

Attachment F
Groundwater Model Report

A-23
11-9-21 Rtt



V.F. Britton Group, LLC

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

**PRELIMINARY
GROUNDWATER MODEL REPORT
CENTER VALLEY MATERIALS
- SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA**

Prepared For:

The H&K Group, Engineering & Environmental Services Division
2052 Lucon Road
P.O. Box 196
Skippack, PA 19474

Prepared By:

V.F. Britton Group, LLC
326 Conestoga Road
Wayne, PA 19087
(610) 964-1462

March 12, 2020

Val F. Britton, P.G.
Technical Consultant



Table of Contents

1.0	General	4
1.1	Background	4
2.0	Model Construction	6
2.1	General	6
2.2	Numeric Flow Model Construction	6
2.3	Numeric Flow Model Calibration	9
3.0	Simulated Groundwater Flow	11
3.1	Existing Site Groundwater Elevation Conditions	11
3.2	Simulation of Maximum Pit Dewatering Conditions	11
4.0	Summary and Conclusions	13
5.0	Limitations	14
6.0	References	15

Tables

Table 1 – Key Hydraulic Parameters

Table 2 – Calibration - Residual Error of Calibration Points

Table 3 – Parameter Sensitivity

Table 4 – Flow Budget

Figures

Figure 1 – Site Location Map

Figure 2 – Site Layout Plan

Figure 3 – General Model Construction – Boundary Conditions

Figure 4 – General Model Construction - Model Grid

Figure 5 – General Model Construction – Geologic Material Distribution

Figure 6 – General Model Construction – Layer Distribution and Hydrogeological Parameters

Figure 7 – Model Calibration

Figure 8 – Simulation of Existing Groundwater Elevation Conditions

Figure 9 - Simulation – Dewatering of Northern Pit Groundwater Elevation Contour (400 Foot Bench Elevation)

Figure 10 - Simulation – Dewatering of Southern Pit Groundwater Elevation Contour (400 Foot Bench Elevation)

Figure 11 – Simulation -Northern Pit Drawdown (400 Foot Bench)

Figure 12 – Simulation -Southern Pit Drawdown (400 Foot Bench)

1.0 General

1.1 Background

The proposed Center Valley Materials surface mining operation is located south of Springfield Street and east of Route 309 (Bethlehem Pike) just south of Coopersburg, in Springfield Township, Bucks County, Pennsylvania (site). The proposed surface mining operation will consist of two quarry pit areas one located in the northern portion of the site (Northern Pit) and one located in the southern portion of the site (Southern Pit). Figure 1 presents the locations of the site and the two pit areas.

It is anticipated that one pit will be mined to completion prior to moving to the second pit location. The current ground elevation at the mining locations is approximately 600 feet mean sea level (ft-msl) and it is proposed that both pits will be mined to a bench elevation of 400 ft-msl. Both pit locations exist in a relatively flat area underlain by poorly drained diabase bedrock material and as a result, wetland areas exist proximate to the pit locations. A general site layout is provided on Figure 2.

Although no groundwater elevation monitoring wells have been installed on the site area, it is anticipated that a shallow water table exists, likely perched on the underlying poorly drained diabase geology.

The purpose of the preliminary groundwater model discussed in this report is to provide a preliminary numeric representation of the hydro-geologic conditions existing at the site and the surrounding area based on the existing site conceptual model. The model will allow the evaluation of groundwater flow at the site and in the surrounding areas under existing site conditions through numeric simulations based on available hydrogeological published data. The preliminary model will then be used for initial predictive evaluation of the groundwater elevation and zone of influence of the proposed active mining operations at the maximum mining limits (400-foot bench elevation). This preliminary model provides an initial evaluation of the hydrogeological conditions and is based on available published hydrogeological material that characterizes the site conditions. Once site-specific data is collected (i.e. monitoring well water level data, stream flow data, etc.), the model and results will be refined based on the site-specific data.

Limited hydro-geologic data has been collected by others related to site characteristic data; however, the data that has been collected has been relied upon for the construction of the groundwater model. It is not the intent of this groundwater model document to describe the methods used to collect this data, however, in some cases a brief explanation of the quality of the data is discussed where interpretation is warranted.

Groundwater Modeling Systems (GMS) software, Version 10.1, developed by the United States Department of Defense and distributed by Aqueveo, Inc. was utilized in the development of the groundwater model for the site. This modeling software consists of numerous modules that are interfaced to allow more accurate representation of hydro-

geologic conditions and greater flexibility in simulating and evaluating flow conditions on the site and surrounding area.

As discussed above, the majority of the preliminary groundwater model provided in this document is based on available hydrogeological published information with very little site-specific data. Once site-specific data is collected, this preliminary groundwater model and results will be refined with the data.

The “site” generally encompasses the entire region of the groundwater model that incorporates numerous properties within the general drainage basin of the site.

It is not the intent of the groundwater model to solely define the hydrogeologic characteristics that exist at the site, but rather this preliminary groundwater model is intended to be used as a preliminary screening tool to evaluate anticipated drawdown conditions associated with the proposed quarry operations.

Figures that have been included as part of this report are provided in an 11 x 17-inch paper size format and are in color allowing the data to be graphically presented. Black and white copies and/or smaller paper size copies of the figures may not present the data in the clarity originally intended.

2.0 Model Construction

2.1 General

The collection and or evaluation of all data desired for a particular investigative purpose may not be possible due to economics and/or logistic limitations. For this reason, some assumptions relative to the site's geologic or hydro-geologic characteristics have been made during the development of this preliminary groundwater model. However, all of the assumptions have been based on sound and accepted geologic and hydro-geologic theory and are identified when utilized.

The model was constructed in three stages. The first stage consisted of developing a three-dimensional conceptual model representing the physical characteristics of the site. The second stage consisted of converting the three-dimensional conceptual model into a numeric model for calibration. MODFLOW 20050, a finite difference model, was utilized for the numeric model. The model was constructed as a steady-state model, which allows the input data to be interpolated through numerous iterations to solve the finite difference equation. The third step consisted of running a predictive flow simulation to represent maximum pumping conditions at the site under average recharge conditions. The modeled simulations presented in this report were run under steady state conditions.

2.2 Numeric Flow Model Construction

Boundary Conditions

The boundary conditions of the model are provided on Figure 3. The selection of the model boundary was based on isolating the groundwater drainage basin that the site is within: groundwater that flows into the basin interacts with the model domain and becomes incorporated into the water budget and water that flows outside of the basin does not interact with the model domain and is not part of the water budget and; therefore, not part of the model. However, it should be noted that the Northern Pit area is located very close to the northern boundary of the regional groundwater divide (watershed boundary) and; therefore, the model domain was expanded in a northern direction into the neighboring watershed to prevent the potential for the Northern Pit dewatering simulation from interacting with the model boundary.

The general model area (model domain), with the exception to the north as noted above, is bordered by MODFLOW "no flow" boundaries that represent watershed divides. MODFLOW drain boundaries represent locations where surface water drainage would simulate the removal of water from the model as base flow. Drain boundaries were used to simulate the tributaries that likely only receive base flow drainage and surface water would not likely enter the underlying porous media.

The elevations of the surface waterways (drain nodes) were based on the United States Geologic Survey (USGS) topographic quadrangle map of the area. The elevations were

estimated from the USGS maps and then 2.0 feet were subtracted from the estimated surface water elevation at each node location to estimate the bottom of the creek bed elevation. The bottom of the creek bed elevation was used in the model as the node elevation. The node locations are presented on Figure 3.

Surface Water

As discussed above, tributaries were mapped as MODFLOW drain arcs. The elevations of the drain nodes were based on the United States Geologic Survey (USGS) topographic quadrangle map of the area as discussed above. The node locations are presented on Figure 3.

The conductance values assigned to the surface water bodies were determined from the estimated creek dimensions and the estimated hydraulic conductivity of the creek bed material. Conductance is the leakage of water through the stream bed material that can discharge as base flow to the stream or leak back into the aquifer as recharge. Conductance is calculated by the product of the creek width and the hydraulic conductivity divided by the creek bed thickness. This provides a conductance value per unit distance (per foot) for the stream bed material. When this value is assigned to MODFLOW, the unit distance is multiplied by the length of the stream bed material in each cell of the model and the conductance of each cell is assigned to the MODFLOW model. A conductance value of 5.0 feet²/day/foot was used for the tributaries within the model domain.

Model Grid

Based on site specific geologic information collected from available publication data (Sloto and Schreffler, 1994, Plate 1), it is apparent that the site exists within a diabase intrusion with no specific preferential groundwater flow direction. For this reason, no specific grid orientation was assigned and the model grid was oriented north to south.

A general grid spacing of approximately 100 by 100 feet was assigned to the entire domain of the model. The model boundary conditions (drains package) were assigned to the grid. The general model grid is presented on Figure 4.

Model Layers and Geologic Characteristics

Two major geologic units exist within the model domain and consist of a diabase intrusion (diabase) and the Triassic age Brunswick Formation. The distribution of these formations within the model domain is presented on Figure 5. The distribution of these geologic units is based on site specific data obtained from publication data (Sloto and Schreffler, 1994, Plate 1). The current site topography has been superimposed on Figure 5 presenting the current site conditions used in the model.

Based on publication data (Sloto and Schreffler, 1994, pp. 17-20), the upper 100 feet of consolidated rock have the highest permeability when compared to the underlying rocks.

Generally, as stated in the published data, based on water-bearing fractures encountered during well installations, there are 4 hydrogeological zones underlying the site area (Sloto and Schreffler, 1994, p. 36). With depth (deeper than 400 feet), these water-bearing fractures eventually disappear reducing the permeability of the deeper aquifer. The diabase has very limited water-bearing capacity below 50 to 100 feet (Sloto and Schreffler, 1994, p.17-20).

For the purpose of the model construction, the model was assigned five MODFLOW layers to reflect the four upper hydrogeologic zones; 0 to 100 feet (layer 1), 100 to 200 feet (layer 2), 200 to 300 feet (layer 3), 300 to 400 feet (layer 4), and the base of the model with no permeability (layer 5). Figure 6 presents the general layer configuration of the model along with hydraulic parameters used in the model and discussed below.

Hydraulic Conductivity Assignment

Hydraulic conductivities were obtained from publication data (Sloto and Schreffler, 1994, pp. 36-41, and Reese and Risser, 2010, Plate 3); however, adjustments were made during the calibration process to the initial values to obtain an appropriate calibration of the model. Table 1 provides a summary of the key hydrogeological publication data and the actual values used in the model for calibration purposes. In addition, the hydrogeological assignments for each layer are provided on Figure 6.

Vertical anisotropy ratios were assigned to the model layers. The vertical hydraulic conductivity ratios assigned to all of the deeper diabase layers was 0.5 based on publication data (Senior 1999). It should be noted that this was not a sensitive parameter in the model.

Recharge

Groundwater recharge is based on annual precipitation, infiltration rates, stream base flow rates, and evapotranspiration rates. As a general “rule of thumb”, recharge is approximately 1/3 of the actual precipitation that occurs in relatively flat and porous terrain. Initial recharge values were obtained from publication data (Sloto and Schreffler, 1994, pp. 52-54, and Reese and Riser, 2010, Plate 3) and were refined during the calibration process. Based on the publication data, recharge in the area of the site ranges from 10.0 to 12.0 inches per year. Specifically, in the area of the diabase, recharge was reported to be approximately 2.0 inches per year and the Brunswick Formation area was reported to be approximately 8 to 12 inches per year. The final mean recharge values used over the entire domain of the model based on the model calibration was 2.0 inches per year for the diabase and 8.5 inches per year for the Brunswick Formation.

A sensitivity analysis of average recharge was conducted to better understand the impact that this parameter has on the groundwater movement on the site. Average recharge and hydraulic conductivity were used for the sensitivity analyses. Higher and lower values of recharge were evaluated. It was determined that the model was very sensitive to recharge: the higher values caused flooding in the model in areas that none was observed, and the

lower recharge values resulted in “dry cells” in the model where groundwater was known to exist. Additionally, the sensitivity analysis was compared to the residual error between the observed groundwater elevations and the simulated groundwater elevations.

2.3 Numeric Flow Model Calibration

General

Calibration refers to the demonstration that the model is capable of producing field measured heads and flows. Calibration can be evaluated both qualitatively and quantitatively; however, even in a quantitative evaluation, the judgment of when the fit between model and reality is satisfactory is a subjective one (Anderson, 1992, pp. 223-246).

The groundwater model was calibrated to estimated groundwater elevation (head) data collected from two site boreholes, two residential wells, six well location data points provided by the Pennsylvania Groundwater Information System (PAGWIS), and three control points (CP) based on stream elevations on USGS topographical quadrangle maps. At this time (preliminary groundwater model development), no site-specific groundwater elevation monitoring wells have been installed on the site for characterization purposes. Once site monitoring wells are installed and data are collected, the model will be recalibrated with the site-specific data.

Model Calibration (Head Elevation)

Groundwater elevation data obtained from the sources discussed above was used to calibrate the preliminary groundwater model. Table 2 provides a tabulation of the groundwater elevation data used for each of the calibration locations. It should be noted that the data obtained provides a general groundwater elevation; however, does not provide the same quality of data that long-term site-specific monitoring well data would provide. Once site-specific data is collected, the groundwater model will be re-calibrated.

During the calibration process, a sensitivity analyses of the recharge values and the hydraulic conductivity values were conducted to identify the most unique parameter values to best match the calibration targets (head elevations at the calibration points). The sensitivity analysis is provided on Table 3. The final hydrogeological values used in the model are discussed above and provided on Figure 6 and Table 1.

The result of the calibration (residual error) is presented in tabular format on Table 2 and is graphically presented on Figure 7. Based on a reasonable distribution of calibration points (groundwater head values) on both sides of the perfect fit line (see Figure 7), a reasonable calibration was achieved using the available data. Based on this calibration, a mean error over the domain of the model of 5.02 feet was achieved which equates to an approximate normalized error of 12.2 % (mean error divided by the range of water elevation within the domain of the model). Additional calibration statistics are provided on Figure 7 and Table 2.

Sensitivity Analyses

Several sensitivity evaluations were conducted on the hydraulic parameters input into the model. The sensitivity analyses allow key parameters of the model to be adjusted independently of the other parameters to evaluate the sensitivity of each of the parameters within the model. Generally, the purpose of the sensitivity analyses confirms the uniqueness of the set of hydrogeologic parameters used in the model. This prevents the use of model boundary conditions that allow broad ranges of parameter values that are non-unique to a specific site.

During the calibration, the recharge values were changed while the average hydraulic conductivity values for each of the four geologic zones were held constant. These values were derived through a trial and error process. Once the best quantitative calibration was obtained, a sensitivity analysis of the parameters was conducted.

Flow Budget

The flow budget of the MODFLOW model was evaluated to determine if reasonable inflows and outflows of the model had been achieved. Based on a conceptual understanding of the site's hydrologic cycle, it was apparent that the aquifer on the site was recharged from precipitation. Groundwater was lost from the aquifer through drainage into surface water creeks (drains). Results of the flow budget are presented on Table 4.

Based on the results of the flow budget, it is evident that the inflow of water into the model domain closely matches the outflow of water from the model domain suggesting a reasonable water budget balance.

3.0 Simulated Groundwater Flow

3.1 Existing Site Groundwater Elevation Conditions

Based on the calibrated groundwater model, Figure 8 presents the existing groundwater flow elevation contours for the existing site static non-pumping conditions on a regional level. A mean recharge value of 8.5 inches per year was used for the Brunswick Formation and mean recharge value of 2.0 inches per year was used for the diabase in this simulation.

3.2 Simulation of Maximum Pit Dewatering Conditions (Bench – 400 ft-msl)

It is anticipated that one pit location will be mined to its entirety prior to mining the second pit. For this reason, the dewatering simulations for each pit (Northern and Southern Pit) were simulated separately and not at the same time. The dewatering simulations represented the maximum drawdown for each pit which correlates to a final bench elevation of 400 ft-msl. For the dewatering simulations each of the pits were dewatered to the maximum depth of 400 ft-msl. The bench configurations for each pit were based on the mining bench plan (50-foot depth expansions down to 400 ft-msl). The pit dewatering was simulated with MODFLOW drains over the area of the benches at the appropriate bench elevation (600 ft-msl down to 400 ft-msl). This configuration allowed the model to simulate the proposed pit configurations under the maximum dewatering scenario.

Figures 9 and 10 provide the groundwater elevations for the dewatering of the Northern Pit and the Southern Pit respectively. Figures 11 and 12 provide the associated simulated drawdown for the Northern Pit and the Southern Pit respectively. The drawdown was obtained from subtracting the maximum pumping groundwater elevation contours (Figures 9 and 10) from the static groundwater elevation contours (Figure 8) within the model software.

As is evident on drawdown Figures 11 and 12, very little dewatering impact is occurring due to the low permeability of the diabase material. Both the Northern Pit and Southern Pit have less than 1000 feet of radial expansion to the 10-foot drawdown mark. Additionally, the deeper the pits are expanded into the diabase material, tighter and less fractured diabase is encountered with very little water-bearing capacity. It is anticipated that the majority of the groundwater impact will occur in the first 50-foot bench expansion since this is the most weathered and water-bearing zone in the diabase. Based on the model simulations, the Northern Pit is estimated to yield an average 21 gallons per minute (gpm) during the maximum dewatering process. The Southern Pit is estimated to yield an average of 17 gpm during the dewatering process.

It should be noted that the model simulations tend to over-predict the drawdown impact from the dewatering operations due to the steady-state nature of the model simulations. The model simulations are 100% efficient in calculating the water budgets when in

reality, dewatering occurs over time and is not instantaneous. This would result in a smaller zone of influence than is presented in this report.

4.0 Summary and Conclusions

Based on the results of the groundwater model simulation discussed in this document, the following conclusions have been reached:

- The proposed Northern and Southern Pit locations are situated on diabase geologic material that has very limited water-bearing capacity. Furthermore, this capacity decreases with depth.
- A very limited horizontal zone of influence is expected to occur from the proposed pit locations under the maximum dewatering scenario (Bench elevations at 400 ft-msl). Less than a 1000-foot radius was calculated for both pit locations and is likely to be much less since model simulations tend to over predict drawdown.
- Vertical expansion of the pits is not likely to increase the zone of influence since the water-bearing capacity of the diabase material decrease with depth. Only the upper 50 to 100 feet are reported to have very limited water-bearing capacity with almost no capacity below 100 feet.
- Dewatering rates are expected to range from 17 to 21 gallons per minute at the deepest pit depth (400 ft-msl) with the majority of the dewatering yield coming from the upper 50 feet.

5.0 Limitations

The modeling in this report was performed using a commercially available software package (Groundwater Modeling System-GMS, Version 10.1 developed by the United States Department of Defense) designed to simulate groundwater flow. Where available, actual data from the site was utilized to calibrate the models and develop the graphical representations presented in this document. In other instances, assumptions were necessary to complete the model and limitations associated with the site data result in a level of uncertainty in the model predictions. Therefore, the results of the model predictions should be independently evaluated using actual site monitoring data.

The results of the model may differ from actual site conditions because of unknown subsurface conditions. The results of the models presented in this document shall not be construed to create any warranty or representation with regard to the site. The conclusions presented in this report were based on the services described, and not on scientific tasks or procedures beyond the described scope of services.

6.0 References

Anderson, M.P., Woessner, W. W., 1992, Applied Groundwater Modeling – Simulation of Flow and Advective Transport, Academic Press, Inc., pp. 223-246.

Reese, S.O., and Risser, D.W., Summary of Groundwater-Recharge Estimates for Pennsylvania Water Resource Report 70, Pennsylvania Geologic Survey, 2010.

Senior, L.A., and Goode, D.J., Ground-Water System, Estimation of Aquifer Hydraulic Properties, and Effects of Pumping on Ground-Water Flow in Triassic Sedimentary Rocks in and near Lansdale, Pennsylvania, U.S. Geologic Survey, Water-Resources Investigations Report 99-4228, 1999.

Sloto, R.A., and Schreffler, C.L., Hydrogeology and Ground-Water Quality of Northern Bucks County, Pennsylvania, U.S. Geological Survey, Water-Resources Investigations Report 94-4109, 1994.

TABLES

TABLE 1

Key Hydraulic Parameters
Preliminary Groundwater Model
Center Valley Materials
Springfield Township
Bucks County, Pennsylvania

Source	Published Value(s)	Model Value	Comments
Hydraulic Conductivity			
USGS - Water-Resources Investigations Report 94-4109 (Sloto, 1994, pp.19, 35-41)	0.475 ft/day Brunswick	0.328 ft/day Brunswick	Assumes aquifer is approximately 400 feet thick as discussed in publication relative to available fracture zones.
USGS - Water-Resources Investigations Report 94-4109 (Sloto, 1994, pp.17, 35-41)	0.1 ft/day Diabase	0.1 ft/day Diabase	Assumes aquifer is approximately 400 feet thick as discussed in publication relative to available fracture zones.
Anisotropy Ratios (Preferential Flow)			
USGS - Water-Resources Investigations Report 99-4228 (Senior, 1999)	20 to 1	1.0	Based on diabase characteristics and site location within diabase area.
Recharge			
USGS - Water-Resources Investigations Report 94-4109 (Sloto, 1994, pp.52-53)	2.0 in/year Diabase 8.5 in/year Brunswick	2.0 in/year Diabase 8.5 in/year Brunswick	Based on statics and model calibration.
Summary of Groundwater- Recharge Estimates for Pennsylvania PAGS- Water Resource Report 70 (Reese and Risser, 2010, Plate 3)	10 to 12 inches per year	2.0 in/year Diabase 8.5 in/year Brunswick	Publication is regional and does not evaluate individual sub-watersheds.

TABLE 2

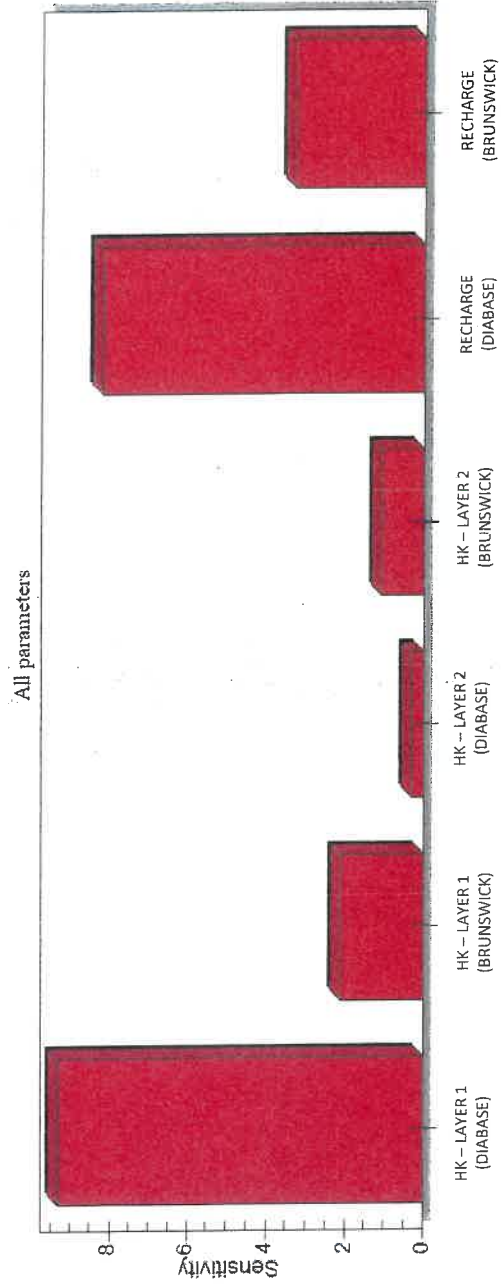
Calibration
Residual Error of Calibration Points
Center Valley Materials
Springfield Township
Bucks County, Pennsylvania

Well ID	Description	Computed (Simulated) Groundwater Elevation (feet/msl)	Observed Groundwater Elevation (feet-msl)	Residual Error (feet)
CP-A	Surface Water Point	589	590	1.0
CP-B	Surface Water Point	571	600	29.0
CP-3	Surface Water Point	596	598	2.5
CM	Measured Residential Well	530	557	27.2
HK-2	Measured Borehole	594	606	12.7
TATOO	Measured Residential Well	594	605	11.0
HK-3	Measured Borehole	593	593	-0.8
5862	PAGWIS Well	601	586	-14.7
73443	PAGWIS Well	571	556	-15.0
474788	PAGWIS Well	603	586	-16.6
73397	PAGWIS Well	621	628	7.1
73460	PAGWIS Well	617	630	12.9
72840	PAGWIS Well	637	646	9.1

Mean Error: 5.02
Absolute Mean Error: 8.07
Root Mean Square Error: 11.07
Normalized RMS: 12.20%

TABLE 3

Parameter Sensitivity
Center Valley Materials
Springfield Township
Bucks County, Pennsylvania



HK - HORIZONTAL HYDRAULIC CONDUCTIVITY

TABLE 4

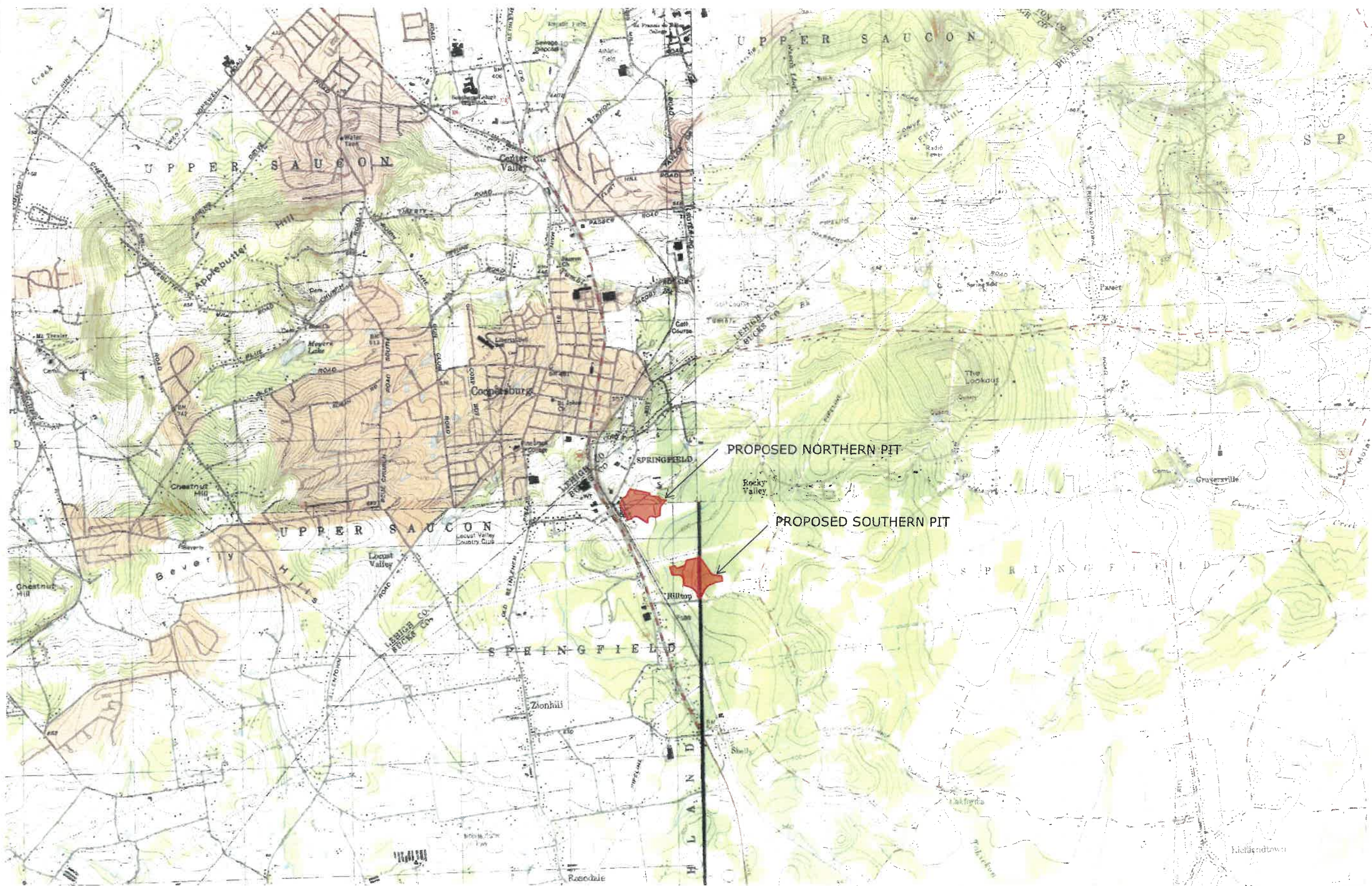
Flow Budget
Preliminary Groundwater Model
Center Valley Materials
Springfield Township
Bucks County, Pennsylvania

	Flow In (ft ³ /day)	Flow Out (ft ³ /day)
Source/Sinks		
Drains (Creeks)	0.00	292624.00
Recharge	292626.00	0.00
Total	292626.00	292624.00
% Difference		0.0010

FIGURES

FIGURE 1. The effect of the concentration of the reactants on the rate of the reaction. The reaction was carried out at 25°C in 0.1 M HCl. The concentration of the reactants was varied as follows: [A] = 0.01 M, [B] = 0.01 M, [C] = 0.01 M, [D] = 0.01 M, [E] = 0.01 M, [F] = 0.01 M, [G] = 0.01 M, [H] = 0.01 M, [I] = 0.01 M, [J] = 0.01 M, [K] = 0.01 M, [L] = 0.01 M, [M] = 0.01 M, [N] = 0.01 M, [O] = 0.01 M, [P] = 0.01 M, [Q] = 0.01 M, [R] = 0.01 M, [S] = 0.01 M, [T] = 0.01 M, [U] = 0.01 M, [V] = 0.01 M, [W] = 0.01 M, [X] = 0.01 M, [Y] = 0.01 M, [Z] = 0.01 M.

FIGURE 2. The effect of the concentration of the reactants on the rate of the reaction. The reaction was carried out at 25°C in 0.1 M HCl. The concentration of the reactants was varied as follows: [A] = 0.01 M, [B] = 0.01 M, [C] = 0.01 M, [D] = 0.01 M, [E] = 0.01 M, [F] = 0.01 M, [G] = 0.01 M, [H] = 0.01 M, [I] = 0.01 M, [J] = 0.01 M, [K] = 0.01 M, [L] = 0.01 M, [M] = 0.01 M, [N] = 0.01 M, [O] = 0.01 M, [P] = 0.01 M, [Q] = 0.01 M, [R] = 0.01 M, [S] = 0.01 M, [T] = 0.01 M, [U] = 0.01 M, [V] = 0.01 M, [W] = 0.01 M, [X] = 0.01 M, [Y] = 0.01 M, [Z] = 0.01 M.



NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC QUADRANGLE MAP.



Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462

val@vbritton.com www.vbritton.com

SITE LOCATION MAP

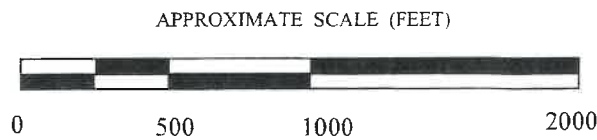
PROJECT LOCATION

CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER

1



NOTES

BASE MAP FROM PEMA 2018 AERIAL PHOTOGRAPH.

EXPLANATION



PROPOSED QUARRY AREA



WETLAND AREA



PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY	VFB	DATE	3/12/20
----------	-----	------	---------

SITE LAYOUT PLAN

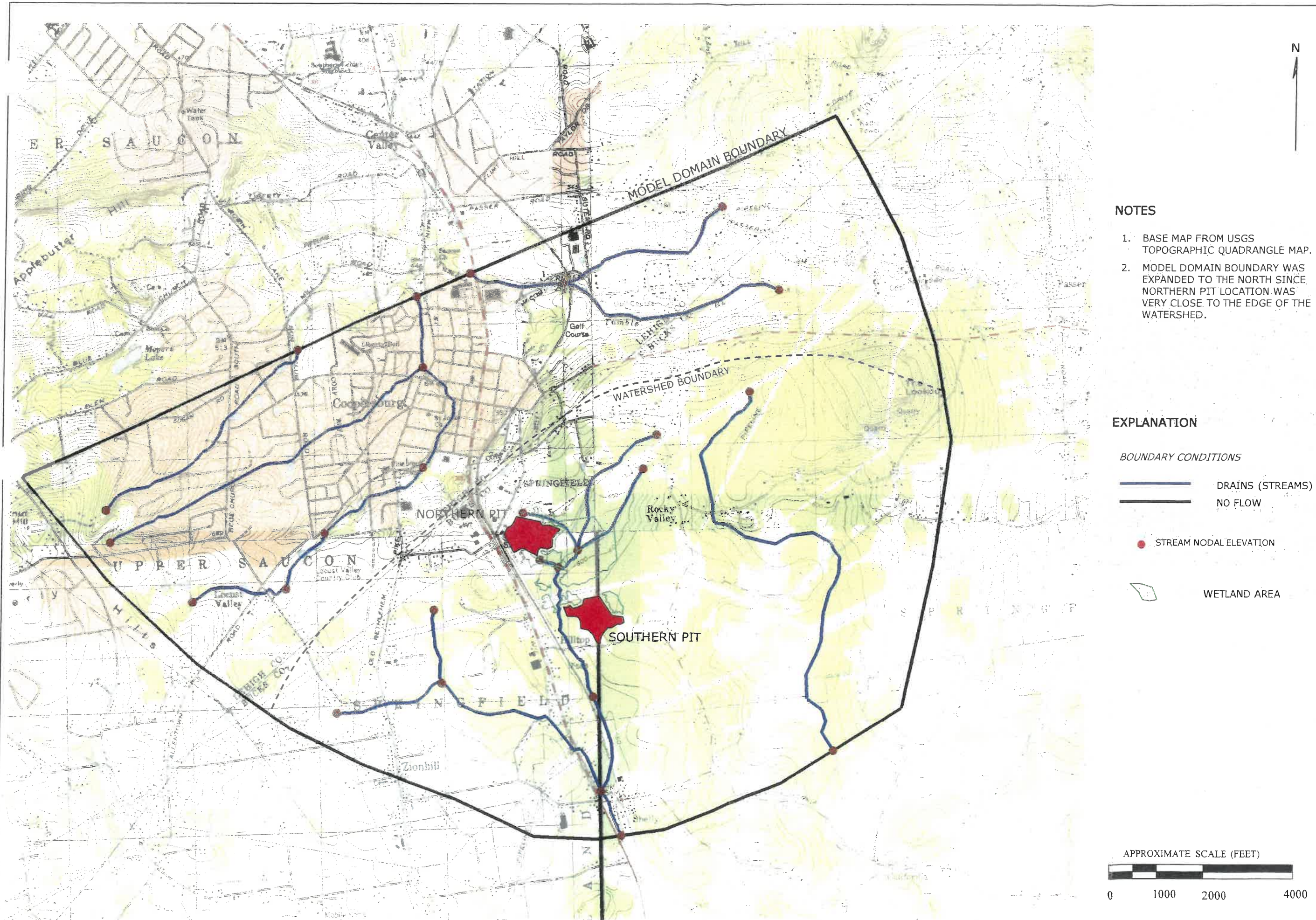


Val F. Britton, P.G.
ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vbritton.com www.vbritton.com

FIGURE NUMBER

2



- NOTES
- 1. BASE MAP FROM USGS TOPOGRAPHIC QUADRANGLE MAP.
 - 2. MODEL DOMAIN BOUNDARY WAS EXPANDED TO THE NORTH SINCE NORTHERN PIT LOCATION WAS VERY CLOSE TO THE EDGE OF THE WATERSHED.

EXPLANATION

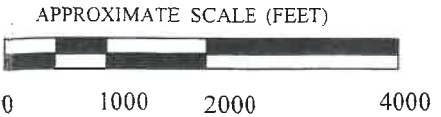
BOUNDARY CONDITIONS

— DRAINS (STREAMS)

— NO FLOW

● STREAM NODAL ELEVATION

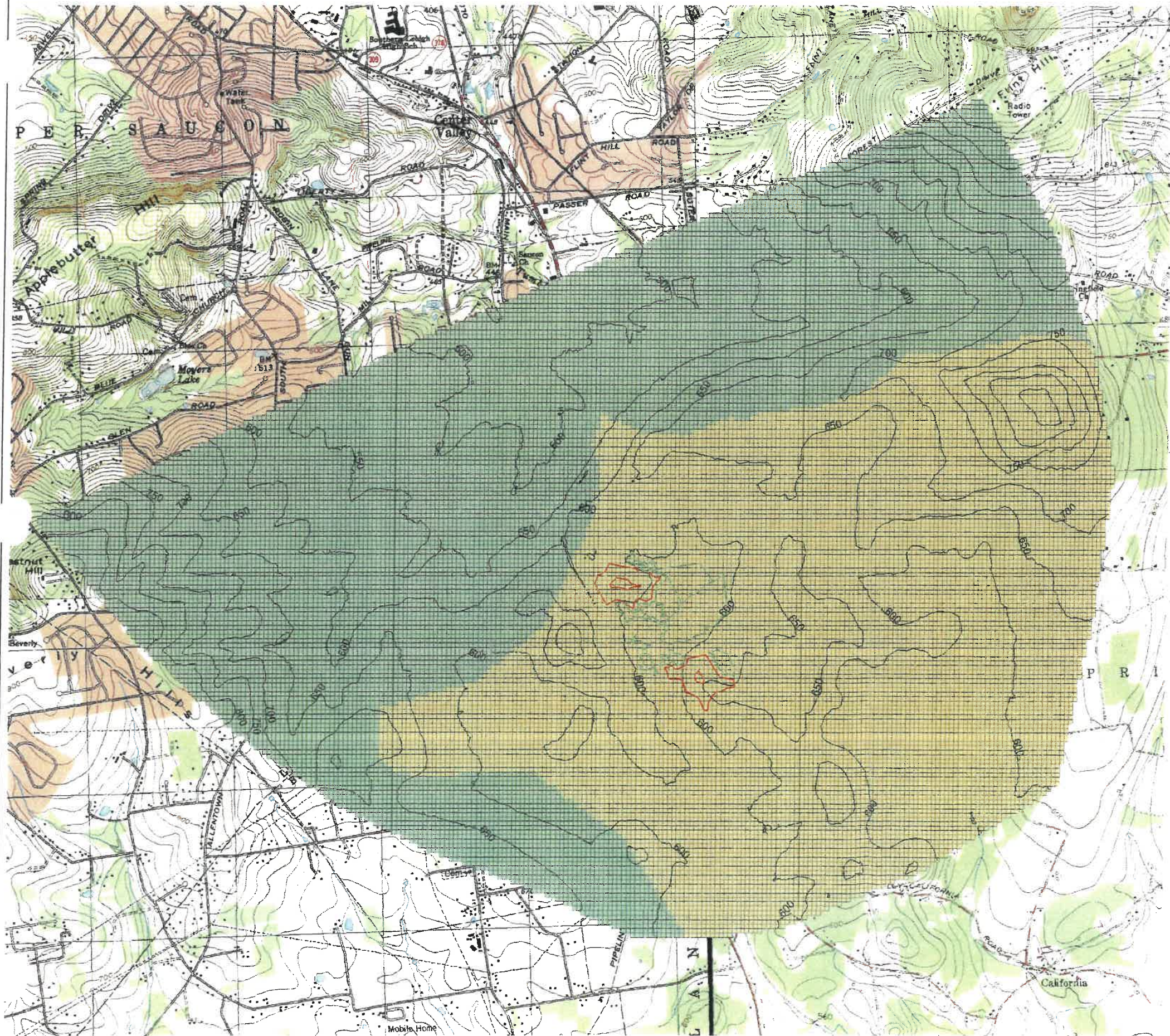
WETLAND AREA



GENERAL MODEL CONSTRUCTION
BOUNDARY CONDITIONS

PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

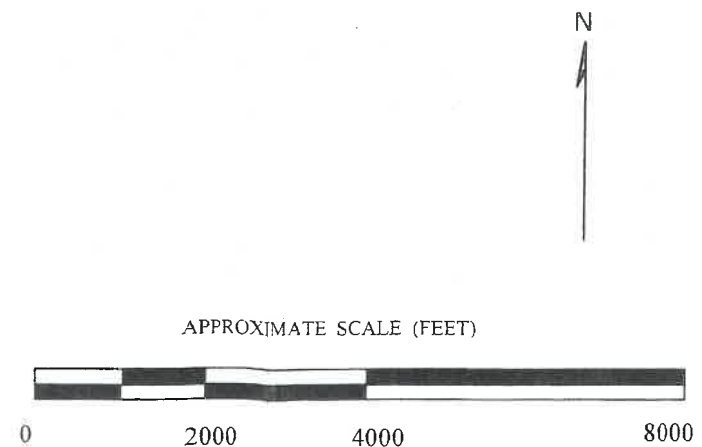


NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC QUADRANGLE MAP.
2. CROSS HATCHES ARE THE MODEL GRID.

EXPLANATION

- DIABASE
- BRUNSWICK FORMATION
- 650 GROUND SURFACE ELEVATION (FEET MEAN SEA LEVEL)
- PROPOSED QUARRY AREA
- WETLAND AREA



Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087

610-964-1462

val@vfbritton.com www.vfbritton.com

GENERAL MODEL CONSTRUCTION GEOLOGIC MATERIAL DISTRIBUTION

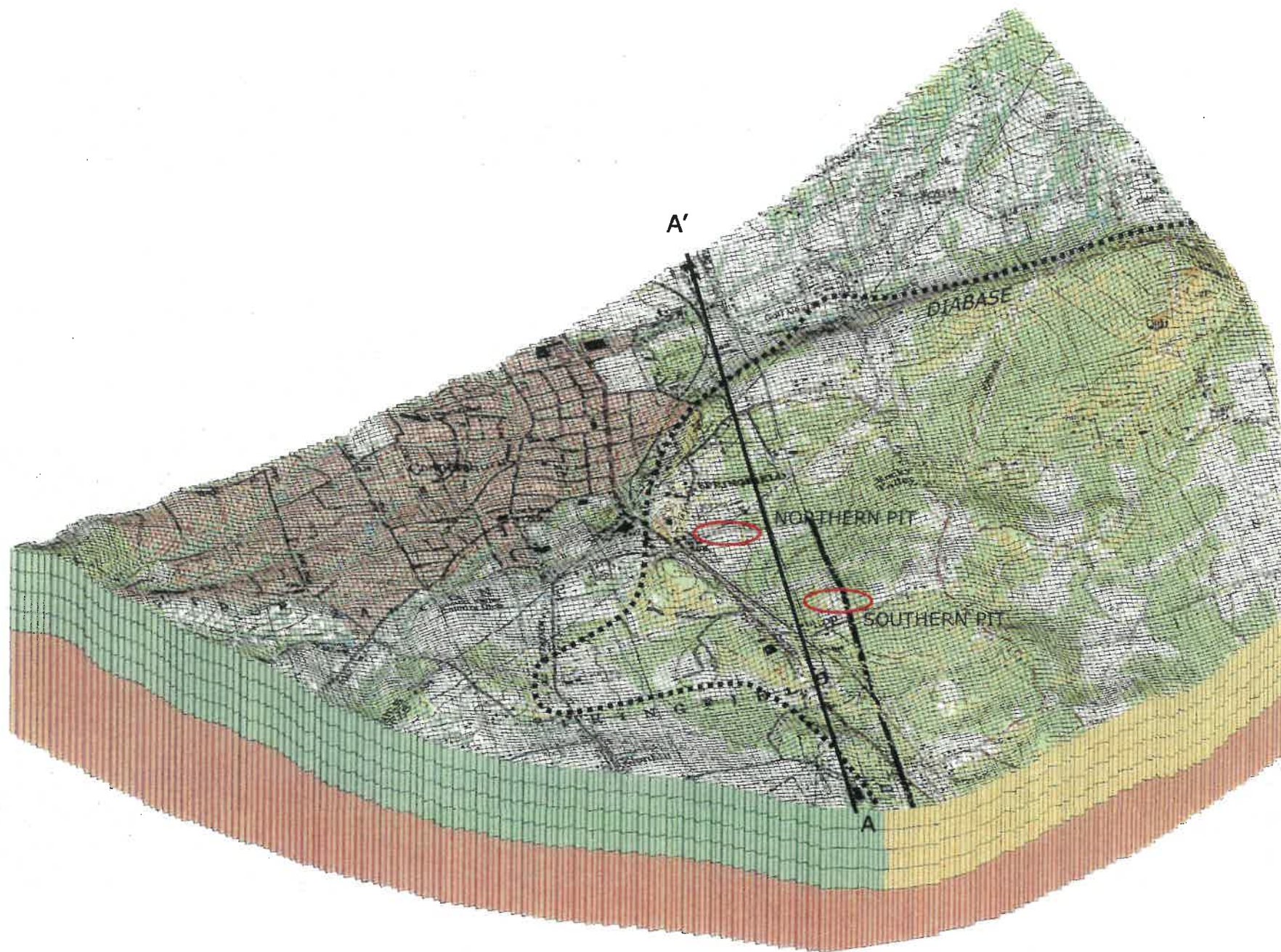
PROJECT LOCATION

CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER

5



EXPLANATION

HYDROGEOLOGIC ZONES

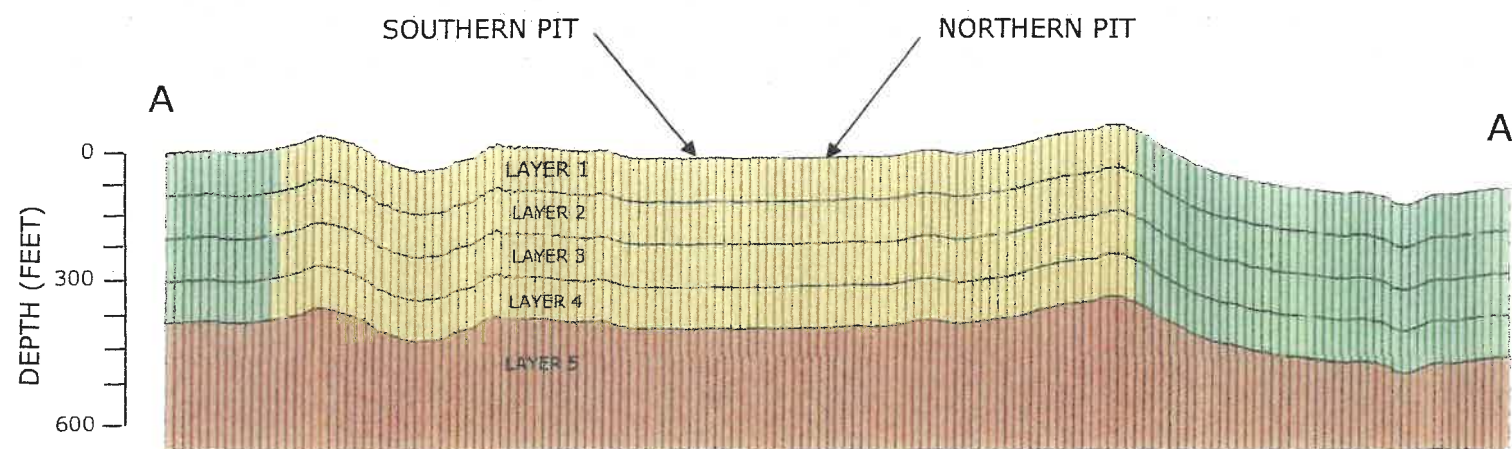
	DIABASE
	BRUNSWICK FORMATION
	BOTTOM OF MODEL

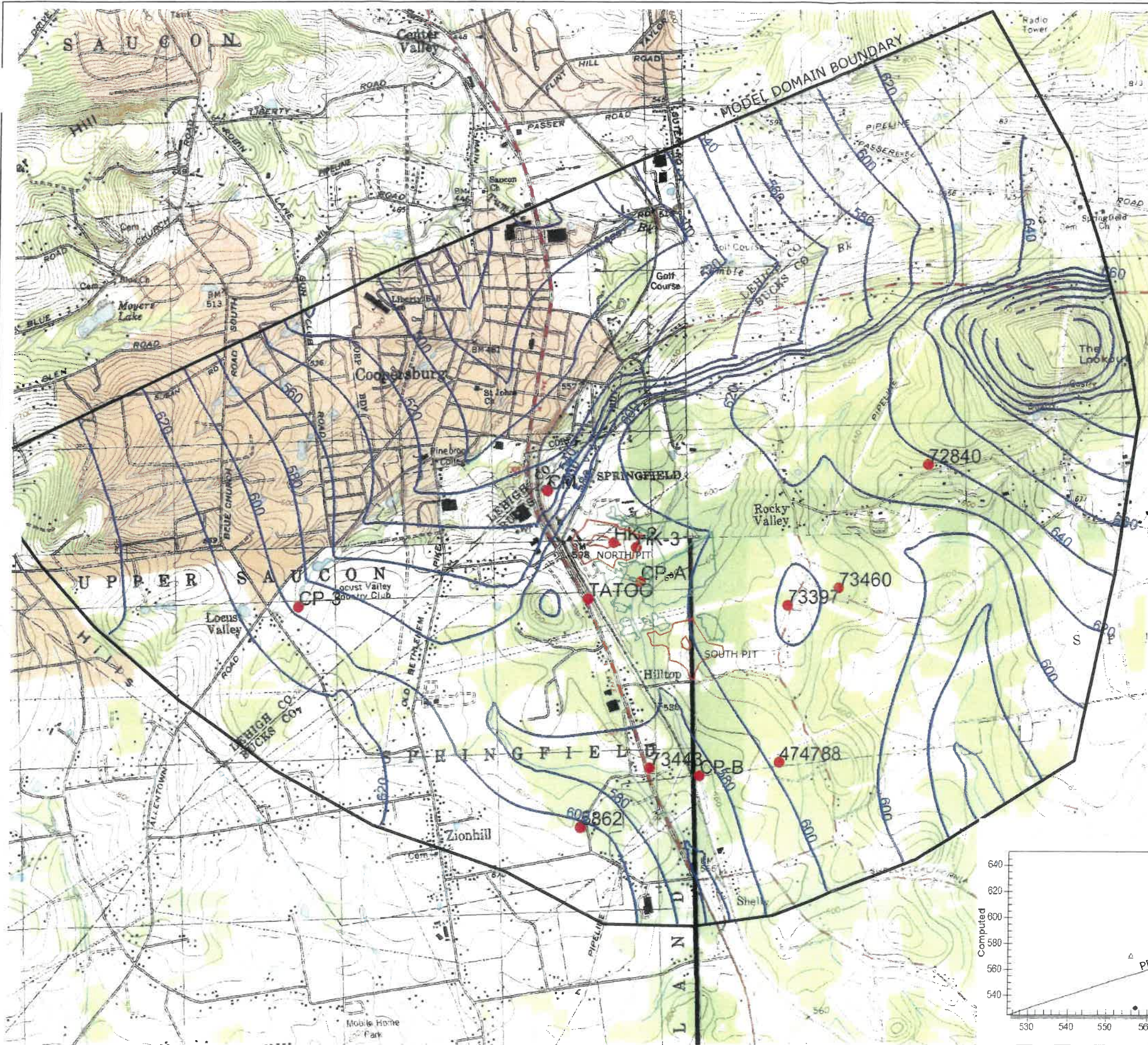
NOTES

1. VERTICAL EXAGGERATION IS 5X.
2. THE RECHARGE VALUE USED IN THE MODEL WAS 8.5 INCHES PER YEAR FOR THE BRUNSWICK FORMATION AREA AND 2.0 INCHES PER YEAR FOR THE DIABASE.

HYDRO-GEOLOGICAL PARAMETERS

	k (ft/d)	kxy (ratio)	kz(ratio)
Diabase (Layer 1)	0.1	1	1
Diabase (Layer 2)	0.01	1	0.5
Diabase (Layer 3)	0.001	1	0.5
Diabase (Layer 4)	0.0001	1	0.5
Brunswick (Layer 1)	0.328	1	1
Brunswick (Layer 2)	0.148	1	1
Brunswick (Layer 3)	0.148	1	1
Brunswick (Layer 4)	0.148	1	1
Layer 5	0.001	1	1



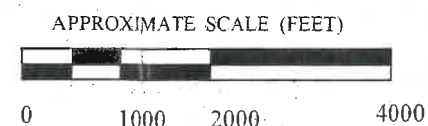


NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC CONTOUR MAP
2. GROUNDWATER ELEVATION CONTOURS REPRESENT THE SIMULATION OF EXISTING SITE CONDITIONS.
3. CALIBRATION RESIDUAL ERROR TABULATION IS PROVIDED ON TABLE 2.
4. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2.0 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.

EXPLANATION

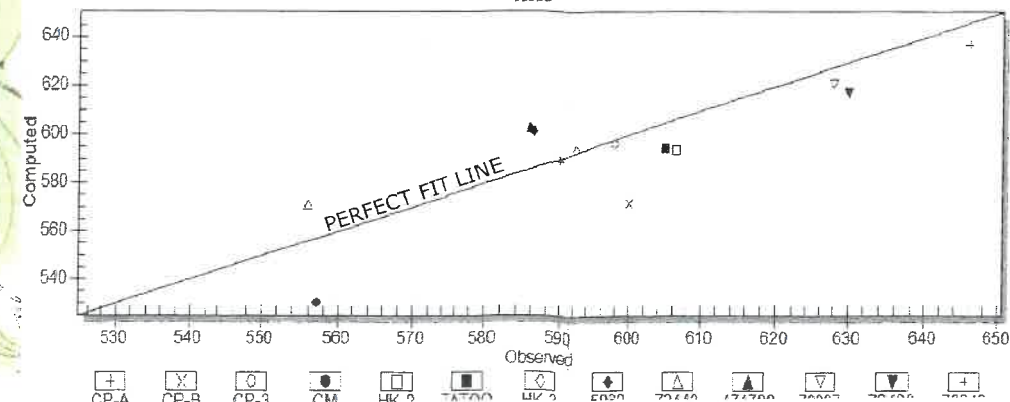
- CALIBRATION LOCATION
- 620— SIMULATED GROUNDWATER ELEVATION CONTOUR (FT/MSL)
- PROPOSED QUARRY AREA
- WETLAND AREA



CALIBRATION

MEAN ERROR:	5.02 FEET
ABSOLUTE MEAN ERROR:	8.07 FEET
ROOT MEAN SQUARE ERROR (RMS):	11.07 FEET
NORMALIZED RMS:	12.2%

Computed vs. Observed Values



Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vbritton.com www.vbritton.com

MODEL CALIBRATION

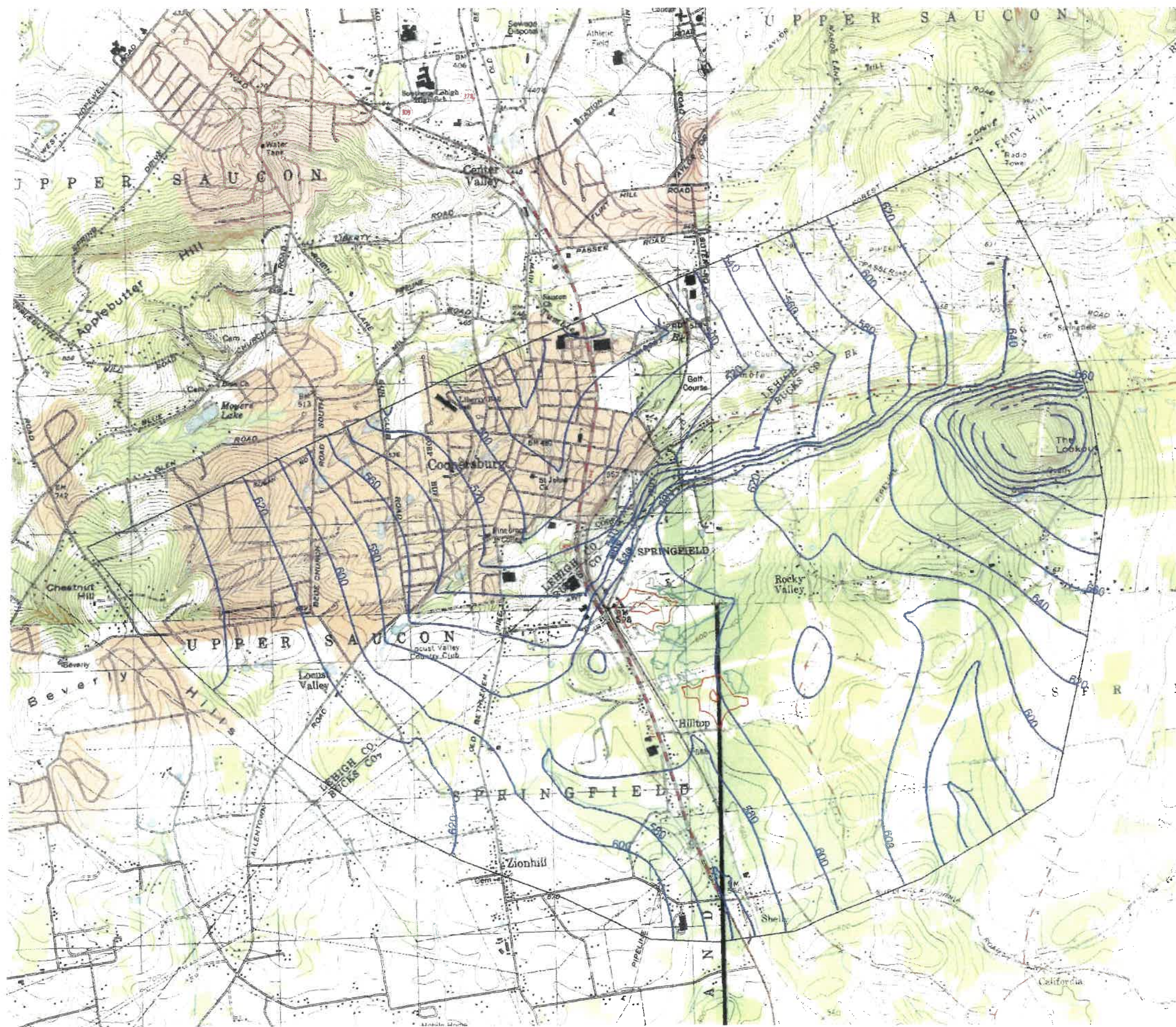
PROJECT LOCATION

CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER




7



NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC CONTOUR MAP
2. GROUNDWATER ELEVATION CONTOURS REPRESENT THE SIMULATION OF EXISTING SITE CONDITIONS.
3. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2.0 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.

EXPLANATION

-  SIMULATED GROUNDWATER ELEVATION CONTOUR (FT/MSL)
-  PROPOSED QUARRY AREA
-  WETLAND AREA

APPROXIMATE SCALE (FEET)



SIMULATION OF EXISTING STATIC GROUNDWATER ELEVATION CONDITIONS

PROJECT LOCATION

CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB

DATE 3/12/20

FIGURE NUMBER

8

Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087

610-964-1462

val@vbritton.com www.vbritton.com



NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC CONTOUR MAP
2. GROUNDWATER ELEVATION CONTOURS REPRESENT THE SIMULATION OF DEWATERING CONDITIONS OF THE NORTHERN PIT TO BENCH ELEVATION OF 400 FEET.
3. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2.0 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.
4. QUARRY (NORTHERN PIT) DEWATERING RATE BASED ON MODEL SIMULATION IS APPROXIMATELY 21 GPM.
5. PURPLE SHADE INDICATES PIT DEWATERING AREA.

EXPLANATION

- SIMULATED GROUNDWATER ELEVATION CONTOUR (FT/MSL)
- PROPOSED QUARRY AREA
- WETLAND AREA



SIMULATION DEWATERING OF NORTHERN PIT GROUNDWATER ELEVATION CONTOUR (400 FOOT BENCH ELEVATION)

Val F. Britton, P.G.
ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING
326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vfbritton.com www.vfbritton.com

PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA
DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER



NOTES

1. BASE MAP FROM USGS TOPOGRAPHIC CONTOUR MAP
2. GROUNDWATER ELEVATION CONTOURS REPRESENT THE SIMULATION OF DEWATERING CONDITIONS OF THE SOUTHERN PIT TO BENCH ELEVATION OF 400 FEET.
3. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2.0 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.
4. QUARRY (SOUTHERN PIT) DEWATERING RATE BASED ON MODEL SIMULATION IS APPROXIMATELY 17 GPM.
5. PURPLE SHADE INDICATES PIT DEWATERING AREA.

EXPLANATION

- 620 SIMULATED GROUNDWATER ELEVATION CONTOUR (FT/MSL)
- PROPOSED QUARRY AREA
- WETLAND AREA

APPROXIMATE SCALE (FEET)



Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vfbritton.com www.vfbritton.com

SIMULATION DEWATERING OF SOUTHERN PIT GROUNDWATER ELEVATION CONTOUR (400 FOOT BENCH ELEVATION)

PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER

10



NOTES

1. BASE MAP FROM PEMA 2018 AERIAL PHOTOGRAPH.
2. INTERIOR DRAWDOWN LINES REMOVED FOR CLARITY.
3. SIMULATION IS OF BENCH AT 400 FEET MEAN SEA LEVEL.
4. DRAWDOWN CONTOURS REPRESENT THE SIMULATION OF DEWATERING CONDITIONS OF THE NORTHERN PIT TO BENCH ELEVATION OF 400 FEET.
5. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2.0 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.
6. QUARRY DEWATERING RATE BASED ON MODEL SIMULATION IS APPROXIMATELY 21 GALLONS PER MINUTE.

EXPLANATION

- 10 DRAWDOWN CONTOUR (FEET) WHITE LINE
- PROPOSED QUARRY AREA
- WETLAND AREA

APPROXIMATE SCALE (FEET)



SIMULATION NORTHERN PIT DRAWDOWN (400 FOOT BENCH ELEVATION)

PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER

11

Val F. Britton, P.G.
ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vbritton.com www.vbritton.com



NOTES

1. BASE MAP FROM PEMA 2018 AERIAL PHOTOGRAPH.
2. INTERIOR DRAWDOWN LINES REMOVED FOR CLARITY.
3. SIMULATION IS OF BENCH AT 400 FEET MEAN SEA LEVEL.
4. DRAWDOWN CONTOURS REPRESENT THE SIMULATION OF DEWATERING CONDITIONS OF THE SOUTHERN PIT TO BENCH ELEVATION OF 400 FEET.
5. AVERAGE RECHARGE VALUE OF 8.5 INCHES PER YEAR FOR BRUNSWICK FORMATION AND 2 INCHES PER YEAR FOR THE DIABASE WAS USED IN MODEL SIMULATION.
6. QUARRY DEWATERING RATE BASED ON MODEL SIMULATION IS APPROXIMATELY 17 GALLONS PER MINUTE.

EXPLANATION

- 10 DRAWDOWN CONTOUR (FEET)
WHITE LINE
- PROPOSED QUARRY AREA
- WETLAND AREA

APPROXIMATE SCALE (FEET)



Val F. Britton, P.G.

ENVIRONMENTAL AND HYDROGEOLOGIC CONSULTING

326 Conestoga Road Wayne, PA 19087
610-964-1462
val@vbritton.com www.vbritton.com

**SIMULATION
SOUTHERN PIT DRAWDOWN
(400 FOOT BENCH ELEVATION)**

PROJECT LOCATION
CENTER VALLEY MATERIALS
SPRINGFIELD TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

DRAWN BY VFB DATE 3/12/20

FIGURE NUMBER

12