2. Monitor Wells R2, R3, and C1

These wells are placed in unmined strata directly between the deep mine and the flowing artesian well. The reviewer should note that these wells were developed to different depths as true piezometers. The choice of well depths is dependent upon the initial reconnaissance work done at the artesian well. Referring to Sheet 8, the reviewer will note that the yield/zone is similar for zones B4, B5, and B6 while the yield/zone is significantly higher for zone B3 (7 gpm) and B2 (26 gpm) indicating different physical hydrologic conditions. Therefore, the wells we developed monitored zone B2 (monitor well R2), zone B3 (monitor well R3), and zone B6 (monitor well C1) - which is the deepest of the four physically similar zones B3, (B4, B5, and B6) and the lowest zone which can also be monitored at the artesian well.

These wells were constructed such that only the zone being monitored was open to the atmosphere; with every other zone being segregated by casing and the annular space fully grouted. In the zone being monitored the casing was perforated and the annular space was not grouted.

The main purposes of the monitoring wells are described below:

a. Describe the normal static water levels in the confined zones which the wells were developed to measure.

b. Describe the change in static water levels which occurs when the gate valve was closed at the artesian well and the flow zones were pressurized to equilibrium.

c. Describe the background fluorescence for each flow system for dye study purposes.

d. Provide an intermediate location for observance of dye migration.

e. Allow for correlation of physical conditions between one flow system and another.

2. METHODS OF DATA ANALYSIS

The methods of data analysis can be divided into phases of work as outlined below:

a. Selection of sampling parameters
b. Measurement and analysis of samples
c. Development of baseline water quality parameters d.
Interpretation of baseline water quality results

The selection of sampling parameters was dictated by the actual conditions at the monitoring point and type of monitoring required by the contract. Basically, two types of parameters were measured, as outlined below:

A. Physical Parameters

Discharge (c . f . s .) - when applicable
Static water elevation - when applicable
Specific Conductance (umhos/am)

B. Chemical Parameters

PH (laboratory – standard units)
Alkalintiy (mg.L – 4.5 pH)
Acidity (mg/L – 8.5 pH)
Sulphates (mg/L)
Total Iron (mg/L)
Ferrous Iron (mg/L)

The physical parameters are easily measured at the site. Discharge was measured utilizing weirs, current meter devices, and continuous stage recorders. Static water levels were measured using well level electrical continuity probes. Specific conductance was measured by use of a conductivity meter.

The chemical parameters were determined by laboratory analysis using the PA DER laboratory at Hawk Run, PA. Standard EPA methods were utilized for laboratory analysis and results were reported with copies to the author and the Office of Resources Management - Division of Mine Hazards.

An important consideration in the development of baseline water quality parameters is the concept of normal seasonal variation, wherein simultaneous, normal fluctuations in physical and chemical parameters are gauged. Development of baseline water quality parameters utilizing seasonal variation concepts allows the reviewer the capability of assessing the relationship between readily observed changes in physical parameters and the resultant chemical concentration changes. The more uniform the relationship between the parameters being compared, the better the correlation between the parameters. To some extent, correlation values can be considered as measurements of the predictability of an unknown parameter utilizing a known parameter as the predictor.

The generation of a relationship expressing the MEAN baseline water quality parameters is best accomplished by developing a function, which forms a line when graphed, that highly correlates with a plot of the original data. The generation of functions which express the mean tendencies of a data set is called regression analysis.

Regression analysis was performed to develop the baseline water. quality parameters. The chemical parameters to be predicted have been previously listed. The physical parameters which could be used as predictors were also previously listed. The next step is the choice of the most significant (best) physical parameter to be used. Regression analyses using discharge as the physical parameter were performed and regression analyses using specific conductance were performed. The regression analyses were initially performed on the three most commonly reported chemical species in a mine drainage study, that is: acidity, sulphate, and total iron. Comparison of results of the analyses are given on the next page for-the streams sampled in this study:

ACIDITY ANALYSIS

Stream Sample	Regression Correlation Using Discharge	Regression Correlation Using Specific Conductance	Improved Correlation Using Specific Conductance
1	.67	.84	.17
2	.34	.34	.00
3	.70	.80	.10
5	.72	.78	.06
6	.53	.88	.35
7	.58	.56	- .02
Average	.59	.70	.11

SULPHATE ANALYSIS

Stream Sample	Regression Correlation Using Discharge	Regression Correlation Using Specific Conductance	Improved Correlation Using Specific Conductance
1	.78	.94	.16
2	.63	.79	.16
3	.81	.92	.11
5	.31	.41	.10
6	.48	.78	.30
7	.77	.84	.07
Average	.63	.78	.15

TOTAL IRON ANALYSIS

Stream Sample	Regression Correlation Using Discharge	Regression Correlation Using Specific Conductance	Improved Correlation Using Specific Conductance
1	.75	.91	.16
2	.20	.40	.20
3	.81	.86	.05
5	.21	.34	.13
6	.36	.59	.23
7	.29	.12	- .17
Average	.44	.54	.10

The results of the comparison between discharge and specific conductance for use as the primary predictor of chemical concentrations are summarized below:

1. Specific Conductance showed higher correlations to chemical species in all cases except two (approximately 90% of the time).

2. The average increase in correlation was:

11% for correlation of acidity 15% for
correlation of sulphates 10% for
correlation of total iron

In addition, two facts concerning the applicability and use of specific conductance rather than discharge can be stated for the remaining sample stations

1. For the piezometers, where no discharge exists, only specific conductance can be considered. Any regression using discharge will produce a correlation of zero (that is, no relationship exists).

2. For the steady-state flowing artesian well, only specific conductance can be considered. Any regression using discharge will produce a correlation of zero (that is, no relationship exists). For comparison purposes, the correlations for acidity, sulphate, and total iron using specific conductance as the predictor for the flowing artesian well were .84, .94, and .91, respectively.

Finally, the use of specific conductance rather than discharge is well-entrenched in the previous studies. This report further examined the possibility that the simultaneous use of both specific conductance and discharge as predictor might significantly increase correlations. This technique is }non as multiple regression. However, there are methods of isolating the highest correlated predictor and assessing whether the added term(s) are contributing significantly to the estimations. Specific conductance was again determined to be the most significant predictor and the addition of multiple terms (i.e., discharge) did NOT statistically increase the significance of the estimation.

The interpretation of baseline water quality parameters can be divided into three main phases of evaluation:

1. Statistical Evaluation Methods

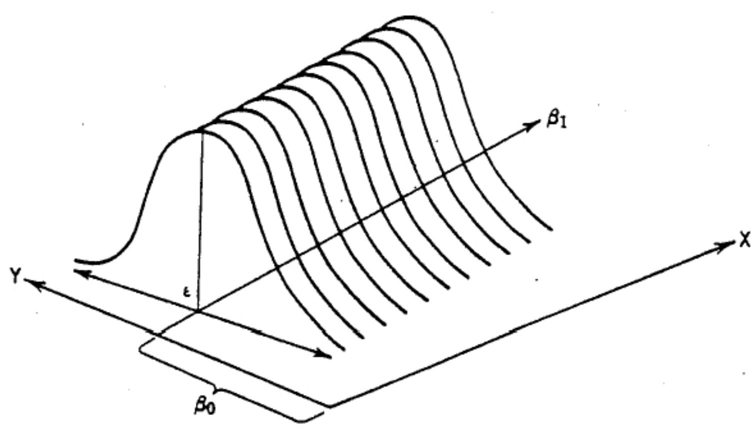
This phase of analysis is concerned with describing the physical and chemical relationships of the individual monitoring point. We wish to develop an estimate of the mean and dispersion of the data for each parameter. We use the regression technique which is explained in detail in Appendix 21. Briefly, the regression technique used is described as follows:

a. A dual-process stepping regression is utilized where the regression estimates X-Y relationships and inverse (Y X) relationships, and continually increases the order of the equation.

b. The appropriate regression which best describes the relationship of the two variables is selected based upon test results of the multiple correlation coefficient, the analysis of variance, and the F-test procedures.

c. The new (regression estimate) mean is displayed on the hydrologic parameter analysis sheets.

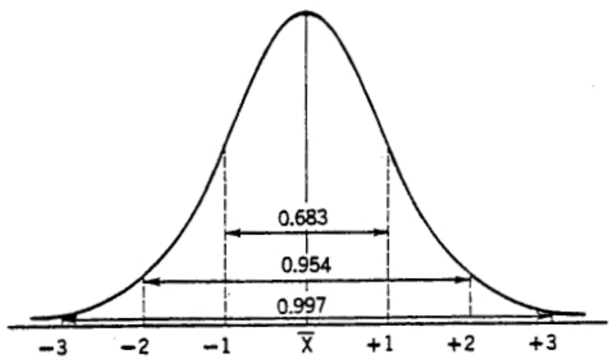
d. The new limits of dispersion are displayed on the hydrologic parameter analysis sheets as the Field of Variance Limit Lines (VH and VL). To better understand how the field of variance limit lines are derived, the following examples are given for each X-Y relationship which is expressed by the regression analysis. -The results of the regression equation are expressed as a line. This line has an intercept (B_o) and one (linear) or more (curvilinear) X-Y estimation teens (having the form: $y = B_o + B X. + B_{2X}2...$). The graphic expression of the components of 'the linear regression model can be seen below.



Components of the regression model $Y_i = \beta_0 + \beta_1 X_i + \epsilon_1$. Error is assumed to be normally distributed about the regression line.

For some value of X, the regression model estimates a value of Y; where the distribution error (variance) of Y values are normally distributed about the mean (Y estimated regression value). For every other X value, the corresponding Y value is an estimate of the mean and the distribution error (variance) is normally distributed.

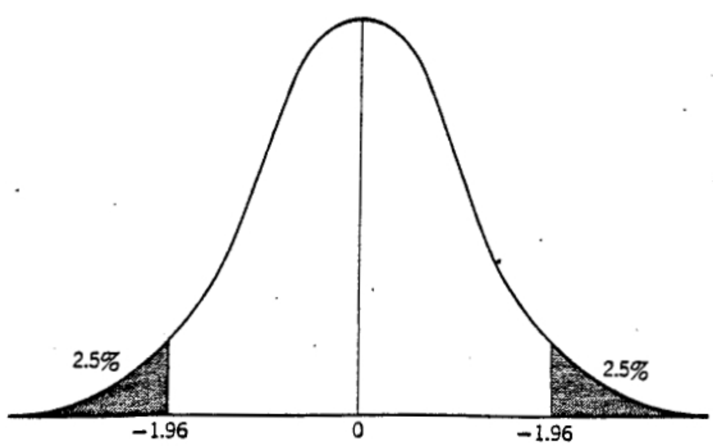
The normal distribution of the Y values about the regression (Y) estimated mean allows for estimation of the distribution (variance) by utilizing standard deviations. We wish to present a model which best represents the mean conditions and shows the expected seasonal variation. We have arbitrarily selected a value of 95% efficiency for the purposes of this report. We then wish to assess the variation to two standard deviations (approximately 95%), as shown graphically below:



Areas enclosed by successive standard deviations of the standard normal distribution.

The value of the field of variance limit lines can be restated as follows:

For each X-Y regression, 95% of the possible observations for those parameters will lie within the field of variance; with only 2.5% occurring above the VH line and 2.5% occurring below the VL line.



Normal distribution curve, with two critical regions (shown by shading) which contain a total of 5% of the area under the curve.

2. Chemical Evaluation Methods

These methods involve the interpretation of trends and relationships developed by analysis of physical hydrologic and statistical methods:

This involves interpretation of regression results and correlation coefficients to determine which chemical parameters or systems are important at a given sample location.

An arbitrary system of assigning relevance to correlation coefficients is outlined below:

Correlation Coefficient	Relationship
.01 - .20	Extremely weak relationship
.21 - .40	Weak relationship
.41 - .60	Moderate relationship
.61 - .80	Strong relationship
.81 - I.00	Extremely strong relationship

B. Chemical Trend Determinations utilizing statistical relationships

This involves interpretation of chemical relationships and physical parameters jointly to evaluate the predictability of a chemical relationship when only the physical can be measured or accurately inferred.

C. Chemical Loadings Estimation

This involves the utilization of the chemical trend determinations to calculate (estimate) the chemical loadings. For the purposes of this report, all loadings have been calculated hourly and summed to achieve the required daily values.

D. Chemical (tracer) Dye Determinations

This involves the injection of dye into an aquifer and then monitoring the movement of the dye. This allows calculation of times of travel, but more importantly allows assessment of the interconnection of aquifers with adjacent flow systems for comparison against piezometer results. The interconnection is proven by finding dye in an adjacent flow system, the degree of interconnection is inferred by the amount of dye present in the adjacent flow system.

3. Abatement (Impact) Evaluation Methods

Impact evaluation of the site centers around the two discharges which are suspected be pollutional in nature and the downstream monitoring points on the receiving stream:

A. Discharge - Sample Station 4 - Big Bertha Well Stream Sample
Station 3 - Slippery Rock Creek

B. Discharge - Sample Station 5 - Strip Pit Outflow Stream Sample
Station 1 - Slippery Rock Creek

The discussion of the potential for removal of pollutional discharges will be addressed in light of the following facts:

Any recommendations made relevant to the discharge at the artesian well (Sample 4) are developed based on the physical and chemical results of the zones tested during this study.

The recommendations made relevant to the surface mine reservoir discharge and associated toe of spoil seepage which may potentially occur must be made to conform to the regulatory aspects of the permit concerning discharges as described below:

NPDES Discharge Requirements:

pH - must be between 6.0-9.0 at all times alkalinity/acidity
balance - alkalinity must exceed
acidity at all times
total iron - instantaneous maximum - 6.0 mg/l
30 day average - 3.0 mg/l
total suspended solids - instantaneous maximum - 70mg/l
30 day average - 35mg/l
manganese - instantaneous maximum - 4.0 mg/l
30 day average - 2.0 mg/l

The form of the abatement recommendations deals with removal of loadings (as opposed to reduction in concentrations) although when possible, the author will also give anticipated reductions in concentrations.

The removal of loadings are expressed as a percent reduction in the downstream receiving stream at the monitoring station.

The recommended abatement methods and anticipated results are developed in the Executive Summary and Recommendations at the front of this report.

PRECIPITATION

Precipitation events were monitored at the site using a bucket rain gauge with automatic chart recorder. The recorder kept continuous 'records of rainfall amounts, with a resolution of .01 inch per step on chart. The chart was divided into hourly increments such that daily values could be calculated by accumulating the hourly values.

The rain gauge was checked weekly and charts were changed at that time. The recorder was kept in a locked steel box and a cable connected it with the bucket rain gauge. The gauge was placed in an unrestricted, open area for full catchment.

The daily values were recorded for the months of April, 1983 through September, 1983 (6 months duration). This period corresponds exactly with the period of record for the two continuous flow recorders, installed at the flowing artesian well and at the trestle station (sample station 3).

For the purposes of comparison, a summary of monthly values for the six month monitoring period is given below for the water treatment plant at Butler and the site (all values are inches of precipitation):

1983 Month	Butler Water Treatment Plant	Site
April	4.08	4.95
May	7.97	7.19
June	3.38	3.46
July	3.88	4.61
August	5.17	7.45
September	2.10	2.24

Daily distributions are given on the next six pages for each of the above locations. All values are in inches of precipitation.

APRIL PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	.00	.00
2.	.02	.08
3.	.45	.36
4.	.16	.20
5.	.00	.00
6.	.10	.14
7.	.39	.35
8.	.13	.10
9.	.48	.60
10.	.37	.35
11.	.28	.19
12.	.00	.02
13.	.00	.00
14.	.00	.73
15.	1.10	.20
16.	.02	.02
17.	.00	.00
18.	.00	.00
19.	.00	.00
20.	.00	.00
21.	.00	.00+
22.	.00	.00+
23.	.00	.46+
24.	.38	.00+
25.	.06	.00+
26.	.00	.00+
27.	.02	.00
28.	.00	.13
29.	.11	1.02
30.	1.00	.00

* Butler records read @ 8:00 AM; Site records read @ 12:00 PM

+ Assumed or calculated values due to interruption by vandalism.

MAY PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	.50	.19
2.	.94	.00
3.	.33	.16
4.	.14	.00
5.	.01	.00
6.	.00	.00
7.	.00	.16
8.	.00	.00
9.	.07	.00
10.	.00	.00
11.	.00	.00
12.	.00	.00
13.	1.00	.60
14.	.00	2.04
15.	.90	.10
16.	.28	.00
17.	.00	.00
18.	.00	.00
19.	.56	.56
20.	.37	.82 +
21.	.00	.00 +
22.	.80	.72 +
23.	1.12	1.24 +
24.	.06	.00 +
25.	.00	.00 +
26.	.14	.00
27.	.00	.00
28.	.00	.00
29.	.00	.60
30.	.75	.00
31.	.00	.00

* Butler records read @ 8:00 AM; Site records read @ 12:00 PM

+ Assumed or calculated values due to interruption by vandalism.

JUNE PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	.03	.00
2.	.09	.00
3.	.00	.78
4.	.96	.12
5.	.00	.00
6.	.00	.22
7.	.16	.00
8.	.00	.00
9.	.00	.00
10.	.00	.00
11.	.00	.00
12.	.00	.00 +
13.	.00	.00 +
14.	.00	.00 +
15.	.00	.00 +
16.	.00	.00 +
17.	.00	.09
18.	.22	.18
19.	.03	.44
20.	.50	.10
21.	.05	.00
22.	.00	.00 +
23.	.00	.00 +
24.	.00	.00 +
25.	.00	.00 +
26.	.00	.00 +
27.	.00	.44 +
28.	.74	.99 +
29.	.60	.08 +
30.	.00	.02

Butler records read @ 8:00 AM; Site records read @ 12:00 AM

+ Assumed or calculated values due to interruption by vandalism.

JULY PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	.56	.00
2.	.15	.15
3.	.00	.38
4.	.80	.64
5.	.45	.14
6.	.00	.00
7.	.00	.00
8.	.00	.00
9.	.00	.00
10.	.00	.00
11.	.00	.00+
12.	.00	.00+
13.	.10	.06+
14.	.00	.00+
15.	.00	.00+
16.	.00	.00+
17.	.00	1.36+
18.	.31	.06+
19.	.96	.06+
20.	.15	.10
21.	.01	.00
22.	.19	.20
23.	.00	.02
24.	.20	.20
25.	.00	.00
26.	.00	.00
27.	.00	.00
28.	.00	.00
29.	.00	.00
30.	.00	.16
31.	.00	1.08

* Butler records read @ 8:00 AM; Site records read @ 12:00 PM

+ Assumed or calculated values due to interruption by vandalism.

AUGUST PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	1.32	1.62
2.	.37	.06
3.	.00	.00
4.	.00	.00
5.	.13	.15
6.	.03	.02
7.	.14	.07
8.	.00	.00
9.	.00	.00
10.	.00	.00
11.	.58	1.42
12.	.12	.00
13.	.00	.00
14.	.00	.00
15.	.00	.00
16.	.00	.00
17.	.00	.00
18.	.08	.00
19.	.00	.12
20.	.00	.00
21.	.00	.76
22.	.00	.00
23.	.00	.64
24.	.00	.44
25.	.00	.00
26.	.00	.00
27.	.00	.00
28.	.05	.05
29.	.23	.26
30.	.00	.00
31.	2.12	1.84

*Butler records read @ 8:00 AM; Site records read @ 12:00 PM

+Assumed or calculated values due to interruption by vandalism.

SEPTEMBER PRECIPITATION COMPARISON (1983)

DAY	BUTLER WATER TREATMENT PLANT	SITE
1.	.02	.02
2.	.00	.00
3.	.00	.00
4.	.00	.00
5.	.00	.00
6.	.02	.02
7.	.72	.74
8.	.00	.00
9.	.00	.00
10.	.00	.00
11.	.00	.00
12.	.01	.01
13.	.03	.03
14.	.00	.00
15.	.00	.00
16.	.35	.39
17.	.46	.52
18.	.00	.00
19.	.00	.00
20.	.00	.00
21.	.45	.49
22.	.02	.02
23.	.00	.00
24.	.00	.00
25.	.00	.00
26.	.02	.00
27.	.00	.00
28.	.00	.00
29.	.00	.00
30.	.00	.00

* Butler records read @ 8:00 AM; Site records read @ 12:00 PM

+ Assumed or calculated values due to interruption by vandalism.