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Mountaintop Mining/Valley Fills in Appalachia Draft Programmatic Environmental Impact Statement

APPENDIX H

ENGINEERING TECHNICAL STUDIES

Engineering Study Category, Appendix H

Study Topic	Filed Date
Comparisons of Peak Discharges Among Sites with and without Valley Fills for the July 8-9, 2001 Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region Southern West Virginia.[Post-2001 WV Flood Analysis]	Report in preparation. Executive Summary included
Comparisons of Storm Response in a Small Unmined and Mountaintop-removal mined Watersheds, 1999-2001, Ballard Fork, West Virginia	Reports in preparation. Executive Summary included
Comparison of Stream Characteristics in Small Gaged, Unmined and Mountaintop-removal Mined Watersheds, Ballard Fork, West Virginia, 1999-2001	Reports in preparation. Executive Summary included
Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large Scale Surface Mining Operations in Appalachia	April 2001
Flood Advisory Technical Taskforce Runoff Analyses of Seng, Scrabble, and Sycamore Creeks Hobet Mine Westridge Valley Fill. Feb 2000 Samples Mine Valley Fill #1. Jan 2000 Samples Mine Valley Fill #2. Mar 2001 Samples Mine Valley Fills #1 and #2. Jan 2000 Samples Mine Valley Fills #1 and #2 combined AOC conditions. Nov 2000 Samples Mine Valley Fills #1 and #2 combined Future Forested Conditions. March 2001 Samples Mine Valley Fills #1 AOC conditions. Sept 2000 Samples Mine Valley Fills #1 Future Forested conditions. Feb 2001 Samples Mine Valley Fills #2 Future Forested conditions. Mar 2001 Samples Mine Valley Fills #2 AOC+ conditions. Oct 2000	June 2002
Long-Term Stability of Valley Fills	March 2002
Mining and Reclamation Technology Symposium	June 1999
Estimation of Southwest Virginia Reserve Base of Surface Mineable Coal	July 2000, presented in Chapter III.O
Estimation of Future Mountain-Top Removal Areas in the Eastern Kentucky Region	July 2000, presented in Chapter III.O
Projecting Future Coal Mining in Steep Terrain of West Virginia	April 2000, presented in Chapter III.O

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These reports are included in the appendix in black and white. Color versions may be viewed on the following website. http://www.epa.gov/region3/mtntop/index.htm

Comparisons of Peak Discharges Among Sites with and without Valley Fills for the July 8-9, 2001 Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region Southern West Virginia. by the United States Geologic Survey

This study was designed to compare peak stream flows generated from mined and un-mined watersheds upstream of summer flooding during 2001. The study was developed to answer, in part, the following:

> *What are the short- and long-term effects of individual mountaintop mining operations and associated valley fills on the following physical, chemical and biological conditions of affected streams and their watersheds, both within the area of direct impact and downstream, and including surface and groundwater. Consider both water quality and quantity, including flooding potential and baseflow. Consider changes on aquatic habitat and stream use.*

Specifically for this study, the interest was in the effect of valley fills on quantity of stream flow resulting from a significant rain storm event. The study determined that peak discharge for a 10-year storm was less downstream from a reclaimed valley fill than downstream of an area without a valley fill. However, the peak discharge for a 25-year storm was greater from two sites with valley fills than two sites without valley fills. Peak discharge downstream from an unreclaimed valley fill was greater than at a reclaimed valley fill.

The limitations of the study are the inherent difficulties of reconstructing the cause-and-effect of results from a storm event based on watershed condition observations and measured high water marks. Only a small number of sites were evaluated, and increased or decreased peaks are attributable to site-specific factors for each watershed. Thus, it is difficult to generalize mining impacts on runoff as a "one-size-fits-all" finding. Also, due to site conditions, increases in peak runoff may not cause or contribute to flooding. Flooding results when stream banks overflow and cause hazards to persons or damage to property, roads, etc (i.e., increased peaks contained within a stream channel would not be considered flooding).

Comparisons of Storm Hydrographs in a Small Valley Filled and Unmined Watershed, 1999-2001, Ballard Fork, West Virginia by the United States Geologic Survey

The study was designed to compare stream flow characteristics in similar sized watersheds with and without a valley fill. The study was designed to answer, in part, the same questions reported in the previous study. Specifically for this study, the committee was interested in the effect of valley fills on quantity of stream flow downstream following a significant rainfall event. The study found that runoff from mined watersheds exceeded runoff from unmined watersheds when rainfall exceeded

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1.0 inch per hour. The study also found that valley fills tend to store a considerable amount of water and release the water more slowly than watersheds without fills.

The limitations of the study are the small number of sites that were evaluated and the difficulty in monitoring for the appropriate period when a major storm event occurs. Despite the occurrence of flooding in southern West Virginia in 2000 and 2001, the sites monitored did not include a major rainfall event. As stated above, increased or decreased peaks are attributable to site-specific factors in the contributing watershed. Thus, it is difficult to generalize mining impacts on runoff from a limited number of sites. It is important to note that increases in peak runoff may not cause or contribute to flooding (i.e., increased peaks contained within a stream channel would not be considered flooding).

Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large Scale Surface Mining Operations in Appalachia by U.S. Army Corps of Engineers Pittsburgh District

The purpose of this study was to evaluate the potential for flooding as a result of the construction of valley fills and the related hydrologic modifications to terrain associated with mountaintop mining. This study was based on computer modeling simulations, which looked at the impacts of rainfall events on three individual valley fills, as well as the cumulative impacts of two fills on a downstream area. The study was designed to answer questions described in the initial study, above.

To summarize, the study found that storm runoff models calculated higher post-mining peak flows than pre-mining peak flows for the same design storms. Model results concluded that peak runoff during mining at one site was also higher than pre-mining flows. The study also reported that the type of ground cover (e.g., trees versus, grass/legumes) and reclaimed topography (e.g., AOC v. non-AOC) influenced post-mining peak runoff. However, none of the predicted increases in peak flow caused flooding outside the downstream channel.

The limitations of the study are the small number of sites modeled as well as the difficulty of modeling during-mining conditions. As previously mentioned, increased or decreased peaks are attributable to site-specific factors in the contributing watershed. Thus it is difficult to generalize mining impacts on runoff.

Flood Advisory Technical Taskforce Runoff Analyses of Seng, Scrabble, and Sycamore Creeks by West Virginia

The studies were designed to determine whether mining caused increases in "peak flow" downstream from the mine sites and if so, the extent to which peak flows were increased. It should be noted that the West Virginia study also evaluated the impacts of logging on peak flows. In general, the study concluded that mining does influence the degree of runoff, but that the extent to which a change in runoff may have actually caused or contributed to flooding were

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site-specific. Site-specific factors may include topographic influences, stream channel conditions, distance downstream from the mine site, man-made channel restrictions, etc.

The study recognized the need for the proper, thorough analysis of peak flow and flooding potential. West Virginia is evaluating their study conclusions and recommendations and considering regulations that would require peak flow analysis and other measures to minimize flooding potential downstream of mine sites and logging operations.

Long-Term Stability of Valley Fills by OSM

This study was designed to address fill stability concerns indicating a perception that potential instability of valley fills would have consequences similar to impoundment structure failure. Scoping concerns also suggested that massive valley fills upstream of populated areas present safety hazards to life and property.

The study design was to evaluate the following questions:

> *Are fills adequately stable under the current regulatory scheme? If not, why and what alternatives are available?*

The study found that valley fill instability (i.e., landslides or land slips on fills) is neither commonplace nor widespread. The study concludes that valley fills, when constructed as designed (i.e., in conformance with the regulatory design and performance standards), are stable structures. Only twenty cases of critical instability (occurring over a large fraction of the fill face and/or requiring a major remediation effort) occurred out of more than 4,000 fills constructed in the past eighteen years.

One limitation of the study is that it relied on reports of known fill instability. No site-specific drilling, testing or analysis of active or completed fills could be performed due to the difficulty and expense of drilling large rock fills, obtaining adequate samples, and performing representative testing. The evaluation of 128 pre-selected fills in four states may not be considered as an appropriately large or representative sample. Other criticisms could include claims that the existing valley fills may not have achieved final consolidation and established a stable phreatic level. As such, the study cannot guarantee against future failures.

Estimation of Southwest Virginia Reserve Base of Surface Mineable Coal by Erik Westman, Department of Mining and Mineral Engineering, Virginia Polytechnic and State University (VPI)

The project was designed to identify areas of potential future surface mining. Remaining resources for Virginia coal seams historically surface mined are delineated using geographic information system (GIS) methods. Specifically, the study was developed to illustrate:

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What are projections for the extent of mountaintop mining in the Appalachian coalfields in the future?

In addition to delineating the remaining coal extent in seams historically surface mined in Virginia, VPI applied GIS techniques assuming "stripping ratio" (15:1), minimum tonnage (greater than 500,000 ton reserve blocks), and minimum coal thickness (18 inches) to each of the five seams. This approach was designed to show potential surface-mineable coal reserve areas based on typical current mining engineering thresholds for viability. However, it is extremely difficult to apply generalized mining engineering assumptions using a GIS model with great confidence. Therefore, the study presents only the projected geologic extent of coal that has not been mined in seams that have historically been mined by surface mining methods in Virginia. This map displays areas where mining exists, but mining may not be feasible, as discussed below:

- Available digital information on past mining is not exhaustive, but is based on the best available comprehensive data. Coal mining in these areas has occurred for more than 100 years and accurate records of all past mining is not possible to portray. Therefore, the maps indicate areas of remaining coal that may have actually been mined.

- A viable mining operation must be capable of efficiently removing a certain volume of overburden relative to each ton of coal extracted (the amount of overburden to coal is termed the "stripping ratio). Therefore, if the coal seam is too thin or too deep in the mountain (i.e., overlain by an amount of overburden than is more expensive to remove than the value of the coal recovered), surface mining may not be feasible. The GIS maps show the possible presence of coal, but do not take into account if the coal thickness and stripping ratio is suited for surface mining. Thus, the maps show a much larger area than will ever actually be mined.

- Currently the *average* stripping ratio is about 15 cubic yards of overburden to one ton of coal. However, the actual stripping ratio for any reserve block is dependent on the type and size of equipment to be used. Some companies may be able to mine areas with ratios as high as 25:1. Also, if a company has certain types of equipment, e.g., trucks, loaders and augers or highwall miners, they may tend to mine a reserve block differently than a company that has trucks and shovels or a dragline.. Because these are very company and site-specific decisions, they can not be easily generalized and modeling by GIS can not always provide credible or reliable results.

- Coal quality is an extremely important factor in mining viability. Mining companies must provide "compliance" coal to meet contracts for electrical generation (to maintain air quality standards) and must attain certain specifications for coking and steel production. Coal quality can be widely variable--even within the same seam over short distances. Thus, some areas of coal shown on the maps may not be mineable due to coal quality, and the GIS process in this study was unable to account for coal quality issues.

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- A surface mine must encompass a coal reserve block of sufficient size to be viable. Therefore some areas shown on the GIS map, after subtracting out poor quality and thin coal and excessive overburden, may not represent enough coal to warrant undertaking a mining operation. A GIS can determine the volume of coal in any given reserve polygon. But, the ability to graphically represent this factor, considering the other issues discussed here, does not overcome the study limitations to represent precise future mining locations.

- Mineral and surface ownership are another crucial factor relevant to surface mining feasibility. Even though there may be a coal reserve block of sufficient size to present viable mining potential, if the mineral ownership is split and rights to mine can not be obtained from all the mineral holders, mining can not occur. Similarly, in some circumstances, failure to obtain surface owner permission to mine will hinder mining. Other surface protected areas (e.g., state and national parks, forests, lakes, rivers, cities, hospitals, highways, etc.) may limit mineability. The costs of dealing with the presence of homes, buildings, gas wells, utility lines, and other features could preclude mining. A GIS can consider some, but not all, of these factors. Thus the GIS maps portray areas which might otherwise be deleted in site-specific analysis.

- Other site-specific factors like environmental constraints may keenly influence decisions to mine. For example, in Virginia, the large amount of past mining presents challenges to future mining. The presence of acid-forming materials in the overburden or pre-existing environmental liabilities (acid mine drainage, hazardous or industrial waste sites, highwalls, coal waste embankments or impoundments, etc.) may make mining costs excessive and limit mining particular reserves. A GIS can not model these factors.

In summary, the maps shown in this EIS identify only very general locations where potential future mining might take place, based on the geologic extent of remaining coal. This illustration is not meant to represent that this constitutes the actual scope of future impacts to the environment in the EIS study area. The actual future mining areas will be somewhere within these areas, but are dependent on complicated interplays of site-specific ownership, existing uses, mining engineering, environmental, and business/economic considerations. The study approach and findings are presented in III.O of the EIS. Due to the GIS nature of the study, a report is not presented in this appendix.

Estimation of Future Mountain-Top Removal Areas in the Eastern Kentucky Region by the Kentucky Geological Survey (KGS)

The project was developed to identify areas of potential future surface mining by delineating remaining areas of coal resources in three historically surface-mined coal zones in eastern

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Kentucky (namely the Richardson, Broas, and Peach Orchard coal zones). The study design was to answer the same questions as described in the Virginia discussion, above.

The GIS data base was provided following the specified procedure to map the geologic extent of coal in the three zones, eliminate known areas of past mining, and represent the remaining coal resource on GIS maps. Like Virginia, KGS attempted to delineate the mineable reserves by applying the mining engineering criteria used in mine planning. However, the same limitations described above for the Virginia study are applicable to Kentucky. For this reason, the EIS only presents the geologic extent of remaining coal, and the reader should not construe that the map illustrates the actual extent of future mining impacts in Kentucky. The study approach and findings are presented in III.O of the EIS. Due to the GIS nature of the study, a report is not presented in this appendix.

Projecting Future Coal Mining in Steep Terrain of Appalachia by the West Virginia Geological and Economic Survey (WVGES)

The project was assimilated into the EIS as a means to identify areas of potential future mountaintop surface coal mining in West Virginia. WVGES delineated potential future mountaintop mining areas by identifying remaining coal resources of the Coalburg zone, Stockton coal seam and overlying riders, and "Block" coal zones (No. 5 Block, No. 6 Block, and No.7 Block). The objective for this study was the same as for Virginia and Kentucky (see Virginia study description, above).

The GIS data base was provided following the specified procedures. Unlike Virginia, WVGES applied no mining engineering considerations to the data layers as part of this study. The EIS only presents the geologic extent of remaining coal. For the same reasons, as discussed above for the Virginia study, the WVGES study only portrays best available information on remaining coal in historically surface-mined seams. The reader should not construe that the map illustrates the actual extent of future mining impacts in West Virginia. The study approach and findings are presented in Chapter III.O. of the EIS. Due to the GIS nature of the study, a report is not presented in this appendix.

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****DRAFT DOCUMENT-- SUBJECT TO REVIEW AND REVISION****

Comparison of Peak Discharges Among Sites With and Without Valley Fills for the July 8-9, 2001 Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region, Southern West Virginia

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EXECUTIVE SUMMARY

The U.S. Geological Survey (USGS), in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of valley fills on the peak discharges for the flood of July 8-9, 2001. Results of this investigation indicate the sites without valley fills had peak discharges with10- to 25-year recurrence intervals. The flood recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and ranged from less than 2 year to greater than 100 years.

Introduction

Six small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province of southern West Virginia were selected for investigation following the flood of July 8-9. The 7-mi^2 area was assumed to be small enough that the rainfall intensities and totals would be approximately equal for the six basins. The six basins and site identifications are: Unnamed Tributary to Lick Run, USGS1; Unnamed Tributary to Clear Fork, USGS2; Unnamed Tributary to Buffalo Fork, MT65C; Buffalo Fork, MT66; Ewing Fork, USGS3 (near MT69); and, Reeds Branch, MT76. The "USGS" prefix indicates the site was selected by the USGS for this study, and the "MT" prefix indicates the site was already being used for preparation of the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). There are three sites in basins without valley fills (USGS1, USGS2, and USGS3) and three sites in basins with valley fills (MT65C, MT66, and MT76). The three sites in basins with valley fills are located downstream from the ponds at the toe of the fills.

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that had moved across northern West Virginia. The thunderstorm complex moved southeast from central West Virginia and into southeastern West Virginia by late morning on July 8, and by early afternoon 3- to 6-inches of rainfall had fallen in 5- to 6-hours.

Flooding from the thunderstorm complex was primarily caused by intense rainfall on relatively dry ground. Rainfall totals for the storm were approximately equal to the monthly average of about five inches (written commun., National Weather Service,

2001). The gaging station for Clear Fork at Whitesville (USGS station number 03198350) has a drainage area of 62.8 mi^2 and is located downstream from the study area. The indirectly measured peak discharge, caused by the July 8-9 storm, at this station had a frequency greater than 100 years.

Indirect Measurements of Peak Discharge

Indirect measurements of peak discharge for the six study sites ranged from 45 to 228 ft^3/s. (table 1).

Table 1. Indirectly measured peak discharges and estimated recurrence intervals for the flood of July 8-9, 2001 at the six study sites, in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

[USGS(n) identifies a site selected by the U.S. Geological for this study; MT(n) indicates that the site being used in this study was part of the Mountaintop Mining/Valley Fill Environmental Impact Statement study, where (n) is a unique numeric or alphanumeric identification.]

Basin name	Site identifier	Latitude	Longitude	Drainage area, in square miles	Indirectly measured peak discharge, in cubic feet per second	Estimated flood recurrence interval, in years[a]
		Basins without valley fills				
Unnamed Tributary to Lick Run	USGS1	37°52’36”	81°18’31”	0.461	140	25
Unnamed Tributary to Clear Fork	USGS2	37°52’42”	81°19’50”	.360	90	10
Ewing Fork[b]	USGS3	37°54’45”	81°19’34”	1.17	228	10
		Basins with valley fills				
Unnamed Tributary to Buffalo Fork	MT65C	37°53’48”	81°19’38”	.189[c]	113	>100[d]
Buffalo Fork	MT66	37°53’47”	81°19’09”	.583	224	50-100[d]
Reeds Branch	MT76	37°54’28”	81°18’46”	.462	45	<2[d]

[a] Flood recurrence interval was determined using Wiley, and others (2000) and considering the sensitivity of calculated discharges to Manning’s roughness coefficients.

[b] Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

[c] Drainage area was revised from the 65 acres (0.102 square miles) used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement and is the value published by Wiley and others (2001).

[d] Flood recurrence interval of indirectly measured peak discharge as though the peak discharge was that from a rural stream without the influence of valley fills.

The study plan assumed the six study basins were within an area (7 mi^2) small enough that rainfall intensities and totals would be approximately equal, but this assumption was determined invalid. The flood recurrence intervals for the three basins without valley fills should be approximately equal if the assumption was correct. Table 1 shows that the flood recurrence intervals for the three basins without valley fills (USGS1, USGS2, and USGS3) are not equal. The flood frequencies were between 10 and 25 years with the greatest flood frequency at the most southern basin, USGS1.

The flood recurrence intervals for the three basins with valley fills (determined as though the peak discharges were those from rural streams without the regulation of valley fills) were between less than 2 years and greater than 100 years (table 1). The smallest recurrence interval was at MT76, the site in the most northern basin with valley fills, no active surface mining, a reclaimed valley fill, and the largest valley fill in this study. The greatest recurrence interval was at MT65C, the site in a basin with active surface mining, one reclaimed and one unreclaimed valley fill. The site MT65C has the only unreclaimed valley fill in this study.

The indirect measurement for the site MT65C was made at the outflow of a pond downstream from two valley fills. The drainage area of MT65C, 0.189 mi^2, is a revised value from the 65 acres (0.102 square miles) previously used to prepare the Mountaintop Mining/Valley Fill EIS and published by Wiley and others (2001). Including only one of the two valley fills in the previous measurement probably caused the incorrect determination of drainage area.

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Wiley, J.B., Evaldi, R.D., Eychaner, J.H., and Chambers, D.B., 2001, Reconnaissance of stream geomorphology, low streamflow, and stream temperature in the mountaintop coal-mining region, southern West Virginia, 1999-2000: U.S. Geological Survey Water-Resources Investigations Report 01-4092, 34 p.

EXECUTIVE SUMMARY: COMPARISON OF STREAM CHARACTERISTICS IN SMALL GAGED, UNMINED AND MOUNTAINTOP-REMOVAL MINED WATERSHEDS, BALLARD FORK, WEST VIRGINIA, 1999-2001

Terence Messinger and Katherine S. Paybins

Introduction: The U.S. Geological Survey (USGS) began a study of the effects of mountaintop removal coal mining on flow in the Ballard Fork watershed, in the upper Mud River basin near Madison, W.Va., in November 1999. Three continuous flow-gaging stations were installed. One gaging station was located on an Unnamed Tributary to Ballard Fork, directly downstream from a valley fill, and upstream from the sediment pond (fig. 1). The entire watershed of this stream

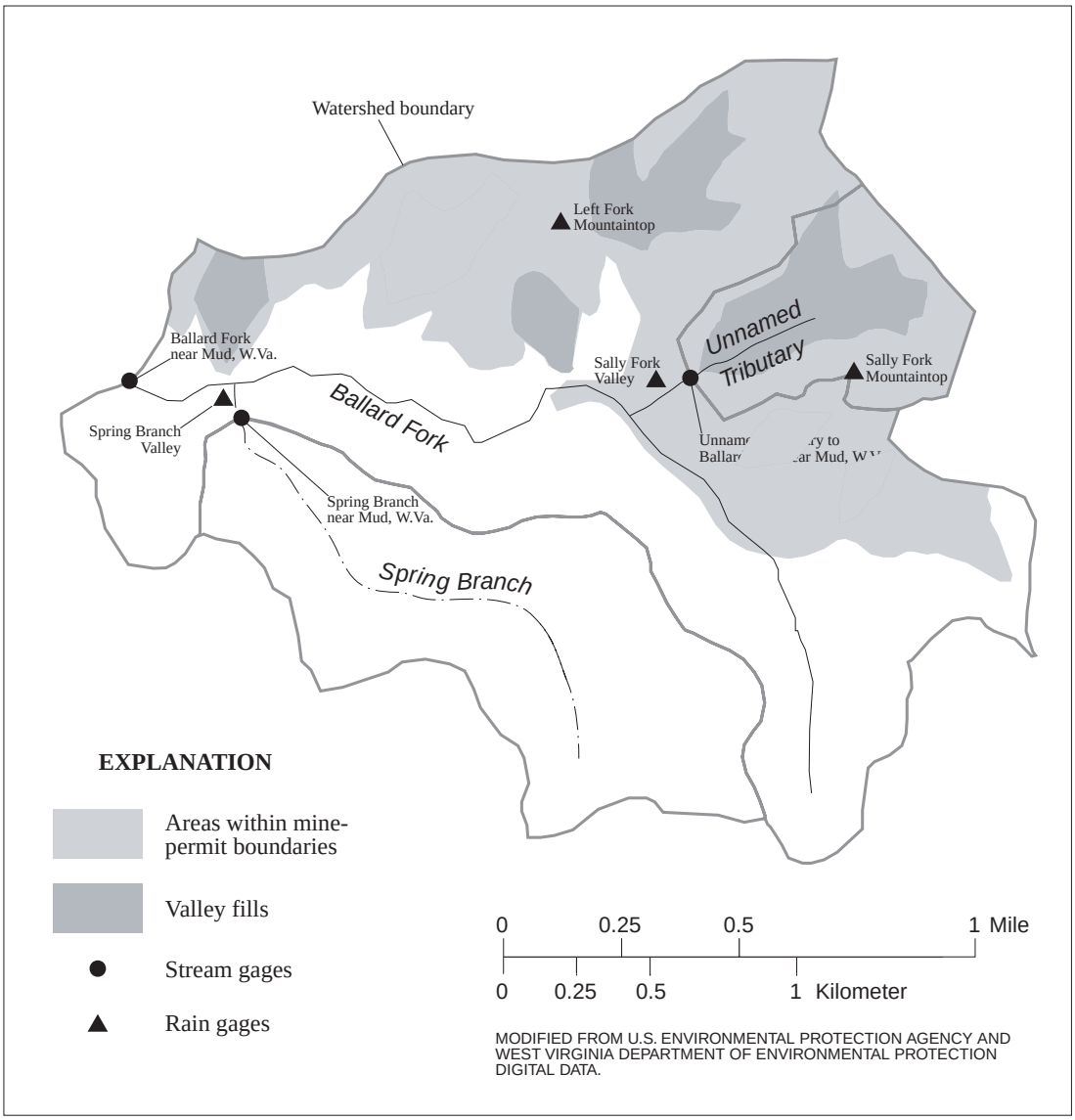

Figure 1. Streams, gages, valley fills, and areas permitted for mining in the Ballard Fork watershed.

(0.19 mi^2) is within an area permitted for mining, and all but a few acres is mined. The second gaging station, near the mouth of Spring Branch, drains an unmined, forested watershed (0.53 mi^2). The third gaging station was located on the main stem of Ballard Fork, which drains an area (2.12 mi^2) that includes both the Unnamed Tributary and Spring Branch watersheds. The entire Ballard Fork watershed is either surface mined or forested. Forty percent of the Ballard Fork watershed is within areas that had been permitted for mining, although less (about 30 percent) of the watershed was actually mined. About 44 percent of the Unnamed Tributary and 12 percent of the Ballard Fork watersheds is covered by valley fills.

Four rain gages were used during this study to collect precipitation data. Two rain gages were operated in mined areas on mountaintops, and the other two were in open areas on the valley floor. Precipitation amounts reported in this document are the average of amounts recorded at these four rain gages.

Mines in the Ballard Fork watershed received a Phase 1 bond release in August 2000, although mine inspection forms filed since November 1997 estimated that grading and backfilling was complete on all but 10 acres. The mined areas had grasses and other herbaceous vegetation typical of a newly reclaimed surface mine. Forest in Spring Branch and the rest of Ballard Fork was second- or third-growth, and dominant canopy species included white and red oak, several hickory species, sycamore, and tulip poplar.

Hydrologic conditions: Because this study began in November 1999, long-term conditions were assessed by comparison with nearby sites with long periods of record. Hydrologic conditions observed during the study period at three nearby long-term sites, the USGS stream-gaging station East Fork Twelvepole Creek near Dunlow, W.Va., and two NOAA rain gages at Madison and Dunlow, W.Va., were drier than long-term averages. Total precipitation in 2000 at both Madison and Dunlow (46.2 and 47.4 inches, respectively) was close to long-term averages (47.8 and 45.7 inches, respectively, 1971-2000), but was decreased substantially in 2001 (40.2 and 35.0 inches, respectively). Flow at East Fork Twelvepole Creek was well below the long-term average both years. The disparity between normal precipitation and low flow in 2000 was caused by the season when the precipitation was received. Precipitation at Madison was 4.71 inches below average from November 1999 through March 2000, the season of maximum recharge and runoff, and exceeded the long-term average during only three months, April (by 0.24 inches), June (by 1.76 inches), and July (by 0.20 inches), in the period of maximum evapotranspiration.

Total Flow: Total unit flow for the two-year study period on the Unnamed Tributary (11,700 $ft^3/s/mi^2$) was almost twice that on Spring Branch (6,260 $ft^3/s/mi^2$), and about 1.75 times that on Ballard Fork (6,690 $ft^3/s/mi^2$). The highest monthly flow in the study period in Spring Branch and Ballard Fork was during May 2001, because of a series of thunderstorms that produced 6.22 in. of rain in eight days, May 15-May 22. In contrast, the maximum monthly total flow on the Unnamed Tributary was in June 2001, although flows were similar from May through July 2001, the usual period of maximum evapotranspiration in forested watersheds.

The daily hydrograph shows that summer and autumn flows were relatively higher in the Unnamed Tributary than Ballard Fork, and relatively higher in Ballard Fork than in Spring Branch (fig. 2). Spring Branch was dry during much of October and November 2000, and its

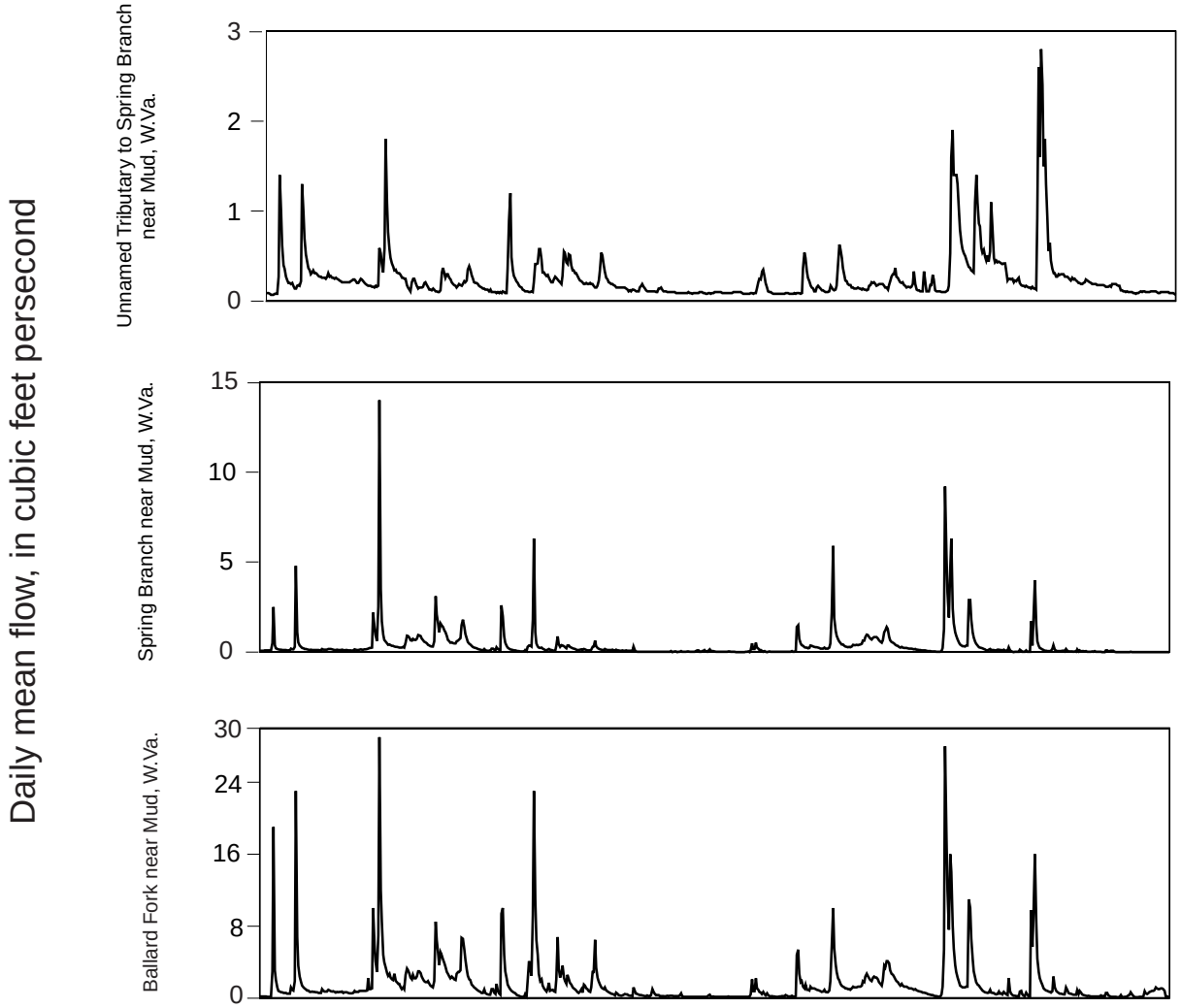

Figure 2. Hydrographs for three streams in the Ballard Fork watershed, W.Va., November 15, 1999-November 14, 2001.

monthly mean flow for October 2001, was zero. Ballard Fork and the Unnamed Tributary had flow throughout the study period. Daily mean flow was significantly ($P < 0.01$) correlated among the three streams in the Ballard Fork watershed. This correlation was strongest between Spring Branch and Ballard Fork ($R^2 = 0.723$), weakest between Spring Branch and the Unnamed Tributary ($R^2 = 0.370$), and intermediate between Ballard Fork and the Unnamed Tributary ($R^2 = 0.569$).

Flow duration: Flow duration curves show the lowest unit flows from Spring Branch, the highest unit flows from the Unnamed Tributary, and intermediate unit flows from Ballard Fork (fig. 3). Unit flow from the Unnamed Tributary watershed was the highest of the three streams at

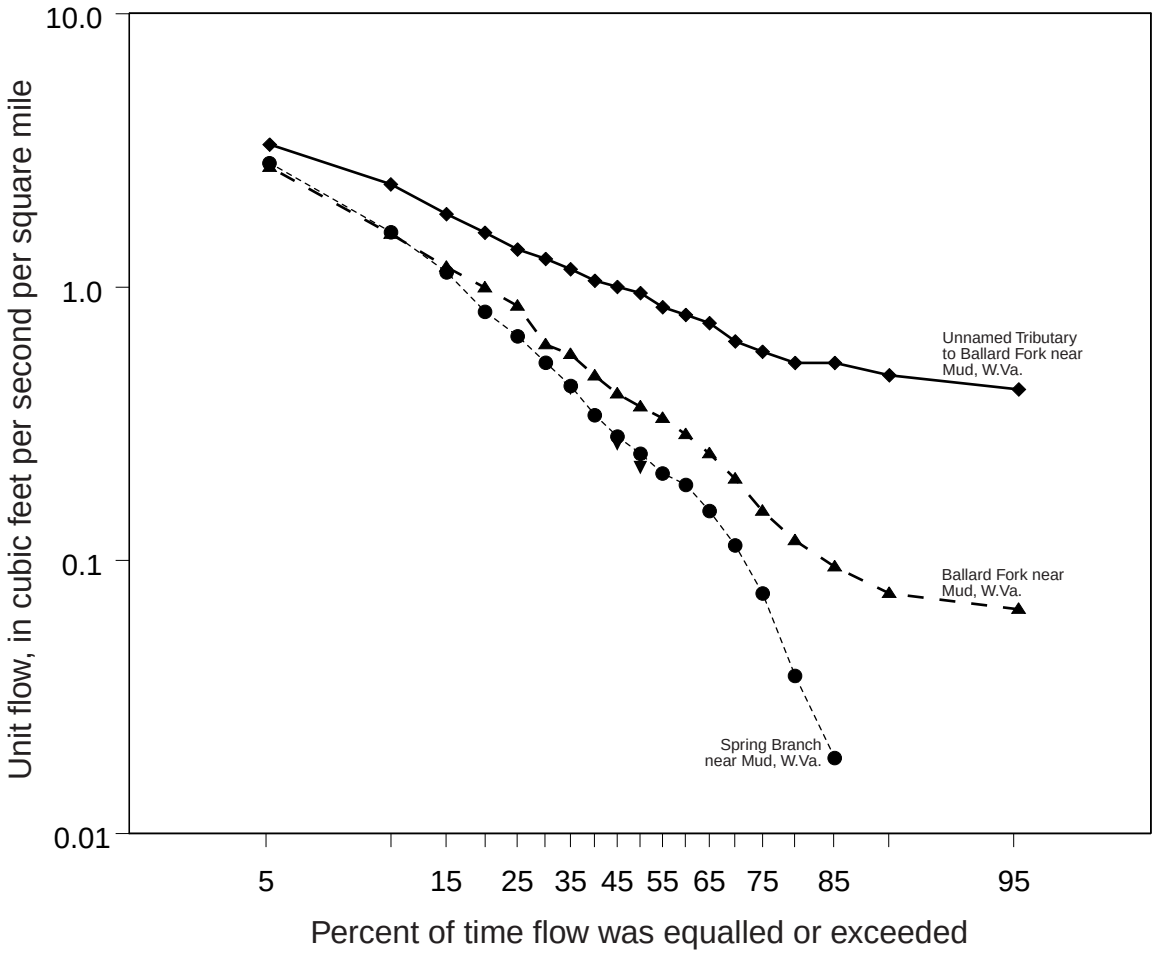

Figure 3. Flow duration of three streams in the Ballard Fork watershed, W.Va.., November 15, 1999-November 14, 2001.

all flows analyzed, between 5 and 95 percent flow duration, but the relative difference was greatest for low flows. Low flows in the Unnamed Tributary were probably increased because of

decreased evapotranspiration on the mine as compared to the forest and delayed drainage of water stored in the valley fill. Unit flows from Ballard Fork and Spring Branch were about the same at higher flows, but unit flow from Ballard Fork was much higher than that from Spring Branch at low flow.

Evapotranspiration: Reduced evapotranspiration in mined areas probably accounts for the marked difference in total and low unit flow between the Unnamed Tributary and Spring Branch watersheds. Evapotranspiration, as a percentage of total rainfall, decreased from the first to the second, drier, year from the Unnamed Tributary watershed (from 61 percent to 45 percent) but changed relatively little from the Spring Branch (from 77 to 74 percent) and Ballard Fork (76 to 78 percent) watersheds. Evapotranspiration from the East Fork of Twelvepole Creek watershed was much higher during the study period (76 percent the first year, and 78 percent the second year) than the 1965-2001 average (60 percent). Most of the mechanisms of evapotranspiration appear to be lower on reclaimed surface mines than in forests, because most of them are mechanisms that evolved in plants to use or conserve water. Plant biomass in the mined areas is much less than in forested areas.

Unit flow per unit precipitation from Spring Branch only exceeded that from the Unnamed Tributary during spring months, February-April 2000 and February-March 2001, but even then, exceeded it by less than measurement error (fig. 4). Unit flow per unit precipitation from the

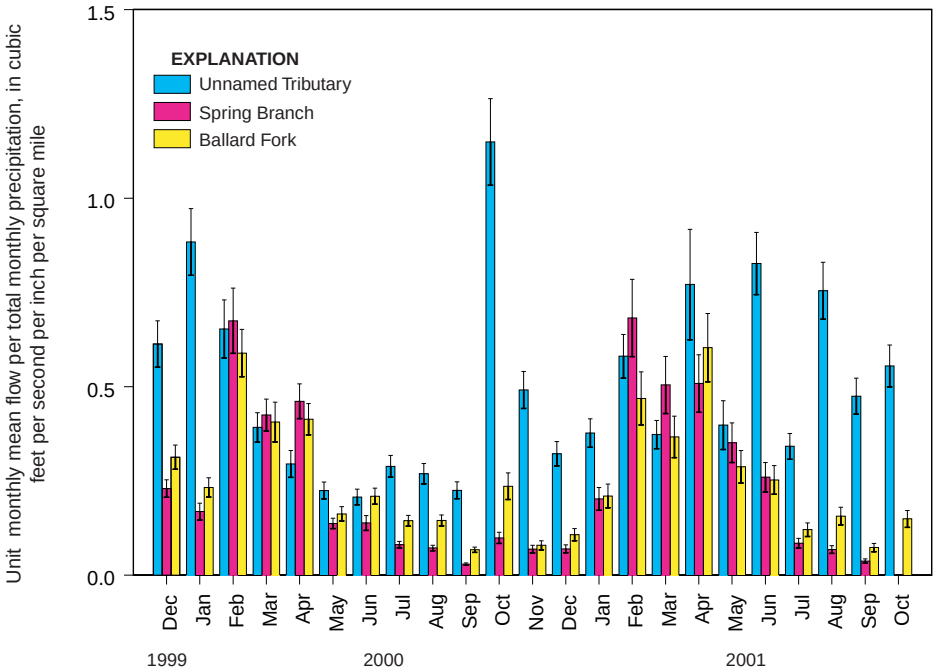

Figure 4. Unit monthly mean flow per total monthly precipitation for three sites in the Ballard Fork watershed, W.Va., 1999-2001. Only whole months are shown. Error bars represent the sum of daily-mean streamflow variance determined from estimates of data quality made by Ward and others (2001, 2002). Spring Branch had an average flow of zero during October, 2001.

Unnamed Tributary watershed was more or much more than that from the Spring Branch watershed during summer and fall months.

Conclusions: Unit daily mean flow was higher from the Unnamed Tributary, which drains a predominantly mined watershed, than from Spring Branch, which drains an unmined, forested watershed, at all flows between 5 and 95 percent duration. The relative difference was greatest at lower flows. Unit daily mean flows from Ballard Fork, which drains a watershed including both these other streams and is about 30 percent mined, were about the same as those from Spring Branch at higher flows (greater than about 15 percent duration), and were intermediate between the Unnamed Tributary and Spring Branch at lower flows. Spring Branch dried up both years of the study, and its mean flow in October 2001 was zero; the Unnamed Tributary had flow throughout the study period. Some mechanism delays some of the flow from the mined area. Storage of water in or under the valley fill is the most likely mechanism.

Total unit flow from the Unnamed Tributary was nearly twice that from Spring Branch during the two-year study period. Storage of water in the mined areas does not account for this difference, because all the flow in the Ballard Fork watershed originated as precipitation, and precipitation was the same on mined and unmined areas. Reduced evapotranspiration in the mined areas probably accounts for the difference in total flow. Evapotranspiration from mined areas was probably less than that from forested areas because most mechanisms of evapotranspiration, such as interception and transpiration, are functions of plants and plant biomass is much less in mined areas than in unmined areas. The difference in total flow and low flow between the mined and unmined areas will probably change as plant cover and biomass change on the reclaimed mines.

EXECUTIVE SUMMARY: COMPARISON OF STORM RESPONSE IN SMALL, UNMINED AND MOUNTAINTOP-REMOVAL MINED WATERSHEDS, 1999-2001, BALLARD FORK, WEST VIRGINIA

Terence Messinger

Abstract: Peak unit flows following summer storms with rainfall exceeding about one inch per hour, approximately the one-year return period, were greater from a watershed comprised of a mountaintop-removal coal mine (Unnamed Tributary) than from an unmined watershed (Spring Branch) in the Ballard Fork watershed in West Virginia. Following all storms with rainfall intensity of about 0.25 in. per hour or more, the storm hydrograph from the Unnamed Tributary watershed showed a sharp initial rise, followed by a decrease in flow, then a delayed secondary peak of water that had apparently flowed through the valley fill. One storm that produced less than an inch of rain before the secondary peak from the previous storm had receded caused peak unit flow from the Unnamed Tributary to exceed peak unit flow from Spring Branch. Peak unit flow from the Unnamed Tributary was less than peak unit flow from Spring Branch following slow, soaking rains. No storms during this study produced 1-hour or 24-hour rainfall in excess of the 5-year return period, and flow during this study never exceeded the 1.5-year return period. Runoff patterns from the Unnamed Tributary watershed appear to be influenced by the compaction of soils on the mine, by the low maximum infiltration rate into the valley fill compared to the forested watershed, by storage of water in the valley fill, and by the absence from the mine of interception from trees and leaf litter.

Introduction: The U.S. Geological Survey (USGS) began a study of the effects of mountaintop removal coal mining on flow in the Ballard Fork watershed, in the upper Mud River basin near Madison, W.Va., in November 1999. Three continuous flow-gaging stations were installed. One gage was located on an Unnamed Tributary to Ballard Fork, directly downstream from a valley fill, and upstream from the sediment pond. The entire watershed of this stream (0.19 mi^2) is within an area permitted for mining, and all but a few acres is mined. The second gage, near the mouth of Spring Branch, drains an unmined, forested watershed (0.53 mi^2). The third gage was located on the main stem of Ballard Fork, which drains an area (2.12 mi^2) that includes both the Unnamed Tributary and Spring Branch watersheds. The entire Ballard Fork watershed is either surface mined or forested, although the forested areas contain some pipelines and all-terrain vehicle trails that probably affect rainfall-runoff relations. Forty percent of the Ballard Fork watershed is within areas that had been permitted for mining, although less (about 30 percent) of the watershed was actually mined. About 44 percent of the Unnamed Tributary and 12 percent of the Ballard Fork watershed is covered by valley fills.

Four rain gages were used during this study to collect precipitation data. Two rain gages were operated in mined areas on mountaintops, and the other two were in open areas on the valley floor. Precipitation amounts reported in this document are the average of amounts recorded at these four rain gages.

Mines in the Ballard Fork watershed received a Phase 1 bond release in August 2000, although mine inspection forms filed since November 1997 estimated that grading and backfilling was complete on all but 10 acres. The mined areas was sparsely covered with grasses, other herbaceous vegetation, and small trees typical of a newly reclaimed surface mine. Forest in Spring Branch and the rest of Ballard Fork was second- or third-growth, and dominant canopy species included white and red oak, several hickory species, sycamore, and tulip poplar.

Precipitation: Greatest average 1-hour total precipitation recorded at the four rain gages (1.63 in., standard deviation = 0.11 in.) during the study period was July 26 between 3:30 p.m. and 4:30 p.m. The greatest 24-hour total precipitation (3.16 in., standard deviation = 0.24 in.) during the study was during the same storm, between 1:00 a.m. July 26 and 1:00 a.m. July 27. The return period for both the 1-hour and 24-hour rainfall from this storm was between two and five years. Average 1-hour precipitation exceeded 1.1 in. (about the 1-hour, 1-year rainfall) on June 6, 2001, and average precipitation plus one standard deviation exceeded 1.1 in. on June 21, 2000, and August 12, 2001. Average 24-hour rainfall exceeded 2.0 in. (about the 24-hour, 1-year rainfall) during one other storm, on November 26, 1999, and average precipitation plus one standard deviation exceeded 2.0 in. during three other storms during the study period.

Most of the intense rainfall in the Ballard Fork watershed during this study fell during summer thunderstorms. Of the 10 largest 1-hour average rainfalls, eight were during May through September, and six of these storms were during June and July. The largest 24-hour total rainfalls were generally recorded in the summer, as well; eight of the ten highest 24-hour rainfall totals were recorded during May, June, or July. In general, rainfall recorded by the Sally Fork Mountaintop rain gage, in the Unnamed Tributary watershed, was less than rainfall recorded at the other three rain gages; for the ten storms with the highest 1-hour rainfall, the Sally Fork Mountaintop rain gage reading was less than the average eight times.

Peak flows: Maximum instantaneous flow during the study period was 8.9 ft^3/s for the Unnamed Tributary (July 26, 2001), 87 ft^3/s for Ballard Fork (May 18, 2001), and 34 ft^3/s for Spring Branch (February 19, 2000). Instantaneous flow recorded during the study period did not exceed the 1.5-year return period at any site.

Peaks with unit flow greater than 20 $ft^3/s/mi^2$ were recorded five times at the Unnamed Tributary, eleven times at Spring Branch, and nine times at Ballard Fork. All three gages recorded flows in this range during four of the five storms, which raised unit flow in the Unnamed Tributary above 20 $ft^3/s/mi^2$, although the Spring Branch gage was not operating during the fifth storm, of May 18, 2001.

Storm response: Response of the Unnamed Tributary to different types of storms was distinctly different from response of Spring Branch and Ballard Fork. Spring Branch and Ballard Fork generally rose when total moisture in their watersheds increased. These streams generally peaked shortly after rainfall ended, and quickly receded.

In contrast, the Unnamed Tributary's storm hydrograph typically showed a double peak when rainfall intensity exceeded about 0.25 in./hour. The hydrograph of November 26-27, 1999, shows this pattern clearly (fig. 1). Total rainfall for this storm exceeded 3.0

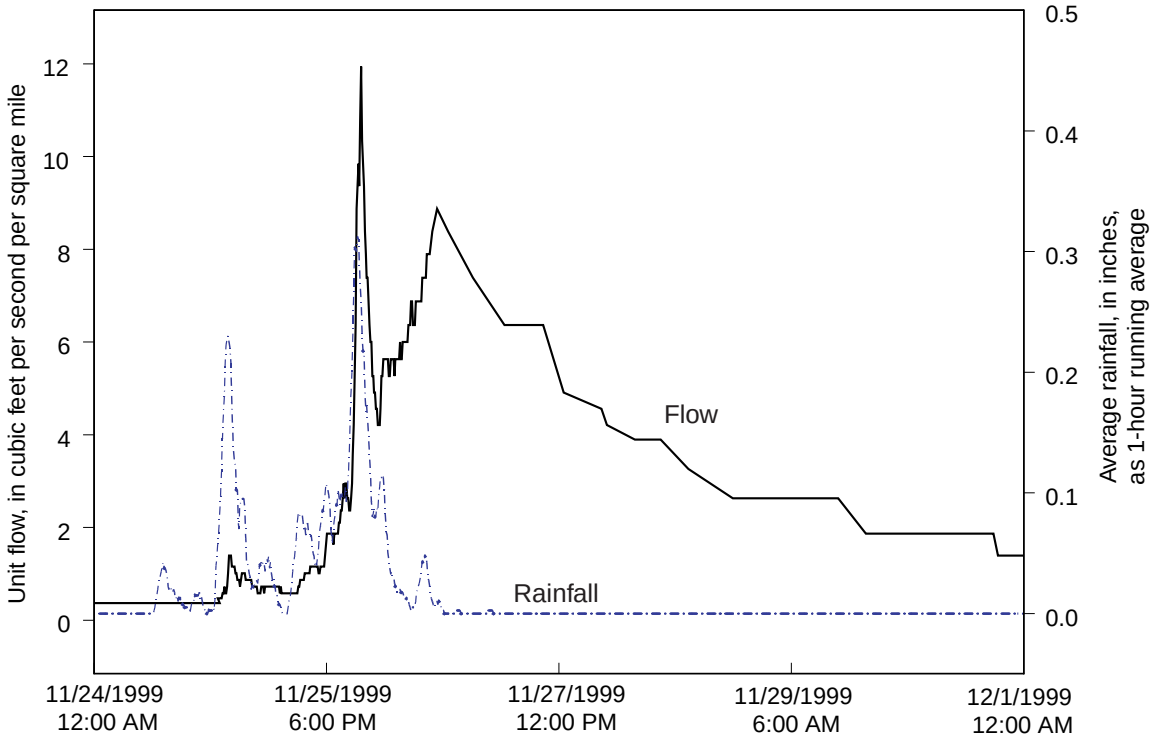

Figure 1. Storm hydrograph at Unnamed Tributary of Ballard Fork near Mud, W.Va., and rainfall, as a 1-hour running average, for four rain gages in the Ballard Fork watershed.

in., and much of it fell as a slow, soaking rain; the maximum one-hour rainfall recorded at any rain gage was 0.48 in. Antecedent conditions were dry; the rain of November 24 was the first since November 2. Although the rain fell in two major bursts, the storm hydrograph had the same shape typical of storms in which rain fell in only one major burst. About 0.73 in. of rain fell on November 25-26 between 9:30 p.m. and 3:30 a.m. When rain was received with an intensity of about 0.3 in. per hour at about midnight on November 26, the infiltration capacity of the watershed was apparently exceeded, causing a sharp peak in flow. This peak quickly receded when rain intensity decreased, but the delayed flow of water that had apparently flowed through the valley fill continued to increase and peaked at 2:00 p.m. on November 26, eight hours after the last rain fell that exceeded 0.10 in./hour.

During most storms, peak unit flow from Spring Branch and Ballard Fork exceeded peak unit flow from the Unnamed Tributary, despite the effects of interception on runoff in the forested watersheds. However, in the two most intense storms during the study period, on June 6, 2001 (maximum average one-hour rainfall = 1.24 in.) and July 26, 2001 (maximum average one-hour rainfall = 1.63 in.), maximum runoff from the Unnamed Tributary exceeded maximum runoff in the forested watersheds. Both of these storms took place in midsummer, when rainfall interception by trees is at its maximum. In the third most intense storm during the study period, June 21, 2000, the gage at the Unnamed Tributary malfunctioned, so relative unit flows from this storm are unknown.

In the storm of July 26, 2001, intense rain apparently exceeded infiltration capacity of the Unnamed Tributary watershed and led to sharp peak in flow that exceeded unit flow at the other two gages (fig. 2). Antecedent conditions to the July 26 storm were moderate; the Ballard Fork watershed received nearly 0.50 in. of rain the afternoon of July 22. The initial substantial rain (maximum rainfall intensity = 0.25 in./hour) beginning about 7:00 a.m. on July 26 did not cause a runoff response from any stream.

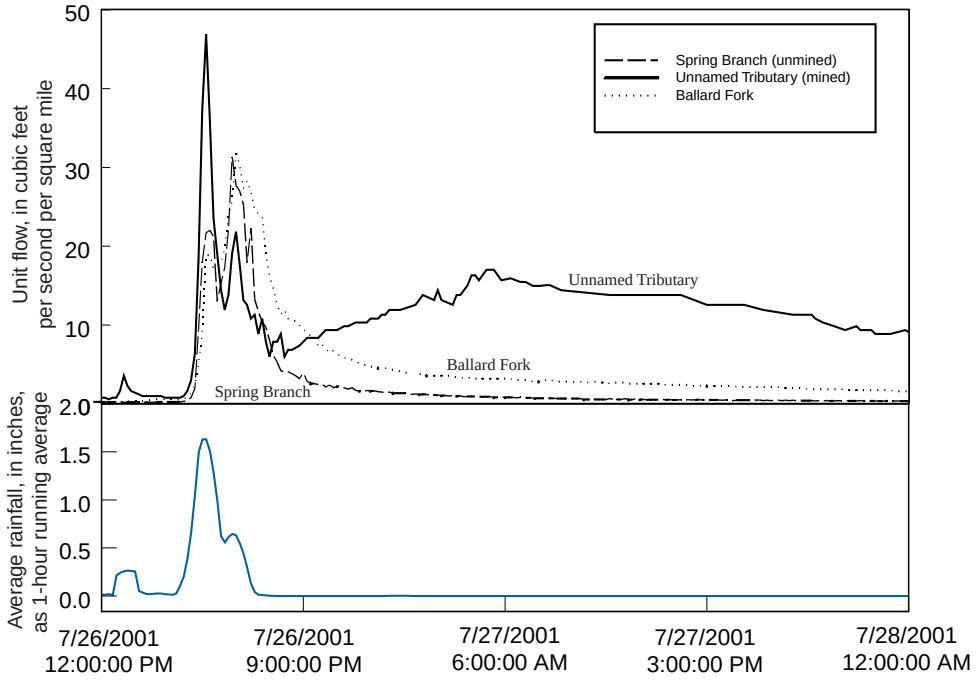

Figure 2. Storm hydrograph for July 26-28, 2001, for three stream gages, and rainfall, as a 1-hour running average for four rain gages, in the Ballard Fork watershed.

The most intense rainfall recorded during this study was received between 3:50 p.m. and 4:30 p.m. on July 26, more than 1.3 in. The Unnamed Tributary rose sharply in response to this rain, and peaked at 4:40 p.m., while rain was still falling but after intensity had decreased. Maximum unit flow for the Unnamed Tributary was 46.9 $ft^3/s/mi^2$. Although the two other watersheds responded to this burst of rain, their peaks were later in the evening, at about 6:00 p.m., at the end of a final spate of rain of 0.63 in./hour. The Unnamed Tributary responded less strongly to the final rain than it had to the earlier, more intense rain, with a maximum unit flow on the second peak of 21.8 $ft^3/s/mi^2$. The initial peak on the Unnamed Tributary receded as quickly as Spring Branch and more quickly than Ballard Fork, but about 8:30 p.m., a secondary peak began on the Unnamed Tributary, apparently of water that had flowed through the valley fill. This attenuated secondary peak reached a maximum unit flow of 19.1 $ft^3/s/mi^2$ at 6:20 a.m. July 27, several hours after Spring Branch and Ballard Fork had largely receded.

Peak unit flow from the valley fill exceeded peak unit flow from the other watersheds on July 29, when rainfall of unexceptional intensity (maximum one-hour rainfall = 0.82 in.) was received before a secondary peak on the Unnamed Tributary had receded. Rain on July 28 caused small initial rises on all three streams. When a hard rain fell on the afternoon of July 29, the peaks on Spring Branch and Ballard Fork had receded, but the Unnamed Tributary was still rising from delayed flow from July 28.

Discussion: Runoff patterns from the Unnamed Tributary watershed appear to be influenced by compaction of soils on the mine, by the low maximum infiltration rate into the mine and valley fill compared to the forested watershed, by storage of water in the valley fill, and by the absence of interception from trees and leaf litter on the mine. Soils on mined areas are typically heavily compacted to prevent erosion, which decreases infiltration capacity. Hortonian (excess overland) flow appears to be important in the Unnamed Tributary watershed following intense storms, and to cause the initial peak on the rising arm of storm hydrographs; Hortonian flow is rare in the eastern U.S. except from urban or other highly disturbed watersheds. The initial sharp peak, the part of the hydrograph that is apparently Hortonian flow, appears following storms with intensity greater than about 0.25 in./hour.

Typical canopy interception rates in eastern hardwood forests are about ten per cent of gross rainfall, and dry leaf litter may intercept several tenths of an inch of water that falls through the canopy. Water that would have been retained by these processes in the Spring Branch watershed was available to run off the Unnamed Tributary watershed. Because of these factors, unit flow from the mined watershed exceeded unit flow from the unmined watershed during storms when rainfall exceeded about 1 in./hour, suggesting that mountaintop removal mining is

likely to increase flooding from intense summer thunderstorms. Once during this study, peak unit flow from the Unnamed Tributary watershed exceeded runoff from the Spring Branch watershed because a hard rain was received before the delayed secondary peak on the Unnamed Tributary had receded. This suggests that mountaintop removal mining is especially likely to increase flooding during summer storm systems that last several days.

A large proportion of storm water received in the Unnamed Tributary watershed runs off during a period 8 to 48 hours after rain stops, compared to 0 to 4 hours in the Spring Branch watershed. Comparison of total volume running off from three selected storms showed that (1) total unit flow during all three storms was greatest from the Unnamed Tributary, (2) for the Unnamed Tributary, flow during recessions exceeded storm runoff during all three storms, although for Spring Branch, storm runoff exceeded flow during recessions in two storms, and (3) total unit flow as storm runoff from the Unnamed Tributary was typically less than unit storm runoff from Spring Branch and Ballard Fork. Although most of the water running off the Unnamed Tributary watershed comes in this delayed flow, the overall peak for most storms is the sharp, initial peak.

Peak unit flow from a storm is expected to be greater from a smaller watershed, if all land-use and other characteristics are identical. In this study, peak unit flow from the Spring Branch watershed usually exceeded peak unit flow from the Unnamed Tributary watershed, and was usually about the same as peak unit flow from the overall Ballard Fork watershed. Rainfall-runoff relations on altered landscapes are site-specific and mining and reclamation practices that affect storm response may vary among mines.

EXECUTIVE SUMMARY: COMPARISON OF PEAK DISCHARGES AMONG SITES WITH AND WITHOUT VALLEY FILLS FOR THE JULY 8-9, 2001 FLOOD IN THE HEADWATERS OF CLEAR FORK, COAL RIVER BASIN, MOUNTAINTOP COAL-MINING REGION, SOUTHERN WEST VIRGINIA

Jeffrey B. Wiley

The U.S. Geological Survey (USGS), in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of valley fills on the peak discharges for the flood of July 8-9, 2001. Results of this investigation indicate the sites without valley fills had peak discharges with10- to 25-year recurrence intervals. The flood recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and ranged from less than 2 year to greater than 100 years.

Introduction

Six small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province of southern West Virginia were selected for investigation following the flood of July 8-9. The 7-mi^2 area was assumed to be small enough that the rainfall intensities and totals would be approximately equal for the six basins. The six basins and site identifications are: Unnamed Tributary to Lick Run, USGS1; Unnamed Tributary to Clear Fork, USGS2; Unnamed Tributary to Buffalo Fork, MT65C; Buffalo Fork, MT66; Ewing Fork, USGS3 (near MT69); and, Reeds Branch, MT76. The “USGS” prefix indicates the site was selected by the USGS for this study, and the “MT” prefix indicates the site was already being used for preparation of the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). There are three sites in basins without valley fills (USGS1, USGS2, and USGS3) and three sites in basins with valley fills (MT65C, MT66, and MT76). The three sites in basins with valley fills are located downstream from the ponds at the toe of the fills.

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that had moved across northern West Virginia. The thunderstorm complex moved southeast from central West Virginia and into southeastern West Virginia by late morning on July 8, and by early afternoon 3- to 6-inches of rainfall had fallen in 5- to 6-hours.

Flooding from the thunderstorm complex was primarily caused by intense rainfall on relatively dry ground. Rainfall totals for the storm were approximately equal to the monthly average of about five inches (written commun., National Weather Service, 2001). The gaging station for Clear Fork at Whitesville (USGS station number 03198350) has a drainage area of 62.8 mi^2 and is located downstream from the study area. The indirectly measured peak discharge, caused by the July 8-9 storm, at this station had a frequency greater than 100 years.

Indirect Measurements of Peak Discharge

Indirect measurements of peak discharge for the six study sites ranged from 45 to 228 ft^3/s. (table 1).

The study plan assumed the six study basins were within an area (7 mi^2) small enough that rainfall intensities and totals would be approximately equal, but this assumption was determined invalid. The flood recurrence intervals for the three basins without valley fills should be approximately equal if the assumption was correct. Table 1 shows that the flood recurrence intervals for the three basins without valley fills (USGS1, USGS2, and USGS3) are not equal. The flood frequencies were between 10 and 25 years with the greatest flood frequency at the most southern basin, USGS1.

Table 1. Indirectly measured peak discharges and estimated recurrence intervals for the flood of July 8-9, 2001 at the six study sites, in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

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Basin name	Site identifier	Latitude	Longitude	Drainage area, in square miles	Indirectly measured peak discharge, in cubic feet per second	Estimated flood recurrence interval, in years[a]
		Basins without valley fills				
Unnamed Tributary to Lick Run	USGS1	37°52’36”	81°18’31”	0.461	140	25
Unnamed Tributary to Clear Fork	USGS2	37°52’42”	81°19’50”	.360	90	10
Ewing Fork[b]	USGS3	37°54’45”	81°19’34”	1.17	228	10
		Basins with valley fills				
Unnamed Tributary to Buffalo Fork	MT65C	37°53’48”	81°19’38”	.189[c]	113	>100[d]
Buffalo Fork	MT66	37°53’47”	81°19’09”	.583	224	50-100[d]
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[a] Flood recurrence interval was determined using Wiley, and others (2000) and considering the sensitivity of calculated discharges to Manning’s roughness coefficients.

[b] Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

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[d] Flood recurrence interval of indirectly measured peak discharge as though the peak discharge was that from a rural stream without the influence of valley fills.

The flood recurrence intervals for the three basins with valley fills (determined as though the peak discharges were those from rural streams without the regulation of valley fills) were between less than 2 years and greater than 100 years (table 1). The smallest recurrence interval was at MT76, the site in the most northern basin with valley fills, no active surface mining, a reclaimed valley fill, and the largest valley fill in this study. The greatest recurrence interval was at MT65C, the site in a basin with active surface mining, one reclaimed and one unreclaimed valley fill. The site MT65C has the only unreclaimed valley fill in this study.

The indirect measurement for the site MT65C was made at the outflow of a pond downstream from two valley fills. The drainage area of MT65C, 0.189 mi^2, is a revised value from the 65 acres (0.102 square miles) previously used to prepare the Mountaintop Mining/Valley Fill EIS and published by Wiley and others (2001). Including only one of the two valley fills in the previous measurement probably caused the incorrect determination of drainage area.

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Source: Wiley, J.B., and Brogan, F.D., 2003, Comparison of peak discharges among sites with and without valley fills for the July 8-9, 2001, flood in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia: U.S. Geological Survey Open-File Report 03-133.

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EXECUTIVE SUMMARY: COMPARISON OF STREAM CHARACTERISTICS IN SMALL GAGED, UNMINED AND VALLEY-FILLED WATERSHEDS, BALLARD FORK, WEST VIRGINIA, 1999-2001

Terence Messinger and Katherine S. Paybins

Introduction: The U.S. Geological Survey (USGS) began a study of the effects on stream flow of surface mines and valley fills in the Ballard Fork watershed, in the upper Mud River basin near Madison, W.Va., in November 1999. Three continuous flow-gaging stations were installed. One gaging station was located on an Unnamed Tributary to Ballard Fork, directly downstream from a valley fill, and upstream from the sediment pond (fig. 1). The entire watershed of this stream

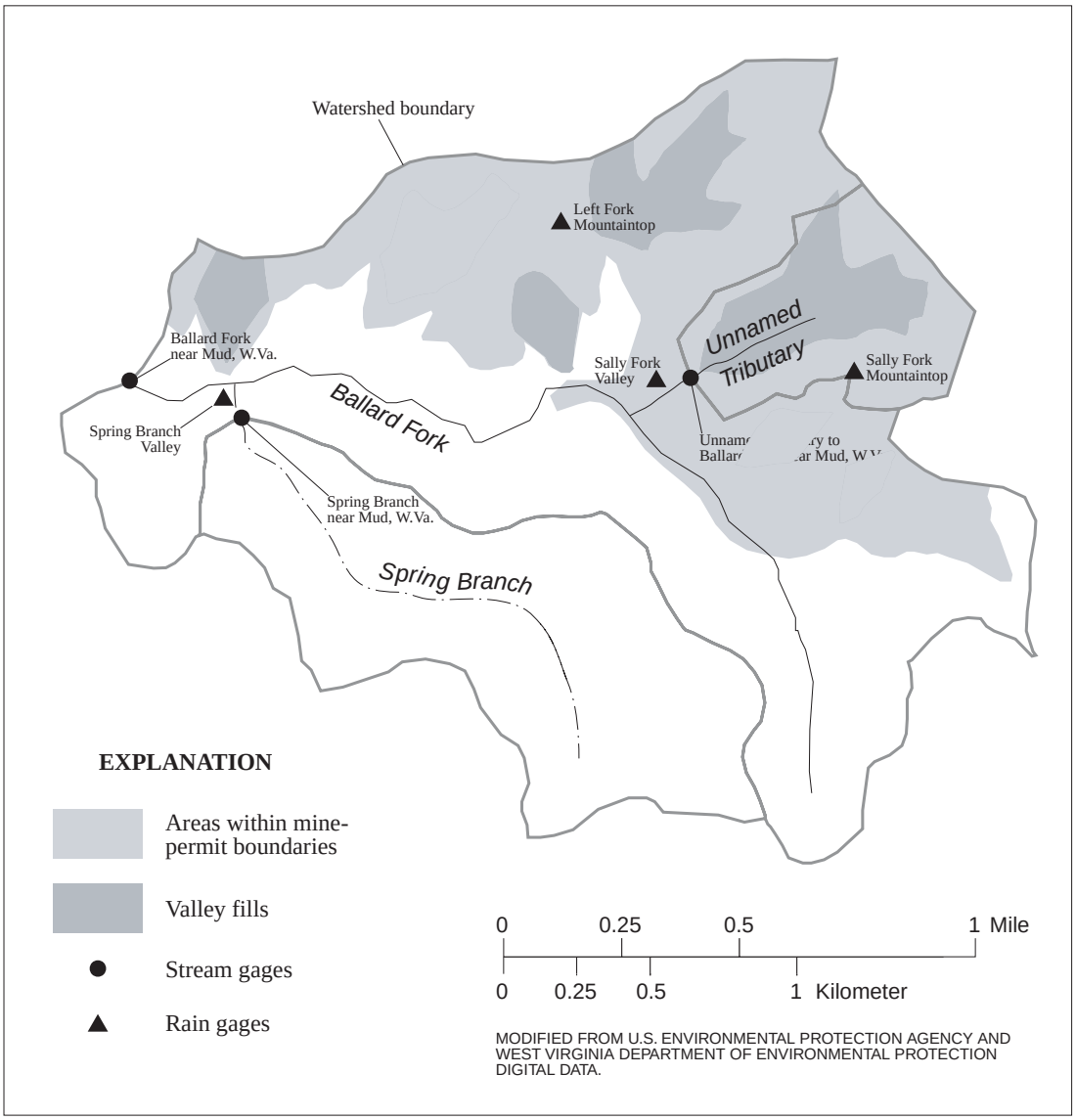

Figure 1. Streams, gages, valley fills, and areas permitted for mining in the Ballard Fork watershed.

(0.19 mi^2) is within an area permitted for mining, and all but a few acres is mined. The second gaging station, near the mouth of Spring Branch, drains an unmined, forested watershed (0.53 mi^2). The third gaging station was located on the main stem of Ballard Fork, which drains an area (2.12 mi^2) that includes both the Unnamed Tributary and Spring Branch watersheds. The entire Ballard Fork watershed is either surface mined or forested. Forty percent of the Ballard Fork watershed is within areas that had been permitted for mining, although less (about 30 percent) of the watershed was actually mined. About 44 percent of the Unnamed Tributary and 12 percent of the Ballard Fork watersheds is covered by valley fills.

Four rain gages were used during this study to collect precipitation data. Two rain gages were operated in mined areas on mountaintops, and the other two were in open areas on the valley floor. Precipitation amounts reported in this document are the average of amounts recorded at these four rain gages.

Mines in the Ballard Fork watershed received a Phase 1 bond release in August 2000, although mine inspection forms filed since November 1997 estimated that grading and backfilling was complete on all but 10 acres. The mined areas had grasses and other herbaceous vegetation typical of a newly reclaimed surface mine. Forest in Spring Branch and the rest of Ballard Fork was second- or third-growth, and dominant canopy species included white and red oak, several hickory species, sycamore, and tulip poplar.

Hydrologic conditions: Because this study began in November 1999, long-term conditions were assessed by comparison with nearby sites with long periods of record. Hydrologic conditions observed during the study period at three nearby long-term sites, the USGS stream-gaging station East Fork Twelvepole Creek near Dunlow, W.Va., and two NOAA rain gages at Madison and Dunlow, W.Va., were drier than long-term averages. Total precipitation in 2000 at both Madison and Dunlow (46.2 and 47.4 inches, respectively) was close to long-term averages (47.8 and 45.7 inches, respectively, 1971-2000), but was decreased substantially in 2001 (40.2 and 35.0 inches, respectively). Flow at East Fork Twelvepole Creek was well below the long-term average both years. The disparity between normal precipitation and low flow in 2000 was caused by the season when the precipitation was received. Precipitation at Madison was 4.71 inches below average from November 1999 through March 2000, the season of maximum recharge and runoff, and exceeded the long-term average during only three months, April (by 0.24 inches), June (by 1.76 inches), and July (by 0.20 inches), in the period of maximum evapotranspiration.

Total Flow: Total unit flow for the two-year study period on the Unnamed Tributary (11,700 $ft^3/s/mi^2$) was almost twice that on Spring Branch (6,260 $ft^3/s/mi^2$), and about 1.75 times that on Ballard Fork (6,690 $ft^3/s/mi^2$). The highest monthly flow in the study period in Spring Branch and Ballard Fork was during May 2001, because of a series of thunderstorms that produced 6.22 in. of rain in eight days, May 15-May 22. In contrast, the maximum monthly total flow on the Unnamed Tributary was in June 2001, although flows were similar from May through July 2001, the usual period of maximum evapotranspiration in forested watersheds.

The daily hydrograph shows that summer and autumn flows were relatively higher in the Unnamed Tributary than Ballard Fork, and relatively higher in Ballard Fork than in Spring Branch (fig. 2). Spring Branch was dry during much of October and November 2000, and its

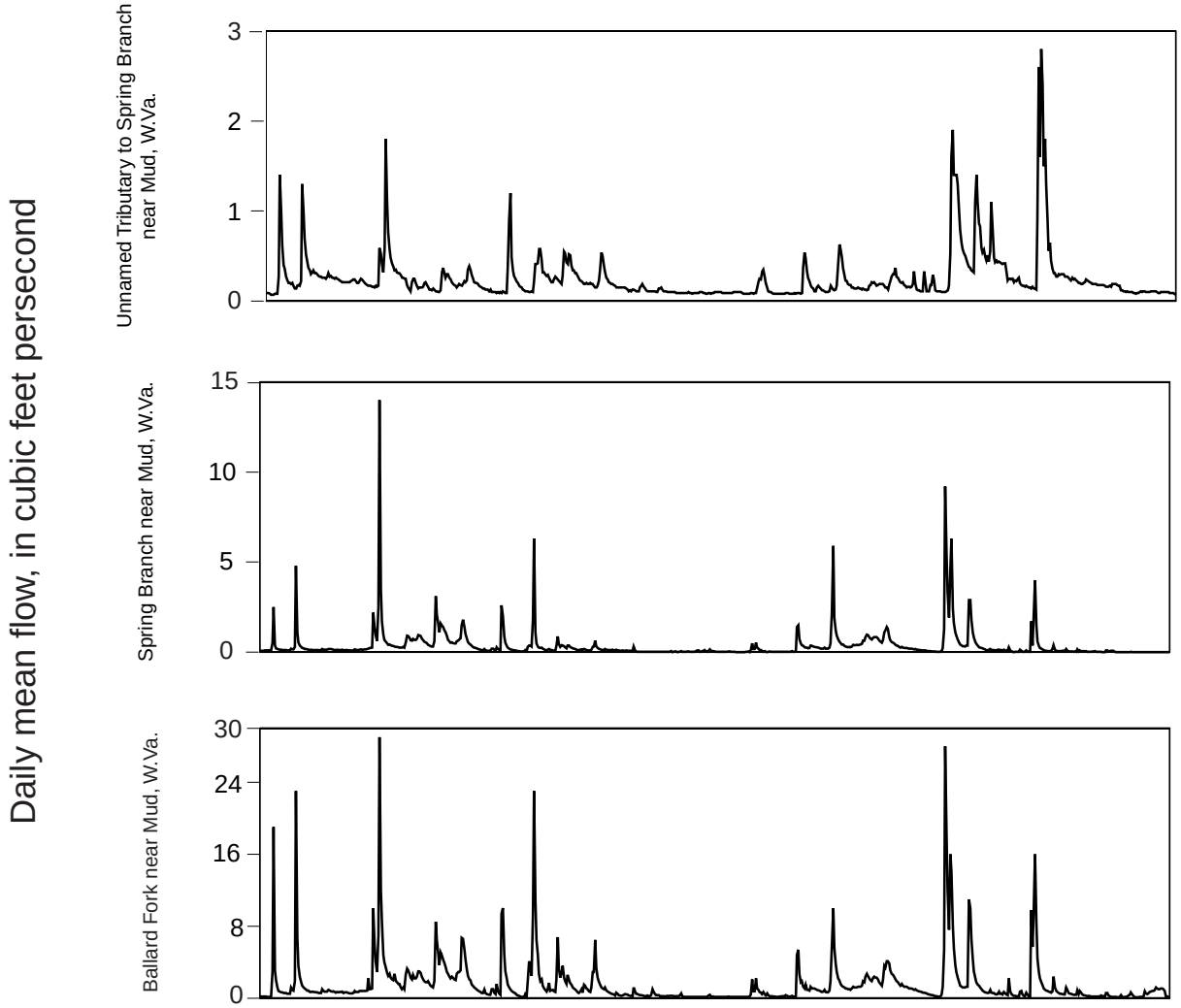

Figure 2. Hydrographs for three streams in the Ballard Fork watershed, W.Va., November 15, 1999-November 14, 2001.

monthly mean flow for October 2001, was zero. Ballard Fork and the Unnamed Tributary had flow throughout the study period. Daily mean flow was significantly ($P < 0.01$) correlated among the three streams in the Ballard Fork watershed. This correlation was strongest between Spring Branch and Ballard Fork ($R^2 = 0.723$), weakest between Spring Branch and the Unnamed Tributary ($R^2 = 0.370$), and intermediate between Ballard Fork and the Unnamed Tributary ($R^2 = 0.569$).

Flow duration: Flow duration curves show the lowest unit flows from Spring Branch, the highest unit flows from the Unnamed Tributary, and intermediate unit flows from Ballard Fork (fig. 3). Unit flow from the Unnamed Tributary watershed was the highest of the three streams at

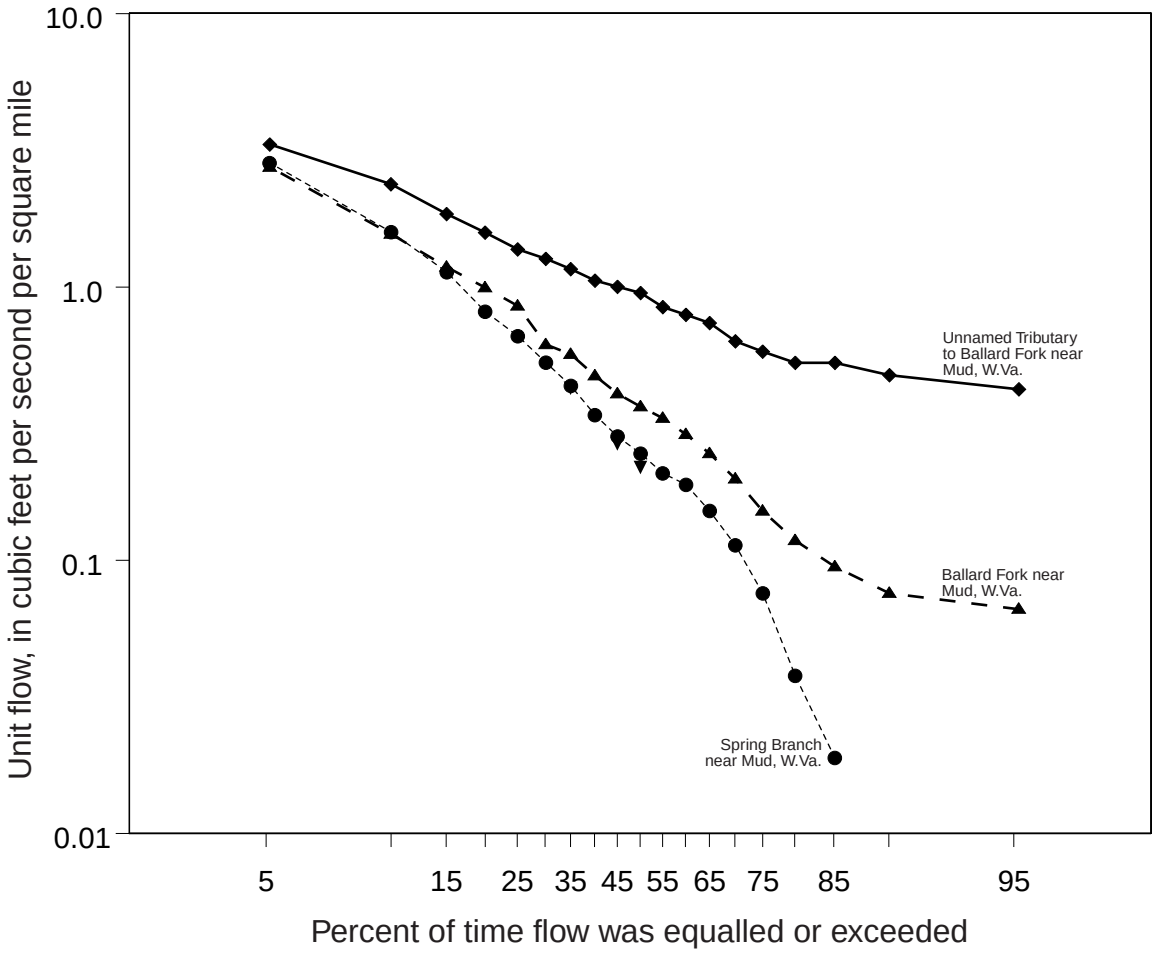

Figure 3. Flow duration of three streams in the Ballard Fork watershed, W.Va.., November 15, 1999-November 14, 2001.

all flows analyzed, between 5 and 95 percent flow duration, but the relative difference was greatest for low flows. Low flows in the Unnamed Tributary were probably increased because of

decreased evapotranspiration on the mine as compared to the forest and delayed drainage of water stored in the valley fill. Unit flows from Ballard Fork and Spring Branch were about the same at higher flows, but unit flow from Ballard Fork was much higher than that from Spring Branch at low flow.

Evapotranspiration: Reduced evapotranspiration in mined areas probably accounts for the marked difference in total and low unit flow between the Unnamed Tributary and Spring Branch watersheds. Evapotranspiration, as a percentage of total rainfall, decreased from the first to the second, drier, year from the Unnamed Tributary watershed (from 61 percent to 45 percent) but changed relatively little from the Spring Branch (from 77 to 74 percent) and Ballard Fork (76 to 78 percent) watersheds. Evapotranspiration from the East Fork of Twelvepole Creek watershed was much higher during the study period (76 percent the first year, and 78 percent the second year) than the 1965-2001 average (60 percent). Most of the mechanisms of evapotranspiration appear to be lower on reclaimed surface mines than in forests, because most of them are mechanisms that evolved in plants to use or conserve water. Plant biomass in the mined areas is much less than in forested areas.

Unit flow per unit precipitation from Spring Branch only exceeded that from the Unnamed Tributary during spring months, February-April 2000 and February-March 2001, but even then, exceeded it by less than measurement error (fig. 4). Unit flow per unit precipitation from the

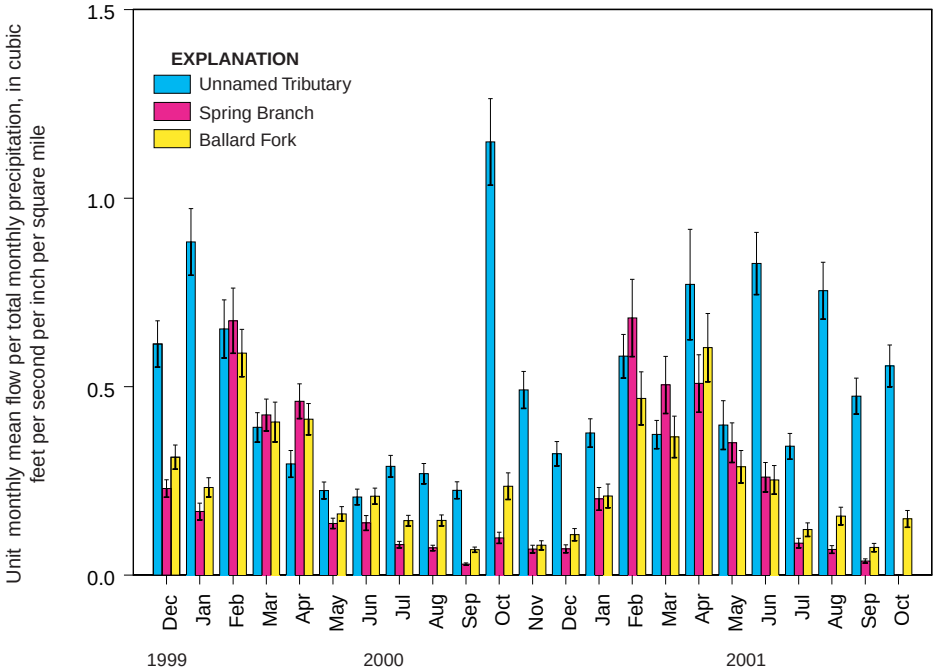

Figure 4. Unit monthly mean flow per total monthly precipitation for three sites in the Ballard Fork watershed, W.Va., 1999-2001. Only whole months are shown. Error bars represent the sum of daily-mean streamflow variance determined from estimates of data quality made by Ward and others (2001, 2002). Spring Branch had an average flow of zero during October, 2001.

Unnamed Tributary watershed was more or much more than that from the Spring Branch watershed during summer and fall months.

Conclusions: Unit daily mean flow was higher from the Unnamed Tributary, which drains a predominantly mined watershed, than from Spring Branch, which drains an unmined, forested watershed, at all flows between 5 and 95 percent duration. The relative difference was greatest at lower flows. Unit daily mean flows from Ballard Fork, which drains a watershed including both these other streams and is about 30 percent mined, were about the same as those from Spring Branch at higher flows (greater than about 15 percent duration), and were intermediate between the Unnamed Tributary and Spring Branch at lower flows. Spring Branch dried up both years of the study, and its mean flow in October 2001 was zero; the Unnamed Tributary had flow throughout the study period. Some mechanism delays some of the flow from the mined area. Storage of water in or under the valley fill is the most likely mechanism.

Total unit flow from the Unnamed Tributary was nearly twice that from Spring Branch during the two-year study period. Storage of water in the mined areas does not account for this difference, because all the flow in the Ballard Fork watershed originated as precipitation, and precipitation was the same on mined and unmined areas. Reduced evapotranspiration in the mined areas probably accounts for the difference in total flow. Evapotranspiration from mined areas was probably less than that from forested areas because most mechanisms of evapotranspiration, such as interception and transpiration, are functions of plants and plant biomass is much less in mined areas than in unmined areas. The difference in total flow and low flow between the mined and unmined areas will probably change as plant cover and biomass change on the reclaimed mines.

EXECUTIVE SUMMARY: COMPARISON OF STORM RESPONSE OF STREAMS IN SMALL, UNMINED AND VALLEY-FILLED WATERSHEDS, 1999-2001, BALLARD FORK, WEST VIRGINIA

Terence Messinger

Abstract: Peak unit flows following summer storms with rainfall exceeding about one inch per hour, approximately the one-year return period, were greater from a watershed comprised of a mountaintop-removal coal mine (Unnamed Tributary) than from an unmined watershed (Spring Branch) in the Ballard Fork watershed in West Virginia. Following all storms with rainfall intensity of about 0.25 in. per hour or more, the storm hydrograph from the Unnamed Tributary watershed showed a sharp initial rise, followed by a decrease in flow, then a delayed secondary peak of water that had apparently flowed through the valley fill. One storm that produced less than an inch of rain before the secondary peak from the previous storm had receded caused peak unit flow from the Unnamed Tributary to exceed peak unit flow from Spring Branch. Peak unit flow from the Unnamed Tributary was less than peak unit flow from Spring Branch following slow, soaking rains. No storms during this study produced 1-hour or 24-hour rainfall in excess of the 5-year return period, and flow during this study never exceeded the 1.5-year return period. Runoff patterns from the Unnamed Tributary watershed appear to be influenced by the compaction of soils on the mine, by the low maximum infiltration rate into the valley fill compared to the forested watershed, by storage of water in the valley fill, and by the absence from the mine of interception from trees and leaf litter.

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Four rain gages were used during this study to collect precipitation data. Two rain gages were operated in mined areas on mountaintops, and the other two were in open areas on the valley floor. Precipitation amounts reported in this document are the average of amounts recorded at these four rain gages.

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Precipitation: Greatest average 1-hour total precipitation recorded at the four rain gages (1.63 in., standard deviation = 0.11 in.) during the study period was July 26 between 3:30 p.m. and 4:30 p.m. The greatest 24-hour total precipitation (3.16 in., standard deviation = 0.24 in.) during the study was during the same storm, between 1:00 a.m. July 26 and 1:00 a.m. July 27. The return period for both the 1-hour and 24-hour rainfall from this storm was between two and five years. Average 1-hour precipitation exceeded 1.1 in. (about the 1-hour, 1-year rainfall) on June 6, 2001, and average precipitation plus one standard deviation exceeded 1.1 in. on June 21, 2000, and August 12, 2001. Average 24-hour rainfall exceeded 2.0 in. (about the 24-hour, 1-year rainfall) during one other storm, on November 26, 1999, and average precipitation plus one standard deviation exceeded 2.0 in. during three other storms during the study period.

Most of the intense rainfall in the Ballard Fork watershed during this study fell during summer thunderstorms. Of the 10 largest 1-hour average rainfalls, eight were during May through September, and six of these storms were during June and July. The largest 24-hour total rainfalls were generally recorded in the summer, as well; eight of the ten highest 24-hour rainfall totals were recorded during May, June, or July. In general, rainfall recorded by the Sally Fork Mountaintop rain gage, in the Unnamed Tributary watershed, was less than rainfall recorded at the other three rain gages; for the ten storms with the highest 1-hour rainfall, the Sally Fork Mountaintop rain gage reading was less than the average eight times.

Peak flows: Maximum instantaneous flow during the study period was 8.9 ft^3/s for the Unnamed Tributary (July 26, 2001), 87 ft^3/s for Ballard Fork (May 18, 2001), and 34 ft^3/s for Spring Branch (February 19, 2000). Instantaneous flow recorded during the study period did not exceed the 1.5-year return period at any site.

Peaks with unit flow greater than 20 $ft^3/s/mi^2$ were recorded five times at the Unnamed Tributary, eleven times at Spring Branch, and nine times at Ballard Fork. All three gages recorded flows in this range during four of the five storms, which raised unit flow in the Unnamed Tributary above 20 $ft^3/s/mi^2$, although the Spring Branch gage was not operating during the fifth storm, of May 18, 2001.

Storm response: Response of the Unnamed Tributary to different types of storms was distinctly different from response of Spring Branch and Ballard Fork. Spring Branch and Ballard Fork generally rose when total moisture in their watersheds increased. These streams generally peaked shortly after rainfall ended, and quickly receded.

In contrast, the Unnamed Tributary's storm hydrograph typically showed a double peak when rainfall intensity exceeded about 0.25 in./hour. The hydrograph of November 26-27, 1999, shows this pattern clearly (fig. 1). Total rainfall for this storm exceeded 3.0 in., and much of it

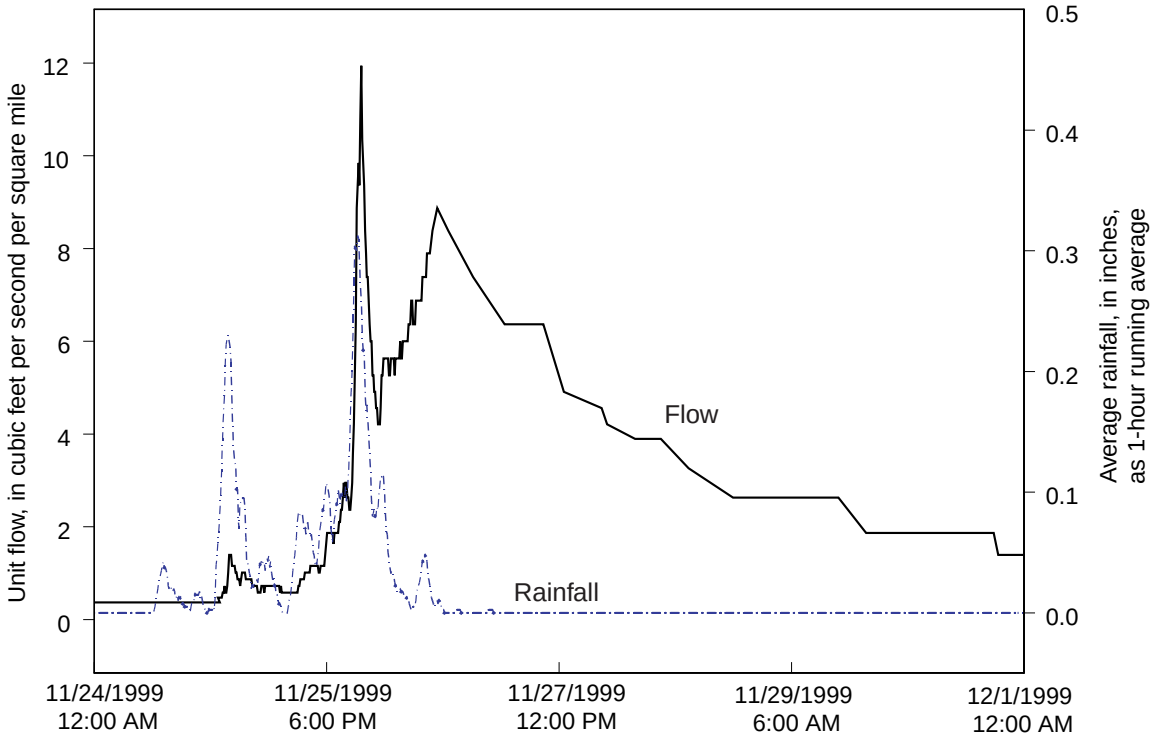

Figure 1. Storm hydrograph at Unnamed Tributary of Ballard Fork near Mud, W.Va., and rainfall, as a 1-hour running average, for four rain gages in the Ballard Fork watershed.

fell as a slow, soaking rain; the maximum one-hour rainfall recorded at any rain gage was 0.48 in. Antecedent conditions were dry; the rain of November 24 was the first since November 2. Although the rain fell in two major bursts, the storm hydrograph had the same shape typical of storms in which rain fell in only one major burst. About 0.73 in. of rain fell on November 25-26 between 9:30 p.m. and 3:30 a.m. When rain was received with an intensity of about 0.3 in. per hour at about midnight on November 26, the infiltration capacity of the watershed was apparently exceeded, causing a sharp peak in flow. This peak quickly receded when rain intensity decreased, but the delayed flow of water that had apparently flowed through the valley fill continued to increase and peaked at 2:00 p.m. on November 26, eight hours after the last rain fell that exceeded 0.10 in./hour.

During most storms, peak unit flow from Spring Branch and Ballard Fork exceeded peak unit flow from the Unnamed Tributary, despite the effects of interception on runoff in the forested watersheds. However, in the two most intense storms during the study period, on June 6, 2001 (maximum average one-hour rainfall = 1.24 in.) and July 26, 2001 (maximum average one-hour rainfall = 1.63 in.), maximum runoff from the Unnamed Tributary exceeded maximum runoff in the forested watersheds. Both of these storms took place in midsummer, when rainfall interception by trees is at its maximum. In the third most intense storm during the study period, June 21, 2000, the gage at the Unnamed Tributary malfunctioned, so relative unit flows from this storm are unknown.

In the storm of July 26, 2001, intense rain apparently exceeded infiltration capacity of the Unnamed Tributary watershed and led to sharp peak in flow that exceeded unit flow at the other two gages (fig. 2). Antecedent conditions to the July 26 storm were moderate; the Ballard Fork watershed received nearly 0.50 in. of rain the afternoon of July 22. The initial substantial rain (maximum rainfall intensity = 0.25 in./hour) beginning about 7:00 a.m. on July 26 did not cause a runoff response from any stream.

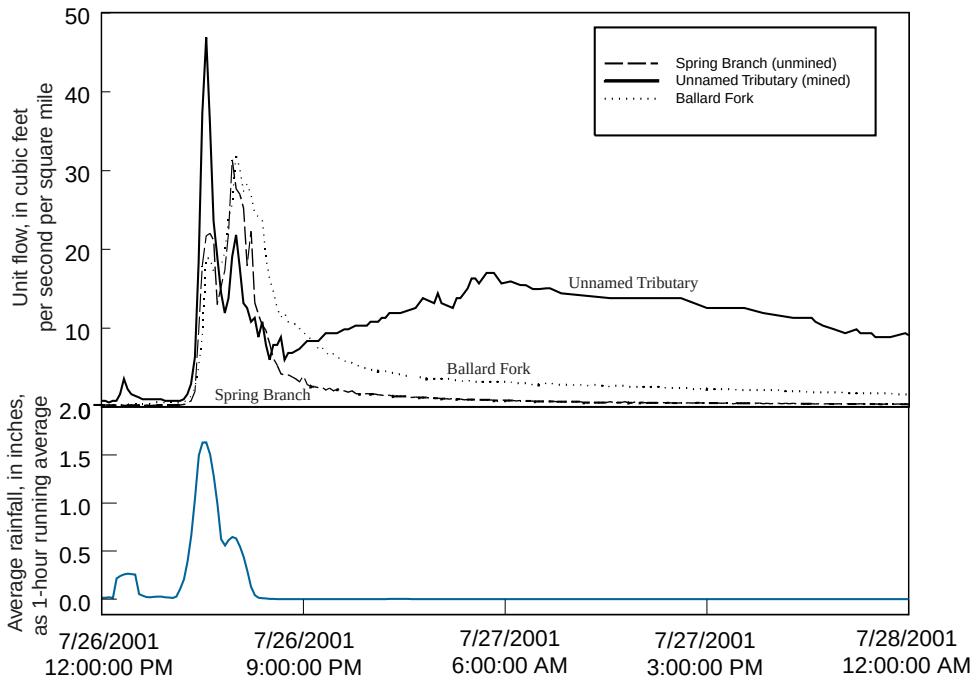

Figure 2. Storm hydrograph for July 26-28, 2001, for three stream gages, and rainfall, as a 1-hour running average for four rain gages, in the Ballard Fork watershed.

The most intense rainfall recorded during this study was received between 3:50 p.m. and 4:30 p.m. on July 26, more than 1.3 in. The Unnamed Tributary rose sharply in response to this rain, and peaked at 4:40 p.m., while rain was still falling but after intensity had decreased. Maximum unit flow for the Unnamed Tributary was 46.9 $ft^3/s/mi^2$. Although the two other watersheds responded to this burst of rain, their peaks were later in the evening, at about 6:00 p.m., at the end of a final spate of rain of 0.63 in./hour. The Unnamed Tributary responded less strongly to the final rain than it had to the earlier, more intense rain, with a maximum unit flow on the second peak of 21.8 $ft^3/s/mi^2$. The initial peak on the Unnamed Tributary receded as quickly as Spring Branch and more quickly than Ballard Fork, but about 8:30 p.m., a secondary peak began on the Unnamed Tributary, apparently of water that had flowed through the valley fill. This attenuated secondary peak reached a maximum unit flow of 19.1 $ft^3/s/mi^2$ at 6:20 a.m. July 27, several hours after Spring Branch and Ballard Fork had largely receded.

Peak unit flow from the valley fill exceeded peak unit flow from the other watersheds on July 29, when rainfall of unexceptional intensity (maximum one-hour rainfall = 0.82 in.) was received before a secondary peak on the Unnamed Tributary had receded. Rain on July 28 caused small initial rises on all three streams. When a hard rain fell on the afternoon of July 29, the peaks on Spring Branch and Ballard Fork had receded, but the Unnamed Tributary was still rising from delayed flow from July 28.

Discussion: Runoff patterns from the Unnamed Tributary watershed appear to be influenced by compaction of soils on the mine, by the low maximum infiltration rate into the mine and valley fill compared to the forested watershed, by storage of water in the valley fill, and by the absence of interception from trees and leaf litter on the mine. Soils on mined areas are typically heavily compacted to prevent erosion, which decreases infiltration capacity. Hortonian (excess overland) flow appears to be important in the Unnamed Tributary watershed following intense storms, and to cause the initial peak on the rising arm of storm hydrographs; Hortonian flow is rare in the eastern U.S. except from urban or other highly disturbed watersheds. The initial sharp peak, the part of the hydrograph that is apparently Hortonian flow, appears following storms with intensity greater than about 0.25 in./hour.

Typical canopy interception rates in eastern hardwood forests are about ten per cent of gross rainfall, and dry leaf litter may intercept several tenths of an inch of water that falls through the canopy. Water that would have been retained by these processes in the Spring Branch watershed was available to run off the Unnamed Tributary watershed. Because of these factors, unit flow from the mined watershed exceeded unit flow from the unmined watershed during storms when rainfall exceeded about 1 in./hour, suggesting that mountaintop removal mining is

likely to increase flooding from intense summer thunderstorms. Once during this study, peak unit flow from the Unnamed Tributary watershed exceeded runoff from the Spring Branch watershed because a hard rain was received before the delayed secondary peak on the Unnamed Tributary had receded. This suggests that mountaintop removal mining is especially likely to increase flooding during summer storm systems that last several days.

A large proportion of storm water received in the Unnamed Tributary watershed runs off during a period 8 to 48 hours after rain stops, compared to 0 to 4 hours in the Spring Branch watershed. Comparison of total volume running off from three selected storms showed that (1) total unit flow during all three storms was greatest from the Unnamed Tributary, (2) for the Unnamed Tributary, flow during recessions exceeded storm runoff during all three storms, although for Spring Branch, storm runoff exceeded flow during recessions in two storms, and (3) total unit flow as storm runoff from the Unnamed Tributary was typically less than unit storm runoff from Spring Branch and Ballard Fork. Although most of the water running off the Unnamed Tributary watershed comes in this delayed flow, the overall peak for most storms is the sharp, initial peak.

Peak unit flow from a storm is expected to be greater from a smaller watershed, if all land-use and other characteristics are identical. In this study, peak unit flow from the Spring Branch watershed usually exceeded peak unit flow from the Unnamed Tributary watershed, and was usually about the same as peak unit flow from the overall Ballard Fork watershed. Rainfall-runoff relations on altered landscapes are site-specific and mining and reclamation practices that affect storm response may vary among mines.

Source: Messinger, Terence, 2003, Comparison of storm response of streams in small, unmined and mountaintop removal mined watersheds, 1999-2001, Ballard Fork, West Virginia: U.S. Geological Survey Water-Resources Investigations Report 02-4303.

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Storm response: Response of the Unnamed Tributary to different types of storms was distinctly different from response of Spring Branch and Ballard Fork. Spring Branch and Ballard Fork generally rose when total moisture in their watersheds increased. These streams generally peaked shortly after rainfall ended, and quickly receded.

In contrast, the Unnamed Tributary's storm hydrograph typically showed a double peak when rainfall intensity exceeded about 0.25 in./hour. The hydrograph of November 26-27, 1999, shows this pattern clearly (fig. 1). Total rainfall for this storm exceeded 3.0 in., and much of it

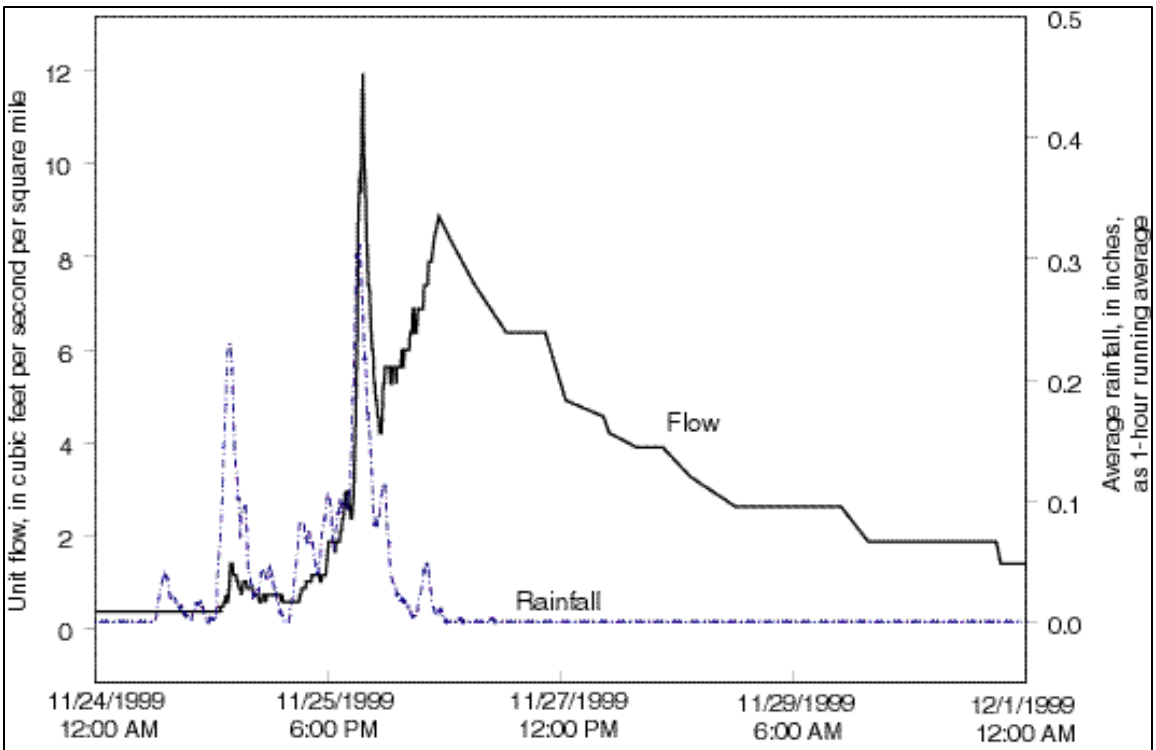

Figure 1. Storm hydrograph at Unnamed Tributary of Ballard Fork near Mud, W.Va., and rainfall, as a 1-hour running average, for four rain gages in the Ballard Fork watershed.

fell as a slow, soaking rain; the maximum one-hour rainfall recorded at any rain gage was 0.48 in. Antecedent conditions were dry; the rain of November 24 was the first since November 2. Although the rain fell in two major bursts, the storm hydrograph had the same shape typical of storms in which rain fell in only one major burst. About 0.73 in. of rain fell on November 25-26 between 9:30 p.m. and 3:30 a.m. When rain was received with an intensity of about 0.3 in. per hour at about midnight on November 26, the infiltration capacity of the watershed was apparently exceeded, causing a sharp peak in flow. This peak quickly receded when rain intensity decreased, but the delayed flow of water that had apparently flowed through the valley fill continued to increase and peaked at 2:00 p.m. on November 26, eight hours after the last rain fell that exceeded 0.10 in./hour.

During most storms, peak unit flow from Spring Branch and Ballard Fork exceeded peak unit flow from the Unnamed Tributary, despite the effects of interception on runoff in the forested watersheds. However, in the two most intense storms during the study period, on June 6, 2001 (maximum average one-hour rainfall = 1.24 in.) and July 26, 2001 (maximum average one-hour rainfall = 1.63 in.), maximum runoff from the Unnamed Tributary exceeded maximum runoff in the forested watersheds. Both of these storms took place in midsummer, when rainfall interception by trees is at its maximum. In the third most intense storm during the study period, June 21, 2000, the gage at the Unnamed Tributary malfunctioned, so relative unit flows from this storm are unknown.

In the storm of July 26, 2001, intense rain apparently exceeded infiltration capacity of the Unnamed Tributary watershed and led to sharp peak in flow that exceeded unit flow at the other two gages (fig. 2). Antecedent conditions to the July 26 storm were moderate; the Ballard Fork watershed received nearly 0.50 in. of rain the afternoon of July 22. The initial substantial rain (maximum rainfall intensity = 0.25 in./hour) beginning about 7:00 a.m. on July 26 did not cause a runoff response from any stream.

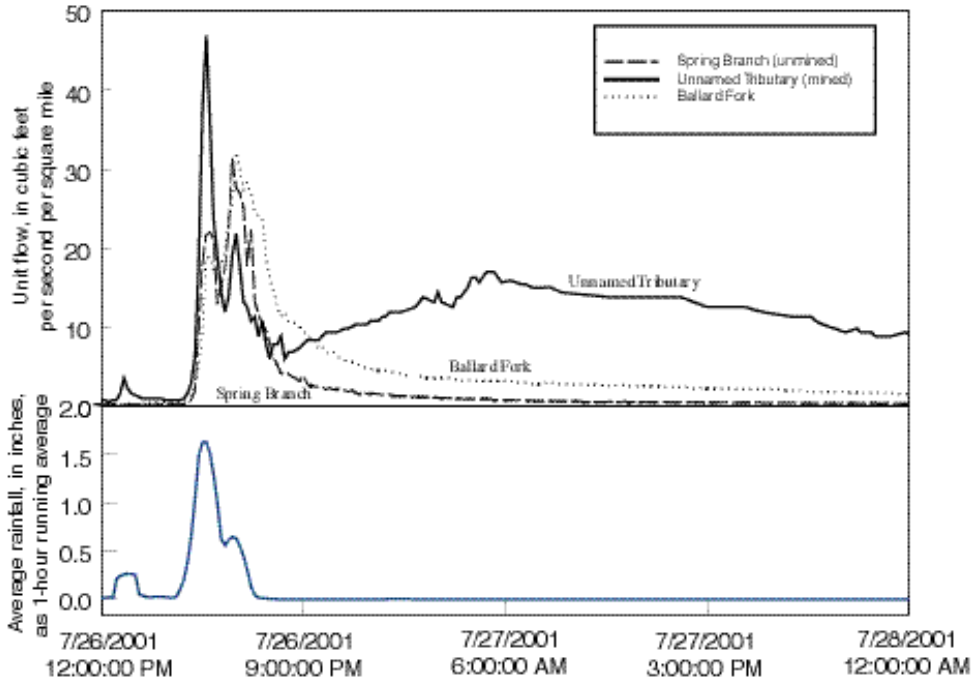

Figure 2. Storm hydrograph for July 26-28, 2001, for three stream gages, and rainfall, as a 1-hour running average for four rain gages, in the Ballard Fork watershed.

The most intense rainfall recorded during this study was received between 3:50 p.m. and 4:30 p.m. on July 26, more than 1.3 in. The Unnamed Tributary rose sharply in response to this rain, and peaked at 4:40 p.m., while rain was still falling but after intensity had decreased. Maximum unit flow for the Unnamed Tributary was 46.9 $ft^3/s/mi^2$. Although the two other watersheds responded to this burst of rain, their peaks were later in the evening, at about 6:00 p.m., at the end of a final spate of rain of 0.63 in./hour. The Unnamed Tributary responded less strongly to the final rain than it had to the earlier, more intense rain, with a maximum unit flow on the second peak of 21.8 $ft^3/s/mi^2$. The initial peak on the Unnamed Tributary receded as quickly as Spring Branch and more quickly than Ballard Fork, but about 8:30 p.m., a secondary peak began on the Unnamed Tributary, apparently of water that had flowed through the valley fill. This attenuated secondary peak reached a maximum unit flow of 19.1 $ft^3/s/mi^2$ at 6:20 a.m. July 27, several hours after Spring Branch and Ballard Fork had largely receded.

Peak unit flow from the valley fill exceeded peak unit flow from the other watersheds on July 29, when rainfall of unexceptional intensity (maximum one-hour rainfall = 0.82 in.) was received before a secondary peak on the Unnamed Tributary had receded. Rain on July 28 caused small initial rises on all three streams. When a hard rain fell on the afternoon of July 29, the peaks on Spring Branch and Ballard Fork had receded, but the Unnamed Tributary was still rising from delayed flow from July 28.

Discussion: Runoff patterns from the Unnamed Tributary watershed appear to be influenced by compaction of soils on the mine, by the low maximum infiltration rate into the mine and valley fill compared to the forested watershed, by storage of water in the valley fill, and by the absence of interception from trees and leaf litter on the mine. Soils on mined areas are typically heavily compacted to prevent erosion, which decreases infiltration capacity. Hortonian (excess overland) flow appears to be important in the Unnamed Tributary watershed following intense storms, and to cause the initial peak on the rising arm of storm hydrographs; Hortonian flow is rare in the eastern U.S. except from urban or other highly disturbed watersheds. The initial sharp peak, the part of the hydrograph that is apparently Hortonian flow, appears following storms with intensity greater than about 0.25 in./hour.

Typical canopy interception rates in eastern hardwood forests are about ten per cent of gross rainfall, and dry leaf litter may intercept several tenths of an inch of water that falls through the canopy. Water that would have been retained by these processes in the Spring Branch watershed was available to run off the Unnamed Tributary watershed. Because of these factors, unit flow from the mined watershed exceeded unit flow from the unmined watershed during storms when rainfall exceeded about 1 in./hour, suggesting that mountaintop removal mining is

likely to increase flooding from intense summer thunderstorms. Once during this study, peak unit flow from the Unnamed Tributary watershed exceeded runoff from the Spring Branch watershed because a hard rain was received before the delayed secondary peak on the Unnamed Tributary had receded. This suggests that mountaintop removal mining is especially likely to increase flooding during summer storm systems that last several days.

A large proportion of storm water received in the Unnamed Tributary watershed runs off during a period 8 to 48 hours after rain stops, compared to 0 to 4 hours in the Spring Branch watershed. Comparison of total volume running off from three selected storms showed that (1) total unit flow during all three storms was greatest from the Unnamed Tributary, (2) for the Unnamed Tributary, flow during recessions exceeded storm runoff during all three storms, although for Spring Branch, storm runoff exceeded flow during recessions in two storms, and (3) total unit flow as storm runoff from the Unnamed Tributary was typically less than unit storm runoff from Spring Branch and Ballard Fork. Although most of the water running off the Unnamed Tributary watershed comes in this delayed flow, the overall peak for most storms is the sharp, initial peak.

Peak unit flow from a storm is expected to be greater from a smaller watershed, if all land-use and other characteristics are identical. In this study, peak unit flow from the Spring Branch watershed usually exceeded peak unit flow from the Unnamed Tributary watershed, and was usually about the same as peak unit flow from the overall Ballard Fork watershed. Rainfall-runoff relations on altered landscapes are site-specific and mining and reclamation practices that affect storm response may vary among mines.

Source: Messinger, Terence, 2003, Comparison of storm response of streams in small, unmined and valley-filled watersheds, 1999-2001, Ballard Fork, West Virginia: U.S. Geological Survey Water-Resources Investigations Report 02-4303.

OSM VALLEY FILL STUDY

HOBET MINE WESTRIDGE VALLEY FILL

Appalachian Regional Coordinating Center

US Army Corps of Engineers
Pittsburgh District

FEBRUARY 2000

OSM VALLEY FILL STUDY
HOBET MINE WESTRIDGE
VALLEY FILL

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining and post mining conditions.

The Hobet Mine Westridge Valley Fill, located on Connelly Branch near the headwaters of the Mud River watershed in Lincoln County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Connelly Branch watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Karen Taylor, Elizabeth Rodriguez, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to post mining conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

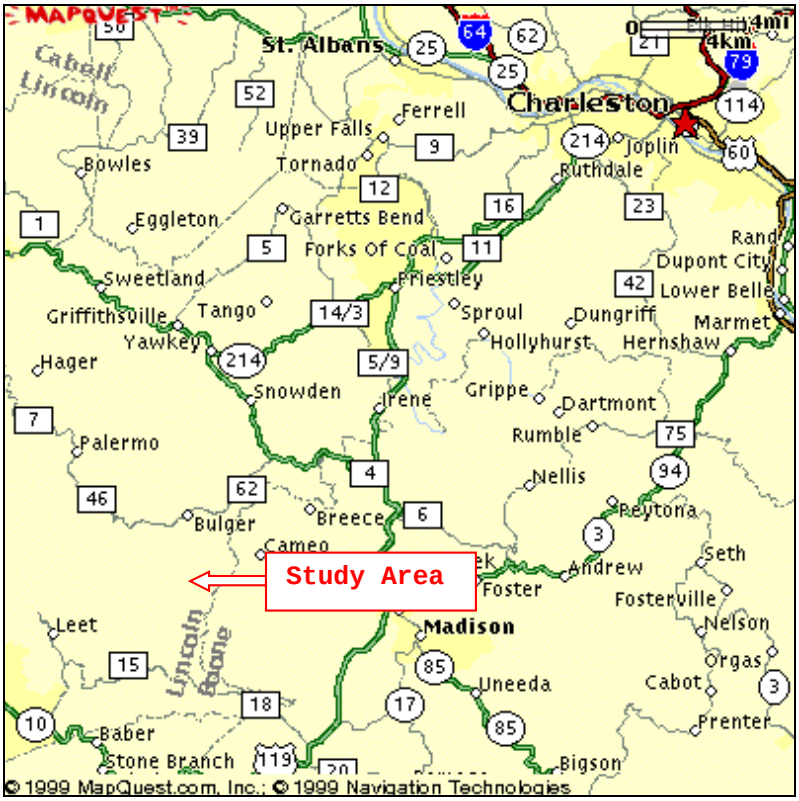
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Hobet Mine Westridge Valley Fill was the fourth site studied. The other three were at the Samples Mine site in Boone County, WV. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Hobet Mine Westridge Valley Fill is located approximately 25 miles southwest of Charleston, WV, on the eastern side of Lincoln County on the boundary with Boone County, WV. It is located near the headwaters of the Mud River (tributary to the Guyandotte River) watershed. The valley fill drainage area occupies the 2.5 square mile (0.7%) Connelly Branch of the 359 square mile Mud River watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Hobet Mine is located on the eastern side of Lincoln County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.55	0.75
15 MIN	1.11	1.60
1 HR	2.04	3.00
2 HR	2.39	3.40
3 HR	2.63	3.66
6 HR	2.99	4.30
12 HR	3.50	5.00
24 HR	3.95	5.40

These values were used for the premining and post mining conditions.

Soil Types

The unpublished Lincoln County, WV, soil survey was used to determine the soil types located in the study area.

The Connelly Branch watershed is contained within the Berks-Shelocta general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from siltstone, shale, and sandstone; on mountainous uplands”. The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining and postmining conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage areas to provide travel times for the channel flow component.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company’s 1:500 scale maps that had a contour interval of 10’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

PREMINING CONDITIONS

Drainage Areas

The premining drainage area was delineated on a USGS 1:24,000 scale topographic map (Mud quadrangle) and on a 1:500 scale regraded drainage map provided by the coal company. The premining drainage area encompasses 2.50 square miles.

The drainage area was divided into ten runoff subareas to define the premining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the premining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
A-1	Most downstream area	43.39	0.07	2.7
A-2		91.95	0.14	5.7
A-3		220.94	0.35	13.8
B-1	Downstream end of Grider Fork	71.39	0.11	4.5
B-2		77.22	0.12	4.8
B-3		38.18	0.06	2.4
B-4	Upstream end of Grider Fork	212.43	0.33	13.3
B-5		53.60	0.08	3.3
C		325.01	0.51	20.3
D	Most upstream area	466.34	0.73	29.2
Total		1600.45	2.50	100

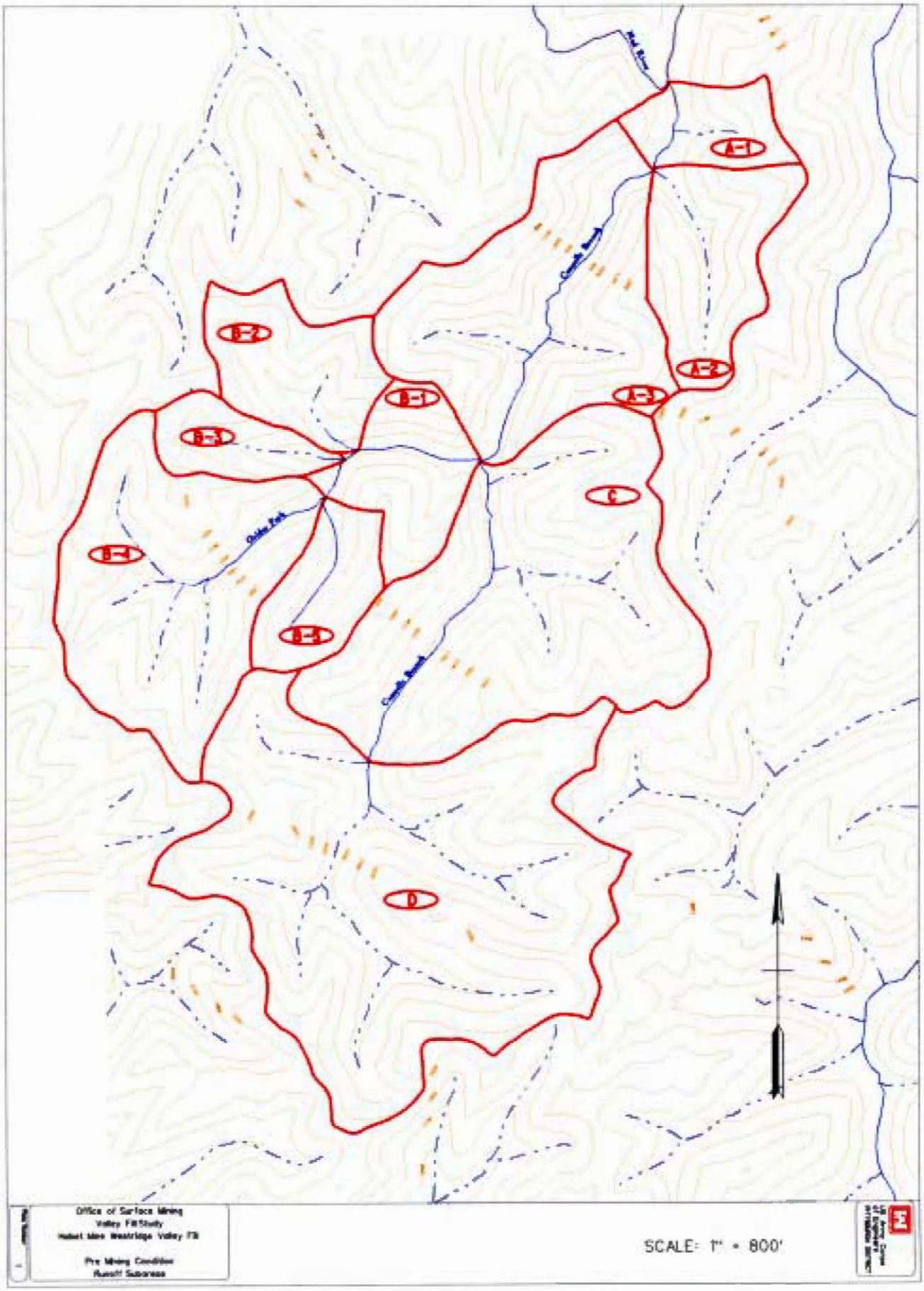
Plate 1 shows the runoff subareas.

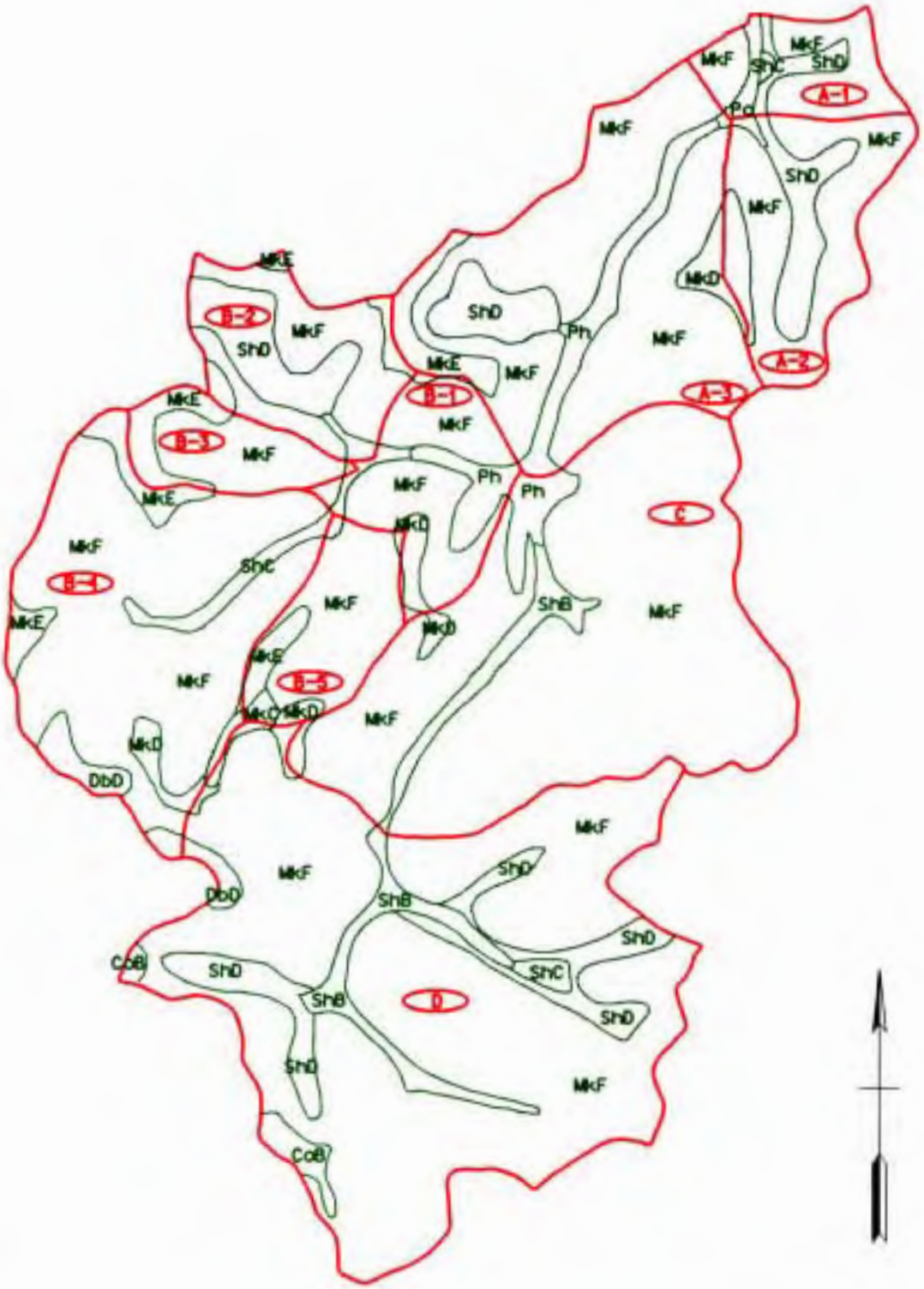
Soil Types and SCS Runoff Curve Numbers

The following table shows the soil types and their percent distribution within the runoff subareas for the premining condition:

Runoff Subarea	Soil Type										
	MkC	MkD	MkE	MkF	ShB	ShC	ShD	Ph	Po	DbD	CoB
	Percent Distribution										
A-1				72.6		2.3	15.9		9.2		
A-2		5.4		70.5			22.7		1.4		
A-3		3.8	5.8	74.1			7.5	8.4	0.4		
B-1		7.2	3.7	68.4		4.9		15.8			
B-2			8.5	53.7		1.8	36.0				
B-3			25.9	74.1							
B-4	0.7	2.7	9.1	79.5		4.4				3.6	
B-5	3.8	6.1	9.7	79.1		1.3					
C		1.4		90.3	4.9			3.4			
D	0.3	0.4		81.7	4.7	0.7	9.3			1.0	1.9
Total	0.5	2.7	6.3	74.3	1.0	1.5	9.1	2.8	1.1	0.5	0.2

Plate 2 shows the soil type subareas.


A-1
A-2
A-3
B-1
B-2
B-3
B-4
B-5
C
D
Office of Surface Mining
Valley Fill Study
Hobet Mine Westridge Valley Fill
Pre Mining Condition
Runoff Subareas
SCALE: 1" = 800'



Office of Surface Mining
Valley Fill Study
Hobet Mine Westridge Valley Fill

Pre Mining Condition
Soil Type Subareas

SCALE: 1" = 800'

This table shows that the Muskingum silt loam (MkF) mapping unit makes up the majority (74%) of the drainage area.

The premining land use for the Connelly Branch watershed is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the premining condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
A-1	69		0.9
A-2	70		0.86
A-3	71		0.82
B-1	70		0.86
B-2	68		0.94
B-3	73		0.74
B-4	72		0.78
B-5	73		0.74
C	72		0.78
D	71		0.82

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the premining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
A-1	36	22	34	20
A-2	33	20	32	19
A-3	73	44	67	40
B-1	25	15	24	14
B-2	32	19	32	19
B-3	37	22	34	21
B-4	49	29	46	28
B-5	32	19	31	19
C	51	31	47	28
D	53	32	53	32

Base Flow

The premining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
A-1	0.07	0.14
A-2	0.14	0.29
A-3	0.35	0.69
B-1	0.11	0.22
B-2	0.12	0.24
B-3	0.06	0.12
B-4	0.33	0.66
B-5	0.08	0.17
C	0.51	1.02
D	0.73	1.46

Routing Reaches

The drainage area was divided into ten runoff subareas to model the premining condition. Seven reaches connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

POST MINING CONDITIONS

Drainage Areas

The post mining drainage area was delineated on a 1:500 scale regraded drainage map provided by the coal company. The post mining drainage area encompasses 2.43 square miles.

The drainage area was divided into thirty six runoff subareas to define the post mining condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The regraded drainage map shows that the post mining land use is reclaimed valley fill and backstack areas for 74% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the post mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
3-A		3.50	0.005	0.2
3-B		18.97	0.030	1.2
3-C		33.46	0.052	2.1
L	Face of lower fill	2.16	0.003	0.1
9-A	Most downstream area on top of lower fill	1.84	0.003	0.1
9-B		51.75	0.081	3.3
9-C		20.47	0.032	1.3
9-D		13.73	0.021	0.9
10-A		36.29	0.057	2.3
10-B	Most upstream area on top of lower fill	51.68	0.081	3.3
U-L	Left side of face of upper fill	4.22	0.007	0.3
11-A	Most downstream left area on top of upper fill	27.61	0.043	1.8
11-B		60.02	0.094	3.9
11-C		18.29	0.029	1.2
11-D		21.69	0.034	1.4
11-E		11.75	0.018	0.8
11-F		27.28	0.043	1.8
11-G		49.14	0.077	3.2
12		70.07	0.109	4.5
13		56.90	0.089	3.7
14-A		45.58	0.071	2.9
14-B	Most upstream center area on top of upper fill	53.07	0.083	3.4
32		61.69	0.096	4.0
15		121.49	0.190	7.8
37-A		10.60	0.017	0.7
37-B		11.23	0.018	0.7
36		25.70	0.040	1.6
35-A		73.26	0.114	4.7
35-B		28.49	0.045	1.8
34-A		69.92	0.109	4.5
34-B		43.69	0.068	2.8
34-C		217.50	0.340	13.9
5		84.64	0.132	5.4
7		34.43	0.054	2.2
U-R	Right side of face of upper fill	4.14	0.006	0.3
33	Most downstream right area on top of upper fill	92.03	0.144	5.9
Total		1558.28	2.435	100

The valley fill extends downstream to cover most of the Connelly Branch drainage area; only portions at the upstream end are relatively unchanged from premining conditions. The regraded drainage map shows that the post mining land use is valley fill and regraded backstacks for 74% of the drainage area.

This area represents a 3% decrease from pre to post mining conditions and mainly reflects differences in the regraded topography on the east side of the drainage area.

Plate 3 shows the runoff subareas.

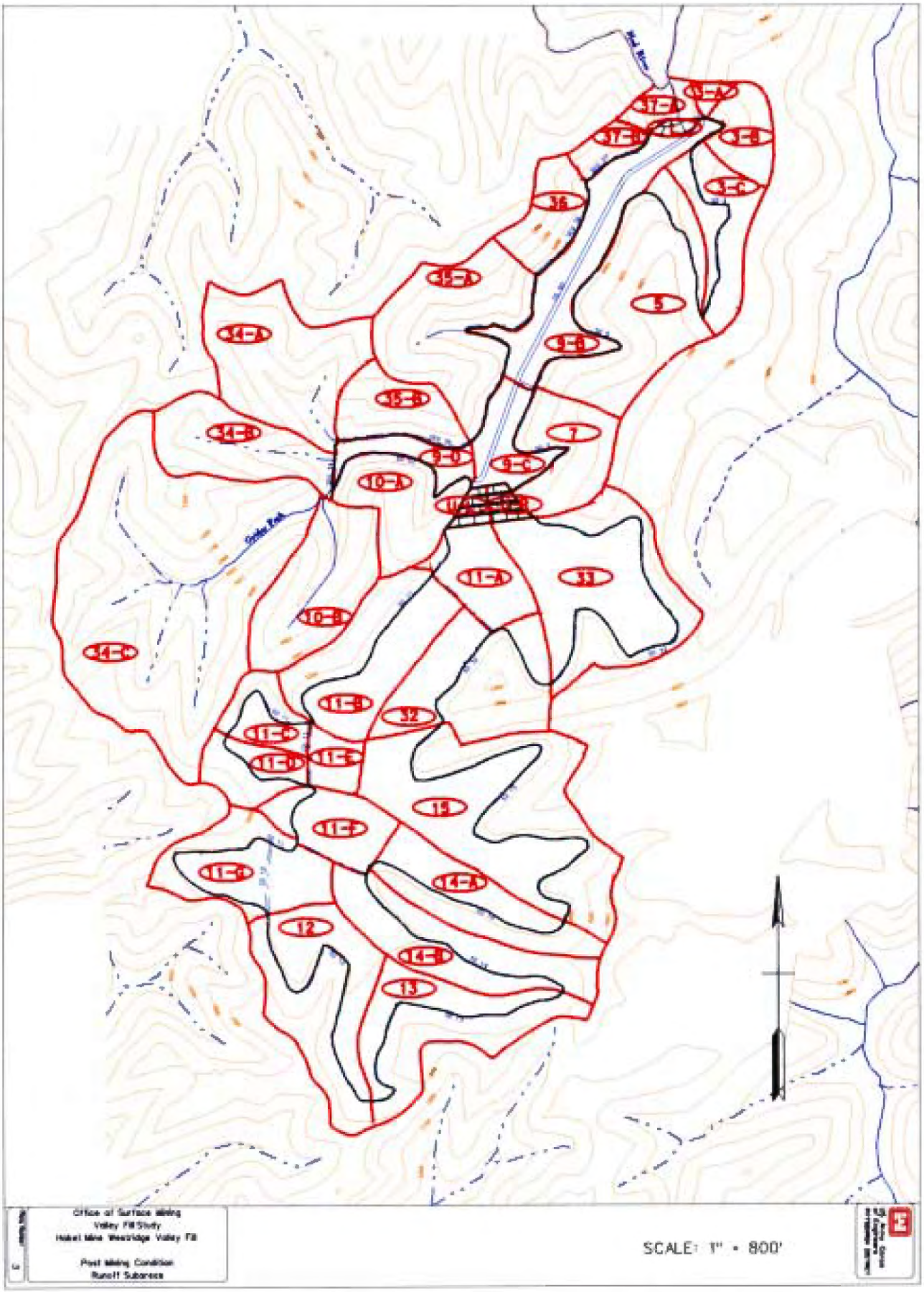
Soil Types and SCS Runoff Curve Numbers

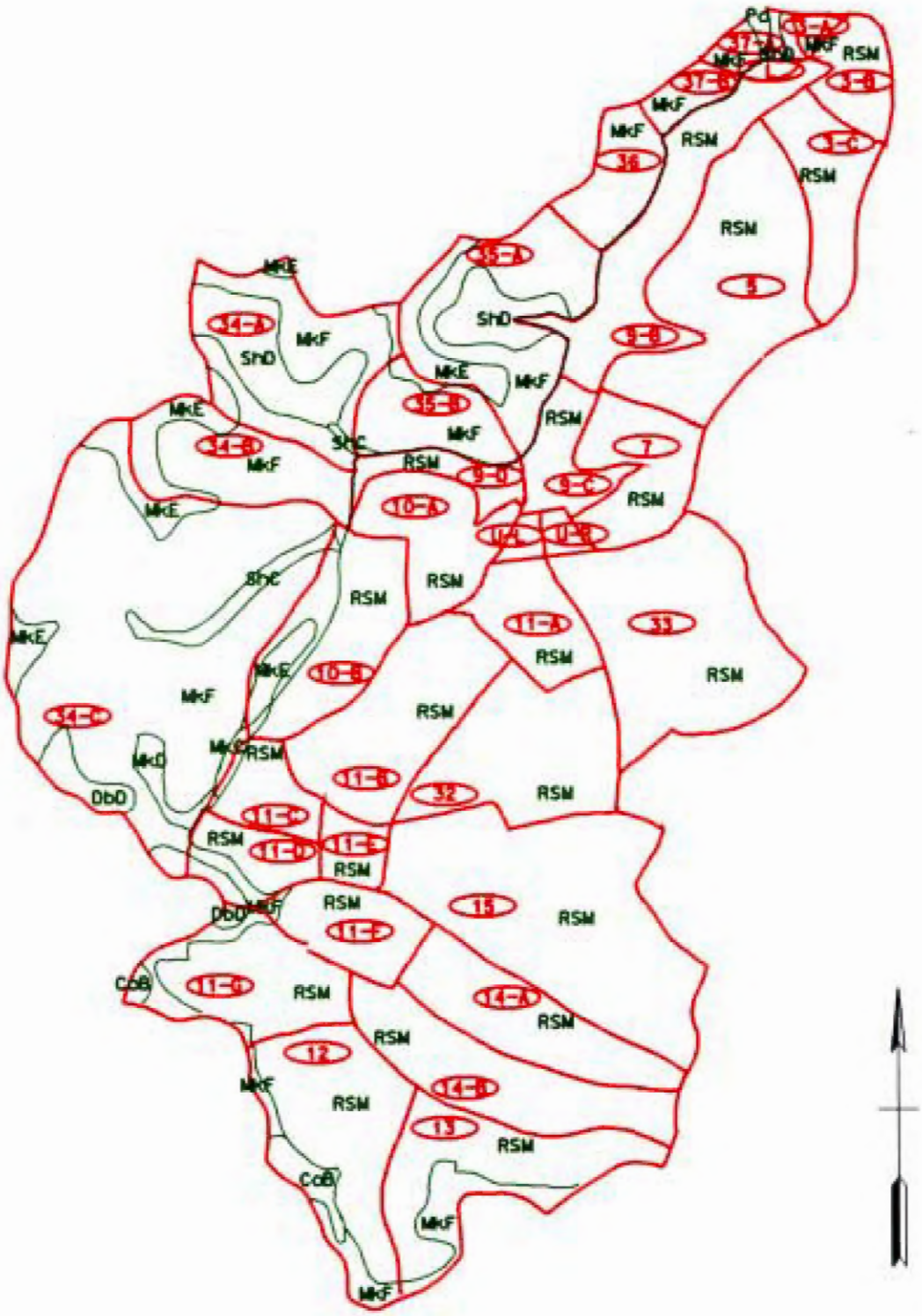
The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be reclaimed surface mine (RSM) areas.

The following table shows the soil types and their percent distribution within the runoff subareas for the post mining condition:

Runoff Subarea	Soil Type									
	MkC	MkD	MkE	MkF	ShC	ShD	Po	DbD	CoB	RSM
	Percent Distribution									
3-A										100
3-B										100
3-C										100
L										100
9-A										100
9-B										100
9-C										100
9-D										100
10-A										100
10-B			12.1	19.5		0.7				67.7
U-L										100
11-A										100
11-B										100
11-C										100
11-D				17.6				11.8		70.6
11-E										100
11-F				3.6						96.4
11-G			16.7					3.5	3.7	76.1
12				12.1					9.9	78.0
13			19.3							80.7
14-A										100
14-B										100
32										100
15										100
37-A				67.5		17.5	15.0			
37-B				100						
36				100						
35-A			20.1	58.9		21.0				
35-B			10.1	88.7		1.2				
34-A			7.9	51.5	1.0	39.6				
34-B			28.7	71.3						
34-C	0.8	2.7	7.4	80.5		4.1		4.5		
5										100
7										100
U-R										100
33										100
Total	0.0	0.1	3.4	18.6	0.0	2.3	0.4	0.6	0.4	74.2

Plate 4 shows the soil type subareas.


Office of Surface Mining
Valley Fill Study
Hobet Mine Weetridge Valley Fill
Post Mining Condition
Runoff Subareas
SCALE: 1" = 800'



Office of Surface Mining
Valley Fill Study
Hobet Mine Westridge Valley Fill

Post Mining Condition
Soil Type Subareas

SCALE: 1" = 800'

This table shows that reclaimed surface mine areas make up the majority (74%) of the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the post mining condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
3-A	75		0.67
3-B	75		0.67
3-C	75		0.67
L	75		0.67
9-A	75		0.67
9-B	75		0.67
9-C	75		0.67
9-D	75		0.67
10-A	75		0.67
10-B	74		0.70
U-L	75		0.67
11-A	75		0.67
11-B	75		0.67
11-C	75		0.67
11-D	74		0.70
11-E	75		0.67
11-F	75		0.67
11-G	75		0.67
12	75		0.67
13	75		0.67
14-A	75		0.67
14-B	75		0.67
32	75		0.67
15	75		0.67
37-A	69		0.90
37-B	73		0.74
36	73		0.74
35-A	70		0.86
35-B	73		0.74
34-A	68		0.94
34-B	73		0.74
34-C	72		0.78
5	75		0.67
7	75		0.67
U-R	75		0.67
33	75		0.67

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the post mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
3-A	14	8	12	7
3-B	18	11	18	11
3-C	38	23	37	22
L	5	3	5	3
9-A	13	8	13	8
9-B	47	28	44	27
9-C	41	24	40	24
9-D	34	20	34	20
10-A	17	10	15	9
10-B	26	16	25	15
U-L	6	4	6	4
11-A	40	24	39	24
11-B	44	26	42	25
11-C	50	30	49	29
11-D	42	26	37	22
11-E	36	21	35	21
11-F	39	23	39	23
11-G	36	22	42	25
12	47	28	44	26
13	46	27	43	26
14-A	45	27	43	26
14-B	42	25	40	24
32	37	22	36	22
15	81	49	74	44
37-A	16	10	16	10
37-B	18	11	18	11
36	26	16	25	15
35-A	51	31	47	28
35-B	43	26	42	25
34-A	27	16	26	16
34-B	33	20	32	19
34-C	43	26	42	25
5	48	29	44	26
7	23	15	21	13
U-R	6	4	6	4
33	68	41	62	37

Base Flow

The post mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
3-A	0.005	0.0
3-B	0.030	0.1
3-C	0.052	0.1
L	0.003	0.0
9-A	0.003	0.0
9-B	0.081	0.2
9-C	0.032	0.1
9-D	0.021	0.0
10-A	0.057	0.1
10-B	0.081	0.2
U-L	0.007	0.0
11-A	0.043	0.1
11-B	0.094	0.2
11-C	0.029	0.0
11-D	0.034	0.1
11-E	0.018	0.0
11-F	0.043	0.1
11-G	0.077	0.2
12	0.109	0.2
13	0.089	0.2
14-A	0.071	0.1
14-B	0.083	0.2
32	0.096	0.2
15	0.190	0.4
37-A	0.017	0.0
37-B	0.018	0.0
36	0.040	0.1
35-A	0.114	0.2
35-B	0.045	0.1
34-A	0.109	0.2
34-B	0.068	0.1
34-C	0.340	0.7
5	0.132	0.3
7	0.054	0.1
U-R	0.006	0.0
33	0.144	0.3

Routing Reaches

The drainage area was divided into two runoff subareas to model the premining condition. One reach connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Westridge Valley Fill drainage area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and the undisturbed Connelly Branch channel downstream of the valley fill was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

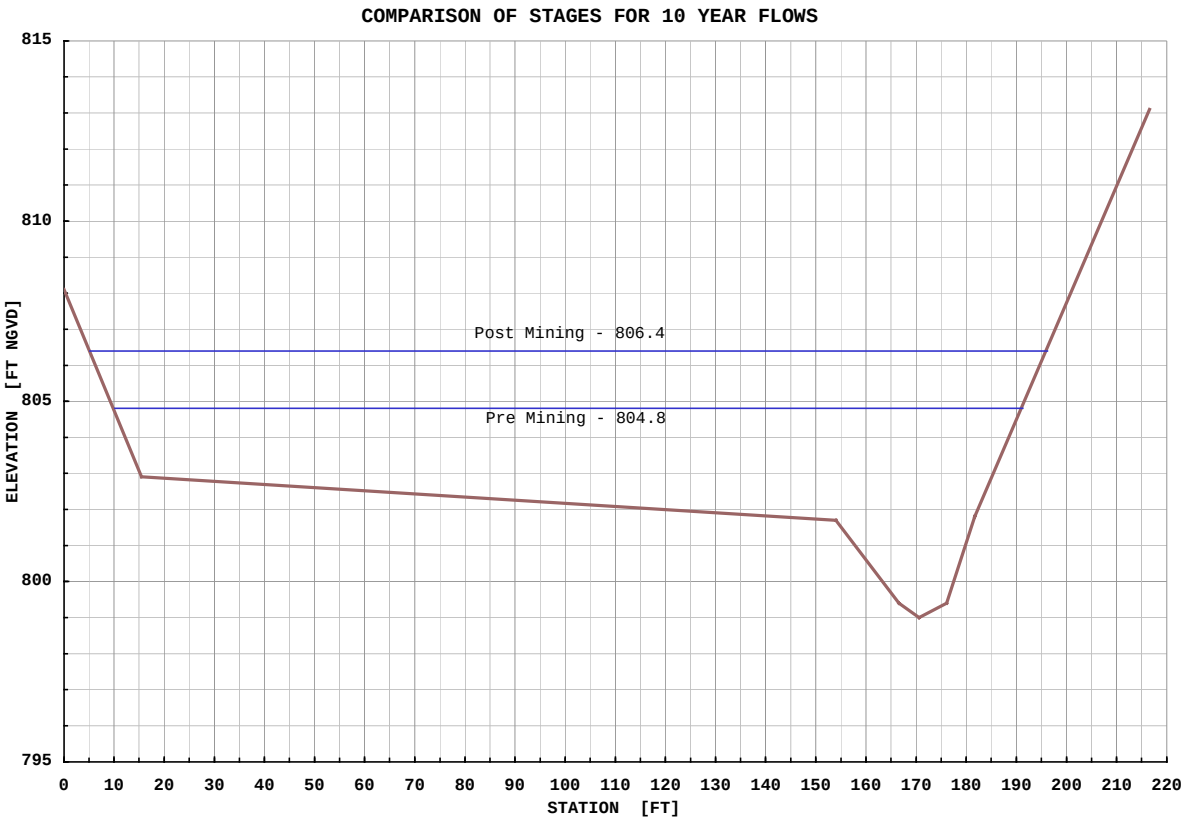
The following table shows the 10 and 100 year flows and water surface elevations:

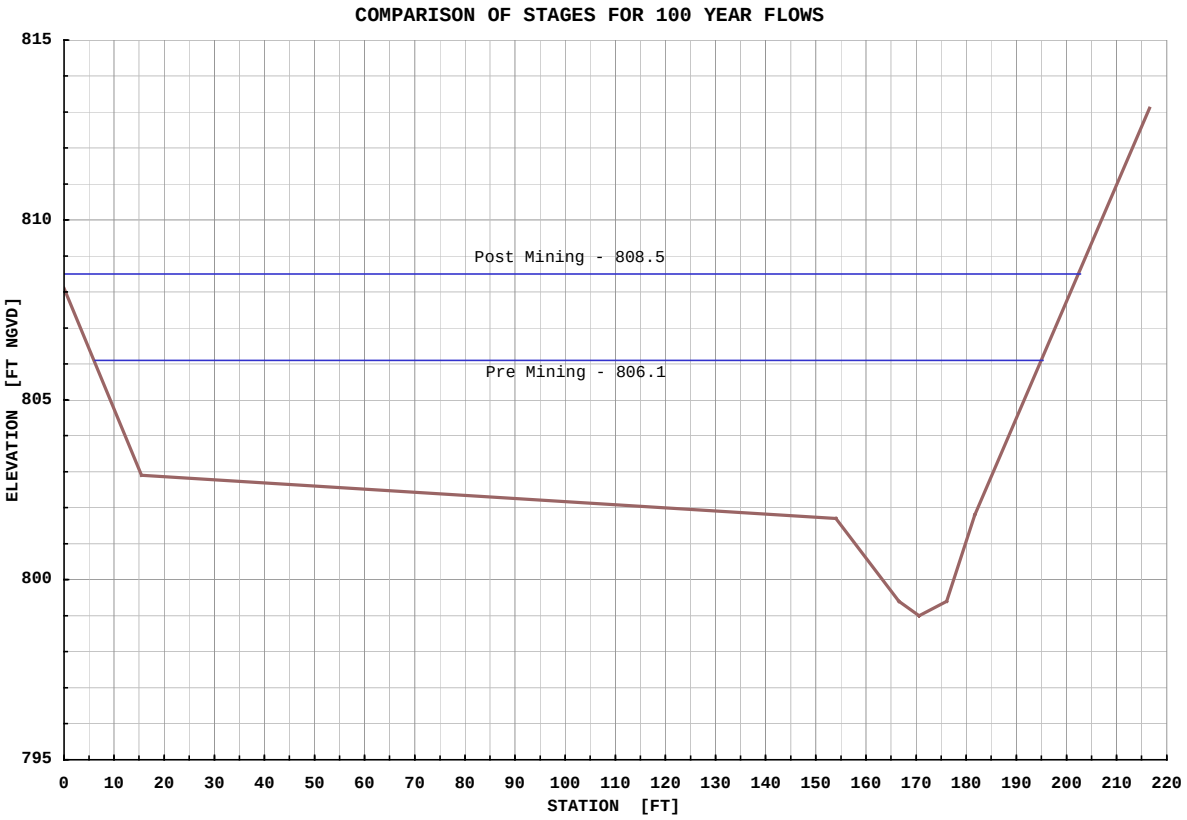
Frequency [YR]	Pre Mining		Post Mining	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	838	804.8	1193	806.1
100	1736	806.4	2459	808.5

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show a 42% (10-100 YR) increase in discharge from premining conditions after the valley fill area is reclaimed in the post mining conditions. The stage increases by 1.3-2.1’ for pre to post mining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOWS
ELEVATION [FT NGVD]
815
810
805
800
795
Post Mining - 806.4
Pre Mining - 804.8
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
STATION [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOWS
ELEVATION [FT NGVD]
815
810
805
800
795
Post Mining - 808.5
Pre Mining - 806.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
STATION [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea.

7. The flat slopes created on the top surfaces of the valley fills and the regraded back stacks help to reduce peak flows by increasing the runoff time of concentration. The long flow paths created by sediment ditches help to reduce peak flows by increasing the runoff travel times.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows a 42% (10-100 YR) increase in discharge from premining conditions after the valley fill area is reclaimed in the post mining conditions. The stage increases by 1.3-2.1’ for pre to post mining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the valley fill area to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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USGS 7.5 minute topographic maps, Mud quadrangle

OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILLS #1 AND 2 COMBINED AOC+ CONDITIONS

Appalachian Regional Coordinating Center

US Army Corps of Engineers
Pittsburgh District

NOVEMBER 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILLS
#1 AND 2 COMBINED
AOC+ CONDITIONS

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, post mining AOC+ (Approximate Original Contour Plus) conditions.

This report covers the results from the AOC+ conditions only. The results of the study for premining and post mining have been previously reported. They will be included in this report by reference and by inclusion in the "HYDROLOGIC AND HYDRAULIC MODEL RESULTS" section.

The Samples Mine Valley Fills SH-1 and 2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, were selected as the study site. The determination of the effects of changes to these drainage areas represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

After studying them separately, the adjacent valley fills were combined in order to determine the cumulative effect of the mining operations on the Seng Creek watershed. This involved combining the separate analysis of the two valley fills with the inclusion of an unmined intervening area. This report will detail the analysis of the unmined intervening area and the cumulative effect on the Seng Creek watershed. The analysis of Valley Fill #1 and 2 are presented in separate reports.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Dennis McCune, Karen Taylor, Elizabeth Rodriguez, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to AOC+ conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version 2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

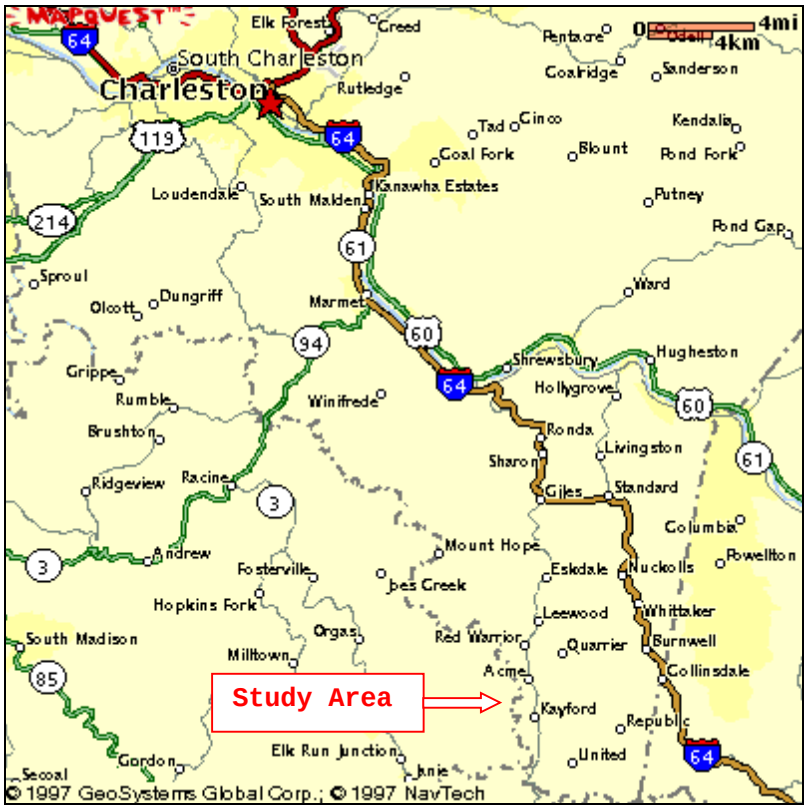
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #1 and 2 combined was the third site studied. The other three were the Samples Mine Valley Fill #1 and 2 separately, and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fills SH-1 and 2 are located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. They are located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage areas and the unmined intervening area occupy the most upstream 1.5 square miles (27%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, post and AOC+ mining conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Kaymine-Cedarcreek-Dekalb (KmF), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining and AOC+ conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage areas to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operations.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the OSM 1:4,800 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge routing method in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the

flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

AOC+ CONDITIONS

Drainage Areas

The AOC+ mining drainage area was delineated on a 1:4,800 scale regraded drainage map provided by the Knoxville Field Office of OSM. The AOC+ mining drainage area encompasses 1.48 square miles – 0.72 square miles for Valley Fill 1, 0.50 square miles for Valley Fill 2 and 0.26 for the unmined intervening area.

The unmined intervening area was divided into two runoff subareas to define the post mining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the AOC+ mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
M	Most downstream area	101.31	0.16	60.7
N	Right bank tributary	65.56	0.10	39.3
Total		166.96	0.26	100

Plate 1 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows that the unmined intervening area was relatively unchanged from preming conditions.

The following table shows the soil types and their percent distribution within the runoff subareas for the AOC+ mining condition:

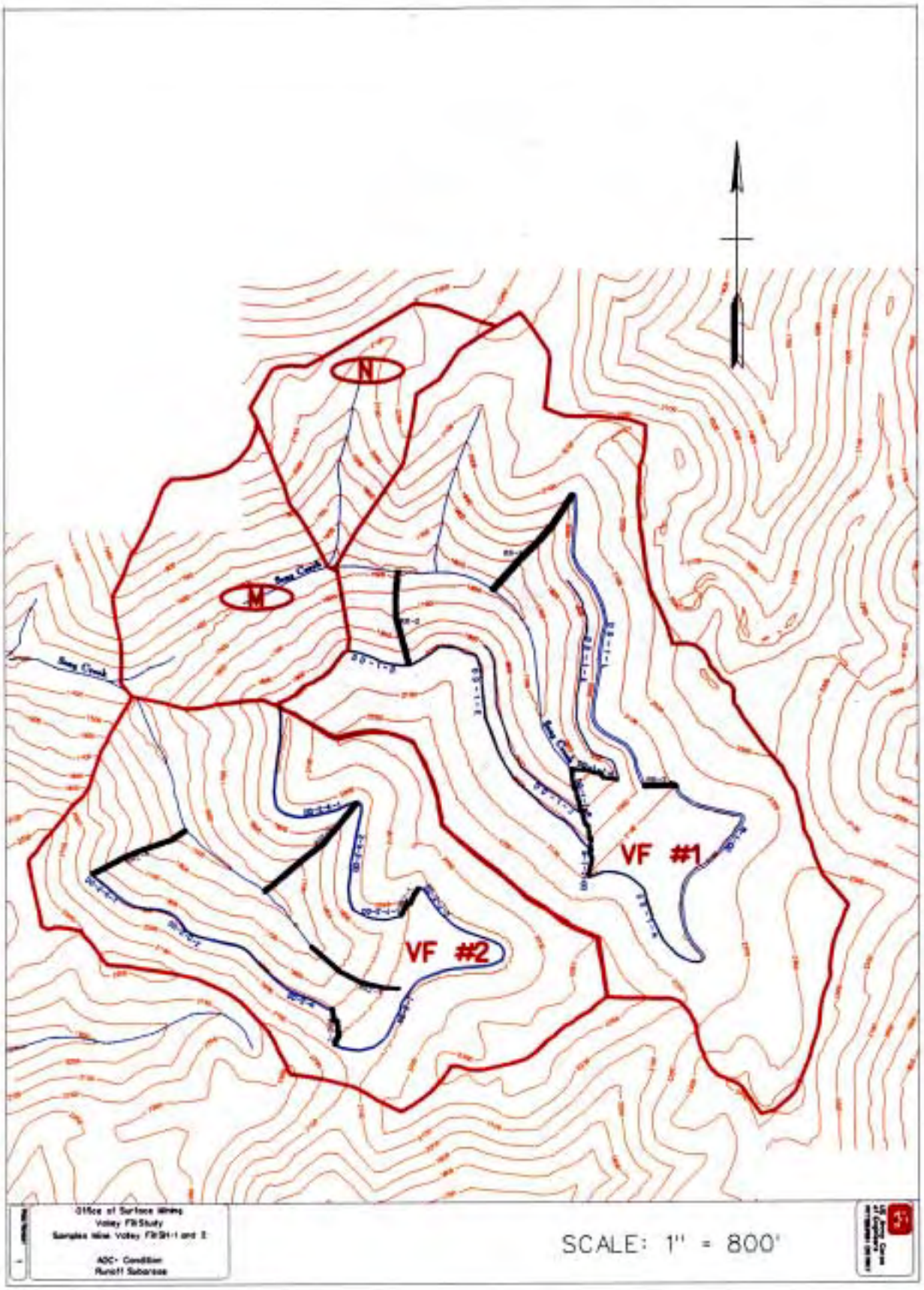
Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	GwE	ImE
	Percent Distribution					
M	3.4	87.9	1.0	6.6	1.1	
N	4.8	84.1			4.5	6.6
Total	4.0	86.4	0.6	4.0	2.4	2.6

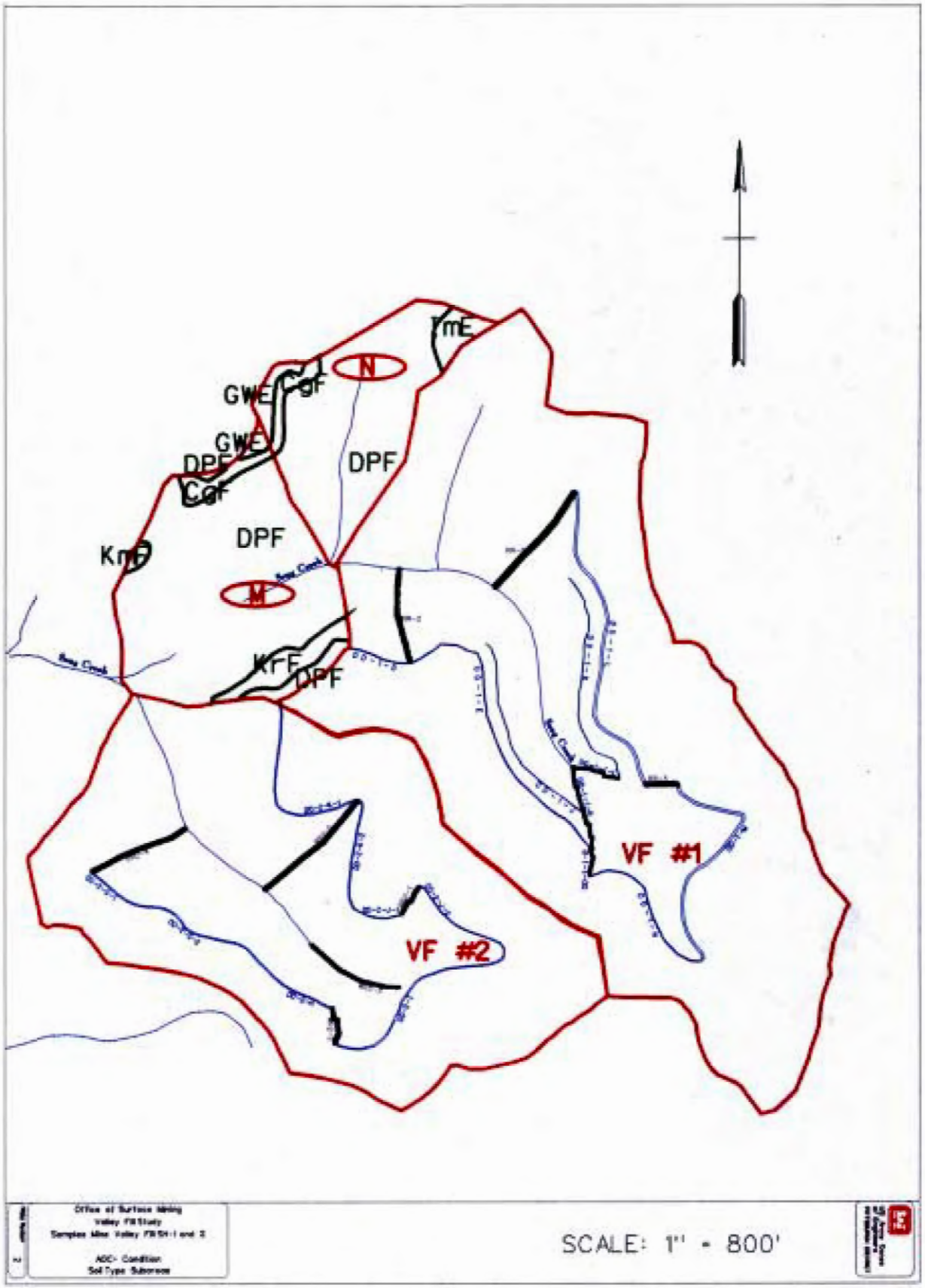
Plate 2 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (86%) of the drainage area.

The land use for the undisturbed portion of the intervening unmined area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the AOC+ mining condition:


N
M
VF #1
VF #2
Office of Surface Mining
Valley Fill Study
Samples near Valley Fill Sites 1 and 2
ADC- Condition
Runoff Subareas
SCALE: 1" = 800'


N
M
GWE
GWE
DPF
DPF
DPF
DPF
KmE
KrF
VF #1
VF #2
SCALE: 1" = 800'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
M	67	1.5	0.99
N	67	0.7	0.99

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the AOC+ mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
M	37	22	36	21
N	33	20	32	19

Base Flow

The AOC+ mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
M	0.16	0.32
N	0.10	0.21

Routing Reaches

The drainage area was divided into two runoff subareas to model the AOC+ mining condition. One reach connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the combined Valley Fill #1 and 2 drainage area and the unmined intervening area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

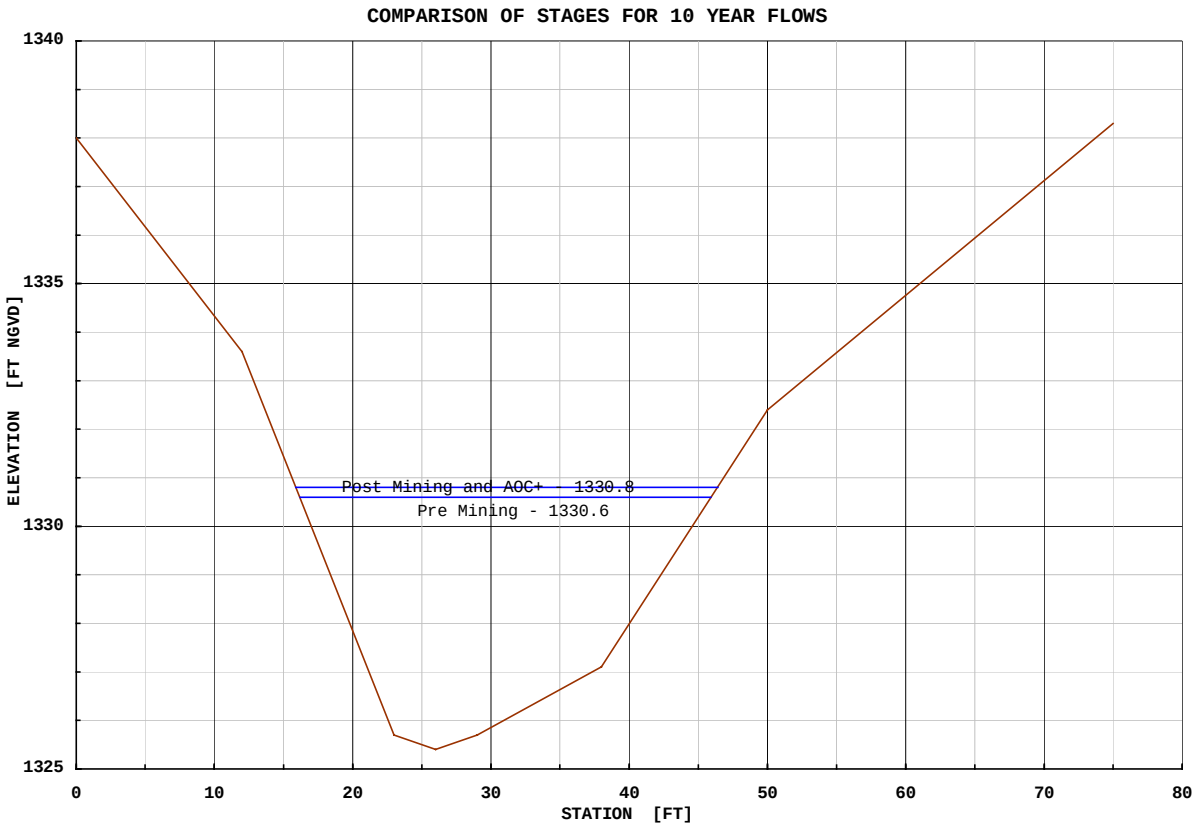
The following table shows the 10 and 100 year flows and water surface elevations:

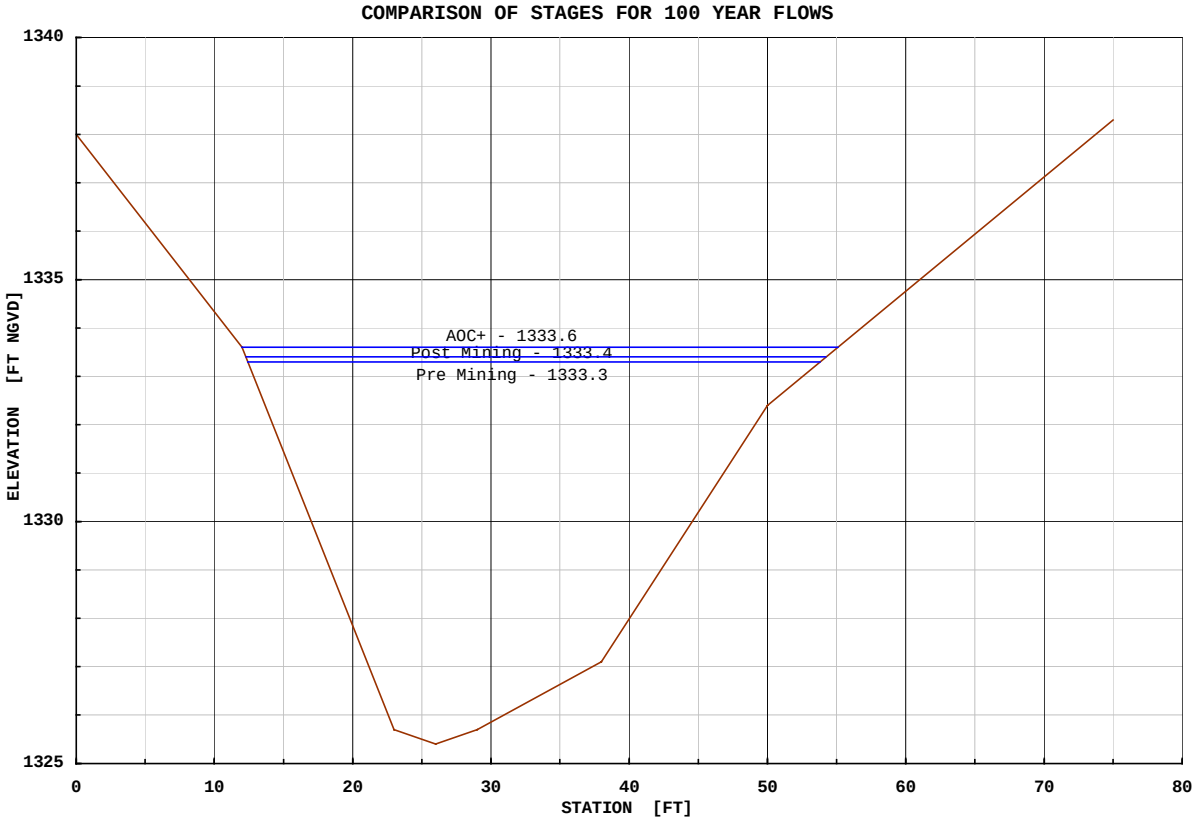
Frequency [YR]	Pre Mining		Post Mining		AOC+	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	765	1330.6	826	1330.8	833	1330.8
100	1711	1333.3	1793	1333.4	1874	1333.6

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show an 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 9-10% (10-100 YR) increase in discharge and a 0.2-0.3’ increase in stage from premining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
Post Mining and AOC+ - 1330.8
Pre Mining - 1330.6
0
10
20
30
40
50
60
70
80
STATION [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
AOC+ - 1333.6
Post Mining - 1333.4
Pre Mining - 1333.3
0
10
20
30
40
50
60
70
80
STATION [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows a 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 9-10% (10-100 YR) increase in discharge and a 0.2-0.3’ increase in stage from premining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the valley fill areas to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

REFERENCES

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USGS 7.5 minute topographic maps, Dorothy and Eskdale quadrangles

OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILLS #1 AND 2 COMBINED FUTURE FORESTED CONDITIONS

Appalachian Regional Coordinating Center

US Army Corps of Engineers
Pittsburgh District

MARCH 2001

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILLS
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FUTURE FORESTED CONDITIONS

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, post mining, AOC+ (Approximate Original Contour Plus) and future forested conditions.

This report covers the results from the future forested conditions only. The results of the study for premining, post mining and AOC+ have been previously reported. They will be included in this report by reference and by inclusion in the “HYDROLOGIC AND HYDRAULIC MODEL RESULTS” section.

The Samples Mine Valley Fill SH-1 and 2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

After studying them separately, the adjacent valley fills were combined in order to determine the cumulative effect of the mining operations on the Seng Creek watershed. This involved combining the separate analysis of the two valley fills with the inclusion of an unmined intervening area. This report will detail the analysis of the unmined intervening area and the cumulative effect on the Seng Creek watershed. The analysis of Valley Fill #1 and 2 are presented in separate reports.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Dennis McCune, Karen Taylor, Elizabeth Rodriguez, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to future forested conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version 2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

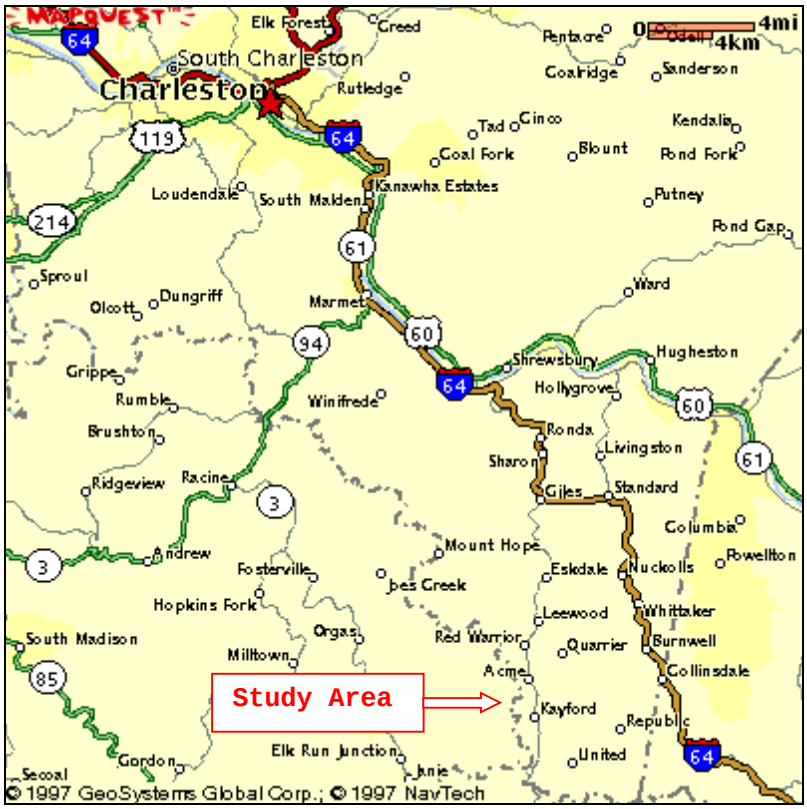
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fills #1 and 2 combined was the third site studied. The other three were the Samples Mine Valley Fill #1, #2 and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fills SH-1 and 2 are located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. They are located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage areas and the unmined intervening area occupy the most upstream 1.5 square miles (27%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, post mining, AOC+ and future forested conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Itmann channery loam (ImE), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining, AOC+ and future forested conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company’s 1:6,000 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect

the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

FUTURE FORESTED CONDITIONS

Drainage Areas

The future forested drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The future forested drainage area encompasses 1.52 square miles – 0.74 square miles for Valley Fill 1, 0.51 square miles for Valley Fill 2 and 0.27 for the unmined intervening area.

The unmined intervening area was divided into two runoff subareas to define the future forested condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the future forested condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
M	Most downstream area	102.21	0.16	59.7
N	Right bank tributary	68.99	0.11	40.3
Total		171.20	0.27	100

The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the future forested land use is wooded for 100% of the drainage area. The future forested conditions represent a 20 year forestry plan which covers the reclaimed surface mine areas with appropriate trees.

This area represents a 5% decrease from pre to future forested conditions and mainly reflects differences in the regraded topography on the east side of the unmined intervening area.

Plate 1 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

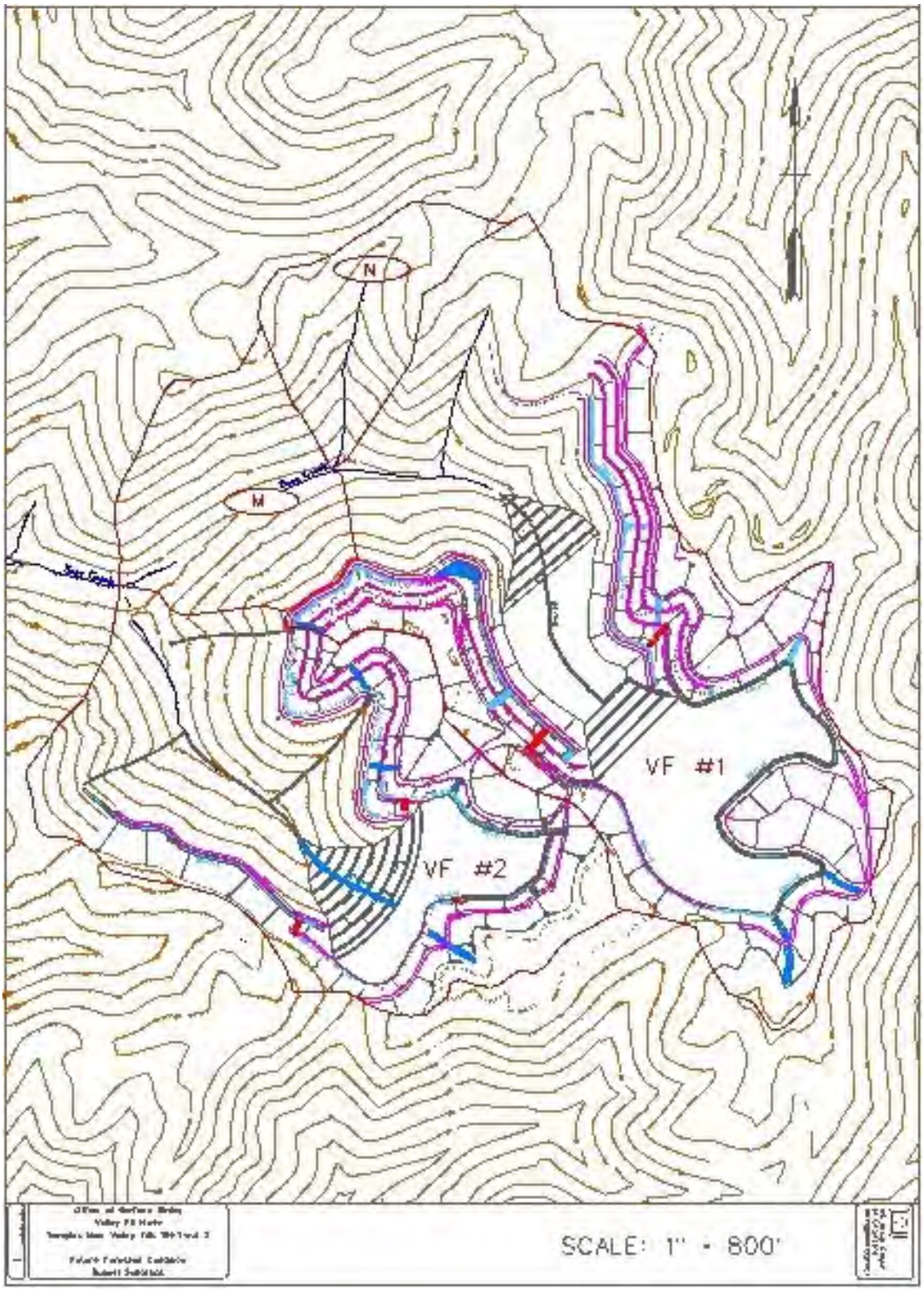
The regraded drainage map shows that the unmined intervening area was relatively unchanged from premining conditions.

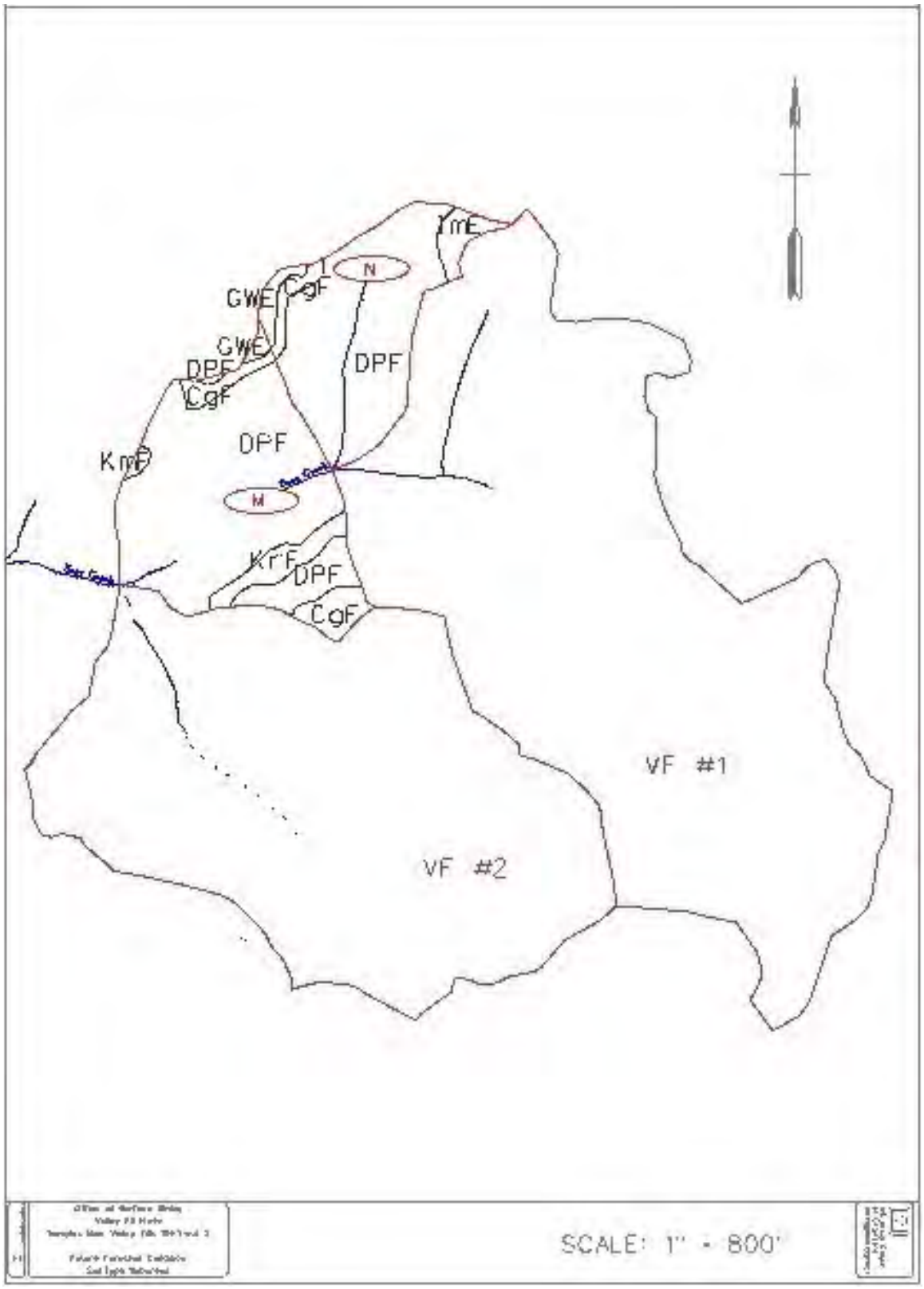
The following table shows the soil types and their percent distribution within the runoff subareas for the future forested condition:

Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	GwE	ImE
	Percent Distribution					
M	3.1	89.4	0.6	6.1	0.8	
N	7.1	80.6			6.2	6.1
Total	5.1	84.9	0.3	3.1	3.5	3.1

Plate 2 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (85%) of the drainage area.


N
M
VF #1
VF #2
SCALE: 1" = 800'


YmE
N
GWE
CgF
GWE
DPF
CgF
DPF
DPF
KmF
M
KrF
DPF
CgF
VF #1
VF #2
SCALE: 1" = 800'

The land use for the undisturbed portion of the intervening unmined area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the future forested condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
M	67	1.9	0.99
N	67	1.1	0.99

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the future forested condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
M	35	21	34	20
N	34	20	32	19

Base Flow

The future forested mining condition base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
M	0.16	0.32
N	0.11	0.22

Routing Reaches

The drainage area was divided into two runoff subareas to model the future forested condition. One reach connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the combined Valley Fills #1 and 2 drainage area and the unmined intervening area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

The following tables show the 10 and 100 year flows and water surface elevations:

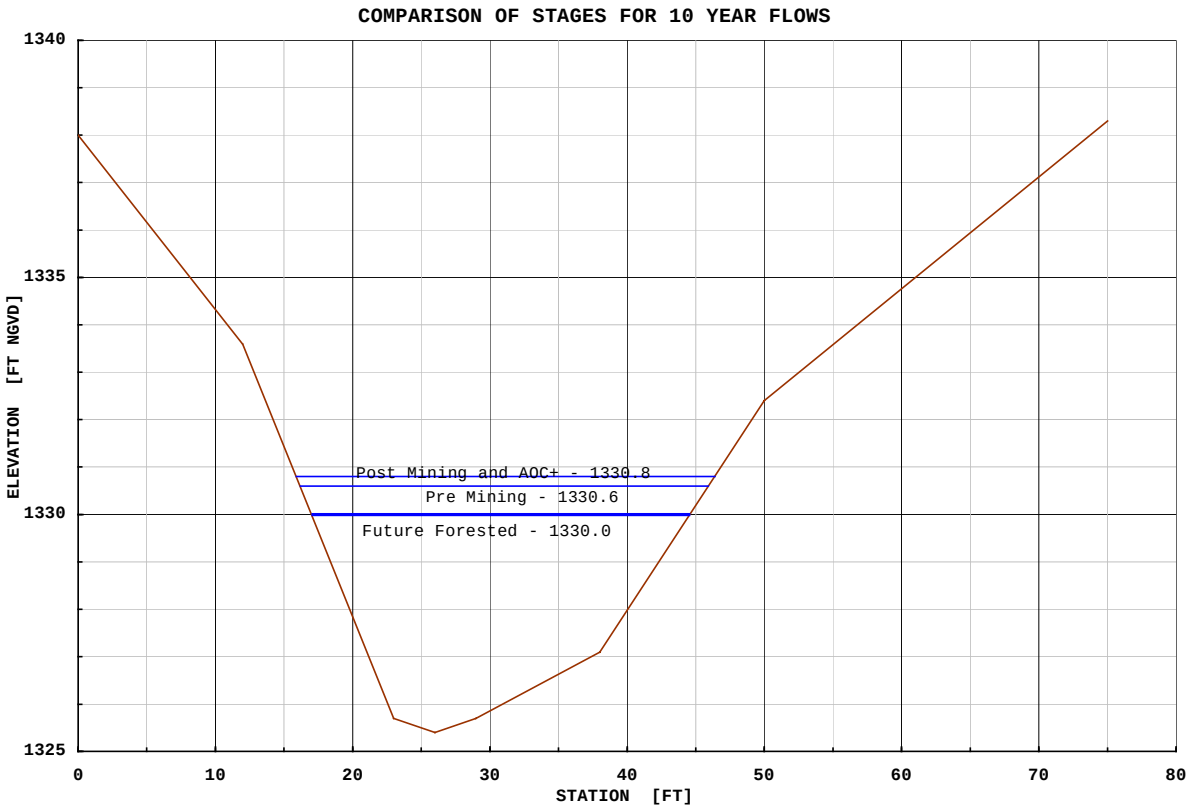
Frequency [YR]	Pre Mining		Post Mining		AOC+	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	765	1330.6	826	1330.8	833	1330.8
100	1711	1333.3	1793	1333.4	1874	1333.6

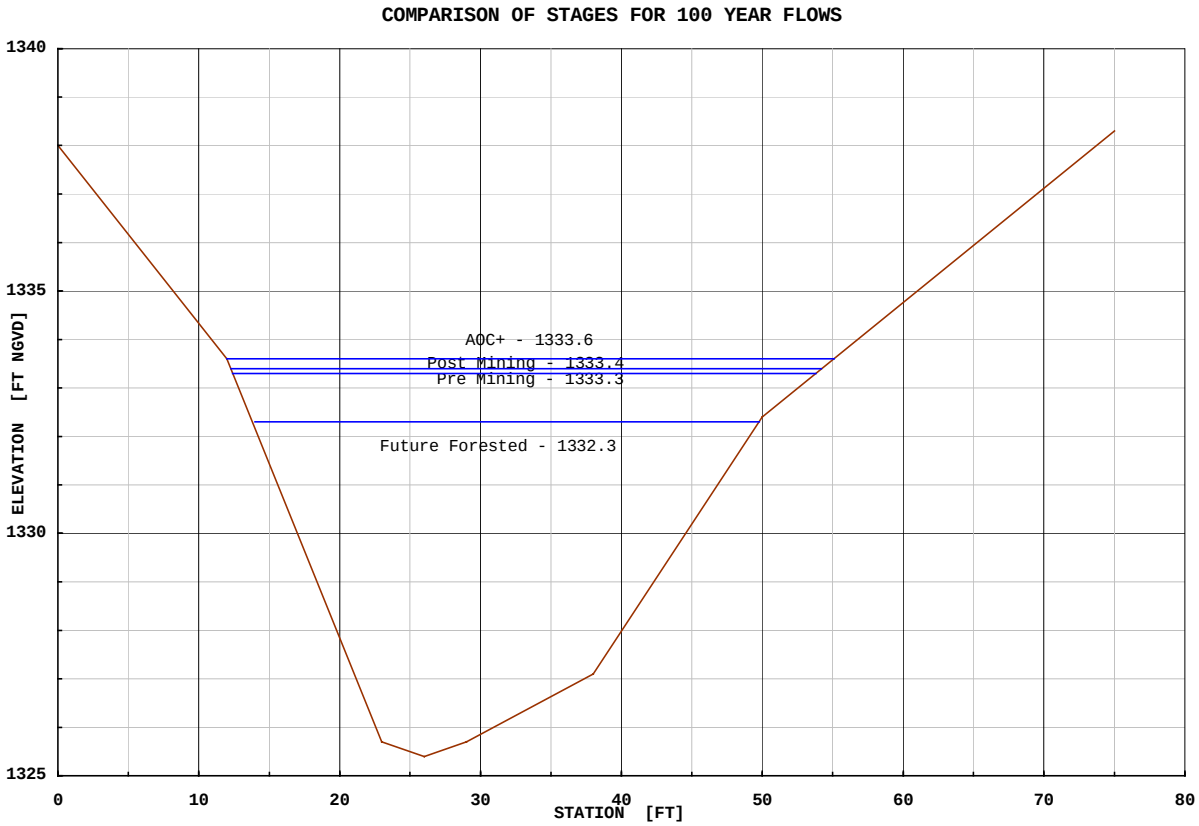
Frequency [YR]	Future Forested	
	Flow [CFS]	Elevation [FT NGVD]
10	605	1330.0
100	1331	1332.3

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show an 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 9-10% (10-100 YR) increase in discharge and a 0.2-0.3’ increase in stage from premining conditions. The future forested conditions would cause a 21-22% (10-100 YR) decrease in discharge and a 0.6’-1.0’ decrease in stage from the premining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
Post Mining and AOC+ - 1330.8
Pre Mining - 1330.6
Future Forested - 1330.0
0
10
20
30
40
50
60
70
80
STATION [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
AOC+ - 1333.6
Post Mining - 1333.4
Pre Mining - 1333.3
Future Forested - 1332.3
0
10
20
30
40
50
60
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80
STATION [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. These results show an 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 9-10% (10-100 YR) increase in discharge and a 0.2-0.3’ increase in stage from premining conditions. The future forested conditions would cause a 21-22% (10-100 YR) decrease in discharge and a 0.6’-1.0’ decrease in stage from the premining conditions.

RECOMMENDATIONS

1. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILLS #1 AND 2 COMBINED

Appalachian Regional Coordinating Center

US Army Corps of Engineers
Pittsburgh District

JANUARY 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILLS
#1 AND 2 COMBINED

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining and post mining conditions.

The Samples Mine Valley Fills SH-1 and 2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, were selected as the study site. The determination of the effects of changes to these drainage areas represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

After studying them separately, the adjacent valley fills were combined in order to determine the cumulative effect of the mining operations on the Seng Creek watershed. This involved combining the separate analysis of the two valley fills with the inclusion of an unmined intervening area. This report will detail the analysis of the unmined intervening area and the cumulative effect on the Seng Creek watershed. The analysis of Valley Fill #1 and 2 are presented in separate reports.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Dennis McCune, Karen Taylor, Elizabeth Rodriguez, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to post mining conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

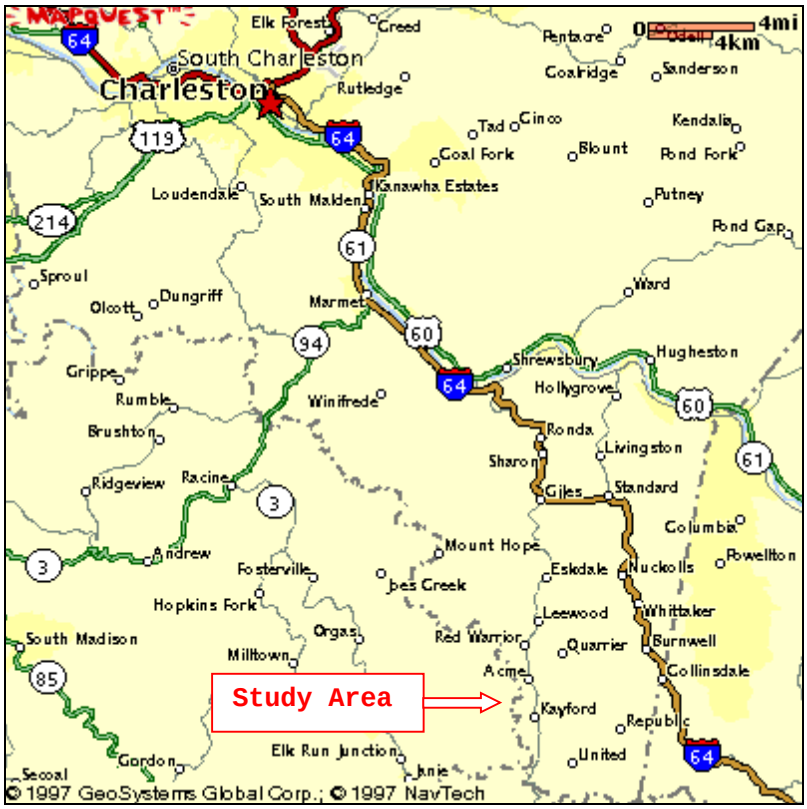
This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #1 and 2 combined was the third site studied. The other three were the Samples Mine Valley Fill #1

and 2 separately, and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fills SH-1 and 2 are located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. They are located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage areas and the unmined intervening area occupy the most upstream 1.5 square miles (27%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining and post mining conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Kaymine-Cedarcreek-Dekalb (KmF), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining and postmining conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage areas to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operations.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company’s 1:6,000 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge routing method in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the

flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

PREMINING CONDITIONS

Drainage Areas`

The premining drainage area was delineated on USGS 1:24,000 scale topographic maps (Dorothy and Eskdale quadrangles) and on a 1:6,000 scale regraded drainage map provided by the coal company. The premining drainage area encompasses 1.52 square miles – 0.68 square miles for Valley Fill 1, 0.55 square miles for Valley Fill 2 and 0.28 for the unmined intervening area.

The unmined intervening area was divided into two runoff subareas to define the premining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the premining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
M	Most downstream area	111.74	0.17	61.8
N	Right bank tributary	68.99	0.11	38.2
Total		180.73	0.28	100

Plate 1 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

The following table shows the soil types and their percent distribution within the runoff subareas for the premining condition:

Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	GwE	ImE
	Percent Distribution					
M	7.1	86.1	0.5	5.6	0.7	
N	7.1	80.6			6.2	6.1
Total	7.1	83.2	0.3	2.8	3.5	3.1

Plate 2 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (83%) of the drainage area.

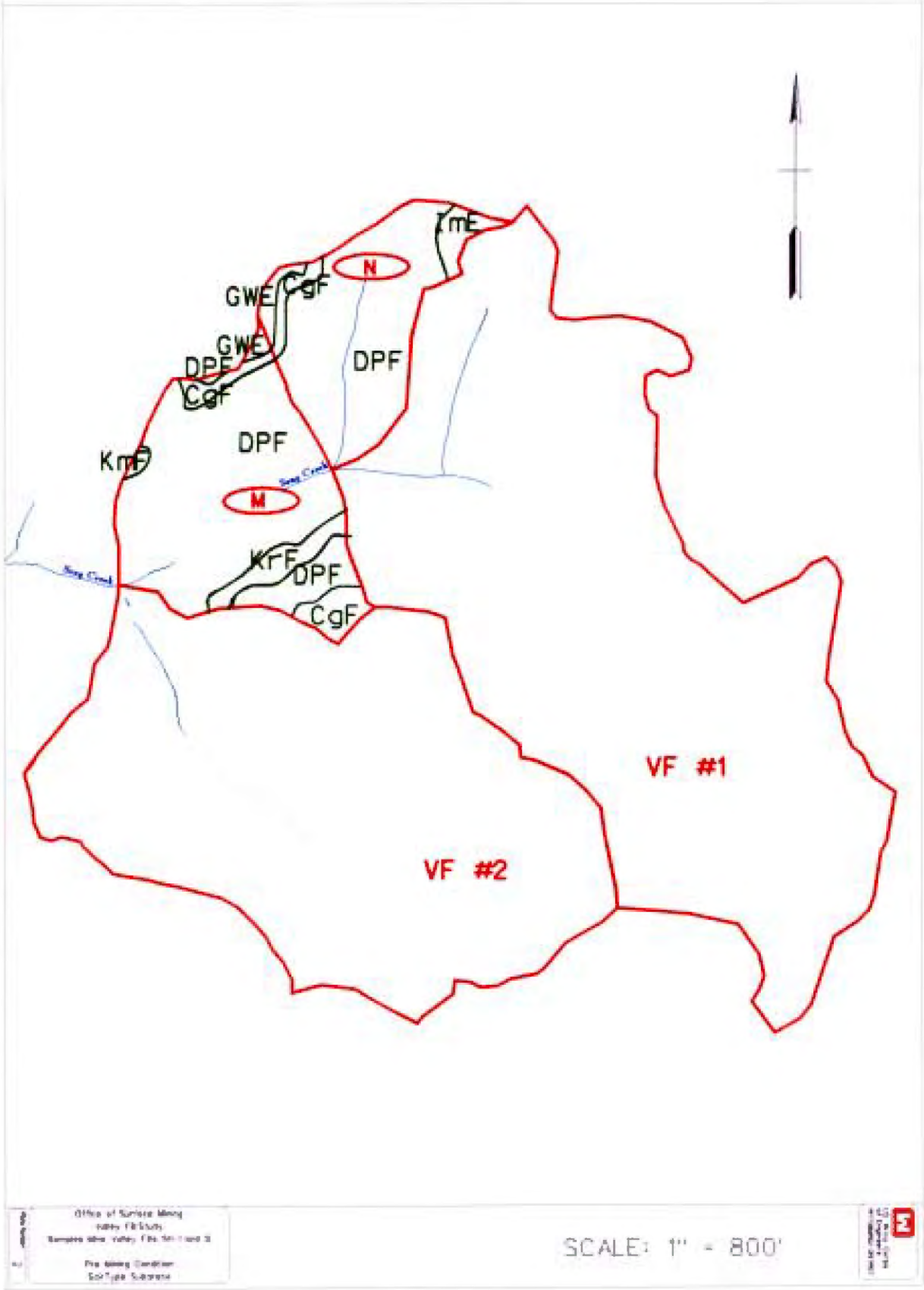
The premining land use for the Seng Creek watershed is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the premining condition:

Office of Surface Mining
Valley Fill Study
Sampson Mine Valley Fills SH-1 and 2

Pre Mining Condition
Runoff Subareas

SCALE: 1" = 800'


TmE
N
GWE
CgF
GWE
DPF
CgF
DPF
DPF
KmF
Sow Creek
M
KrF
DPF
CgF
Sow Creek
VF #1
VF #2
SCALE: 1" = 800'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
M	67	1.9	0.99
N	67	1.1	0.99

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the premining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
M	37	22	37	22
N	34	20	33	20

Base Flow

The premining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
M	0.17	0.35
N	0.11	0.22

Routing Reaches

The drainage area was divided into two runoff subareas to model the premining condition. One reach connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

POST MINING CONDITIONS

Drainage Areas

The post mining drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The post mining drainage area encompasses 1.52 square miles – 0.74 square miles for Valley Fill 1, 0.51 square miles for Valley Fill 2 and 0.27 for the unmined intervening area.

The unmined intervening area was divided into two runoff subareas to define the post mining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the post mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
M	Most downstream area	102.21	0.16	59.7
N	Right bank tributary	68.99	0.11	40.3
Total		171.20	0.27	100

The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the post mining land use is wooded for 100% of the drainage area.

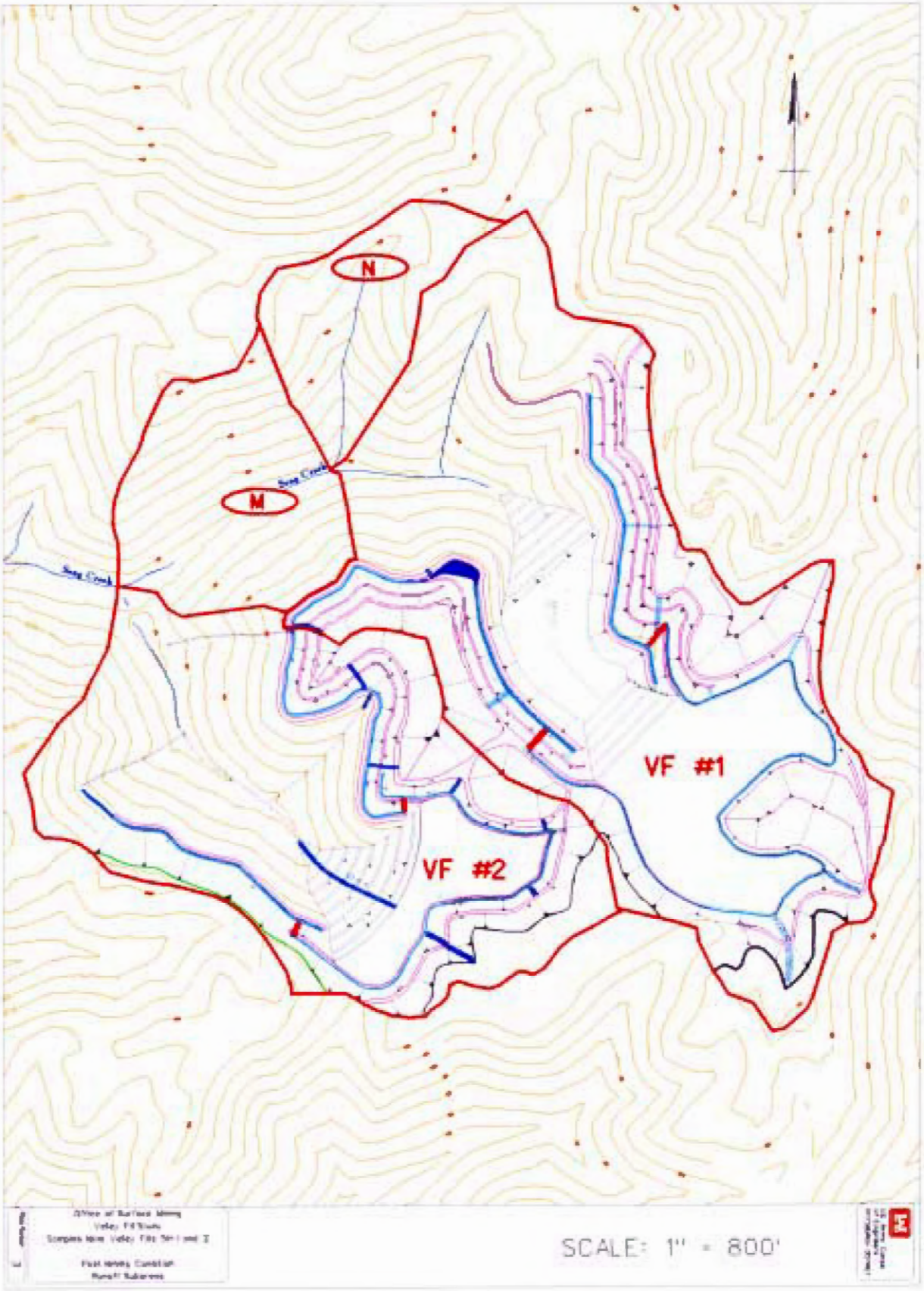
This area represents a 5% decrease from pre to post mining conditions and mainly reflects differences in the regraded topography on the east side of the unmined intervening area.

Plate 3 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows that the unmined intervening area was relatively unchanged from preming conditions.

The following table shows the soil types and their percent distribution within the runoff subareas for the post mining condition:


N
M
VF #1
VF #2
SCALE: 1" = 800'

Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	GwE	ImE
	Percent Distribution					
M	3.1	89.4	0.6	6.1	0.8	
N	7.1	80.6			6.2	6.1
Total	5.1	84.9	0.3	3.1	3.5	3.1

Plate 4 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (85%) of the drainage area.

The land use for the undisturbed portion of the intervening unmined area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the post mining condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
M	67	1.9	0.99
N	67	1.1	0.99

Time of Concentration and Lag

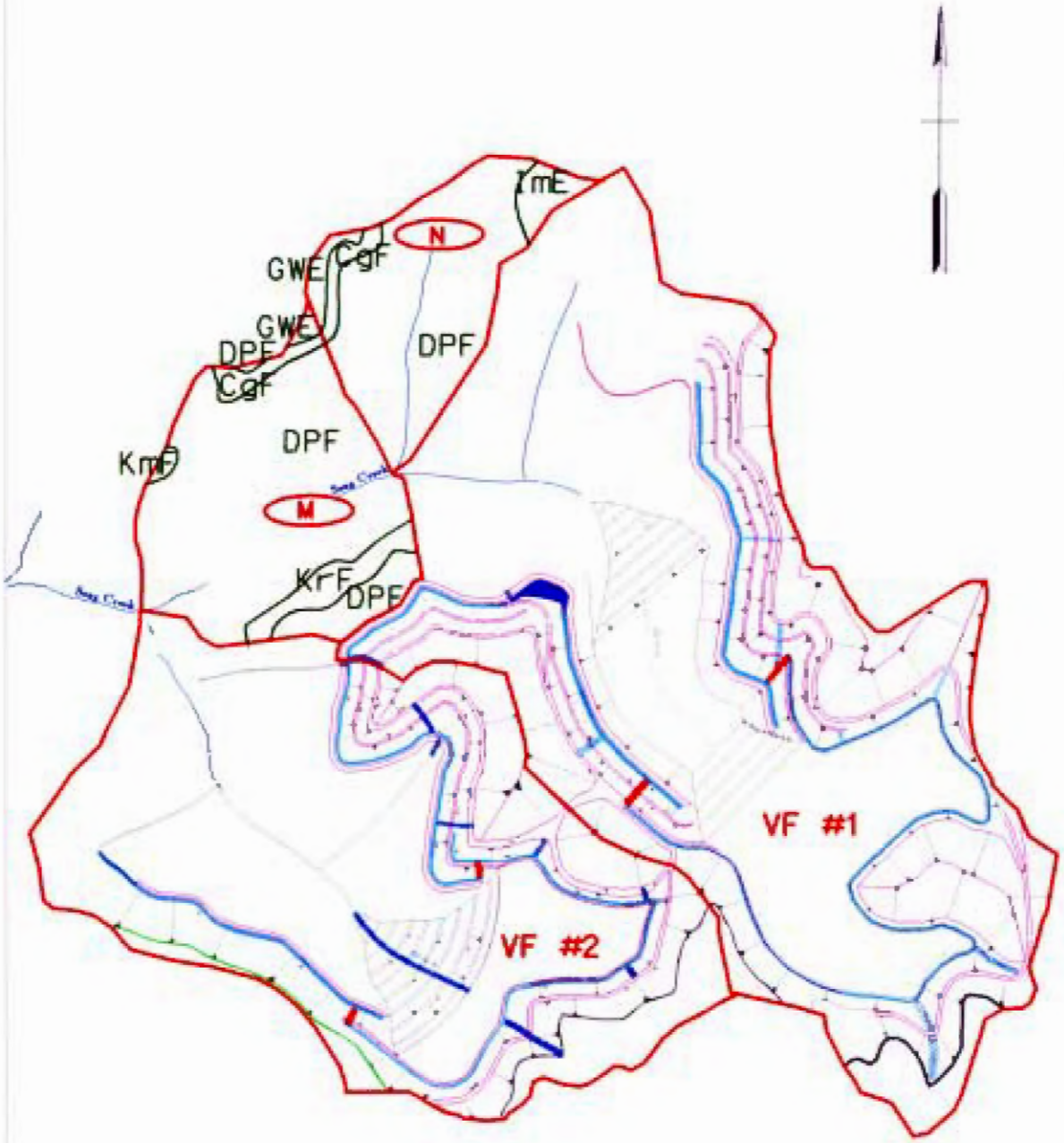
The following table shows the results of the time of concentration and lag calculations for the post mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
M	37	22	36	22
N	34	20	34	20

Base Flow

The post mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
M	0.16	0.32
N	0.11	0.22



Office of Surface Mining
Valley Fill Study
Sampled Mine Valley Fills Sri Lanka 2

Pre-Mining Condition
Soil Type Subsidence

SCALE: 1" = 800'

3

Routing Reaches

The drainage area was divided into two runoff subareas to model the post mining condition. One reach connected the runoff subareas and routed the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the combined Valley Fill #1 and 2 drainage area and the unmined intervening area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

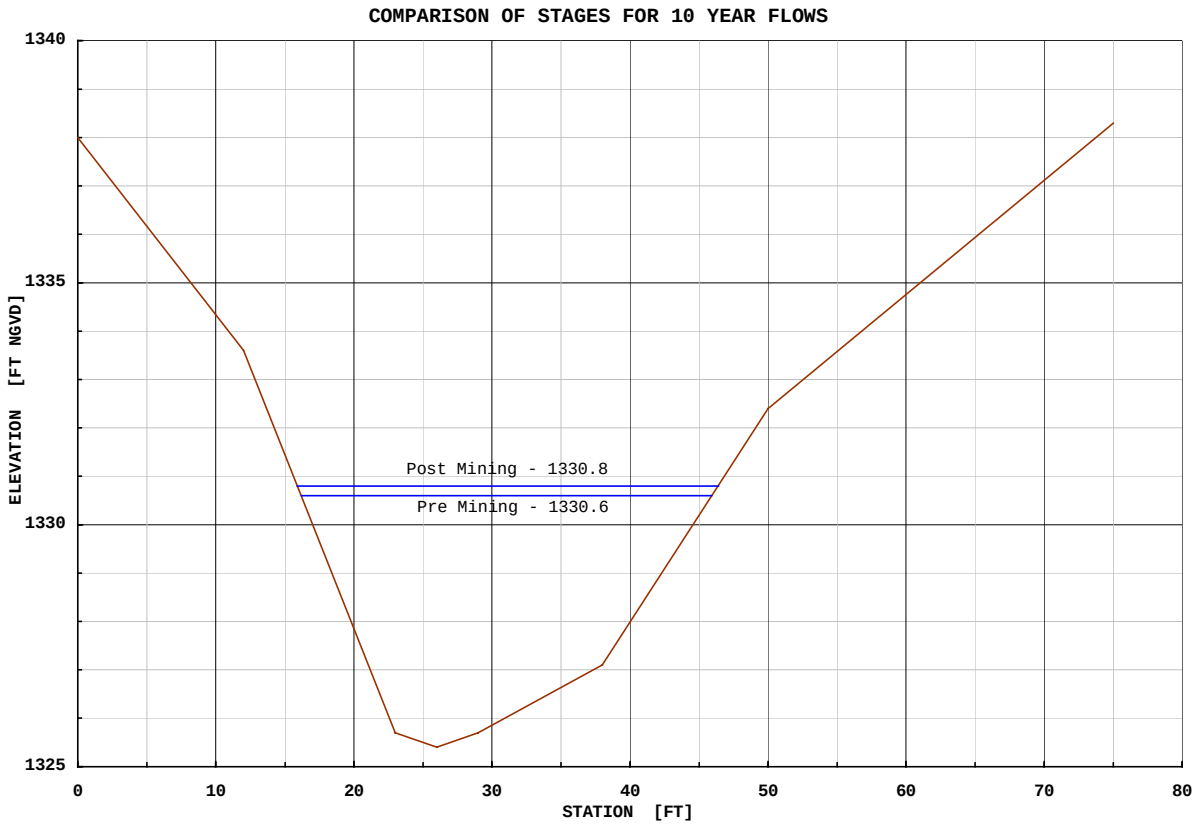
The following table shows the 10 and 100 year flows and water surface elevations:

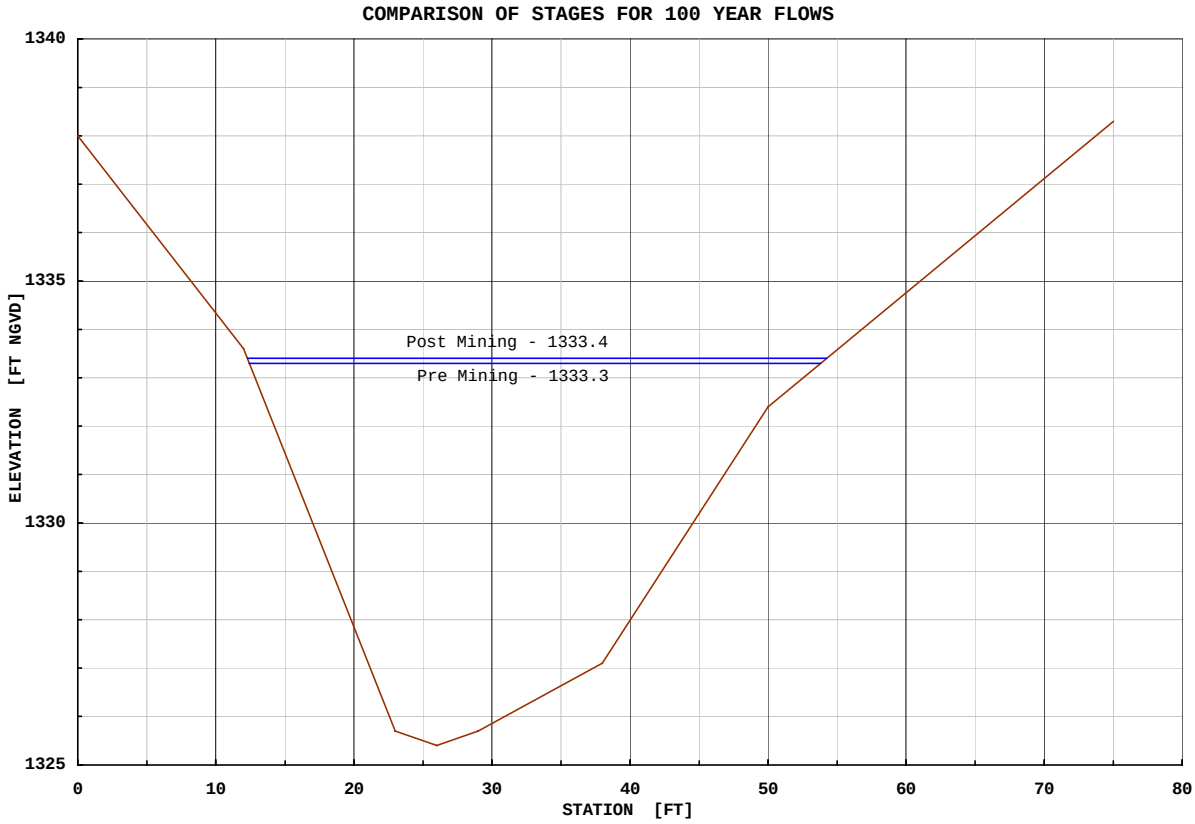
Frequency [YR]	Pre Mining		Post Mining	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	765	1330.6	826	1330.8
100	1711	1333.3	1793	1333.4

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show an 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
Post Mining - 1330.8
Pre Mining - 1330.6
0
10
20
30
40
50
60
70
80
STATION [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOWS
1340
1335
1330
1325
ELEVATION [FT NGVD]
Post Mining - 1333.4
Pre Mining - 1333.3
0
10
20
30
40
50
60
70
80
STATION [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea.

7. The flat slopes created on the top surfaces of the valley fills and the regraded back stacks help to reduce peak flows by increasing the runoff time of concentration. The long flow paths created by sediment ditches help to reduce peak flows by increasing the runoff travel times.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows a 8-5% (10-100 YR) increase in discharge from premining conditions after the valley fill areas are reclaimed in the post mining conditions. The stage increases by 0.2-0.1’ for pre to post mining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the valley fill areas to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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USGS 7.5 minute topographic maps, Dorothy and Eskdale quadrangles

OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #1
AOC+ CONDITIONS

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

SEPTEMBER 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #1
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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, during mining, post mining and AOC+ (Approximate Original Contour Plus) conditions.

This report covers the results from the AOC+ conditions only. The results of the study for premining, during mining and post mining have been previously reported. They will be included in this report by reference and by inclusion in the “HYDROLOGIC AND HYDRAULIC MODEL RESULTS” section.

The Samples Mine Valley Fill SH-1, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Karen Taylor, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to AOC+ conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version 2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

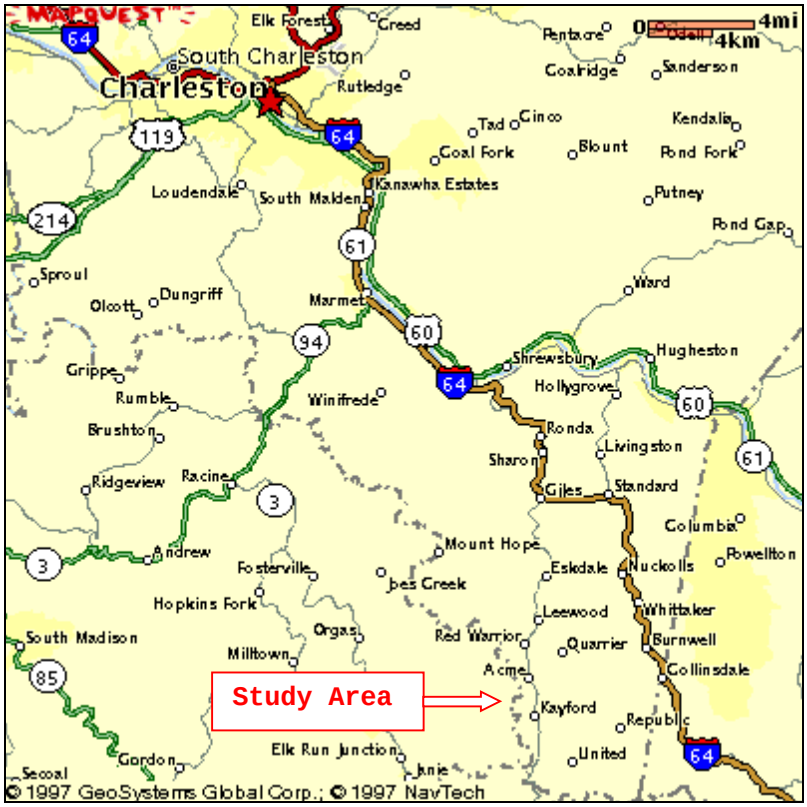
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #1 was the first site studied. The other three were the Samples Mine Valley Fill #2, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-1 is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. The valley fill drainage area occupies the most upstream 0.7 square miles (13%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, during mining, post mining and AOC+ conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Itmann channery loam (ImE), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining and AOC+ conditions or the aerial photographs for the during mining condition; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a)

is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the OSM 1:4,800 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

AOC+ CONDITIONS

Drainage Areas

The AOC+ mining condition drainage area was delineated on a 1:4,800 scale regraded drainage map provided by the Knoxville Field Office of OSM. The AOC+ mining condition drainage area encompasses 0.72 square miles.

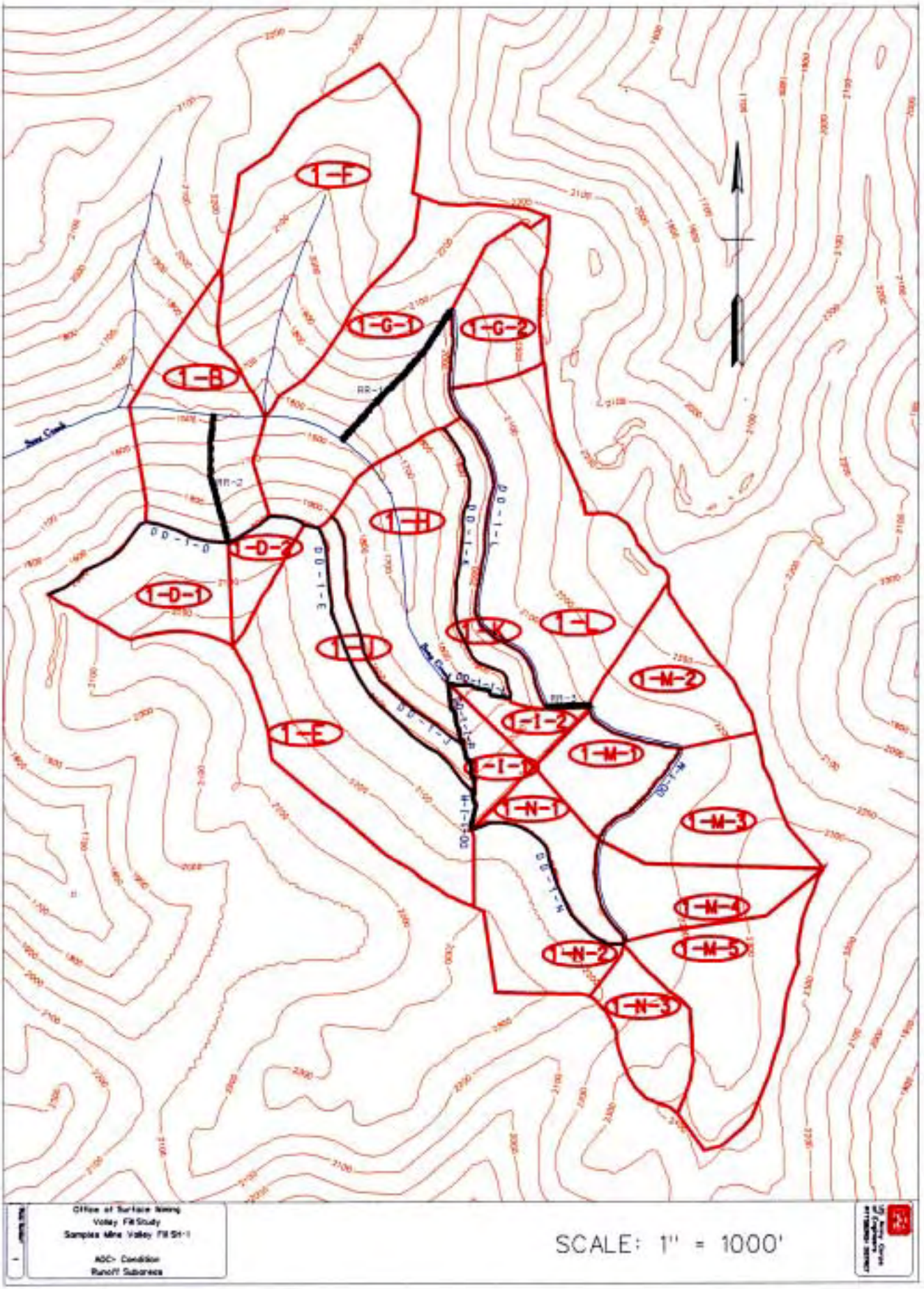
The drainage area was divided into twenty one runoff subareas to define the AOC+ mining condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the AOC+ mining condition land use is reclaimed valley fill and backstack areas for 74% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the AOC+ mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
1-B	Most downstream area	28.61	0.04	6.2
1-F	Right bank tributary	53.48	0.08	11.6
1-G-1	Subarea below valley fill	46.30	0.07	10.0
1-H	Subarea below valley fill	35.91	0.06	7.8
1-I-1	Left face of valley fill	5.62	0.01	1.2
1-I-2	Right face of valley fill	5.27	0.01	1.1
1-J	Left diversion area	7.26	0.01	1.6
1-K	Right diversion area	9.44	0.01	2.0
1-N-1	Left top of valley fill	9.86	0.02	2.1
1-N-2	Middle diversion area	19.63	0.03	4.3
1—N-3	Upstream diversion area	11.81	0.02	2.6
1-D-1	Downstream left diversion area	17.58	0.03	3.8
1-D-2	Middle left diversion area	5.89	0.01	1.3
1-E	Upstream left diversion area	46.31	0.07	10.0
1-G-2	Downstream right diversion area	14.94	0.02	3.2
1-L	Middle right diversion area	46.80	0.07	10.2
1-M-1	Right top of valley fill	11.33	0.02	2.5
1-M-2	Middle right diversion area	18.46	0.03	2.3
1-M-3	Middle right diversion area	21.92	0.03	4.8
1-M-4	Middle right diversion area	15.37	0.02	3.3
1-M-5	Upstream right diversion area	29.14	0.05	6.3
Total		460.93	0.72	100

This area represents a 5% increase from pre to AOC+ mining conditions.

Plate 1 shows the runoff subareas.


1-F
1-G-1
1-G-2
1-B
1-H
1-D-2
1-D-1
1-K
1-L
1-M-2
1-I-2
1-M-1
1-N-1
1-M-3
1-M-4
1-N-2
1-M-5
1-N-3
Sam Creek
Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill St-1
ASC- Condition
Runoff Subareas
SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be reclaimed surface mine (RSM) areas.

The following table shows the soil types and their percent distribution within the runoff subareas for the AOC+ mining condition:

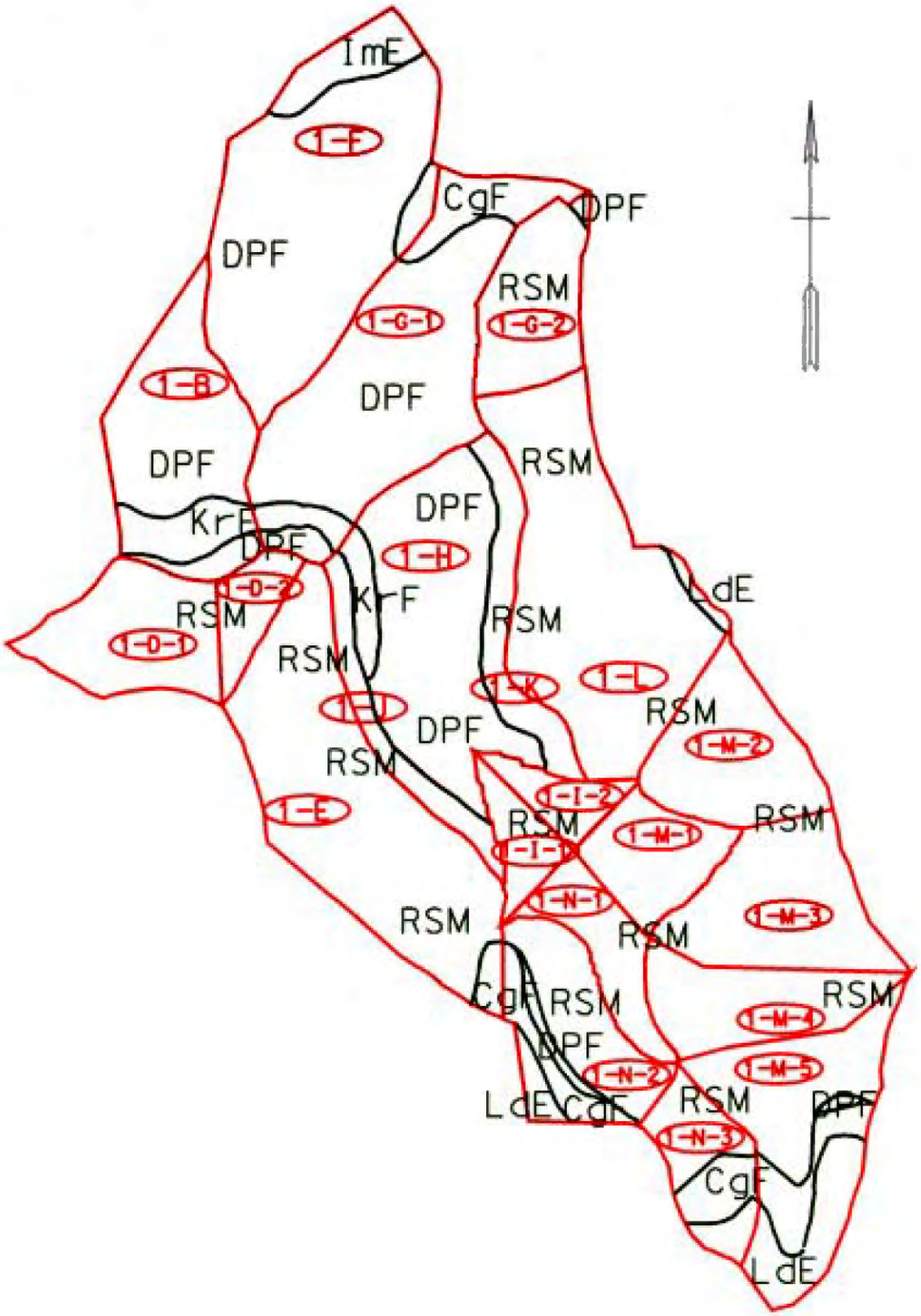
Runoff Subarea	Soil Type					
	CgF	DPF	ImE	LdE	KrF	RSM
	Percent Distribution					
1-B		81.0			19.0	
1-F	3.3	85.8	10.9			
1-G-1	12.9	82.3			4.8	
1-H		91.6			8.4	
1-I-1						100
1-I-2						100
1-J						100
1-K						100
1-N-1						100
1-N-2	20.9	7.0		9.5		62.6
1-N-3	31.5			17.2		51.3
1-D-1						100
1-D-2						100
1-E	3.3					96.7
1-G-2		2.6				97.4
1-L				2.1		97.9
1-M-1						100
1-M-2						100
1-M-3						100
1-M-4						100
1-M-5	16.8	1.3		27.5		54.4
Total	4.2	16.7	0.5	2.7	1.5	74.4

Plate 2 shows the soil type subareas.

This table shows that reclaimed surface mine areas make up the majority (74%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the AOC+ mining condition:



Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill 94-1

ASC- Condition
Soil Type Substrate

SCALE: 1" = 1000'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
1-B	68	2.9	0.94
1-F	67	0.5	0.99
1-G-1	67	2.7	0.99
1-H	67	1.3	0.99
1-I-1	75		0.67
1-I-2	75		0.67
1-J	75		0.67
1-K	75		0.67
1-N-1	75		0.67
1-N-2	73	3.1	0.74
1-N-3	73	4.7	0.74
1-D-1	75		0.67
1-D-2	75		0.67
1-E	75	0.5	0.67
1-G-2	75		0.67
1-L	75		0.67
1-M-1	75		0.67
1-M-2	75		0.67
1-M-3	75		0.67
1-M-4	75		0.67
1-M-5	72	2.5	0.78

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the AOC+ mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
1-B	19	11	18	11
1-F	35	21	33	20
1-G-1	16	10	16	9
1-H	11	7	9	5
1-I-1	7	4	7	4
1-I-2	7	4	7	4
1-J	24	15	22	13
1-K	27	16	24	14
1-N-1	23	14	22	13
1-N-2	19	11	17	10
1-N-3	13	8	13	8
1-D-1	27	16	25	15
1-D-2	12	7	11	7
1-E	24	14	22	13
1-G-2	11	7	11	7
1-L	26	16	23	14
1-M-1	29	17	26	16
1-M-2	14	8	13	8
1-M-3	34	20	33	20
1-M-4	34	20	32	19
1-M-5	27	16	27	16

Base Flow

The AOC+ mining condition base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
1-B	0.04	0.09
1-F	0.08	0.17
1-G-1	0.07	0.14
1-H	0.06	0.11
1-I-1	0.01	0.02
1-I-2	0.01	0.02
1-J	0.01	0.02
1-K	0.01	0.03
1-N-1	0.02	0.03
1-N-2	0.03	0.06
1-N-3	0.02	0.04
1-D-1	0.03	0.05
1-D-2	0.01	0.02
1-E	0.07	0.14
1-G-2	0.02	0.05
1-L	0.07	0.15
1-M-1	0.02	0.04
1-M-2	0.03	0.06
1-M-3	0.03	0.07
1-M-4	0.02	0.05
1-M-5	0.05	0.09

Routing Reaches

The valley fill drainage area was divided into twenty one runoff subareas to model the AOC+ mining condition. Nineteen reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes, natural drains and channels down the sides of the valley fill); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (0.5%) sediment and diversion ditches and the undisturbed portion of the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #1 drainage area at the downstream permit limit.

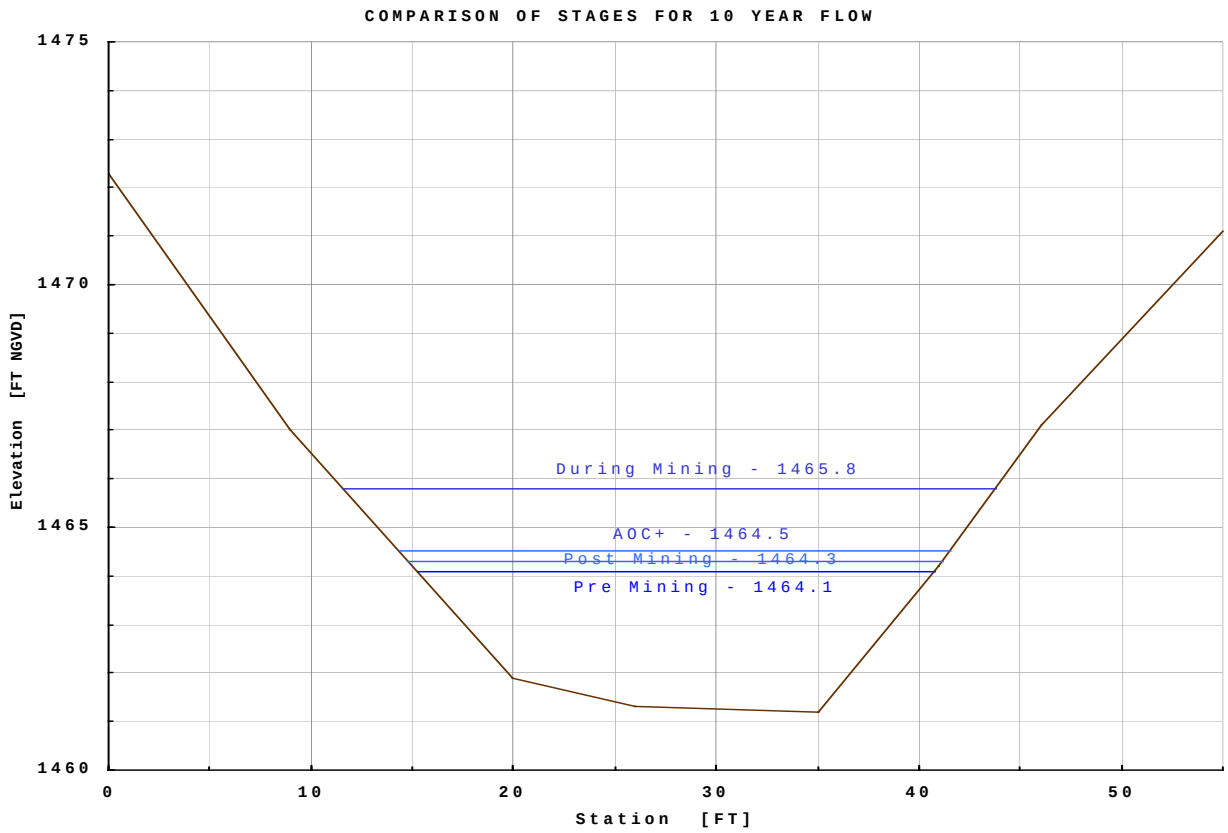
The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

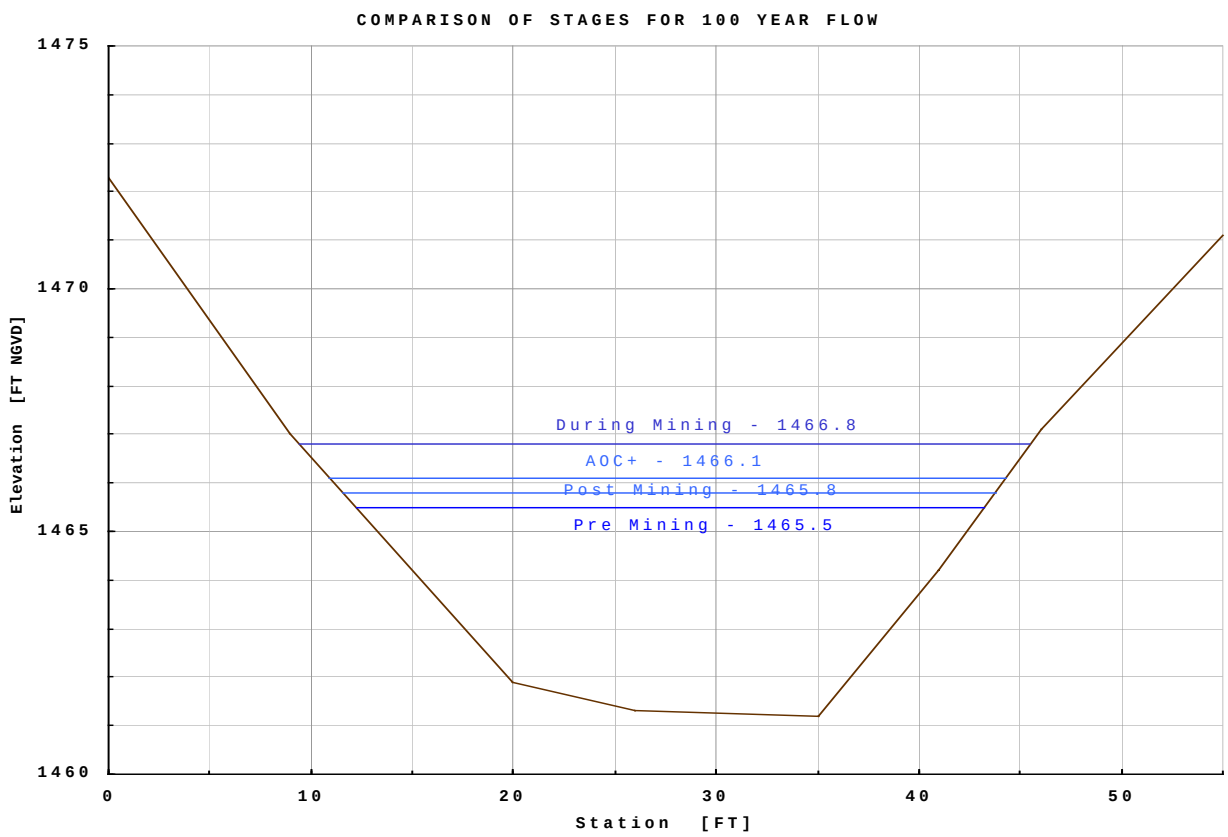
The following table shows the 10 and 100 year flows and water surface elevations:

Frequency [YR]	Pre Mining		During Mining		Post Mining		AOC+	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	330	1464.1	525	1465.8	376	1464.3	432	1464.5
100	742	1465.5	931	1466.8	832	1465.8	932	1466.1

These results show a 25-59% (10-100 YR) increase in discharge from premining conditions as the area is disturbed during mining operations; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 31-26% (10-100 YR) increase in discharge and a 0.4-0.6’ increase in stage from premining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1465.8
AOC+ - 1464.5
Post Mining - 1464.3
Pre Mining - 1464.1
0
10
20
30
40
50
Station [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1466.8
AOC+ - 1466.1
Post Mining - 1465.8
Pre Mining - 1465.5
0
10
20
30
40
50
Station [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows that an ongoing valley fill operation will increase the discharge from 25-59% (10-100 YR) from premining conditions; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 31-26% (10-100 YR) increase in discharge and a 0.4-0.6’ increase in stage from premining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the drainage area to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #1
FUTURE FORESTED CONDITIONS

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

FEBRUARY 2001

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #1
FUTURE FORESTED CONDITIONS

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, during mining, post mining, AOC+ (Approximate Original Contour Plus) and future forested conditions.

This report covers the results from the future forested conditions only. The results of the study for premining, during mining, post mining and AOC+ have been previously reported. They will be included in this report by reference and by inclusion in the “HYDROLOGIC AND HYDRAULIC MODEL RESULTS” section.

The Samples Mine Valley Fill SH-1, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Karen Taylor, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to future forested conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version 2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

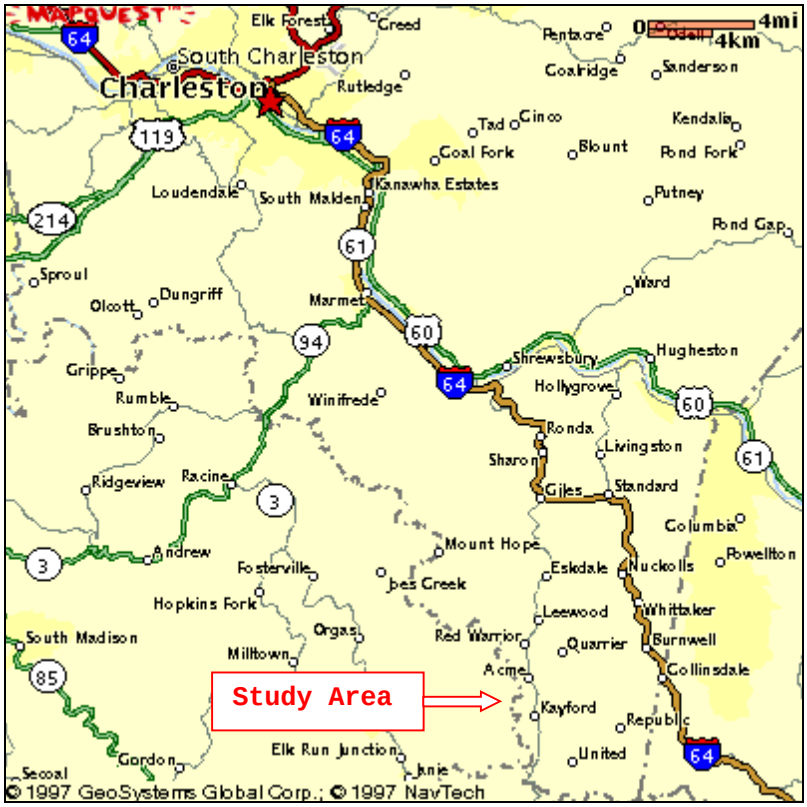
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #1 was the first site studied. The other three were the Samples Mine Valley Fill #2, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-1 is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. The valley fill drainage area occupies the most upstream 0.7 square miles (13%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, during mining, post mining, AOC+ and future forested conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Itmann channery loam (ImE), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining, AOC+, and future forested conditions or the aerial photographs for the during mining condition; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company's 1:6,000 scale maps that had a contour interval of 20'. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

FUTURE FORESTED CONDITIONS

Drainage Areas

The future forested drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The future forested drainage area encompasses 0.74 square miles.

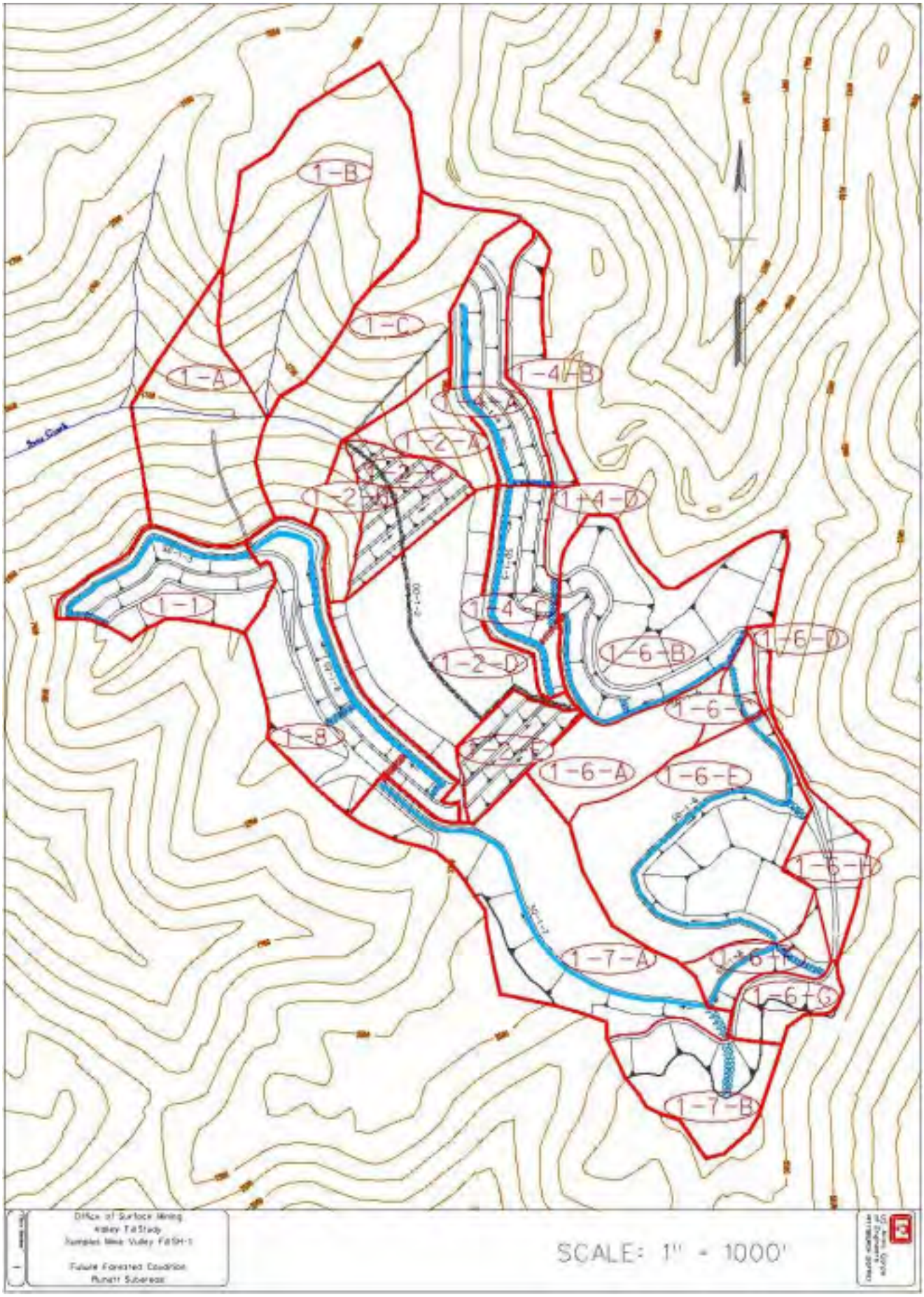
The drainage area was divided into fifteen runoff subareas to define the future forested condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the future land use is forested valley fill and backstack areas for 72% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the future forested condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
1-A	Most downstream area	29.78	0.05	6.3
1-B	Right bank tributary	53.48	0.08	11.2
1-C	Subarea below valley fill	36.06	0.06	7.6
1-2-A	Right abutment of lower valley fill	7.21	0.01	1.5
1-2-B	Left abutment of lower valley fill	6.34	0.02	1.3
1-2-C	Face of lower valley fill	12.00	0.02	2.5
1-2-D	Top of lower valley fill	37.23	0.06	7.9
1-2-E	Face of upper valley fill	9.55	0.01	2.0
1-1	Downstream left diversion area	18.37	0.03	3.9
1-8	Middle left diversion area	32.37	0.05	6.8
1-7-AB	Upstream left diversion area	61.39	0.10	12.9
1-4-AB	Downstream right diversion area	25.36	0.04	5.4
1-4-CD	Middle right diversion area	16.89	0.03	3.5
1-6-AD	Middle right diversion area	57.05	0.09	12.0
1-6-EH	Upstream right diversion area	71.49	0.10	15.2
Total		474.57	0.74	100

This area represents an 8% increase from pre to future forested conditions and mainly reflects differences in the regraded topography on the southwest side of the drainage area.

Plate 1 shows the runoff subareas.


1-B
1-C
1-A
1-4-B
1-4-A
1-2-A
1-2-C
1-2-B
1-4-D
1-1
1-4-C
1-6-B
1-6-D
1-2-D
1-6-C
1-8
1-2-E
1-6-A
1-6-E
1-6-H
1-7-A
1-6-F
1-6-G
1-7-B
Office of Surface Mining
Valley Fill Study
Sunnyside Mine Valley Fill SH-1
Future Forested Condition
Runoff Subareas
SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be future forested (FF) areas. The future forested conditions represent a 20 year forestry plan which covers the reclaimed surface mine areas with appropriate trees.

The following table shows the soil types and their percent distribution within the runoff subareas for the future forested condition:

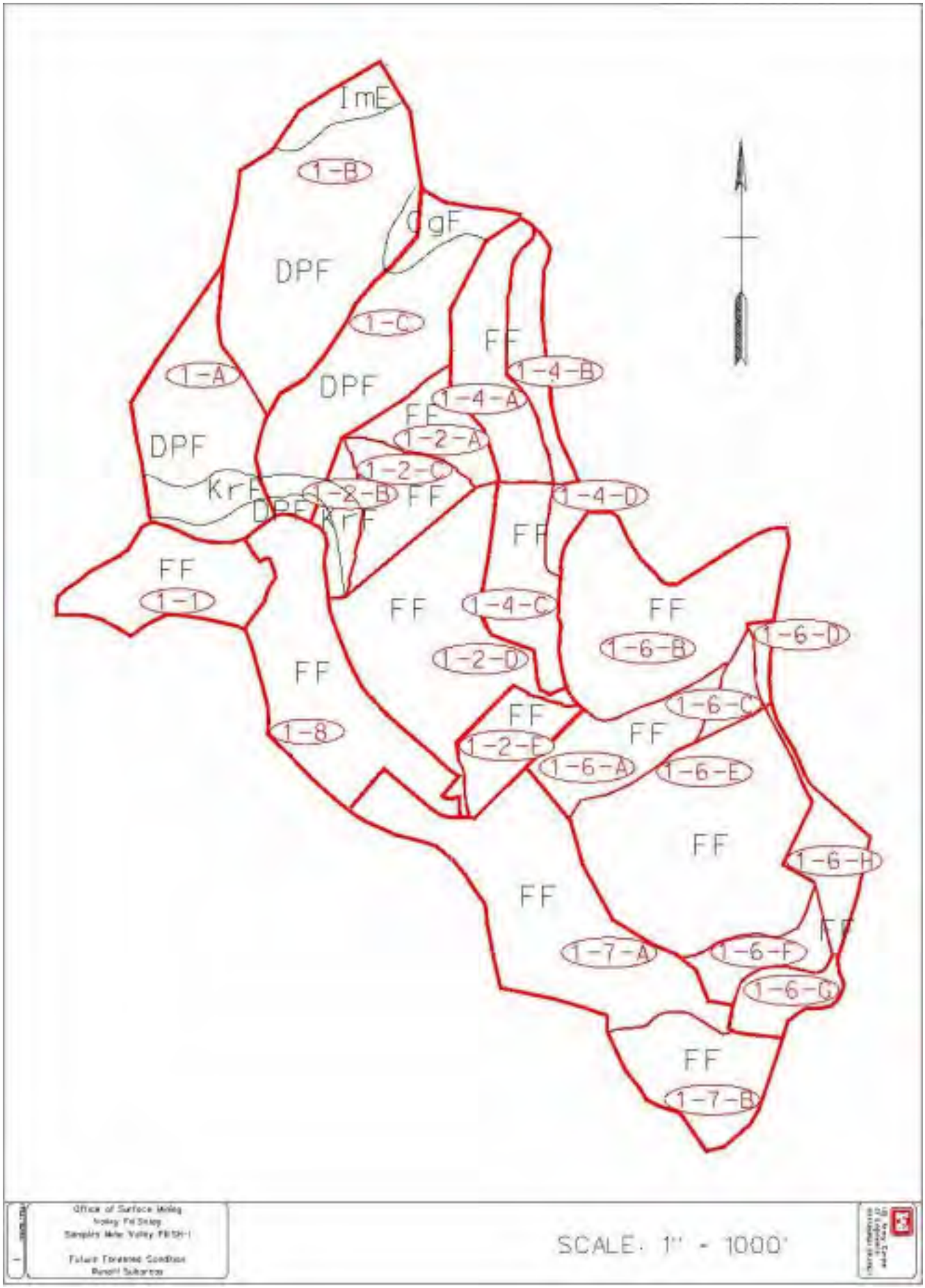
Runoff Subarea	Soil Type				
	CgF	DPF	ImE	KrF	FF
	Percent Distribution				
1-A		77.8		22.5	
1-B	1.9	88.9	9.2		
1-C	13.0	82.0		5.0	
1-2-A		100			
1-2-B		66.4		33.6	
1-2-C					100
1-2-D					100
1-2-E					100
1-1					100
1-8					100
1-7-AB					100
1-4-AB					100
1-4-CD					100
1-6-AD					100
1-6-EH					100
Total	1.2	23.5	1.0	2.2	72.1

Plate 2 shows the soil type subareas.

This table shows that future forested areas make up the majority (72%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the future forested condition:


ImE
1-B
CgF
DPF
1-C
FF
1-4-B
1-A
DPF
1-4-A
FF
1-2-A
DPF
1-2-C
KrF
1-2-B
FF
1-4-D
DPF
KrF
FF
FF
1-1
FF
1-4-C
FF
1-6-B
1-6-D
1-2-D
FF
1-6-C
FF
1-8
FF
1-2-E
1-6-A
1-6-E
FF
1-6-H
FF
FF
1-7-A
1-6-F
1-6-G
FF
1-7-B
SCALE: 1" = 1000'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
1-A	67	3.3	0.99
1-B	67	0.3	0.99
1-C	67	2.7	0.99
1-2-A	64		1.13
1-2-B	66	5.1	1.03
1-2-C	71		0.82
1-2-D	71		0.82
1-2-E	71		0.82
1-1	71		0.82
1-8	71		0.82
1-7AB	71		0.82
1-4-AB	71		0.82
1-4-CD	71		0.82
1-6-AD	71		0.82
1-6-EH	71		0.82

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the future forested condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
1-A	18	11	18	11
1-B	35	21	33	20
1-C	25	15	25	15
1-2-A	15	9	15	9
1-2-B	14	8	14	8
1-2-C	14	8	12	7
1-2-D	41	25	39	23
1-2-E	24	14	22	13
1-1	38	23	35	21
1-8	33	20	30	18
1-7-AB	84	50	77	46
1-4-AB	17	10	15	9
1-4-CD	27	16	26	16
1-6-AD	69	41	66	40
1-6-EH	67	40	58	35

Base Flow

The future forested condition base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
1-A	0.05	0.09
1-B	0.08	0.17
1-C	0.06	0.11
1-2-A	0.01	0.02
1-2-B	0.01	0.02
1-2-C	0.02	0.04
1-2-D	0.06	0.12
1-2-E	0.01	0.03
1-1	0.03	0.06
1-8	0.05	0.10
1-7-AB	0.10	0.19
1-4-AB	0.04	0.08
1-4-CD	0.03	0.05
1-6-AD	0.09	0.18
1-6-EH	0.10	0.22

Routing Reaches

The valley fill drainage area was divided into fifteen runoff subareas to model the future forested condition. Fifteen reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes, natural drains and channels down the sides of the valley fill); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (2%) sediment and diversion ditches and the undisturbed portion of the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #1 drainage area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

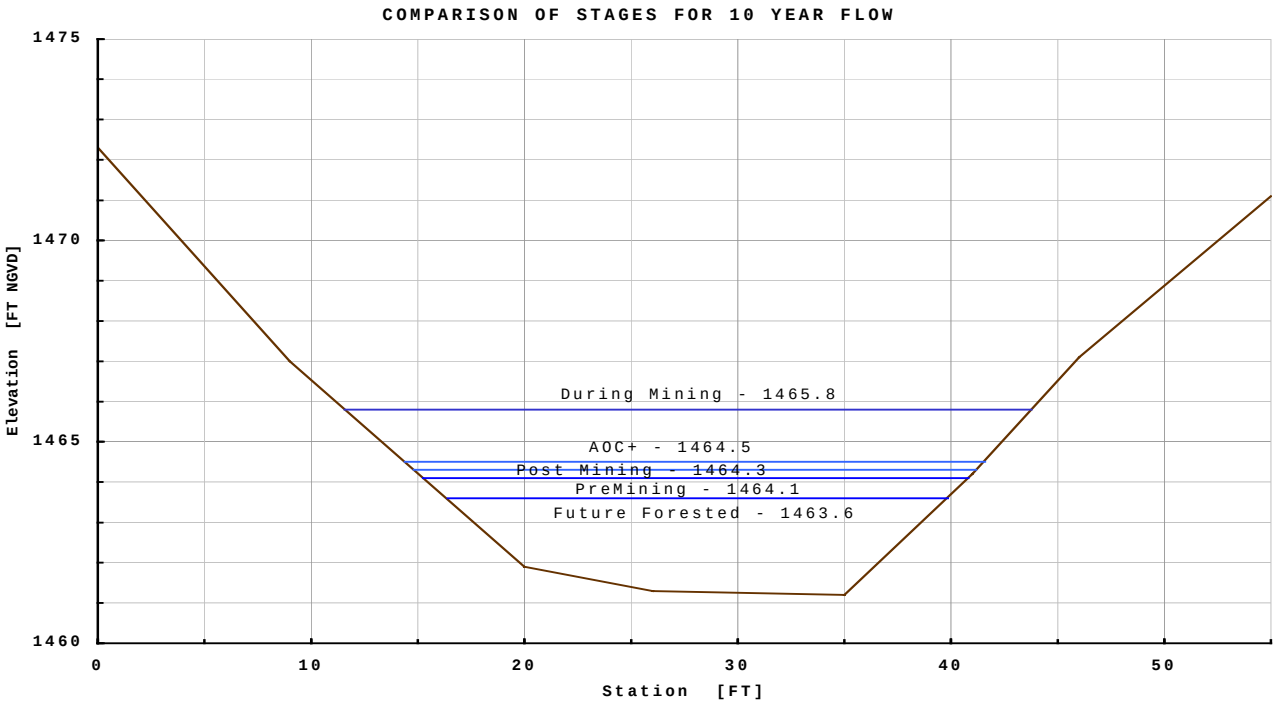
The following tables show the 10 and 100 year flows and water surface elevations:

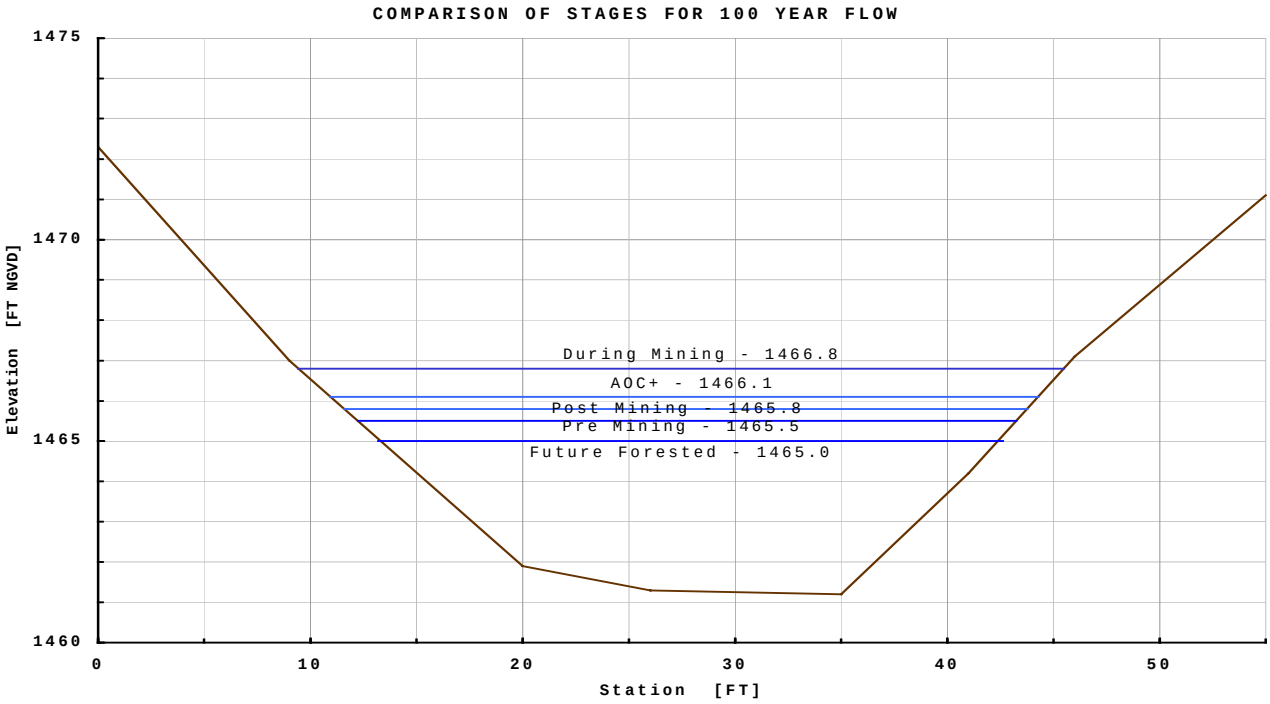
Frequency [YR]	Pre Mining		During Mining		Post Mining	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	330	1464.1	525	1465.8	376	1464.3
100	742	1465.5	931	1466.8	832	1465.8

Frequency [YR]	AOC+		Future Forested	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	432	1464.5	246	1463.6
100	932	1466.1	580	1465.0

These results show a 25-59% (10-100 YR) increase in discharge from premining conditions as the area is disturbed during mining operations; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions. The AOC+ conditions would cause a 31-26% (10-100 YR) increase in discharge and a 0.4-0.6’ increase in stage from premining conditions. The future forested conditions would cause a 25-22% (10-100 YR) decrease in discharge and a 0.5’ decrease in stage from the premining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1465.8
AOC+ - 1464.5
Post Mining - 1464.3
PreMining - 1464.1
Future Forested - 1463.6
0
10
20
30
40
50
Station [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1466.8
AOC+ - 1466.1
Post Mining - 1465.8
Pre Mining - 1465.5
Future Forested - 1465.0
0
10
20
30
40
50
Station [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows that an ongoing valley fill operation will increase the discharge from 25-59% (10-100 YR) from premining conditions; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions. The AOC+ conditions would cause a 31-26% (10-100 YR) increase in discharge and a 0.4-0.6’ increase in stage from premining conditions. The future forested conditions would cause a 25-22% (10-100 YR) decrease in discharge and a 0.5’ decrease in stage from the premining conditions.

RECOMMENDATIONS

1. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #1

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

JANUARY 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #1

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, during mining and post mining conditions.

The Samples Mine Valley Fill SH-1, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Walt Leput, Mark Zaitsoff, Ray Rush, Karen Taylor, Paul Donahue), the Hydrologic Engineering Center (HEC) (Harry Dotson) and the Waterways Experiment Station (WES) (Bill Johnson), and Office of Surface Mining (OSM) personnel (Don Stump, Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to post mining conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

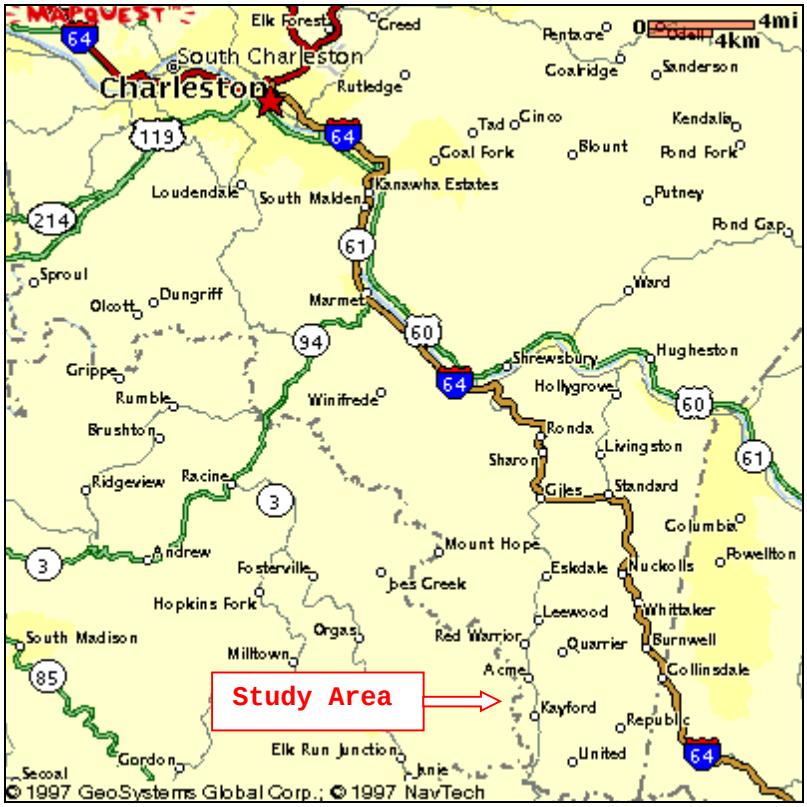
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #1 was the first site studied. The other three were the Samples Mine Valley Fill #2, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-1 is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. The valley fill drainage area occupies the most upstream 0.7 square miles (13%) of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, during mining and post mining conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Itmann channery loam (ImE), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining and postmining conditions or the aerial photographs for the during mining condition; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a)

is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company’s 1:6,000 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

PREMINING CONDITIONS

Drainage Areas`

The premining drainage area was delineated on USGS 1:24,000 scale topographic maps (Dorothy and Eskdale quadrangles) and on a 1:6,000 scale regraded drainage map provided by the coal company. The premining drainage area encompasses 0.68 square miles.

The drainage area was divided into six runoff subareas to define the premining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the premining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
A	Most downstream area	37.28	0.06	8.5
B	Right bank tributary	52.94	0.08	12.0
C	Subarea below proposed valley fill	46.23	0.07	10.5
D	Main channel	155.62	0.24	32.5
E	Right tributary	71.88	0.11	16.3
F	Left tributary	77.13	0.12	17.5
Total		441.08	0.68	100

Plate 1 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

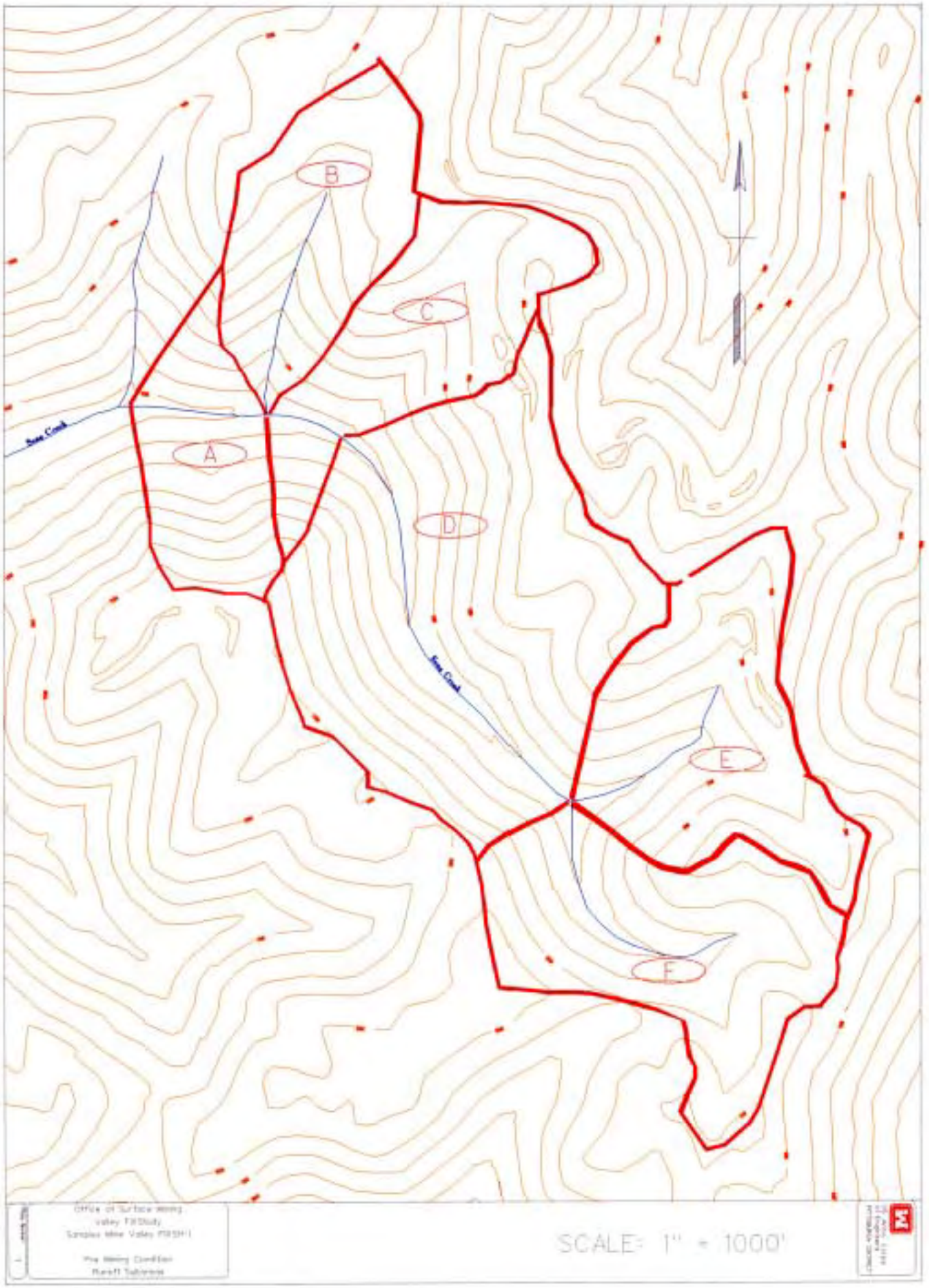
The following table shows the soil types and their percent distribution within the runoff subareas for the premining condition:

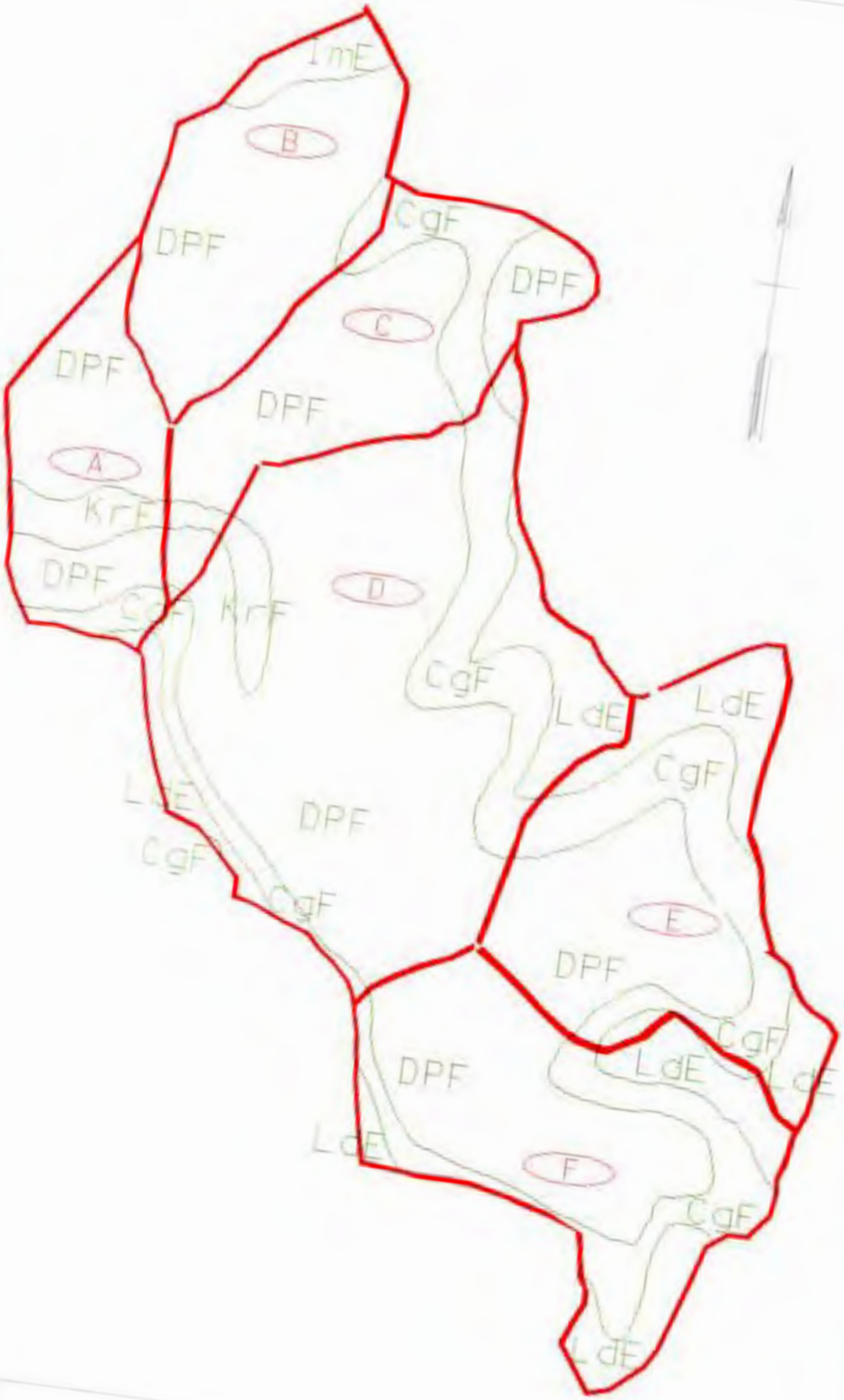
Runoff Subarea	Soil Type				
	CgF	DPF	ImE	KrF	LdE
	Percent Distribution				
A	8.7	73.6		16.5	1.2
B	2.1	87.2	10.7		
C	18.1	77.9		4.0	
D	18.5	66.3		2.6	12.6
E	29.9	46.1			24.0
F	30.1	50.3			19.6
Total	17.9	66.8	1.8	3.9	9.6

Plate 2 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (67%) of the drainage area.

The premining land use for the Seng Creek watershed is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.


A
B
C
D
E
F
Sugar Creek
Sugar Creek
SCALE: 1" = 1000'


ImE
B
DPF
CgF
DPF
C
DPF
DPF
A
KrF
DPF
CgF
KrF
D
CgF
LdE
LdE
CgF
LdE
DPF
CgF
CgF
E
DPF
CgF
LdE
LdE
DPF
LdE
F
CgF
LdE

The following table shows the results of the weighted curve number calculations for the premining condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
A	68	3.8	0.94
B	67	0.3	0.99
C	68	3.3	0.94
D	68	3.2	0.94
E	68	4.5	0.94
F	68	4.5	0.94

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the premining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
A	20	12	20	12
B	32	19	30	18
C	19	12	19	11
D	36	21	34	20
E	39	23	37	22
F	39	23	37	22

Base Flow

The premining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
A	0.06	0.12
B	0.08	0.17
C	0.07	0.14
D	0.24	0.49
E	0.11	0.22
F	0.12	0.24

Routing Reaches

The drainage area was divided into six runoff subareas to model the premining condition. Four reaches connected the runoff subareas and route the flows through the drainage area.

The Muskingum-Cunge method of hydrologic routing was used to route the runoff flows through the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

DURING MINING CONDITIONS

Drainage Areas

The during mining drainage area was delineated on 1:200 and 1:600 scale aerial photographs and 1:6,000 scale regraded drainage map provided by the coal company. The during mining drainage area encompasses 0.64 square miles.

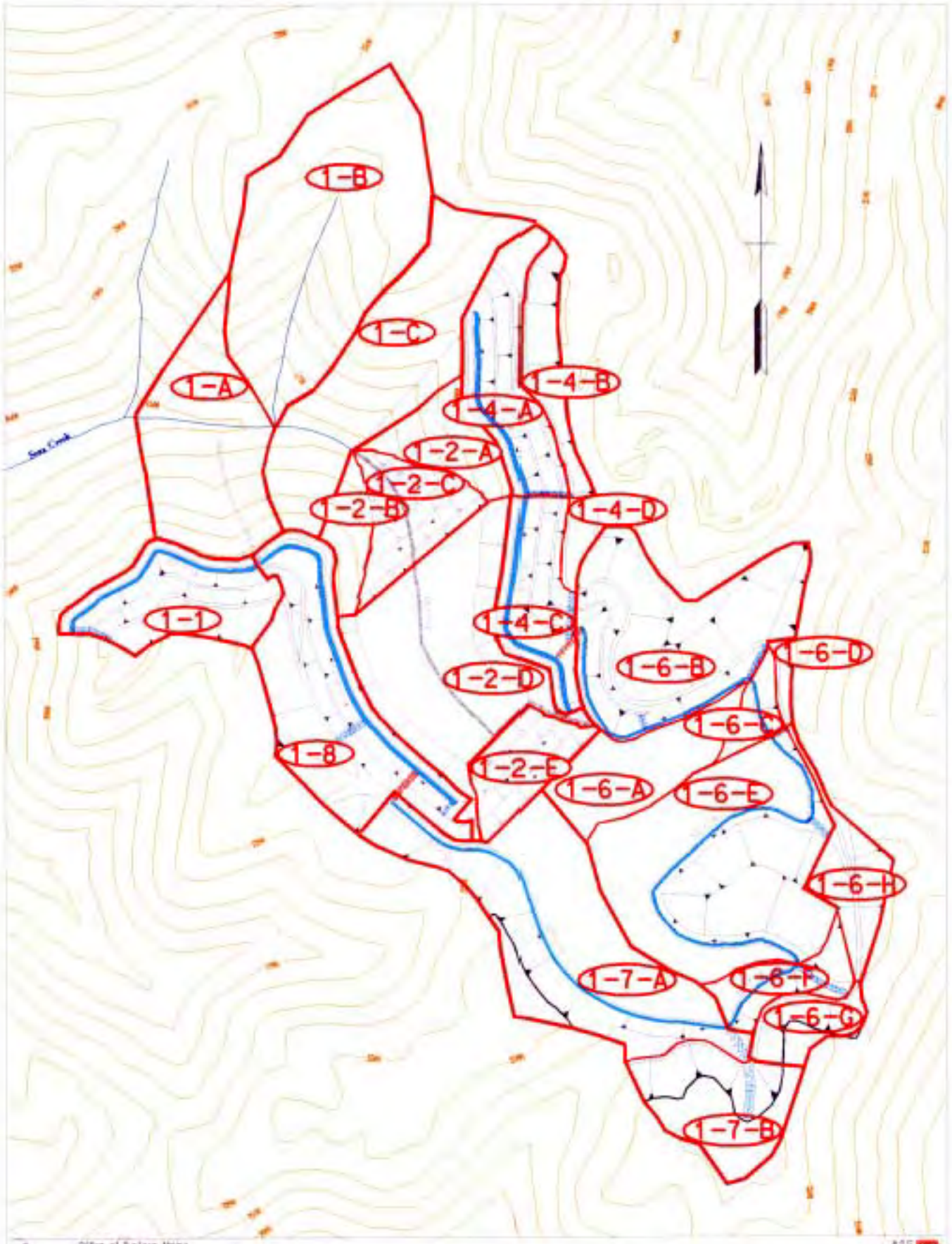
The drainage area was divided into ten runoff subareas to define the during mining condition. These subareas were selected to define tributary areas created by the ongoing valley fill operation and the hydrologic routing reaches connecting them. The downstream end is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision.

The ongoing valley fill operation has created a very compartmented drainage area with a confused runoff system. There are no established drainage channels within the valley fill area. The aerial photographs and field reconnaissance were used to divide the drainage area into four tributary areas with ten runoff subareas. Two of the subareas on the valley fill contained significant depressions, were judged to not contribute to surface runoff flows leaving the valley fill area, and were treated as sinks. The four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) the right noncontributing area, and 4) the left noncontributing area. The following table shows the runoff subareas for the during mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
A	Most downstream area	37.11	0.06	9.0
B	Right bank tributary	18.37	0.03	4.5
C	Subarea below valley fill	33.78	0.05	8.2
D-1-A	Face of valley fill	13.63	0.02	3.3
D-1-B	Right down valley area	24.58	0.04	6.0
D-1-C	Right up valley area	69.26	0.11	16.8
D-1-D	Left down valley area	85.45	0.13	20.7
D-1-E	Left up valley area	58.30	0.09	14.2
D-2	Right noncontributing area	61.12	0.10	14.9
D-3	Left noncontributing area	9.86	0.02	2.4
Total		411.46	0.64	100

This area represents a 7% decrease from premining to during mining conditions and mainly reflects differences in the disturbed topography on the eastern side of the drainage area.

Plate 3 shows the runoff subareas.



Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill SH-1

Post Mining Condition
Runoff Subareas

SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The aerial photographs show the area that is being covered by the ongoing valley fill operation. This area was considered to be disturbed surface mine area with raw (RS) and graded (GS) spoils.

The following table shows the soil types and their percent distribution within the runoff subareas for the during mining condition:

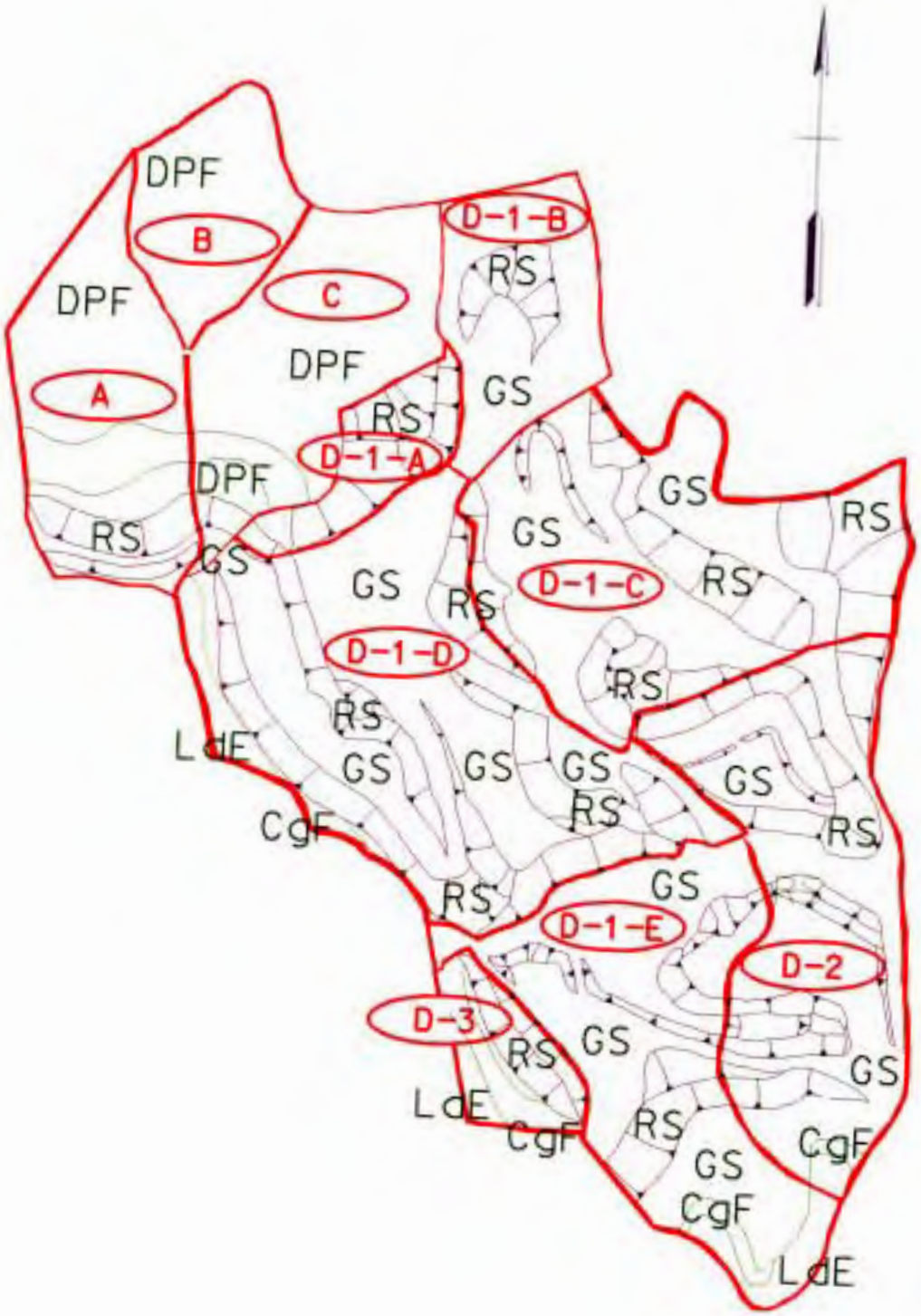
Runoff Subarea	Soil Type						
	CgF	DPF	KrF	LdE	MnF	RS	GS
	Percent Distribution						
A		62.6	17.4	0.7		16.2	3.1
B		100					
C		84.7	11.5			2.7	1.1
D-1-A						100	
D-1-B						19.5	80.5
D-1-C						50.5	49.5
D-1-D	0.8			6.0		38.1	55.1
D-1-E	3.4			7.0	3.6	24.1	61.9
D-2	1.8			2.5		68.1	27.6
D-3	20.8			20.8		58.4	
Total	1.4	17.1	2.5	3.2	0.5	37.5	37.8

Plate 4 shows the soil type subareas.

This table shows that the disturbed surface mine areas in the ongoing valley fill operation makes up the majority (75%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the during mining condition:



Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill Study

During Mining Condition
Soil Type Subareas

SCALE: 1" = 1000'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
A	71	2.6	0.82
B	66		1.03
C	67	1.0	0.99
D-1-A	88		0.27
D-1-B	85		0.35
D-1-C	86		0.33
D-1-D	84	0.2	0.38
D-1-E	83	0.2	0.41
D-2	86	0.3	0.33
D-3	81	3.1	0.47

Time of Concentration and Lag

The aerial photographs were used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered the ongoing valley fill operation. No open channels were formed in the ongoing valley fill operation and there were no open channel portions of the time of concentration computed.

The following table shows the results of the time of concentration and lag calculations for the during mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
A	21	13	19	12
B	21	13	19	12
C	29	17	26	15
D-1-A	1	1	1	1
D-1-B	9	5	9	5
D-1-C	15	9	15	9
D-1-D	15	9	15	9
D-1-E	34	21	34	21
D-2	30	18	30	18
D-3	19	11	19	11

Base Flow

The during mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
A	0.06	0.12
B	0.03	0.06
C	0.05	0.11
D-1-A	0.02	0.04
D-1-B	0.04	0.08
D-1-C	0.11	0.22
D-1-D	0.13	0.27
D-1-E	0.09	0.18
D-2	0.10	0.19
D-3	0.02	0.03

Routing Reaches

The valley fill drainage area was divided into ten runoff subareas to model the during mining condition. Eight reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for the subareas within the ongoing valley fill operation; the amount of lag was computed from the shallow concentrated flow component of the travel time computations. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the undisturbed portion of the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

The flow hydrographs were also routed through the two sediment ponds located downstream of the ongoing valley fill operation. These ponds do not have low flow outlets and all flow passes over their spillways. Therefore, their pools are at the spillway elevation and little or no storage is available. The storage, elevation and outflow relationships were determined and input to the HEC-HMS hydrology models; the results confirmed that the sediment ponds do not cause any attenuation of the flow hydrographs.

POST MINING CONDITIONS

Drainage Areas

The post mining drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The post mining drainage area encompasses 0.74 square miles.

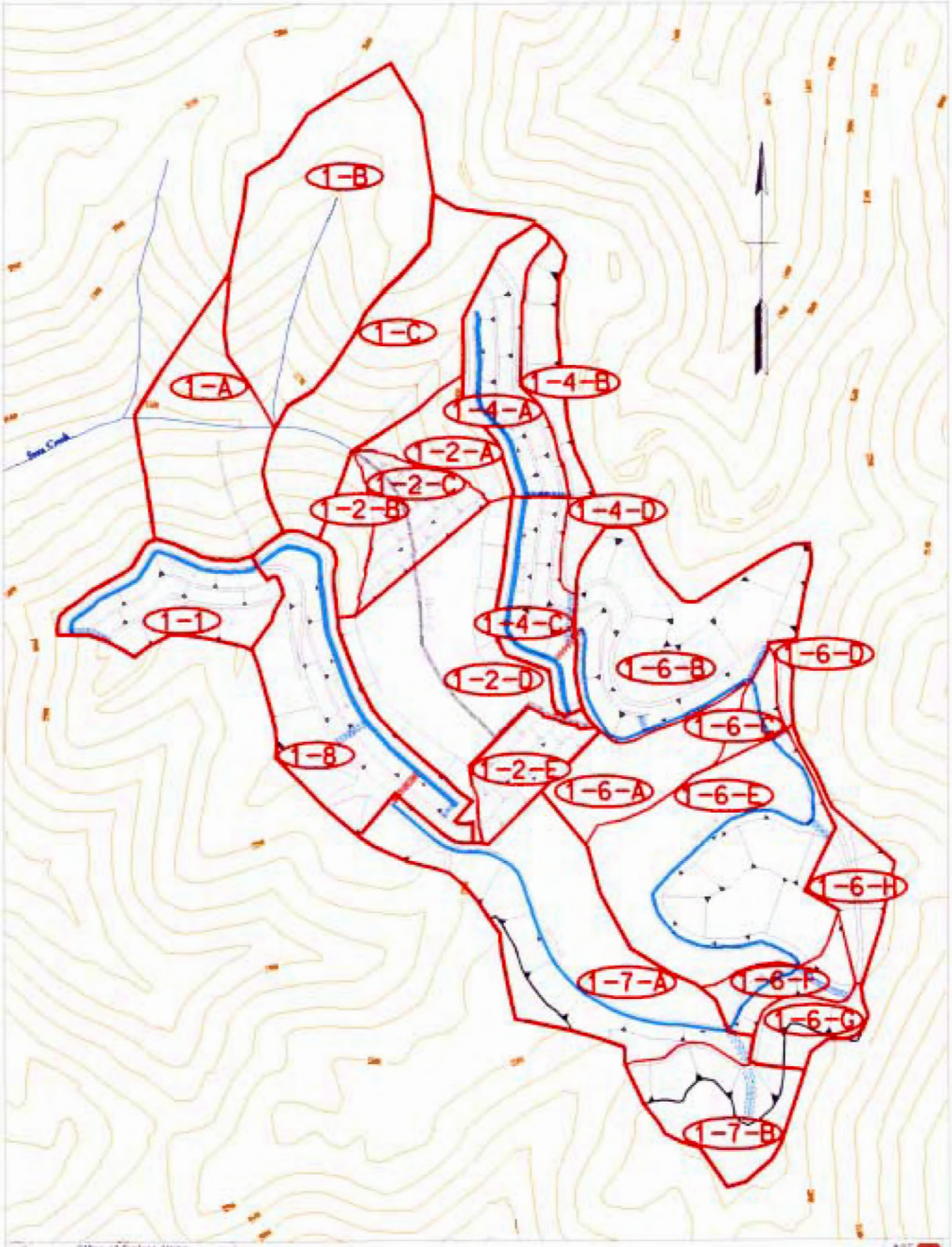
The drainage area was divided into fifteen runoff subareas to define the post mining condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the post mining land use is reclaimed valley fill and backstack areas for 72% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the post mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
1-A	Most downstream area	29.78	0.05	6.3
1-B	Right bank tributary	53.48	0.08	11.2
1-C	Subarea below valley fill	36.06	0.06	7.6
1-2-A	Right abutment of lower valley fill	7.21	0.01	1.5
1-2-B	Left abutment of lower valley fill	6.34	0.02	1.3
1-2-C	Face of lower valley fill	12.00	0.02	2.5
1-2-D	Top of lower valley fill	37.23	0.06	7.9
1-2-E	Face of upper valley fill	9.55	0.01	2.0
1-1	Downstream left diversion area	18.37	0.03	3.9
1-8	Middle left diversion area	32.37	0.05	6.8
1-7-AB	Upstream left diversion area	61.39	0.10	12.9
1-4-AB	Downstream right diversion area	25.36	0.04	5.4
1-4-CD	Middle right diversion area	16.89	0.03	3.5
1-6-AD	Middle right diversion area	57.05	0.09	12.0
1-6-EH	Upstream right diversion area	71.49	0.10	15.2
Total		474.57	0.74	100

This area represents an 8% increase from pre to post mining conditions and mainly reflects differences in the regraded topography on the southwest side of the drainage area.

Plate 5 shows the runoff subareas.



Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill SH-1

Post Mining Condition
Runoff Subwatersheds

SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be reclaimed surface mine (RSM) areas.

The following table shows the soil types and their percent distribution within the runoff subareas for the post mining condition:

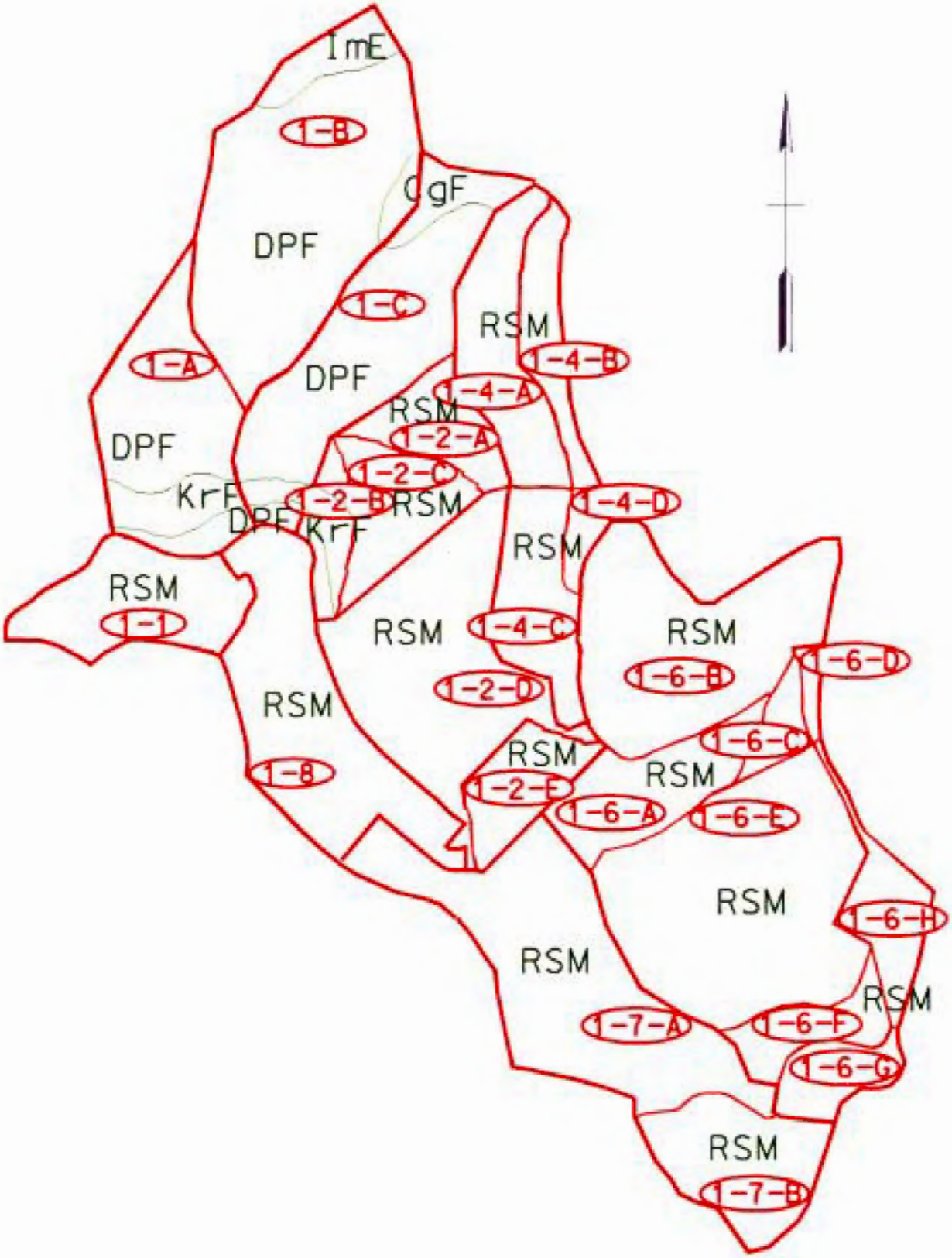
Runoff Subarea	Soil Type				
	CgF	DPF	ImE	KrF	RSM
	Percent Distribution				
1-A		77.8		22.5	
1-B	1.9	88.9	9.2		
1-C	13.0	82.0		5.0	
1-2-A		100			
1-2-B		66.4		33.6	
1-2-C					100
1-2-D					100
1-2-E					100
1-1					100
1-8					100
1-7-AB					100
1-4-AB					100
1-4-CD					100
1-6-AD					100
1-6-EH					100
Total	1.2	23.5	1.0	2.2	72.1

Plate 6 shows the soil type subareas.

This table shows that reclaimed surface mine areas make up the majority (72%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the post mining condition:



Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill Site

Final Mining Condition
Soil Type Subareas

SCALE: 1" = 1000'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
1-A	67	3.3	0.99
1-B	67	0.2	0.99
1-C	67	2.8	0.99
1-2-A	64	5.1	1.13
1-2-B	65		1.03
1-2-C	75		0.67
1-2-D	75		0.67
1-2-E	75		0.67
1-1	75		0.67
1-8	75		0.67
1-7AB	75		0.67
1-4-AB	75		0.67
1-4-CD	75		0.67
1-6-AD	75		0.67
1-6-EH	75		0.67

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The rnoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the post mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
1-A	18	11	18	11
1-B	36	21	33	20
1-C	25	15	25	15
1-2-A	15	9	15	9
1-2-B	14	8	14	8
1-2-C	11	6	9	6
1-2-D	22	13	20	12
1-2-E	20	12	16	9
1-1	25	15	23	14
1-8	19	11	17	10
1-7-AB	52	31	43	26
1-4-AB	10	6	8	5
1-4-CD	14	9	13	8
1-6-AD	34	20	32	19
1-6-EH	50	30	43	26

Base Flow

The post mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
1-A	0.05	0.09
1-B	0.08	0.17
1-C	0.06	0.11
1-2-A	0.01	0.02
1-2-B	0.01	0.02
1-2-C	0.02	0.04
1-2-D	0.06	0.12
1-2-E	0.01	0.03
1-1	0.03	0.06
1-8	0.05	0.10
1-7-AB	0.10	0.19
1-4-AB	0.04	0.08
1-4-CD	0.03	0.05
1-6-AD	0.09	0.18
1-6-EH	0.10	0.22

Routing Reaches

The valley fill drainage area was divided into fifteen runoff subareas to model the post mining condition. Fifteen reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes, natural drains and channel down the face of the lower valley fill); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (2%) sediment and diversion ditches and the undisturbed portion of the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #1 drainage area at the downstream permit limit.

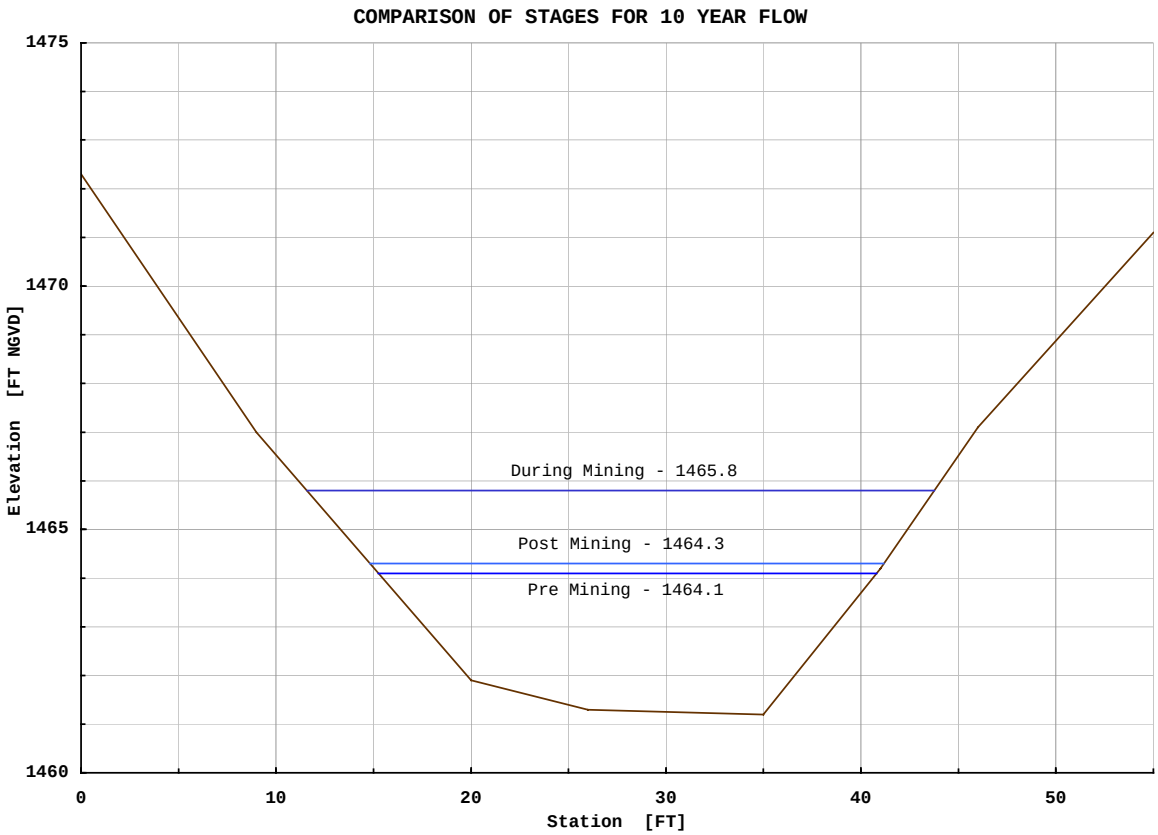
The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and approximately 800’ of the undisturbed Seng Creek channel downstream of the permit limit was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

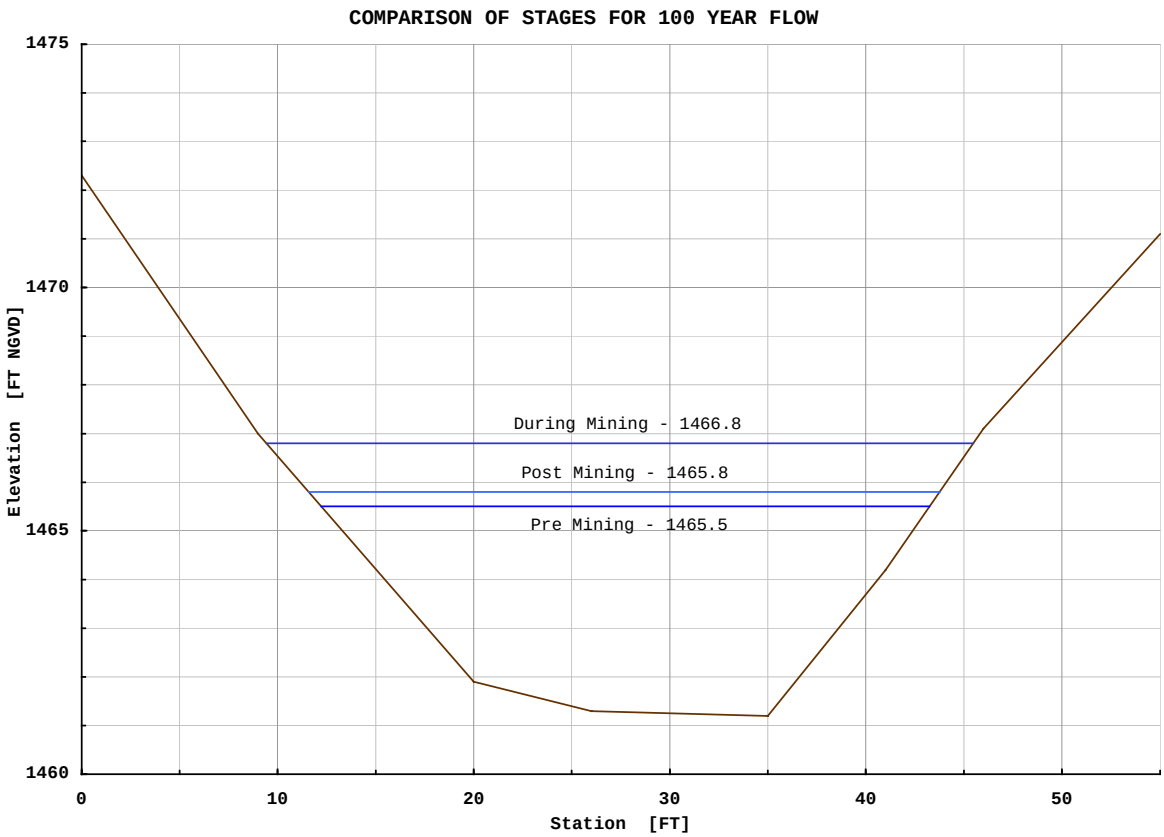
The following table shows the 10 and 100 year flows and water surface elevations:

Frequency [YR]	Pre Mining		During Mining		Post Mining	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	330	1464.1	525	1465.8	376	1464.3
100	742	1465.5	931	1466.8	832	1465.8

These results show a 25-59% (10-100 YR) increase in discharge from premining conditions as the area is disturbed during mining operations; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1465.8
Post Mining - 1464.3
Pre Mining - 1464.1
0
10
20
30
40
50
Station [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOW
1475
1470
1465
1460
Elevation [FT NGVD]
During Mining - 1466.8
Post Mining - 1465.8
Pre Mining - 1465.5
0
10
20
30
40
50
Station [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc. The during mining condition produces a very confused runoff system which changes almost daily and must be verified on the ground.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea.

7. The flat slopes created on the top surfaces of the valley fills and the regraded back stacks help to reduce peak flows by increasing the runoff time of concentration. The long flow paths created by sediment ditches help to reduce peak flows by increasing the runoff travel times.

8. The ongoing valley fill operation creates a very compartmented drainage area with a confused runoff system that changes almost daily. Any ‘snapshot’ of the ongoing operation may not be representative of the current or worst case condition.

9. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

10. This study shows that an ongoing valley fill operation will increase the discharge from 25-59% (10-100 YR) from premining conditions; this decreases to about 13% after the area is reclaimed in the post mining conditions. The stage increases by 1.3-1.7’ from pre to during mining operations; this decreases to about a 0.2-0.3’ increase for pre to post mining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the drainage area to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #2
AOC+ CONDITIONS

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

OCTOBER 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #2
AOC+ CONDITIONS

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, post mining and AOC+ (Approximate Original Contour Plus) conditions.

This report covers the results from the AOC+ conditions only. The results of the study for premining and post mining have been previously reported. They will be included in this report by reference and by inclusion in the "HYDROLOGIC AND HYDRAULIC MODEL RESULTS" section.

The Samples Mine Valley Fill SH-2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Mark Zaitsoff, Dennis McCune, Elizabeth Rodriguez) and Office of Surface Mining (OSM) personnel (Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to AOC+ conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

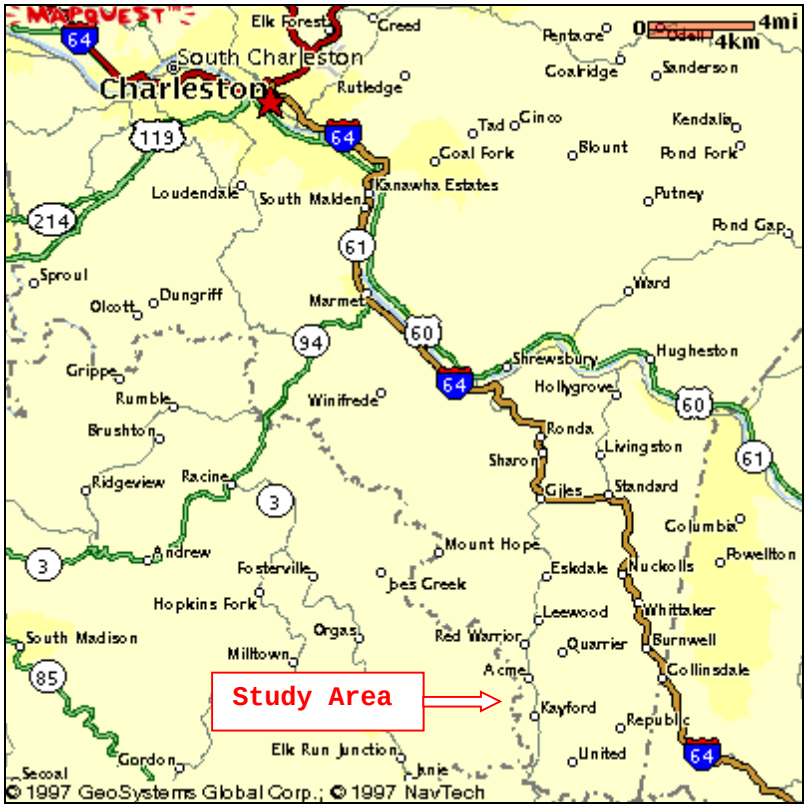
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled "Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia", between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #2 was the second site studied. The other three were the Samples Mine Valley Fill #1, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-2 is located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. It is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage area occupies a 0.6 square mile (10%) unnamed tributary near the upstream end of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, post and AOC+ mining conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Kaymine-Cedarcreek-Dekalb (KmF), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining and AOC+ conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of the unnamed tributary was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the OSM 1:4,800 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the

flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

AOC+ CONDITIONS

Drainage Areas

The AOC+ mining condition drainage area was delineated on a 1:4,800 scale regraded drainage map provided by the Knoxville Field Office of OSM. The AOC+ mining condition drainage area encompasses 0.50 square miles.

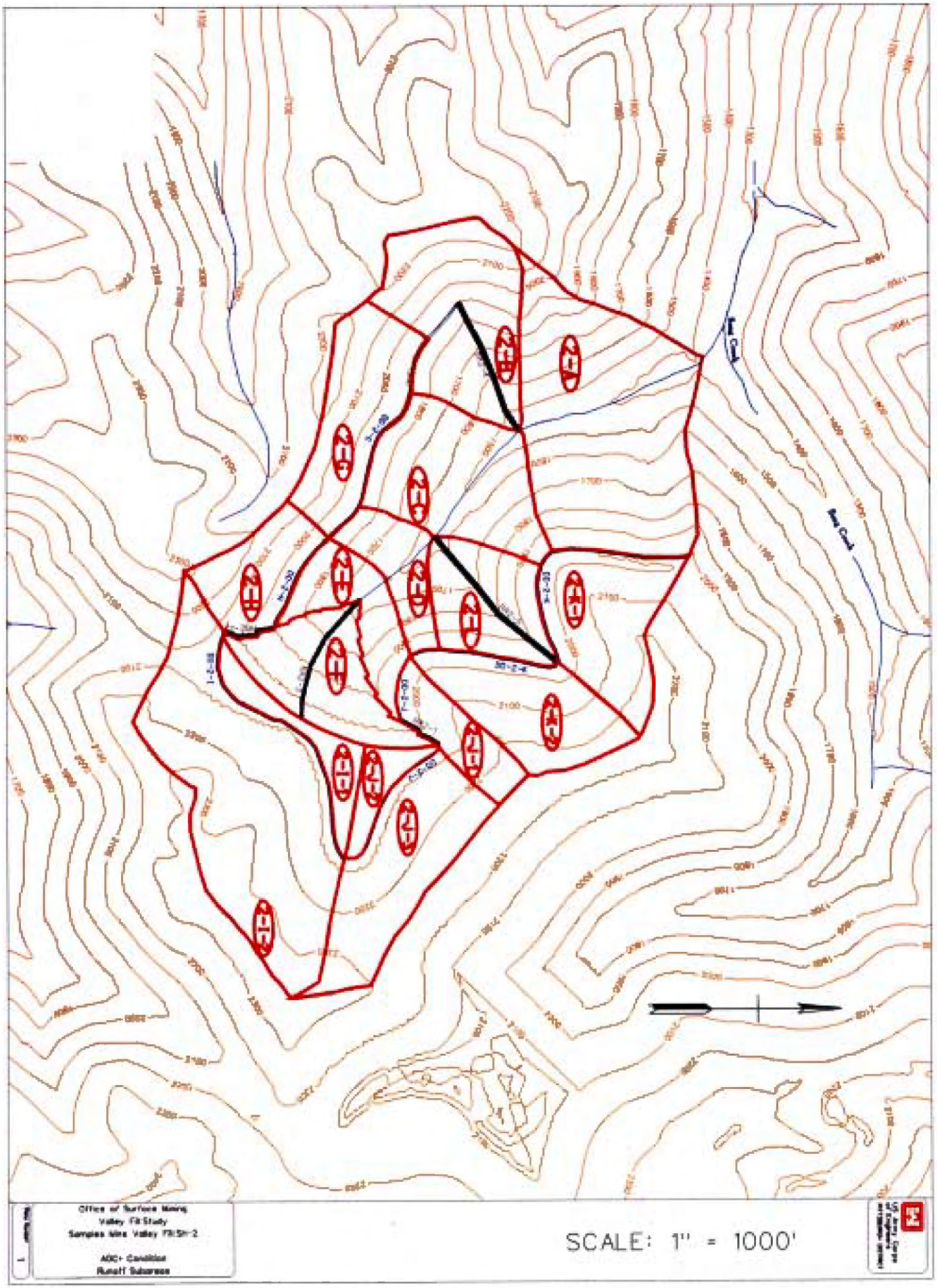
The drainage area was divided into sixteen runoff subareas to define the AOC+ mining condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the AOC+ mining land use is reclaimed valley fill and backstack areas for 56% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the AOC+ mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
2-A	Most downstream area	50.32	0.08	15.8
2-C	Subarea below valley fill	24.26	0.04	7.6
2-D	Right bank tributary	8.96	0.01	2.8
2-E	Subarea below valley fill	11.02	0.02	3.5
2-F	Face of valley fill	17.25	0.03	5.4
2-B	Downstream left diversion area	27.15	0.04	8.5
2-G	Middle left diversion area	19.21	0.03	6.0
2-H	Upstream left diversion area	12.01	0.02	3.8
2-I-1	Left top of valley fill	7.17	0.01	2.2
2-I-2	Left backstack area	50.53	0.08	15.8
2-L	Downstream right diversion area	14.84	0.02	4.6
2-K-1	Downstream right diversion area	20.36	0.03	6.4
2-K-2	Middle right diversion area	18.98	0.03	5.9
2—J-1	Upstream right diversion area	8.85	0.01	2.8
2-J-2	Right top of valley fill	4.61	0.01	1.4
2-J-3	Right backstack area	23.86	0.04	7.5
Total		319.38	0.50	100

This area represents a 9% decrease from pre to AOC+ mining conditions.

Plate 1 shows the runoff subareas.


Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill Sh-2
ADC+ Condition
Runoff Subareas
SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers
The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be reclaimed surface mine (RSM) areas.

The following table shows the soil types and their percent distribution within the runoff subareas for the AOC+ mining condition:

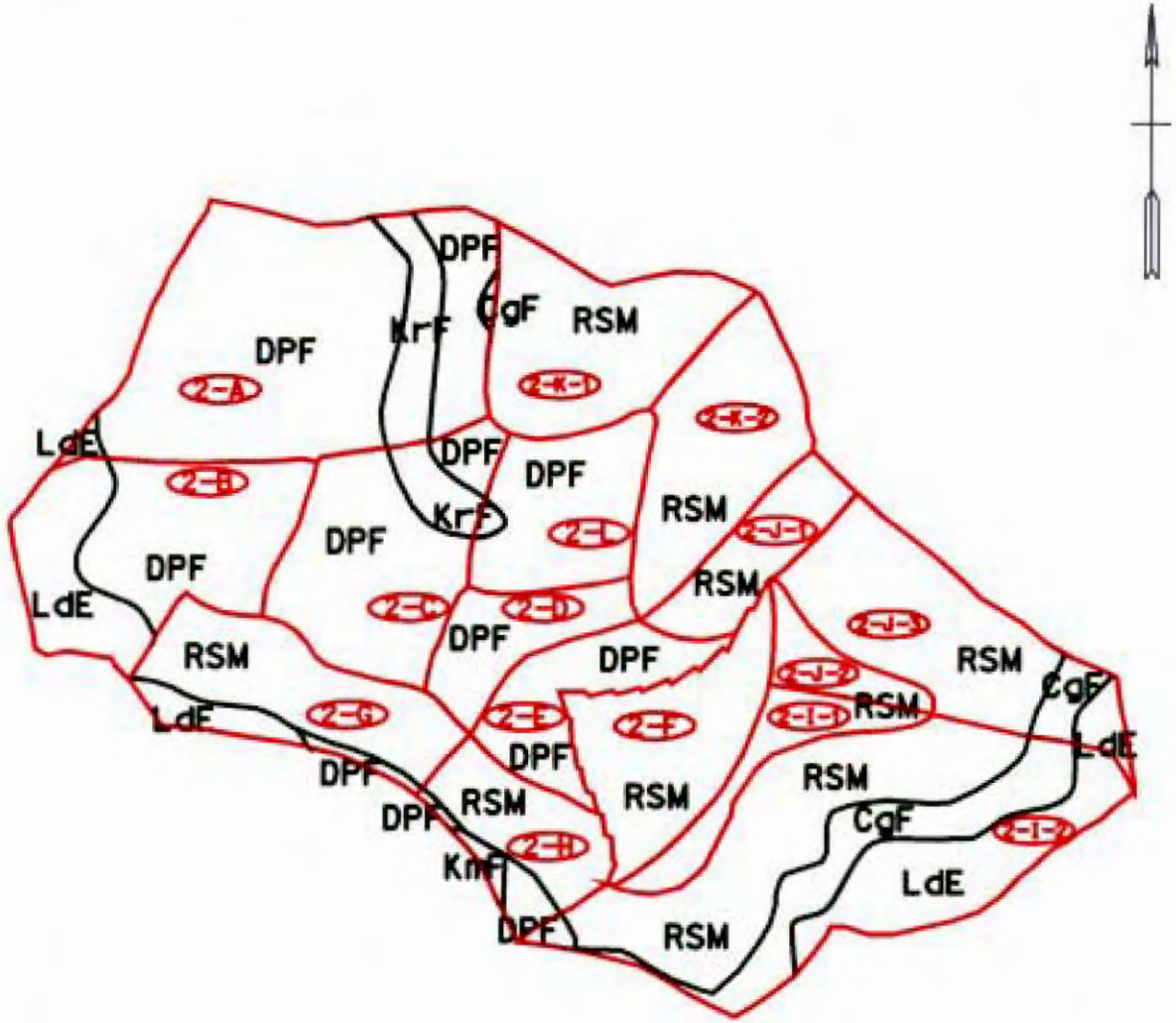
Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	LdE	RSM
	Percent Distribution					
2-A	0.7	87.0		11.1	1.2	
2-C		87.8		12.2		
2-D		100				
2-E		100				
2-F						100
2-B		62.9			37.1	
2-G		4.5			14.8	80.7
2-H		16.3	7.0			76.7
2-I-1						100
2-I-2	23.6	1.3			26.5	48.6
2-L		97.0		3.0		
2-K-1						100
2-K-2						100
2-J-1						100
-J-2						100
2-J-3	9.0				7.8	83.2
Total	2.1	34.8	0.4	1.6	5.5	55.6

Plate 2 shows the soil type subareas.

This table shows that reclaimed surface mine areas make up the majority (56%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the AOC+ mining condition:



SCALE: 1" = 1000'

US Army Corps of Engineers PITTSBURGH DISTRICT

Office of Surface Mining
Valley Fill Study
Samples Mine Valley Fill SH-3

NOC- Condition
Soil Type Subareas

Plate Number 2

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
2-A	67	1.8	0.99
2-C	67	1.8	0.99
2-D	66		1.03
2-E	66		1.03
2-F	75		0.67
2-B	66		1.03
2-G	73		0.74
2-H	73		0.74
2-I-1	75		0.67
2-I-2	72	3.5	0.78
2-L	66	0.4	1.03
2-K-1	75		0.67
2-K-2	75		0.67
2-J-1	75		0.67
2-J-2	75		0.67
2-J-3	74	1.3	0.70

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the AOC+ mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
2-A	19	11	18	11
2-C	17	10	17	10
2-D	8	5	7	4
2-E	10	6	10	6
2-F	12	7	11	6
2-B	20	12	19	11
2-G	15	9	13	8
2-H	12	7	11	7
2-I-1	41	25	38	23
2-I-2	36	21	33	20
2-L	8	5	7	4
2-K-1	29	17	27	16
2-K-2	17	10	15	9
2-J-1	13	8	13	8
2-J-2	29	17	28	17
2-J-3	24	14	22	13

Base Flow

The AOC+ mining condition base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
2-A	0.08	0.16
2-C	0.04	0.08
2-D	0.01	0.03
2-E	0.02	0.03
2-F	0.03	0.05
2-B	0.04	0.08
2-G	0.03	0.06
2-H	0.02	0.04
2-I-1	0.01	0.02
2-I-2	0.08	0.16
2-L	0.02	0.05
2-K-1	0.03	0.06
2-K-2	0.03	0.06
2-J-1	0.01	0.03
2-J-2	0.01	0.01
2-J-3	0.04	0.07

Routing Reaches

The valley fill drainage area was divided into sixteen runoff subareas to model the AOC+ mining condition. Twelve reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes and natural drains); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (0.5%) sediment and diversion ditches. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #2 drainage area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and the undisturbed unnamed tributary channel was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

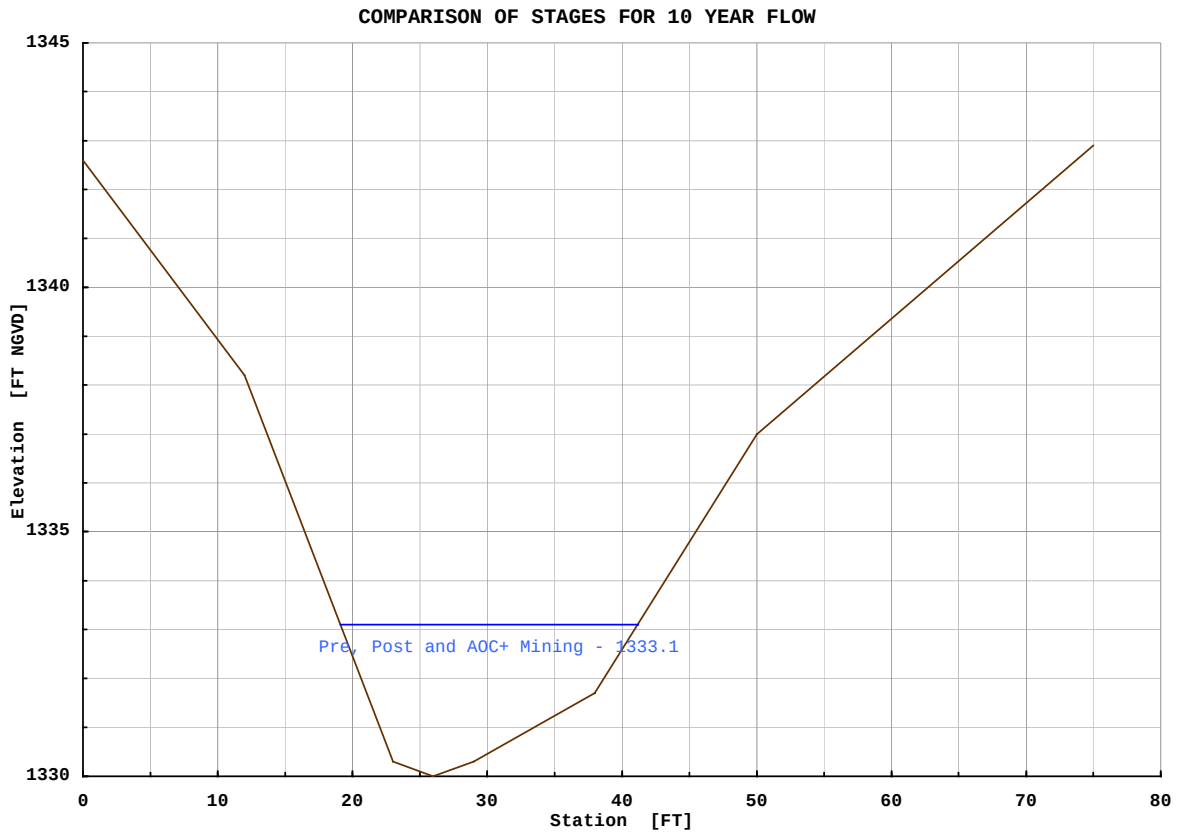
The following table shows the 10 and 100 year flows and water surface elevations:

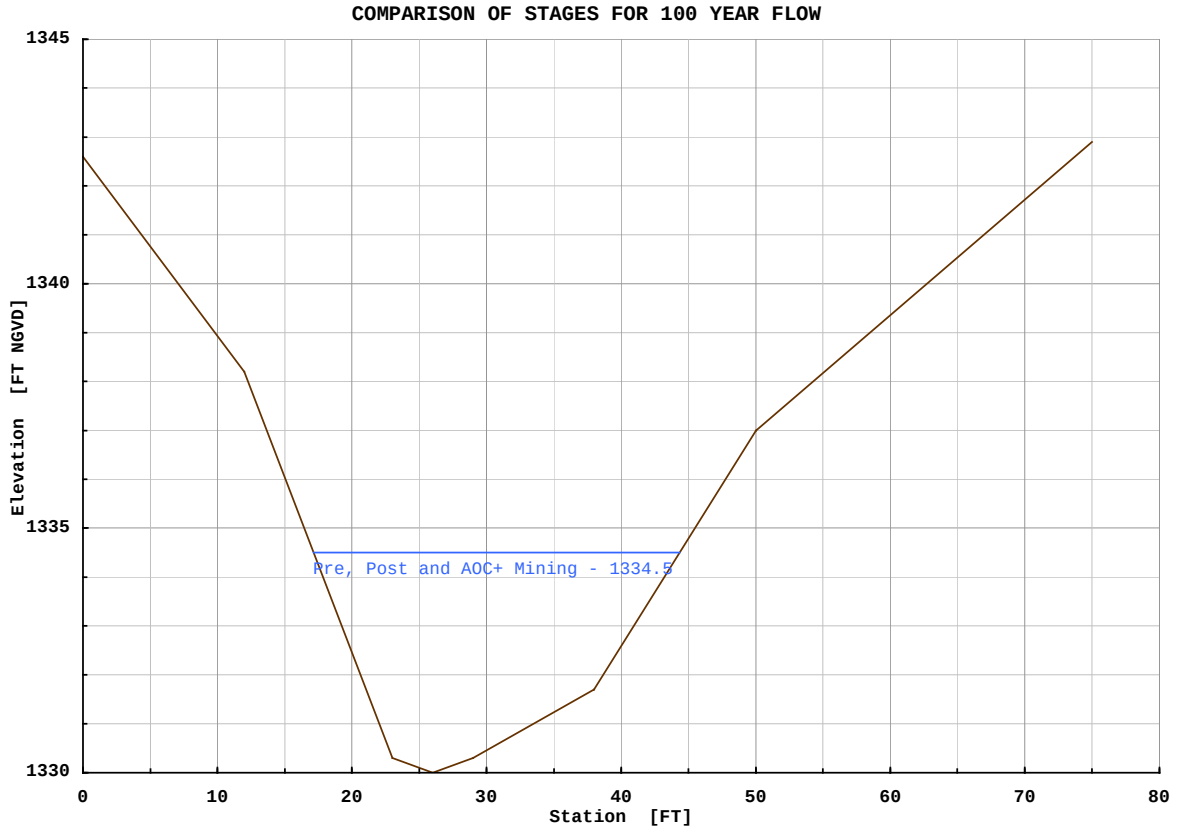
Frequency [YR]	Pre Mining		Post Mining		AOC+	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	293	1333.1	302	1333.1	295	1333.1
100	664	1334.5	671	1334.5	658	1334.5

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 1% (10 YR) increase and 1% (100 YR) decrease in discharge with no change in stage from premining condition.

The following cross section shows comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOW
1345
1340
1335
1330
Elevation [FT NGVD]
Pre, Post and AOC+ Mining - 1333.1
0
10
20
30
40
50
60
70
80
Station [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOW
1345
1340
1335
1330
Elevation [FT NGVD]
Pre, Post and AOC+ Mining - 1334.5
0
10
20
30
40
50
60
70
80
Station [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 1% (10 YR) increase and 1% (100 YR) decrease in discharge with no change in stage from premining condition.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the drainage area to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #2
FUTURE FORESTED CONDITIONS

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

MARCH 2001

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #2
FUTURE FORESTED CONDITIONS

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining, post mining, AOC+ (Approximate Original Contour Plus) and future forested conditions.

This report covers the results from the future forested conditions only. The results of the study for premining, post mining and AOC+ have been previously reported. They will be included in this report by reference and by inclusion in the “HYDROLOGIC AND HYDRAULIC MODEL RESULTS” section.

The Samples Mine Valley Fill SH-2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Mark Zaitsoff, Dennis McCune, Elizabeth Rodriguez) and Office of Surface Mining (OSM) personnel (Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to future forested conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS (version 1.1) rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS (version 2.2) hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

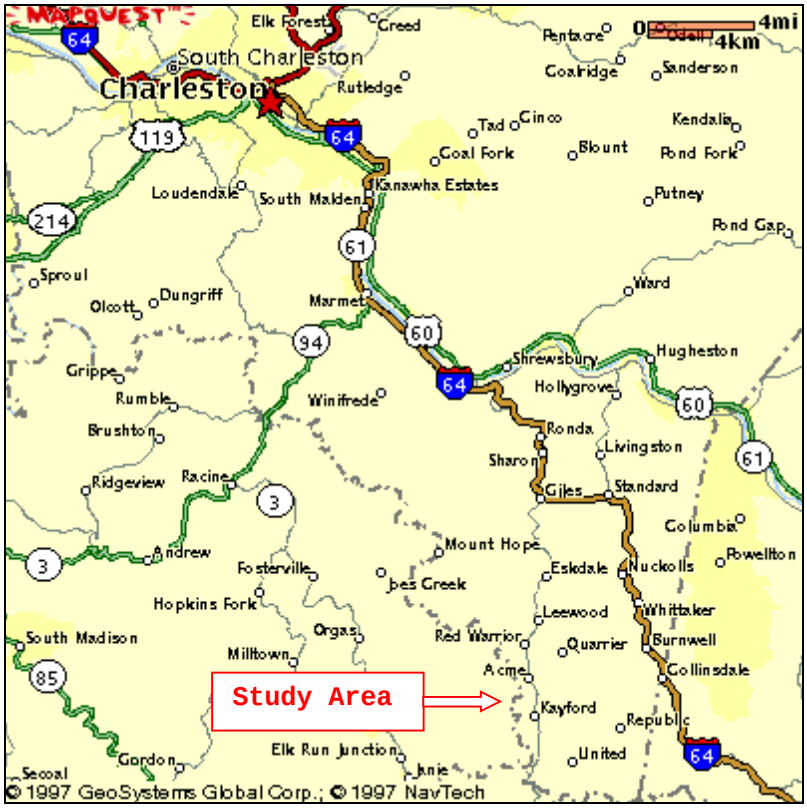
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #2 was the second site studied. The other three were the Samples Mine Valley Fill #1, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. Results from these other sites have been reported separately. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-2 is located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. It is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage area occupies a 0.6 square mile (10%) unnamed tributary near the upstream end of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining, post mining, AOC+ and future forested conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Itmann channery loam (ImE), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining, postmining, AOC+, and future forested conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a)

is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of Seng Creek was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company's 1:6,000 scale maps that had a contour interval of 20'. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

FUTURE FORESTED CONDITIONS

Drainage Areas

The future forested drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The future forested drainage area encompasses 0.51 square miles.

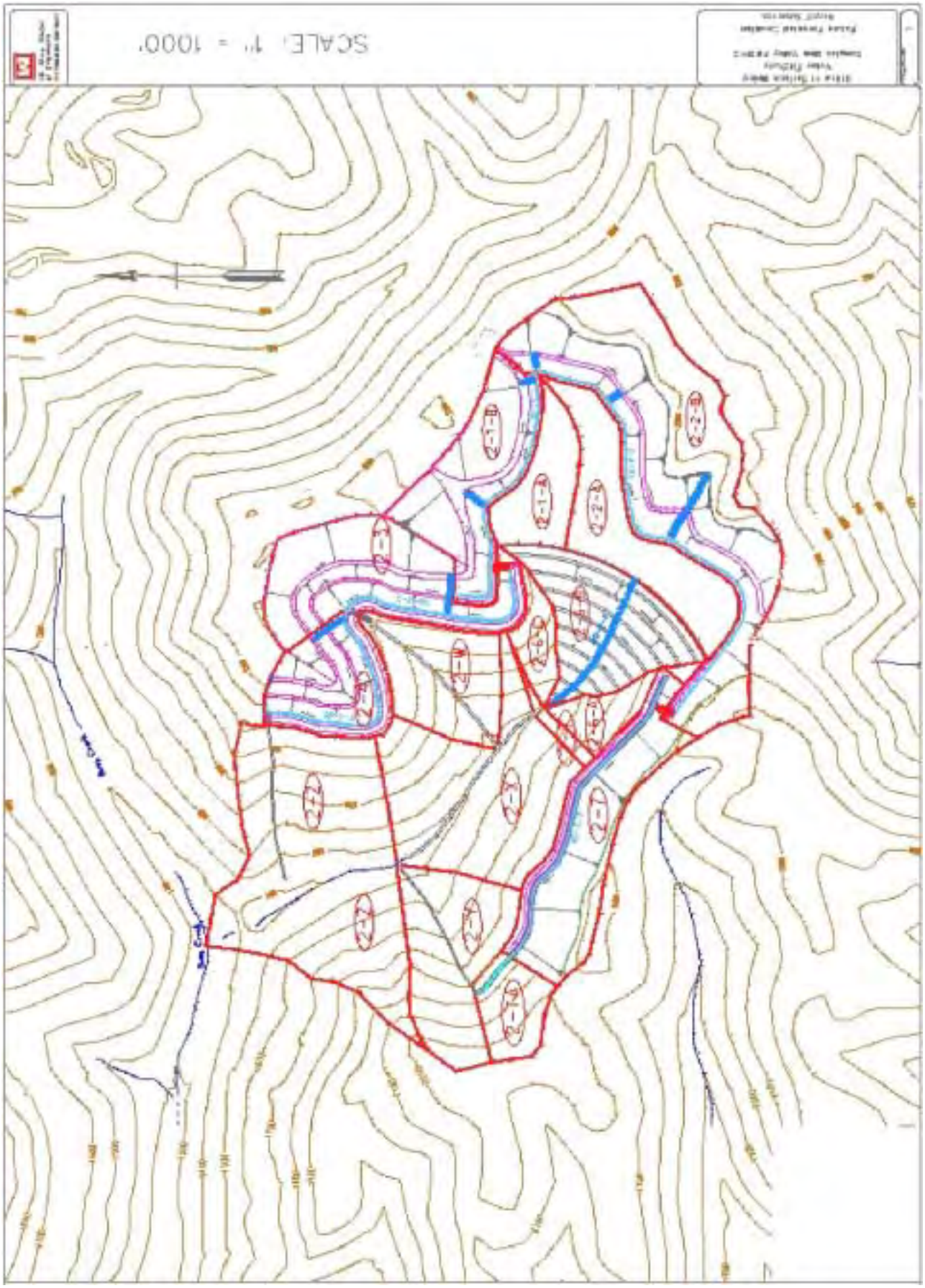
The drainage area was divided into sixteen runoff subareas to define the future forested condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regarded drainage map shows that the future land use is forested valley fill and backstack areas for 56% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the future forested condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
2-Z	Most downstream area	53.76	0.08	16.5
2-Y	Left bank tributary	19.39	0.03	5.9
2-X	Subarea below valley fill	31.81	0.05	9.7
2-W	Right bank tributary	16.06	0.03	4.9
2-V	Subarea below valley fill	1.73	0.003	0.5
2-6-A	Left abutment of valley fill	5.38	0.01	1.6
2-6-B	Face of lower valley fill	19.71	0.03	6.1
2-6-C	Right abutment of valley fill	5.06	0.01	1.5
2-7A	Downstream left diversion area	7.42	0.01	2.3
2-7	Middle left diversion area	23.55	0.04	7.2
2-2-A	Left top of valley fill	19.01	0.03	5.8
2-2-B	Left backstack area	53.18	0.08	16.3
2-4	Downstream right diversion area	14.21	0.02	4.3
2-3	Middle right diversion area	25.66	0.04	7.9
2-1-A	Right top of valley fill	10.30	0.02	3.1
2-1-B	Right backstack area	20.99	0.03	6.4
Total		327.22	0.51	100

This area represents a 7% decrease from pre to future forested conditions and mainly reflects differences in the regraded topography on the northeast side of the drainage area.

Plate 1 shows the runoff subareas.


SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be future forested (FF) areas. The future forested conditions represent a 20 year forestry plan which covers the reclaimed surface mine areas with appropriate trees.

The following table shows the soil types and their percent distribution within the runoff subareas for the future forested condition:

Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	LdE	FF
	Percent Distribution					
2-Z	0.8	87.1		9.8	2.3	
2-Y		75.6			24.4	
2-X		91.1		8.9		
2-W		99.2		0.8		
2-V		100				
2-6-A		100				
1-2-B						100
2-6-C		100				
2-7A						100
2-7						100
2-2-A						100
2-2-B						100
2-4						100
2-3						100
2-1-A						100
2-1-B						100
Total	0.1	40.8	0	1.2	1.7	56.2

Plate 2 shows the soil type subareas.

This table shows that future forested areas make up the majority (56%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the future forested condition:

SCALE: 1" = 1000'
FF
DPF
KrF
LdE

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
2-Z	67	1.6	0.99
2-Y	66	0	1.03
2-X	67	1.3	0.99
2-W	66	0.1	1.03
2-V	66	0	1.03
2-6-A	64	0	1.13
2-6-B	71	0	0.82
2-6-C	64	0	1.13
2-7A	67	0	0.99
2-7	71	0	0.82
2-2-A	71	0	0.82
2-2-B	71	0	0.82
2-4	71	0	0.82
2-3	71	0	0.82
2-1-A	71	0	0.82
2-1-B	71	0	0.82

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the future forested condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
2-Z	18	11	18	11
2-Y	15	9	15	9
2-X	18	11	17	10
2-W	20	12	20	12
2-V	14	8	14	8
2-6-A	18	11	18	11
2-6-B	21	13	17	10
2-6-C	20	12	20	12
2-7A	17	10	16	10
2-7	44	26	41	25
2-2-A	63	38	59	35
2-2-B	47	28	42	25
2-4	44	27	40	24
2-3	25	15	24	14
2-1-A	57	34	55	33
2-1-B	41	24	38	23

Base Flow

The future forested mining condition base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
2-Z	0.08	0.17
2-Y	0.03	0.06
2-X	0.05	0.10
2-W	0.03	0.05
2-V	0.003	0.01
2-6-A	0.01	0.02
2-6-B	0.03	0.06
2-6-C	0.01	0.02
2-7A	0.01	0.02
2-7	0.04	0.07
2-2-A	0.03	0.06
2-2-B	0.08	0.17
2-4	0.02	0.04
2-3	0.04	0.08
2-1-A	0.02	0.03
2-1-B	0.03	0.07

Routing Reaches

The valley fill drainage area was divided into sixteen runoff subareas to model the future forested condition. Twelve reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes, natural drains and channels down the sides of the valley fill); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (2%) sediment and diversion ditches and the undisturbed portion of the drainage area. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #2 drainage area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and the undisturbed unnamed tributary channel was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

The following tables show the 10 and 100 year flows and water surface elevations:

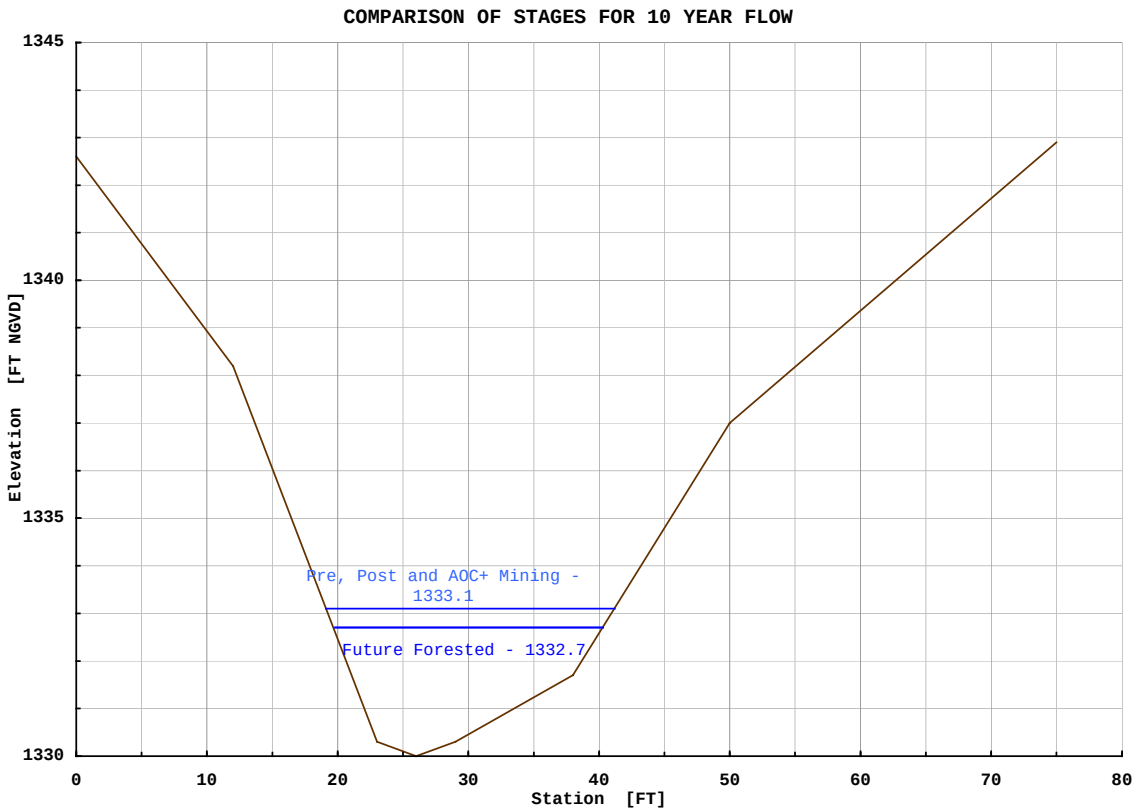
Frequency [YR]	Pre Mining		Post Mining		AOC+	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	293	1333.1	302	1333.1	295	1333.1
100	664	1334.5	671	1334.5	658	1334.5

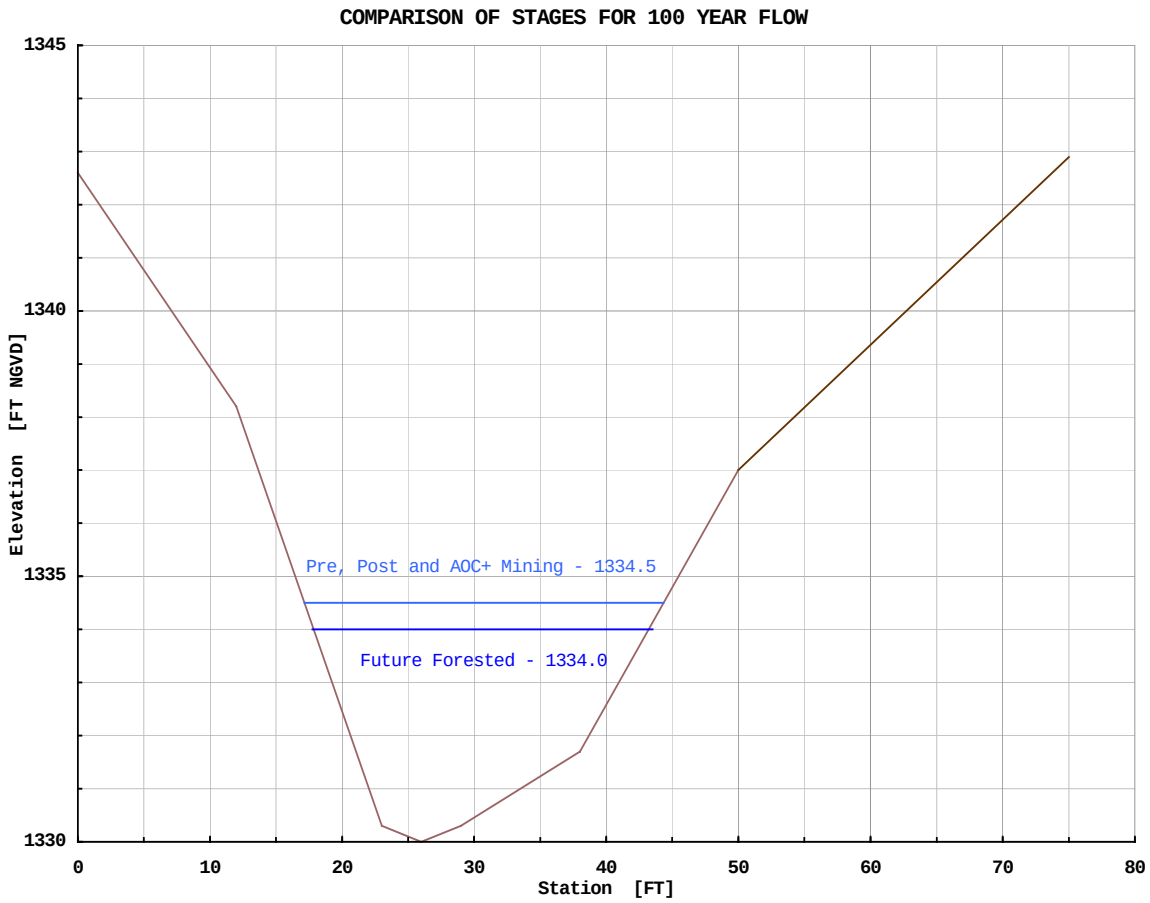
Frequency [YR]	Future Forested	
	Flow [CFS]	Elevation [FT NGVD]
10	209	1332.7
100	502	1334.0

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 1% (10 YR) increase and 1% (100 YR) decrease in discharge with no change in stage from premining condition. The future forested conditions would cause a 29-24% (10-100 YR) decrease in discharge and a 0.4’-0.5’ decrease in stage from the premining conditions.

The following cross sections show comparisons of the water surfaces for each condition.


COMPARISON OF STAGES FOR 10 YEAR FLOW
1345
1340
1335
1330
Elevation [FT NGVD]
Pre, Post and AOC+ Mining - 1333.1
Future Forested - 1332.7
0
10
20
30
40
50
60
70
80
Station [FT]


COMPARISON OF STAGES FOR 100 YEAR FLOW
1345
1340
1335
1330
Elevation [FT NGVD]
Pre, Post and AOC+ Mining - 1334.5
Future Forested - 1334.0
0
10
20
30
40
50
60
70
80
Station [FT]

CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea. Subdivision will increase the complexity of the hydrologic and hydraulic models.

7. It is not possible to generalize the impacts of changes to the drainage area on the discharge. Changes to the topography, soils, land use, vegetation will cause corresponding changes to the discharge. Changes to the flow paths will affect the discharge by changing the runoff time of concentration, flow routing times and hydrograph combination.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. These results show a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions. Alternatively, the AOC+ conditions would cause a 1% (10 YR) increase and 1% (100 YR) decrease in discharge with no change in stage from premining condition. The future forested conditions would cause a 29-24% (10-100 YR) decrease in discharge and a 0.4’-0.5’ decrease in stage from the premining conditions.

RECOMMENDATIONS

1. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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OSM VALLEY FILL STUDY

SAMPLES MINE VALLEY FILL #2

Appalachian
Regional
Coordinating
Center

US Army Corps
of Engineers
Pittsburgh District

JANUARY 2000

OSM VALLEY FILL STUDY
SAMPLES MINE VALLEY FILL #2

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GENERAL

The intent of this study was to determine the effect on storm runoff by changes to topography, soils, land use, vegetation, etc, caused by mountain top removal / valley fill surface coal mining operations. The changes to the 10 and 100 year flows and water surface elevations were determined and compared for the premining and post mining conditions.

The Samples Mine Valley Fill SH-2, located in the headwaters of the Seng Creek watershed in Boone County, West Virginia, was selected as the study site. The determination of the effects of changes to this drainage area represents a classic ungaged watershed study. The Seng Creek watershed is ungaged and no historic hydrologic information is available.

Corps of Engineers personnel from the Pittsburgh District (Mark Zaitsoff, Dennis McCune, Elizabeth Rodriguez) and Office of Surface Mining (OSM) personnel (Dan Rahnema) visited the site.

Discussions were held to determine the methods of analysis that could be used to achieve the required results. Since great changes occur to the drainage area from pre to post mining conditions, the method of analysis needed to be able to subdivide it and model the changed areas as appropriate. Those involved concurred that the HEC-HMS (Hydrologic Modeling System) and HEC-RAS (River Analysis System) models would provide the methods of analysis and results needed for the study.

A HEC-HMS rainfall runoff model was used to evaluate the changes in flow magnitude. The runoff curve number (CN) method developed by the Soil Conservation Service (SCS) (now National Resource Conservation Service, NRCS) was used to determine the rainfall losses and the transformation from rainfall excess to runoff. This method has the advantage over regional parameter methods of rainfall-runoff determination of being based on observable physical properties of the watershed and of being able to model great changes in the runoff characteristics of the watershed.

A HEC-RAS hydraulic model was used to provide peak flow timing and routing input to the HEC-HMS hydrologic model. Flows generated by the hydrology model were input to the hydraulic model until the input and output from both models were consistent. The HEC-RAS model was then used to determine the changes in water surface elevation.

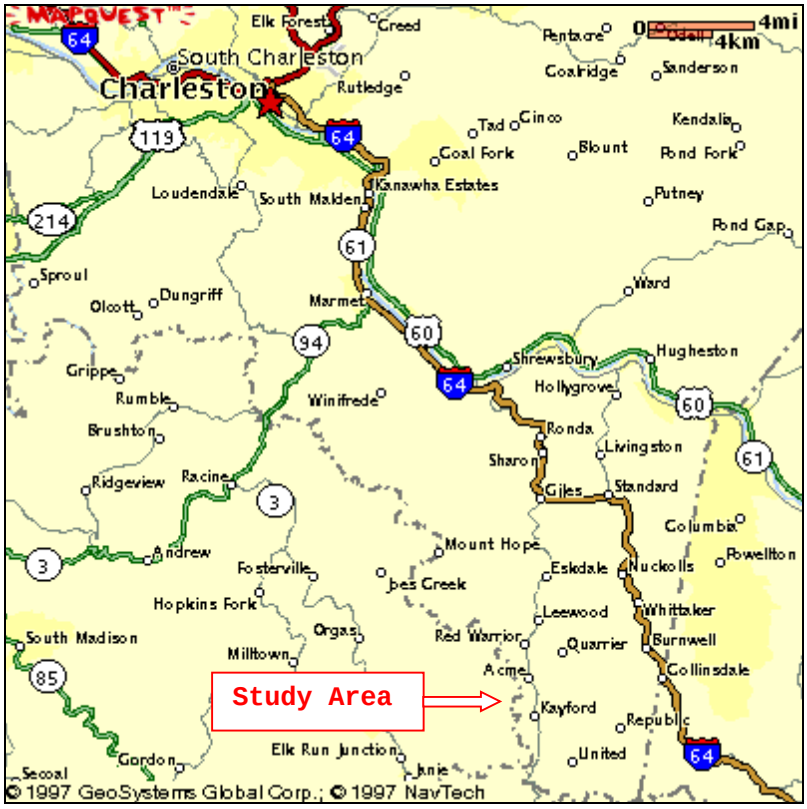
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

This study was conducted under interagency agreement number 143868-IA98-1244, entitled “Model Analysis of Potential Downstream Flooding as a Result of Valley Fills and Large-Scale Surface Coal Mining Operations in Appalachia”, between the Office of Surface Mining Reclamation and Enforcement and the U.S. Army Corps of Engineers. The Samples Mine Valley Fill #2 was the second site studied. The other three were the Samples Mine Valley Fill #1, #1 and 2 combined and the Hobet Mine Westridge Valley Fill in Lincoln County, WV. The study was initiated 24 September 1998.

DESCRIPTION OF HYDROLOGIC AND HYDRAULIC MODELS

Drainage Area

The Samples Mine Valley Fill SH-2 is located approximately 25 miles southeast of Charleston, WV, on the eastern side of Boone County on the boundaries with Kanawha and Raleigh Counties, WV. It is located in the headwaters of the Seng Creek (tributary to the Big Coal and Kanawha Rivers) watershed. The valley fill drainage area occupies a 0.6 square mile (10%) unnamed tributary near the upstream end of the 5.55 square mile Seng Creek watershed.



Precipitation

Precipitation depths were determined using the National Weather Service publications HYDRO35 and Technical Paper 40 (TP40). HYDRO 35 provides maps of rainfall depths for 5, 15 and 60 minute durations, and 2 and 100 year frequencies. Equations are provided to calculate the precipitation depths for other frequencies. TP40 provides maps of precipitation depths for 2, 3, 6, 12 and 24 hour durations, and 1 to 100 year frequencies.

The Samples Mine is located on the eastern side of Boone County, WV, and that location was used to determine the precipitation depths. The following table shows the precipitation depths determined from HYDRO 35 and TP40 for the study area:

Duration	Frequency [YR]	
	10	100
	Depth [IN]	
5 MIN	0.54	0.74
15 MIN	1.09	1.57
1 HR	1.86	2.70
2 HR	2.38	3.44
3 HR	2.68	3.76
6 HR	3.05	4.44
12 HR	3.53	5.06
24 HR	3.98	5.65

These values were used for the premining and post mining conditions.

Soil Types

The Boone County, WV, soil survey was used to determine the soil types located in the study area.

The Seng Creek watershed is contained within the Dekalb-Pineville-Guyandotte general soil unit. The soils within this unit are described as “very steep, well drained soils that formed mainly in material weathered from sandstone; on mountainous uplands”. The various soil types within this unit are the Cedarcreek-Rock outcrop (CgF), Dekalb-Pineville-Guyandotte association (DPF), Kaymine-Cedarcreek-Dekalb (KmF), Kaymine-Rock outcrop complex (KrF), and Lily-Dekalb complex (LdE). The soil survey provides information on the detailed make up of the soil types, giving such information as component soil types, impervious area, etc.

The soil type subareas were traced onto the USGS topographic or regraded drainage maps for the premining and postmining conditions; the areas of each soil type within the runoff subareas were determined by planimetering.

SCS Runoff Curve Numbers

The SCS runoff curve number (CN) method was used to convert precipitation depth into runoff excess. The curve number method is based on observable physical properties (soil and cover) of the runoff subareas.

A hydrologic soil group (HSG) characterizes the soil properties. The soil survey provides information on the detailed make up of the various soil types, making it possible to classify their component soils into HSG A (low runoff potential and high infiltration rates) through HSG D (high runoff potential and very low infiltration rates).

The cover takes into account the land use, vegetation type, surface treatment, etc.

The curve number is determined by the combination of the component soil types and cover. Curve numbers were selected from the tables published and provided by the SCS. It is possible to calculate areal weighted curve numbers for the overall soil types and each runoff subarea.

The curve number is also used to calculate the initial abstraction (all losses before runoff begins) for each runoff subarea. This initial abstraction (I_a) is defined as 20% of the maximum available retention capacity of the soil after the runoff begins.

Time of Concentration and Lag

The time of concentration (T_c) of each runoff subarea is the amount of time that it takes for runoff to travel from the hydraulically most distant point to the outlet. It is the sum of the travel times (T_t) through the components of the runoff system.

The SCS method provides procedures for computing three travel time components for the time of concentration calculations: 1) sheet flow, 2) shallow concentrated flow, and 3) open channel flow.

Sheet flow is the runoff that occurs over the surface of the ground prior to becoming concentrated into small gullies. It is limited, by definition in the SCS method, to a maximum of 300 feet from the most upstream drainage divide. Shallow concentrated flow occurs from the end of sheet flow until the runoff enters a channel, by definition a stream shown on a USGS map. Appropriate changes in slopes were incorporated into the calculations of sheet and shallow concentrated flows. HEC-HMS computed values for the 10 and 100 year flows were input to the HEC-RAS hydraulic model of the valley fill drainage area to provide travel times for the channel flow component. The undisturbed portion of the unnamed tributary was used for the open channel flow component for the subareas below the valley fill operation.

The sum of the three travel time components is the time of concentration for a runoff subarea.

Several flow routes were considered when calculating the time of concentration for each runoff subarea. The different routes were selected to maximize the effect of each of the three components on the time of concentration. They maximized the flow distances for each component; the flow route giving the greatest time of concentration was selected.

The lag (L) is defined as the time from the center of mass of the excess rainfall to the peak of the calculated hydrograph. The lag is defined and calculated by the SCS method as 60% of the time of concentration.

Base Flow

A base flow of 2 CFS/SM was adopted for each runoff subbasin. Since the base flow contribution to the volume and peak discharge is minor, the recession constant and threshold were estimated in the HEC-HMS model to be 1 (no recession) and 0 CFS, respectively. This gives a constant base flow value of 2 CFS/SM during the entire flow hydrograph.

Routing Reaches

A HEC-RAS hydraulic model was used to determine the required inputs for the hydrologic routing. This model was formulated using survey cross sections and topographic map information. Channel reach lengths and slopes were estimated from the mining company’s 1:6,000 scale maps that had a contour interval of 20’. Cross section geometry, channel roughness, reach lengths, energy slopes and average travel times from the HEC-RAS model were used as input to the Muskingum-Cunge and Lag routing methods in the HEC-HMS models.

The HEC-HMS hydrology models route upstream flows through intervening runoff subareas, then combine routed flows and local runoff at the downstream end of the routing reaches. This hydrologic routing provides the translation of the

flow hydrograph along the channels and the timing and attenuation that reflect the storage characteristics of the channel and overbank sections of the routing reaches.

The HEC-RAS model was formulated to add in the local runoff in five increments through each routing reach, increasing the channel flow progressing downstream. The HEC-HMS model results show that there was little change in the routed flow through the routing reaches, so this assumption of local flow increasing along a routing reach was not affected by routing considerations.

PREMINING CONDITIONS

Drainage Areas`

The premining drainage area was delineated on USGS 1:24,000 scale topographic maps (Dorothy and Eskdale quadrangles) and on a 1:6,000 scale regraded drainage map provided by the coal company. The premining drainage area encompasses 0.55 square miles.

The drainage area was divided into five runoff subareas to define the premining condition. These subareas were selected to define tributary areas and hydrologic routing reaches. There were no significant differences in land use or soil type to justify any further subdivision.

The following table shows the runoff subareas for the premining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
Z	Most downstream area	61.44	0.10	17.5
Y	Left bank tributary	33.79	0.05	9.6
X	Subarea below proposed valley fill	48.32	0.08	13.8
W	Right bank tributary	54.78	0.09	15.6
V	Proprosed valley fill area	152.64	0.24	43.5
Total		350.97	0.55	100

Plate 1 shows the runoff subareas.

Soil Types and SCS Runoff Curve Numbers

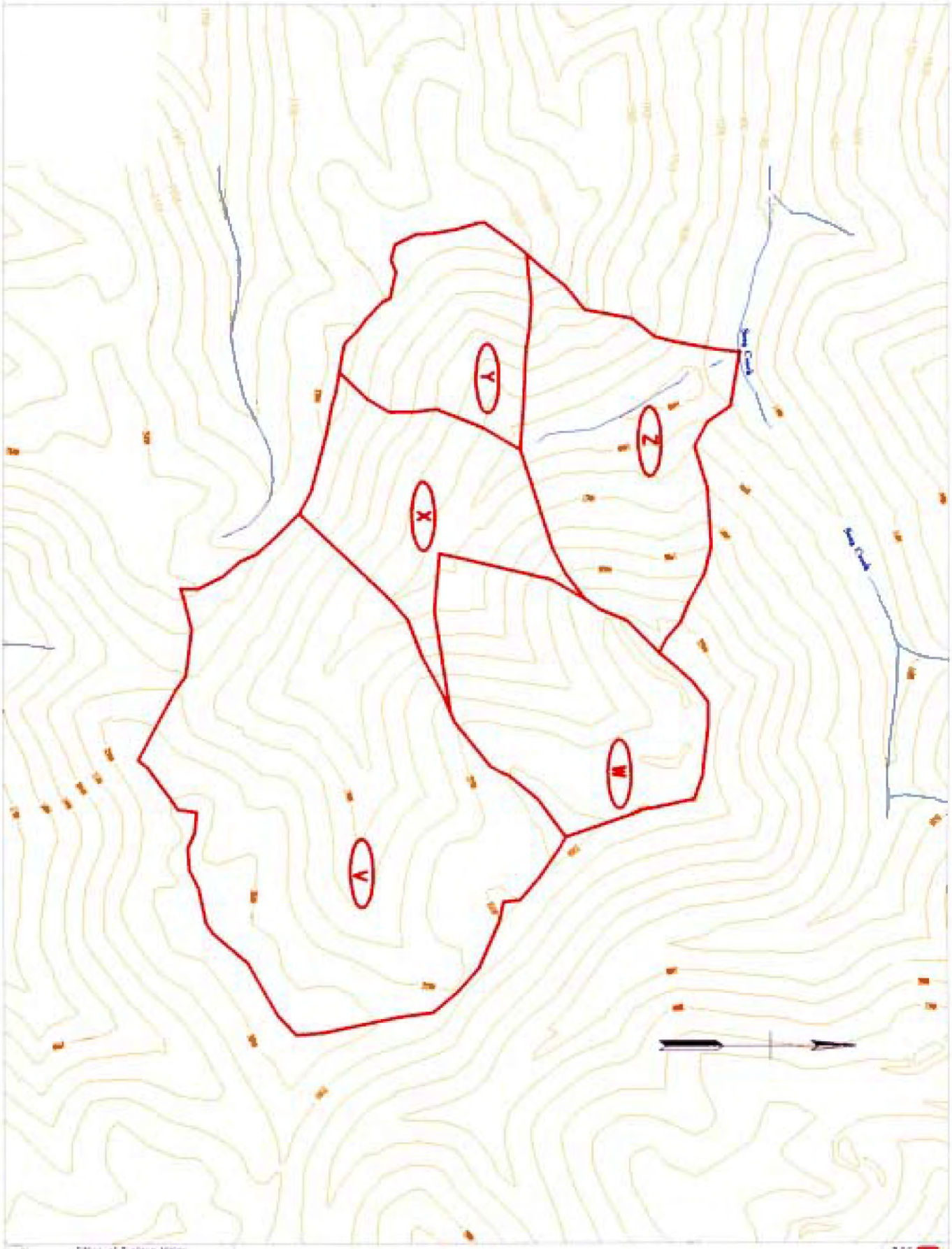
The following table shows the soil types and their percent distribution within the runoff subareas for the premining condition:

Runoff Subarea	Soil Type				
	CgF	DPF	KmF	KrF	LdE
	Percent Distribution				
Z	7.9	80.8		8.2	3.1
Y		63.8			36.2
X		90.2		6.5	3.3
W	47.6	43.7		0.4	8.3
V	26.6	60.4	0.3		12.7
Total	16.4	67.8	0.1	3.0	12.7

Plate 2 shows the soil type subareas.

This table shows that the Dekalb-Pineville-Guyandotte association (DPF) makes up the majority (68%) of the drainage area.

The premining land use for the Seng Creek watershed is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.



Office of Surface Mining
Valley Fill Study
Compass Mine Valley Fill Sh 2

Pre Mining Condition
Runoff Subareas

SCALE: 1" = 1000'

SCALE: 1" = 1000'

Office of Surface Mining
Valley Fill/Haul
Spruces Mine Valley Fill-2
Pre Mining Condition
Soil Type Subdivision

Map Number

The following table shows the results of the weighted curve number calculations for the premining condition:

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
Z	67	2.4	0.99
Y	66	0.0	1.03
X	67	1.0	0.99
W	69	7.2	0.90
V	68	4.0	0.94

Time of Concentration and Lag

The following table shows the results of the time of concentration and lag calculations for the premining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
Z	31	19	30	18
Y	17	10	17	10
X	20	12	19	12
W	30	18	30	18
V	35	21	32	19

Base Flow

The premining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
Z	0.10	0.19
Y	0.05	0.11
X	0.08	0.15
W	0.09	0.17
V	0.24	0.48

Routing Reaches

The drainage area was divided into five runoff subareas to model the premining condition. Three reaches connected the runoff subareas and route the flows through the drainage area.

The Lag method was used since the channel slopes were greater than 10%; the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation.

POST MINING CONDITIONS

Drainage Areas

The post mining drainage area was delineated on a 1:6,000 scale regraded drainage map provided by the coal company. The post mining drainage area encompasses 0.51 square miles.

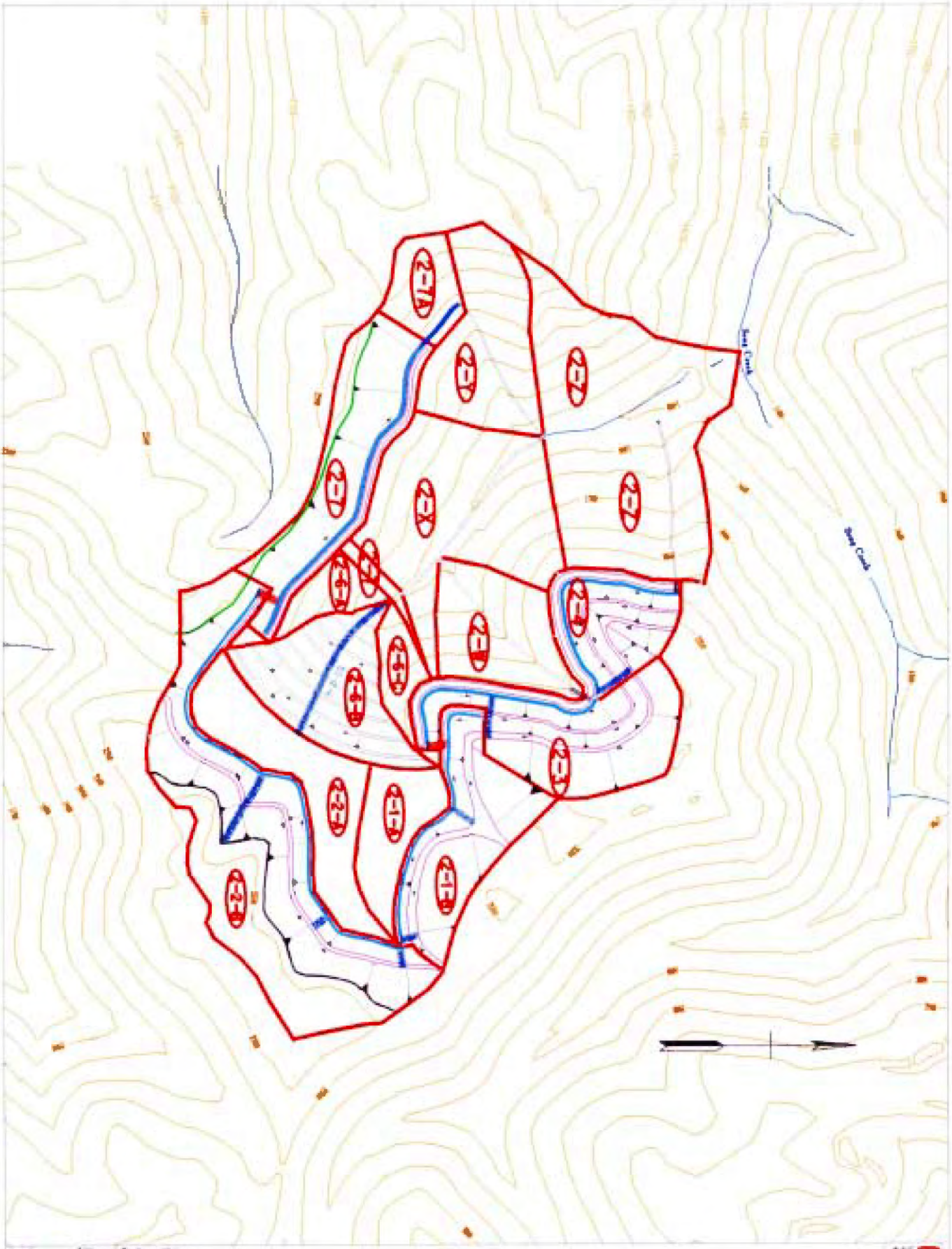
The drainage area was divided into sixteen runoff subareas to define the post mining condition. These subareas were selected to define tributary areas created by sediment and diversion ditches in the regrading plan and the hydrologic routing reaches connecting them. The downstream end of the drainage area is relatively unchanged from premining conditions; the unchanged land use, soil types and tributary justified further subdivision. The regraded drainage map shows that the post mining land use is reclaimed valley fill and backstack areas for 56% of the drainage area.

The regraded drainage plan used sediment and diversion ditches to create four tributary areas. These four tributary areas were: 1) below the valley fill, 2) the valley fill area, 3) flows diverted around the left side of the valley fill, and 4) flows diverted around the right side of the valley fill. The following table shows the runoff subareas for the post mining condition:

Runoff Subarea	Description	Area		
		[ACRES]	[MI^2]	[%]
2-Z	Most downstream area	53.76	0.08	16.5
2-Y	Left bank tributary	19.39	0.03	5.9
2-X	Subarea below valley fill	31.81	0.05	9.7
2-W	Right bank tributary	16.06	0.03	4.9
2-V	Subarea below valley fill	1.73	0.003	0.5
2-6-A	Left abutment of valley fill	5.38	0.01	1.6
2-6-B	Face of lower valley fill	19.71	0.03	6.1
2-6-C	Right abutment of valley fill	5.06	0.01	1.5
2-7A	Downstream left diversion area	7.42	0.01	2.3
2-7	Middle left diversion area	23.55	0.04	7.2
2-2-A	Left top of valley fill	19.01	0.03	5.8
2-2-B	Left backstack area	53.18	0.08	16.3
2-4	Downstream right diversion area	14.21	0.02	4.3
2-3	Middle right diversion area	25.66	0.04	7.9
2-1-A	Right top of valley fill	10.30	0.02	3.1
2-1-B	Right backstack area	20.99	0.03	6.4
Total		327.22	0.51	100

This area represents a 7% decrease from pre to post mining conditions and mainly reflects differences in the regraded topography on the northeast side of the drainage area.

Plate 3 shows the runoff subareas.



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Valley Fill Study
Sunnyside Mine Valley Fill SH-2

Post Mining Condition
Runoff Subareas

SCALE: 1" = 1000'

Soil Types and SCS Runoff Curve Numbers

The regraded drainage map shows the area that was covered by the valley fill and regraded backstacks. These areas were considered to be reclaimed surface mine (RSM) areas.

The following table shows the soil types and their percent distribution within the runoff subareas for the post mining condition:

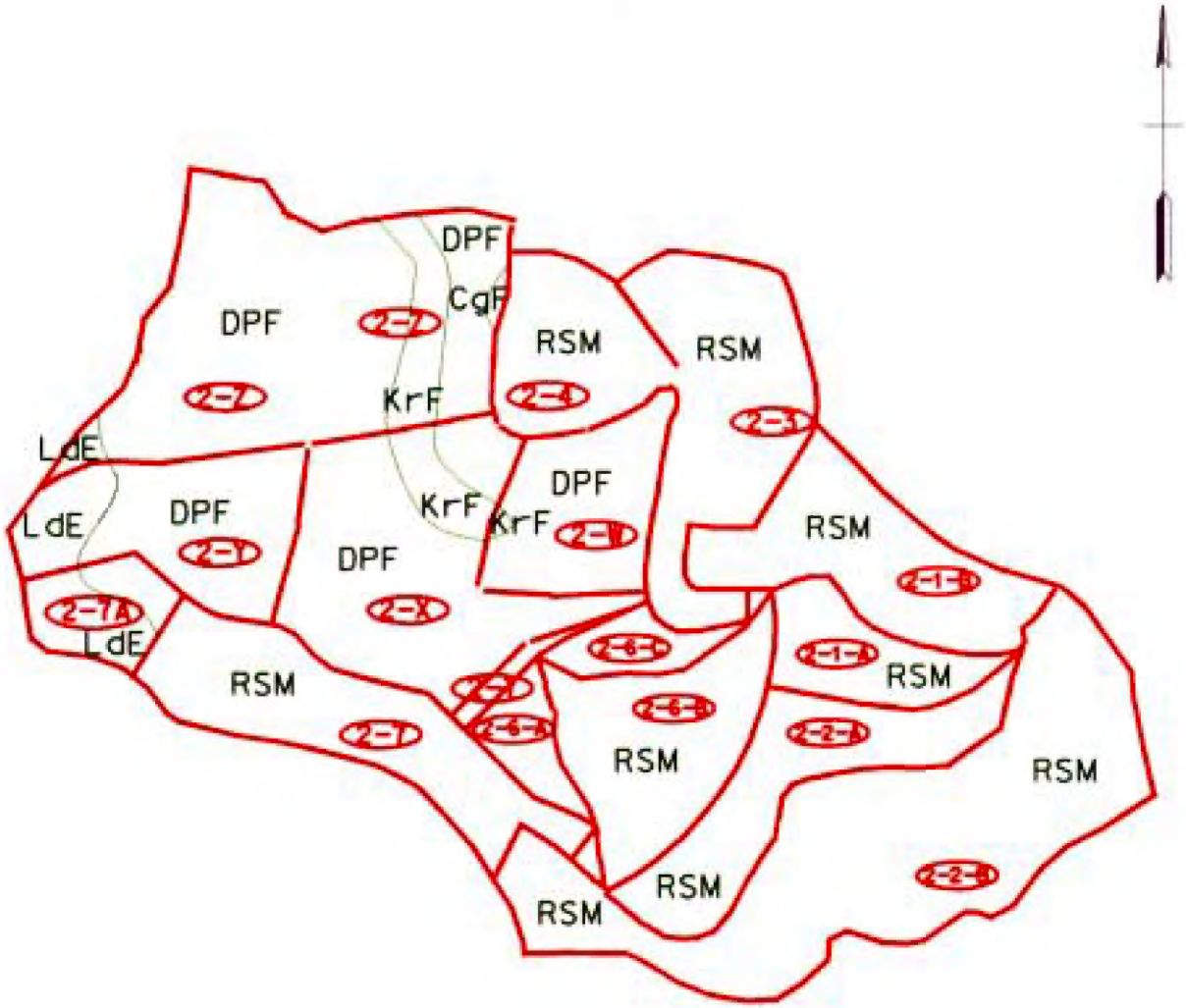
Runoff Subarea	Soil Type					
	CgF	DPF	KmF	KrF	LdE	RSM
	Percent Distribution					
2-Z	0.8	87.1		9.8	2.3	
2-Y		75.6			24.4	
2-X		91.1		8.9		
2-W		99.2		0.8		
2-V		100				
2-6-A		100				
1-2-B						100
2-6-C		100				
2-7A						100
2-7						100
2-2-A						100
2-2-B						100
2-4						100
2-3						100
2-1-A						100
2-1-B						100
Total	0.1	40.8	0	1.2	1.7	56.2

Plate 4 shows the soil type subareas.

This table shows that reclaimed surface mine areas make up the majority (56%) of the land use in the drainage area.

The land use for the undisturbed portion of the valley fill drainage area is wooded with a fair hydrologic condition due to its disturbance by previous logging and surface mining activity.

The following table shows the results of the weighted curve number calculations for the post mining condition:


DPF
DPF
CgF
RSM
RSM
KrF
LdE
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RSM
DPF
LdE
RSM
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SCALE: 1" = 1000'

Runoff Subarea	Weighted CN	% Impervious	I_a [IN]
2-Z	67	1.6	0.99
2-Y	66	0	1.03
2-X	67	1.3	0.99
2-W	66	0.1	1.03
2-V	66	0	1.03
2-6-A	64	0	1.13
2-6-B	75	0	0.67
2-6-C	64	0	1.13
2-7A	67	0	0.99
2-7	75	0	0.67
2-2-A	75	0	0.67
2-2-B	75	0	0.67
2-4	75	0	0.67
2-3	75	0	0.67
2-1-A	75	0	0.67
2-1-B	75	0	0.67

Time of Concentration and Lag

The regraded drainage map was used to define the distance for sheet flow. The runoff was considered to have concentrated once it encountered a road or bench and continued to flow downslope to a sediment ditch. The sediment ditches were considered the open channel portion of the flow components.

The following table shows the results of the time of concentration and lag calculations for the post mining condition:

Runoff Subarea	Frequency [YR]			
	10		100	
	Time of Concentration	Lag	Time of Concentration	Lag
	[MIN]			
2-Z	18	11	18	11
2-Y	15	9	15	9
2-X	18	11	17	10
2-W	20	12	20	12
2-V	14	8	14	8
2-6-A	8	5	8	5
2-6-B	14	8	13	8
2-6-C	9	5	9	5
2-7A	7	4	7	4
2-7	23	14	21	12
2-2-A	33	20	30	18
2-2-B	42	25	38	23
2-4	30	18	27	16
2-3	12	7	11	7
2-1-A	27	16	26	15
2-1-B	26	15	23	14

Base Flow

The post mining base flow values were as follows:

Runoff Subarea	Area [MI^2]	Base Flow [CFS]
2-Z	0.08	0.17
2-Y	0.03	0.06
2-X	0.05	0.10
2-W	0.03	0.05
2-V	0.003	0.01
2-6-A	0.01	0.02
2-6-B	0.03	0.06
2-6-C	0.01	0.02
2-7A	0.01	0.02
2-7	0.04	0.07
2-2-A	0.03	0.06
2-2-B	0.08	0.17
2-4	0.02	0.04
2-3	0.04	0.08
2-1-A	0.02	0.03
2-1-B	0.03	0.07

Routing Reaches

The valley fill drainage area was divided into sixteen runoff subareas to model the post mining condition. Twelve reaches connected the runoff subareas and routed the flows through the drainage area.

Two methods of hydrologic routing were used to route the runoff flows through the drainage area. The Lag method was used for channels with slopes greater than 10% (flumes and natural drains); the amount of lag was taken as the average travel time through the reach from the HEC-RAS model. Since these channels have little if any storage they were modeled to translate the flow hydrograph with no attenuation. The Muskingum-Cunge method was used to route the runoff flows through the flatter sloped (2%) sediment and diversion ditches. This method has the advantage over others of using physically based parameters that can be modified to represent changes to the watershed conditions.

HYDROLOGIC AND HYDRAULIC MODEL RESULTS

The HEC-HMS hydrology models were formulated to calculate the outflow from the Valley Fill #2 drainage area at the downstream permit limit.

The HEC-RAS hydraulic model was formulated to calculate the corresponding stages. Survey sections were taken and the undisturbed unnamed tributary channel was modeled. The flows from the HEC-HMS model were used to perform the backwater analysis.

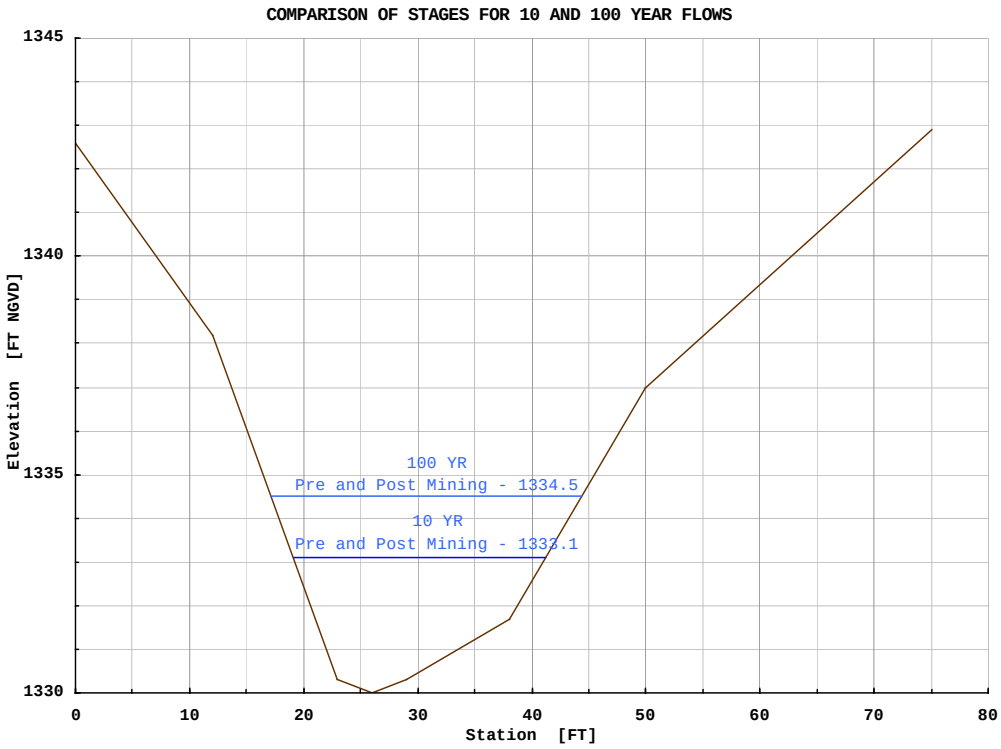
The following table shows the 10 and 100 year flows and water surface elevations:

Frequency [YR]	Pre Mining		Post Mining	
	Flow [CFS]	Elevation [FT NGVD]	Flow [CFS]	Elevation [FT NGVD]
10	293	1333.1	302	1333.1
100	664	1334.5	671	1334.5

YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

These results show a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions.

The following cross section shows comparisons of the water surfaces for each condition.



CONCLUSIONS

1. The SCS, HEC-HMS and HEC-RAS methods are appropriate for computing flows and stages from a valley fill operation.

2. The information typically contained in a permit application is suitable for hydrologic and hydraulic analysis. Some interpretation of the information, aerial photos and maps is required.

3. Required additional information about soil types is available from soil surveys.

4. Field views are required to determine the type and extent of cover for HEC-HMS, to verify drainage routes, etc. The during mining condition produces a very confused runoff system which changes almost daily and must be verified on the ground.

5. Field surveys are required to determine channel size and compute stages in HEC-RAS.

6. Subdivision of the valley fill area by soil type, slopes, etc, is required to model the runoff characteristics of each subarea.

7. The flat slopes created on the top surfaces of the valley fills and the regraded back stacks help to reduce peak flows by increasing the runoff time of concentration. The long flow paths created by sediment ditches help to reduce peak flows by increasing the runoff travel times.

8. Differences in stages are very site specific and may depend on conditions in receiving streams. Stage differences cannot be translated up or down stream away from the computed location and results should not be generalized. Unchanged watershed and channel downstream of a valley fill operation may tend to return stages to the premining condition.

9. This study shows a 3-1% (10-100 YR) increase in discharge from premining conditions after the area is reclaimed in the post mining conditions. There are no stage increases from pre to post mining conditions.

RECOMMENDATIONS

1. The site should be analyzed with a mature growth of trees covering all or part of the drainage area to represent a future condition. Incremental analysis of increasing tree cover should not be undertaken.

2. Valley fill operations should be sized and located to minimize their impacts.

3. Recording streamflow and rainfall gages should be installed and maintained in a valley fill area from before mining begins until after the area is reclaimed. Data logger type streamflow gages should be installed at good hydraulic control points and be set to record at five minute intervals. Tipping bucket type rainfall gages should be located to capture representative rainfall amounts. A formal maintenance and data retrieval/reduction plan should be established. Analysis of actual rainfall/runoff relations should be conducted.

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USGS 7.5 minute topographic maps, Dorothy and Eskdale quadrangles

FATT Responsive Summary

August 6, 2002

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FATT Responsive Summary

The following is the Flood Analysis Technical Team's (FATT) response to comments received by citizens, members of the mining and timbering industries and members of the Flood Investigation Advisory Committee (FIAC).

A. Comments of the Flood Investigation Advisory Committee

The committee was in general support of the conclusions contained in the FATT report. Mining industry representatives on the committee offered several dissenting opinions on the mining recommendations, which are more specifically addressed in FATT's responses to the comments submitted by the West Virginia Coal Association (WVCA). These comments generally involved what was perceived as an overly broad approach, lack of flexibility and the lack of support in the study for the recommendation. FATT disagrees with these comments and cites the depth of research and analysis contained in the study. The majority of the committee members present at the meeting were supportive of the mining recommendations.

Forest industry representatives generally opposed limiting logging activities and FATT's response has been addressed herein. Strong sentiment was voiced by most committee members that most of the forestry impacts noted in this report resulted from poor harvesting practices which highlights the need for additional WVDOF enforcement resources. The committee unanimously supported dedication of additional resources for WVDOF. The technical team concurs with this position.

FIAC suggested and the technical team concurs that the following issues be noted as areas of additional concern:

- The effects of sedimentation and scouring (dynamic effects) from previous flooding.
- The DOF is participating in a 20-state study with the USFS and hopefully this study can include additional research on logging impacts.
- The viability of dredging and damming for improvements in flooding impacts.
- Methods to reduce the margin of error in similar studies.
- Determining the accuracy of rainfall data.
- The beneficial impacts of AOC variances.

The technical team believes that additional efforts by other groups are underway to address the foregoing concerns.

The committee suggested that the report acknowledge the importance of the timbering and mining industry to the state and those employed by both industries. FATT concurs with this sentiment and further emphasizes that the recommendations in this report reduce the potential flood damage threat posed by these industries without drastically interfering with their ability to successfully operate.

Numerous comments from individuals representing environmental and industry factions were received after the end of comment period for the FATT study. The issues presented were evaluated and have been addressed by this responsive summary.

FIAC Comments and FATT Responses

1. FIAC members suggest that a new paragraph be inserted after the introductory paragraph of the FATT conclusion introduction (page 70) which would include the statement that the scope of the flood analysis includes only southern West Virginia.

Response: One goal of the Governor's Executive Order (16-01) and the technical team's mission was to determine "the impact on the flooding from current or past methods of coal mining and timbering practices in the affected counties and watersheds." This assignment was achieved with the choice of watersheds and focused on the storm events of July 8, 2001, which occurred primarily in southern West Virginia. The report also emphasizes that the modeling technique and the findings can be generally extrapolated throughout West Virginia.

2. FIAC members suggest that the report underscore the important role played by the mining and timbering industries in West Virginia's economy.

Response: The members of the technical team recognize the important contribution of the mining and timbering industries to West Virginia's economy.

3. A FIAC member expressed the need for the following concept to be explicitly stated, "If logging increases, then runoff increases."

Response: The evaluation of the hydrologic impacts of logging and/or other disturbances within a watershed cannot be accurately projected in a linear relationship. The determination of industry or urbanization impacts within a watershed can be quite complex. This is due to the differences in modeling parameters such as soil classification, soil physical characteristics, topography, watershed area, watershed orientation, watershed geology and many other site-specific attributes. However, generally speaking, if the acreage of similar land disturbances, such as logging, increases in a watershed, the runoff would be expected to increase.

4. FIAC desires that the FATT study have specific paragraphs rewritten in order to clarify FATT's conclusions to the general public.

Response: FATT has prepared and written the FATT study at a reading and comprehensive level that should be understandable by the general public. Clarity of unusual terms and acronyms were defined wherever needed. However, FATT recognizes that unless the reader has read the entire FATT study, then there will be statements and findings of the study that appear difficult to understand or out of context. This is true of any document or manuscript. Therefore, FATT determined that it is important that all readers read and review the study in the format presented, otherwise ideas can be taken out of context and the implied meaning from specific language can be misunderstood or misinterpreted by the reader.

B. Responses to Forestry Comments

1. The studied watersheds have no rain or stream gaging information. Therefore, the study results are inherently inaccurate and the impacts of logging cannot be determined.

Response: This assertion is unfounded. FATT agrees and has stated that there is no stream gaging within the proximate vicinity of the study watersheds. There were gages located far downstream from the studied watersheds, but such data was not applicable. Therefore, Doppler radar imagery, certified by NOAA, was deemed the most accurate information and was used to assimilate the July 8, 2001, event storm. These rainfall amounts were modeled using the HEC1 program, which is an accepted modeling method to determine watershed runoff responses. The calculated runoff values were verified by using the HEC-RAS model to predict the calculated maximum water elevations. These values were then compared to the corresponding July 8, 2001, surveyed highwater marks in the study watersheds. These differences in water elevation of calculated versus actual values constitute the method used to establish model accuracy for the FATT study.

2. No research shows that logging contributes to overland flow in undisturbed portions of a forest. Therefore, the increases identified in the study are not due to logging.

Response: The technical team's review of relevant literature revealed that significant overland flow does not occur in the undisturbed forest floor. As stated by Dr. Rhett Jackson in his July 12, 2002, response to the technical team, "Most rainfall reaching the forest floor infiltrates, and overland flow occurs only during very intense rainfall events." Overland flow from undisturbed forest floors as discussed is considered flow across the cutting area of tree removal and does not include flow from forest roads, landings, etc.

However, Dr. Jackson further stated in his response that, "In small basins, road runoff can substantially increase peak flows and volumes. If roads are cut into hillside subsoils, road cuts can serve to collect shallow groundwater flow from the hillside above." A study on the Fernow Experimental Forest using West Virginia Best Management Practices (BMPs) found that both growing-season peak flows and total growing-season storm flows increased significantly after logging (Kochenderfer, et al., 1997). This study also found that, five years after cutting, 23.5% of the road areas remained as exposed bare ground.

This phenomenon is shown in pictures #1 and #2, taken of recent West Virginia timber operations during the study. The road cuts usually expose bedrock and are between four and eight feet in height. Flow from the undisturbed forest floor, and fom ephemeral and intermittent stream channels reach these road surfaces and become overland flow. Picture #3 underscores the technical team's observations that although West Virginia BMPs state that skid and truck roads should remove outer berms and outslope to direct runoff to the undisturbed forest floor, this is not a common practice. Roads reviewed during the study had outer berms generally intact and ranging from six inches to 2 feet high. This practice resulted in increased flows from the watersheds studied and the movement of debris to and from stream channels as observed in the flood impacted areas after the July 8, 2001, event.

Picture 1 – Abandoned skid road excavation bisecting both the forest floor and bedrock.

Picture 2 – Abandoned skid road excavation bisecting the forest floor.

Picture 3 – Evidence of flow channelization from forest floor along an abandoned skid road.

When roads/landings do not disperse water to the undisturbed forest floor and are located within the stream management zones, then increases in overland flow can be expected. "Preplanning and having the entire road system laid out carefully on the ground prior to harvesting operations, although not a standard guideline, was probably the single most important procedure for reducing impacts to soil and water resources" (Kochenderfer, et al., 1997). These findings underscore the recommendations made in the FATT study concerning site inspections by the WVDOF. The Kochenderfer study states that the relatively small, although significant, increases in growing-season storm flows were attributed to: 1) a road system that was well laid out; 2) the use of water control structures that effectively dispersed road water; 3) placement of roads, landings and machinery at least 30 meters from streams, except at crossing sites; and 4) minimal soil disturbance and compaction on the logged areas, thereby minimizing overland flow. FATT recommendations 1e, 1f, 1g, and 1h address these issues by increasing site inspections both prior to commencement of operations, during operations, and at the end of operations.

As can be seen in pictures #4 and #5, overland flows on the skid roads completely washed to bedrock, eroded through a waterbar and became overland flow into a nearby stream channel. Although these skid roads were several years old, little evidence of leaves, natural woody debris or any other material remains on the roads, indicating movement by overland flow in what has become a channel. This occurrence was exacerbated by failure to remove the outside road berm and failure to outslope the road. FATT recommendations 1b and 1c prohibiting slash disposal on roads and requiring outsloping (berm removal) were drafted to address these conditions.

Picture 4 – Flow channelization and erosion through a waterbar on a skid road.

Picture 5 – Abandoned skid road with outer berm in place showing erosion to bedrock.

Pictures #6, #7 and #8 show an abandoned landing located next to a perennial stream in violation of the BMP 100-foot stream management zone, although there was clearly sufficient space to place it elsewhere. FATT recommendation 1c addresses this issue with the proposed slash disposal plan. All recommendations address areas of poor harvesting practices as discussed by the FIAC.

Picture 6 – Abandoned log landing site with remaining slash.

Picture 7 – Same landing site showing more areas of slash disposal near perennial stream.

Picture 8 – Same landing site with slash adjacent to perennial stream.

Pictures #9, #10, and #11 show an existing logging operation with a skid road within the stream management zone. The treetops and slash have been placed in the stream and road material from a water bar has also been placed in the stream. Picture #12 shows a timber haul road which had no pipes installed at any stream crossing although they were clearly available on the site.

Picture 9 – Active skid road within stream management zone.

Picture 10 – Same skid road with treetops lying within stream area.

Picture 11 – Treetops and road material deposited within an intermittent stream.

Picture 12 – Uninstalled stream crossing pipes on an active timber haulroad.

3. *Studies show no difference in runoff between large timber operations versus small jobs or based upon percentage of tree removal.*

Response: A 1993 study on the Fernow Experimental Forest showed that harvesting timber increased water yield by an amount roughly proportional to the amount of timber harvested (Hornbeck, et al., 1993). A year 2000 study by Princeton University found significant increases in water yield for four treated watersheds when compared to a control watershed. Although not all years had significantly higher yields, the effects of different timbering treatments took between four and seventeen years to recover (N. Bates, Princeton University, 2000). This same study examined hydrographs of individual storm events and found that clearcut watersheds may take at least 20 years to recover from storm response when compared to a control watershed.

Forestry recommendations 1.a and 1.d of the report were developed with this type of information in mind. Many comments from members of the timbering industry focused on this recommendation out of concern that acreage limits would be imposed on all logging operations. This concern is unfounded. Professional foresters should examine the watershed where their operations occur and recognize that existing disturbances (past logging, fire damage and other land disturbance) can contribute to increased water runoff. They should take these influences into account in development of their operations and should adjust their methods of harvesting by acreage, basal area removed, silvicultural methods or any combination thereof to minimize runoff velocities and channelization of flows. For example, adjusting an operation to reduce the number of roads would, in effect, limit the acreage disturbed.

4. *Peak flows from the FATT study are insignificant and the technical team failed to compare its conclusions to experimental results referenced in scientific literature.*

Response: The FATT study found increases in peak flows ranging from 0 to 5.9 percent. Various studies involving timber harvesting have found peak flow rates of up to 20 percent (Thomas and Megahen 1998, Lewis, et al., 2001), while others ranged from one to seven percent (Beschta, et al., 2000). The technical team's findings compare favorably with results from these previous studies.

FATT disagrees that the quantified peak flow increases are insignificant. The two studied watersheds having logging and mining disturbances, i.e., Seng and Scrabble Creeks, are characterized as steep sloped, high gradient watersheds with minimal cross-sectional stream areas. Such watersheds exhibit a high propensity for out-of-bank flows and resulting impacts from nominal precipitation events. Notably, these are similar characteristics of other small watersheds in southern West Virginia. This study identified that significant land disturbances created from logging or mining operations can exacerbate peak runoff quantities. Any increase in runoff quantity creates concern, particularly for residents living near such streams. For this reason, any increase in peak runoff (> 0%) attributable to logging and/or mining was deemed to be potentially "significant."

C. Responses to Mining Comments

The WVCA provided comments regarding the flood analysis and the proposed rule changes necessary to implement the recommendations. It should be noted that the proposed rules that the WVCA commented upon have now been revised to clarify various issues. These changes are reflected in the errata sheet on page 24.

1. *FATT's position that any contribution to flooding is significant is misleading, is not supported by the report, and is indefensible when other activities being conducted within the watersheds are considered.*

Response: All land disturbances within the study watersheds were considered in the hydrologic modeling. Any measured peak increases must be considered potentially significant due to the restrictive topographical conditions in the watersheds.

2. *The FATT Report and its recommendations ignore the single instance where the technical analysis demonstrated that current interpretation and application of guidelines relating to post-mining land configuration restore a watershed's propensity to flood.*

Response: FATT did not ignore this instance. In fact, the quantified results of the report highlight this fact. Restoring a surface mined area to approximate original contour (AOC) does not necessarily restore the watershed's propensity to flood. Likewise, flattening a mountain and reclaiming the land in a configuration less than AOC doesn't always decrease the watershed's propensity to flood, either. There is more to runoff control than just altering the topography. Consequently, current permitting standards require a surface water runoff analysis (SWROA) to

limit runoff peaks to pre-mining values or less. This is accomplished by constructing attenuation structures to slow the release of precipitation runoff from the permit.

3. *In the context of a 100-year storm event, such as the one experienced on July 8, 2001, the runoff increases attributed to mining as indicated by the Report are insignificant. Any runoff contribution below 20 percent is acceptable.*

Response: This statement is not correct for the studied watersheds. The areas did not experience a 100-year precipitation event. In reality, the peak discharge was calculated to be less than a 25 year/24 hour event. Industry runoff contribution may be "diluted" by larger storm events, i.e., a 100-year storm, but the storm of July 8, 2001, was not of that magnitude. From the model results, the technical team considers the measured effects of mining and logging as valid, quantifiable flow volumes with discernable impacts.

4. *DEP's position of significant impact is not applicable to every contribution of runoff. The State of Washington for example, has established a minimum threshold standard that requires an increase of runoff by 20 percent before any measures are required to address increased flooding potential.*

Response: The technical team did not study the topography of the State of Washington or its statutory/regulatory structure pertaining to flood control. Also, the team did not study the regulatory schemes or topographic characteristics of any other states. Given West Virginia's steep slope topography with narrow inhabited hollows and the technical team's observed effects in the studied watersheds, imposing a twenty percent standard before finding potential significance would be ill-advised.

5. *FATT was charged by Executive Order 16-01 to investigate alternative mining or forestry practices if such current practices are found to have had a deleterious impact on peak flows in affected watersheds, but instead ignored this charge.*

Response: FATT did not ignore this charge. Alternative mining and forestry practices are discussed at length in the FATT report on pages 71-73. Many of the stated recommendations represent alternative mining and forestry practices as a result of this study.

6. *The WVCA charges that several of the changes made from the draft to the final version are quite interesting and warrant reference*

Response: There should be no surprise that the final version of the report varies from an earlier draft. The narrative was edited until it accurately reflected the analysis and recommendations of the team.

7. *The technical team should have made more of the reference to the beneficial effect that a variance to AOC can provide relating to runoff attenuation.*

Response: This point needs little clarification. Coal must be mined in a lawful manner. The federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) established that

AOC shall be the rule, with an AOC variance being the exception. West Virginia, under SMCRA's primacy provision, cannot violate this requirement. Consequently, it was not the technical team's intention or charge to exclude one mining method over another, e.g., AOC versus AOC variance. Regardless of the chosen mining method, a storm water runoff analysis is required to assure that runoff from mining operations will produce no net increase in runoff when compared to the pre-mining watershed condition. The permit applicant chooses their mining method, not WVDEP.

8. *The WVCA was critical of the technical team's concluding statement that, "…mining and timbering impacts did influence the study watersheds by increasing surface water runoff and the resulting stream flows at various evaluation points."*

Response: The technical team made this statement to highlight the fact that runoff impact assessment was discernable only at the studied evaluation points within the study watersheds. This statement was never intended to mislead, but was presented to clarify the conclusion from a hydrologic standpoint. Flows at every point along the streams were not quantified. From a hydrologic viewpoint, this statement was to preface the conclusion within the context of the modeling procedure.

D. Comments on Proposed Mining Rule Changes

(Note: Underscore denotes proposed changes in regulations. The attached errata sheet presents the most recent revisions to the proposed changes and additions.)

1. *The coal industry opposes Recommendation 2.c., which states, "Revise regulations to require the condition of the total watershed be reviewed prior to any approved placement of excess spoil material. Conditions that should be considered include the proximity of residents, structures, etc., to excess spoil structure." They also oppose the associated rule change. The re-drafted rule states:*

   3.7.d. A survey of the watershed identifying all man-made structures and residents in proximity to the disposal area to determine potential storm runoff impacts. At least thirty (30) days prior to any beginning of placement of material, the accuracy of the survey shall be field verified. Any changes shall be documented and brought to the attention of the Secretary.

   The coal industry contends that this recommendation and rule change is too broad. They question the meaning of "watershed" in this context.

Response: The technical team intended that the downstream consequences be determined for areas immediately downstream of any excess spoil disposal area. Currently this type of survey is part of the SWROA. This survey is useful to both the permittee and the agency for siting purposes relative to excess spoil disposal sites.

The intent of this rule change was to assign greater significance to a disposal area if residents and man-made structures are downstream and in near proximity to the disposal site. In

this context, "watershed" would primarily indicate the immediate watershed where the fill is located. However, under certain circumstances, the Agency may require a larger survey area to account for downstream residents. Each excess disposal facility design has to be site-specific, but should utilize a siting evaluation, in addition to a SWROA, to minimize all potential runoff impacts.

2. *The coal industry opposes Recommendation 2.d., which states, "Revise regulations to require that valley fill designs minimize erosion within the watershed during precipitation. The permittee shall consider the total disturbance of the disposal area." The associated rule change is:*

   5.4.b.4. Have the capacity to store 0.125 Acre/ft. of sediment for each acre of disturbed area in the structures watershed; provided, that consideration may be given for reduced storage volume where the preplan and site conditions reflect controlled placement, concurrent reclamation practices, or use of sediment control structures; provided further, that reduced storage volume will be approved only where the operator demonstrates that the effluent limitations of subdivision 14.5.b of this rule will be met. The disturbed area for which the structure is to be designed will include all land affected by previous surface mining operations that are not presently stabilized and all land that will be disturbed throughout the life of the permit. <u>All sediment control for valley fills, including durable rock fills, shall be designed for the entire disturbed acreage associated with the watershed of the fill and shall take into account the length of time the area is to be disturbed.</u>

   The coal industry contends that such a restriction would increase stream disturbance, contradict the Clean Water Act, and establish a broad, "cookbook" approach to design standards.

<u>Response</u>: The technical team disagrees with this extreme view of possible consequences. This rule change will enhance the effectiveness of sediment control, which will likely decrease stream degradation. Further, this requirement compliments the SWROA requirements and the necessary designs to assure no increase in peak flows. In no way does the proposed rule prohibit on-bench drainage. It only serves to assure effective sediment control for fills, assuming worst-case design standards. The current practice of this agency is to not allow reduced factors for sediment control for fills. This change is to clearly state that full-factor ponds are required for fills and the engineering must accommodate for long-term exposure. The SWROA requirements, when combined with this rule, will result in more effective sediment control for excess spoil disposal facilities while insuring sufficient runoff attenuation.

3. *The coal industry presents opposition to the following recommendation and rule change: Recommendation 1.a.- Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions. Recommendation 1.b.- Revise regulations so that the post-mining drainage design of all existing and future mining permits corresponds with the permitted post-mining land configuration. The rule as changed would read as follows:*

5.4.b.11. Control discharge by use of energy dissipaters, riprap channels or other devices to reduce erosion, to prevent deepening or enlargement of stream channels and to minimize disturbance of the hydrologic balance. Discharge structures shall be designed using standard engineering procedures. The location of discharge points and the volume to be released shall not cause a net increase in runoff in a watershed when compared to pre-mining conditions and shall be compatible with the post-mining configuration and adequately address watershed transfer.

Response: DEP's goal is to codify the SWROA requirements. This rule change is necessary to assure that mining operations will not exacerbate peak runoff volumes. The intent of this rule change is to apply SWROA to all permits, i.e., existing, pending and future. FATT anticipates that pending and future permits will not be difficult to address. However, the team recognizes that existing permits are more varied in nature. In actuality, existing permits can be categorized as not-started, inactive-disturbed, inactive-undisturbed, on-going operations and reclaimed. The technical team recognizes that historically permits that have been reclaimed to Phase I bond release standards and have also been revegetated have not experienced significant runoff problems. Therefore, the technical team will exclude reclaimed and revegetated permits from this requirement. For all other types of existing permits, a SWROA analysis will be required to demonstrate compliance with this proposed rule change. Accordingly, WVDEP is willing to exempt from the SWROA requirements those permits, or portions thereof, having achieved Phase I bond release standards and have been revegetated.

4. *The coal industry opposes the following recommendation, claiming that the existing associated rule (§8.2.e.) is adequate.*

Recommendation 2.f. states, "Revise regulations to prohibit placement of windrowed material in areas that encroach into natural drainageways."

Response: This comment is unfounded. Based upon numerous field observations by WVDEP inspectors and citizens, hydraulic transport of woody debris is a common occurrence that can cause debris blockages and resulting backwater flows. This recommendation and associated rule change will assure that windrowed materials are not placed within the immediate vicinity of a watercourse where they can be mobilized during heavy precipitation events.

5. *The coal industry opposes the following recommendation and associated rule:*

Recommendation 2.e. Revise regulations to prohibit "wing dumping" of spoil in excess spoil disposal structures.

14.14.a.8. All material placement into valley fills including durable rock fills must occur over the developing face or mechanically placed in lifts down the centerline of the valley. Under no circumstances shall material be placed in fills from the sides of the valley.

Response: Based upon field observations and experience, wing dumping and/or cast blasting into the hollow downstream of the advancing fill toe creates a condition where the fill is

highly vulnerable to erosion. Also, such areas can increase surface runoff from precipitation events. The elimination of this mining practice, in addition to bottom-up fill construction, will ensure that excessive erosion and runoff will be minimized from excess spoil disposal activities. It should be noted that WVDEP has never acknowledged any necessity for wing dumping, although the Agency has allowed its use. Even with the limits imposed by the wing dumping policy (November 13, 1992), increased sediment loads upon the sediment control structures have occurred. This proposal does not impact side-hill fill construction.

6. *The coal industry objects to the recommendation and associated rule change limiting durable rock fill construction to bottom up techniques. The recommendation and rule are as follows:*

Recommendation 2.b. Revise regulations to require durable rock fills be limited to "bottom up or incremental lift construction" methods for enhanced runoff and sediment control.

14.14.g.9 The durable rock fill shall be constructed in lifts from the toe upwards. The design plans and specifications shall specify the thickness of the lifts. The permittee shall provide certification from a registered professional engineer that such thickness will insure stability and meet all safety and environmental protection standards.

Response: Based upon field observations and experience, the technical team drafted this limitation upon construction techniques for excess spoil disposal facilities. The following photos show a recent occurrence of excessive erosion from an end-dumped durable rock fill at Lyburn in Logan County. Clearly, a heavy storm event caused a marked increase of erosion of a durable rock fill and ultimately overwhelmed the sediment control structure. Refer to Pictures #13 and #14.

Picture 13 – Lyburn durable rock fill showing face erosion.

Picture 14 – Hydraulic transport of the face material within toe area.

The requirement to construct valley fills from the bottom up will complement the prohibition of wing dumping. In some areas, minimal fill volumes and/or watershed confines could present challenges for siting fills. Because of space limitations and equipment grade requirements, a road constructed by "dumping" to the toe area might not be possible along the centerline of the hollow. However, alternate design methods for toe access roads could be implemented. In limited situations, a fill might have to be located in a different watershed more conducive to bottom up construction.

7. *The coal industry opposes Recommendations 1.a., 1.c., 2.g., and 2.i.,which include requirements to install, operate and maintain rain gages at all mine sites. Other recommendations include SWROA implementation and limits on areas to be cleared/grubbed within excess spoil disposal areas.*

Response: WVDEP proposes to codify the SWROA Guidelines in an effort to enhance the hydrologic reclamation plan.

Rain gauges are currently required by NPDES within three miles of the site. However, such placement may not be near the watershed associated with the closest fill site. This data is important to determine SWROA functionality and should be part of the permit and agency records. Moreover, it is important during a heavy precipitation event to recognize the possibility of impacts and the need to initiate drainage system reconnaissance to repair damage and further address offsite impacts.

A contention by the industry is that limiting clearing/grubbing conflicts with bottom up fill construction. For bottom up construction, the entire fill area will require clearing of all significant vegetation. However, the critical foundation area beneath the fill is required to be grubbed, which means cleared of vegetation, including root balls. Historically, these types of disturbances have produced fewer sedimentation/erosion problems than end-dumped fill construction techniques. By requiring bottom up construction or incremental lift construction and full-factor sediment control designed for the entire fill, the overall sediment contribution downstream of the activity will be minimized when compared to current practices.

8. *The coal industry opposes the regulatory revision requiring that each application for a permit contain a sediment retention plan to emphasize runoff control and minimize downstream sediment deposition during precipitation events, claiming that such change is duplicative and that the study results do not support the regulatory change. The industry also questions the selection of .30 inches per hour as "heavy precipitation event" as referenced in the proposed rule change. The proposed rule states:*

5.6.c. Each application for a permit shall contain a sediment retention plan to minimize downstream sediment deposition within the watershed resulting from heavy precipitation events (over 0.30 inch per hour). Sediment retentions plans may include decant ponds, secondary control structures, increased frequency for cleaning out sediment control structures, or other methods approved by the Secretary.

Response: The technical team proposes to codify the SWROA guidelines in an effort to enhance the hydrologic reclamation plan. The results of the report clearly support this recommendation. The flood analysis and attendant conclusions were based upon both quantitative and observed conclusions. The modeling results support the finding that mining disturbances in the studied watersheds increased peak runoff volumes. From on-ground observations of the study watersheds, it was evident that sediment was conveyed beyond the sediment structures. Moreover, based upon observations of excess spoil areas beyond the studied watersheds, it is evident that the .125 sediment volume standard alone may be insufficient to prevent off-site damage if adequate runoff controls are not implemented. Pictures #15 and #16 are examples of what the Agency is attempting to prevent with these recommendations and rule changes.

Picture 15 – Face erosion that flowed through the sediment pond and down Lyburn Hollow.

Picture 16 – Lyburn Hollow community immediately downstream of the eroded end-dumped valley fill.

The intent of the recommendation and rule is for the sediment plan to complement the SWROA. The designs are interrelated, so both the overall performance and function are integral to accomplish effective water quality/quantity control. It should be noted that WVDEP adopted the 0.30 inch per hour precipitation threshold value because this standard is used by the National Oceanic Atmospheric Administration (NOAA) to classify rainfall intensity. The 0.30 inch per hour precipitation rate, or greater, is defined as a heavy rainfall event by NOAA.

9. *The coal industry opposes the following recommendation and rule because they are perceived to be too inclusive. The industry also objects to retroactive application of new mining and reclamation standards. The recommendation and rule change are as follows:*

Recommendation 1.a. Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions.

5.6.d. After the first day of January two thousand three all active mining operations must be consistent with the requirements of this subdivision. The permittee must demonstrate in writing that the operation is in compliance or a revision shall be prepared and submitted to the Secretary for approval within 180 days. Full compliance with the permit revision shall be accomplished within 180 days from the date of the Secretary approval.

Response: The technical team's intent is to obtain an evaluation of all hydrologic reclamation plans to assure that no increase in surface water discharge will result when compared to pre-mining conditions. As previously stated, a SWROA will not be required for existing operations that have obtained at least a Phase I bond release and are vegetated. In addition, the Agency will consider excluding portions of existing permits from the SWROA requirement that are vegetated and qualify for Phase I release.

10. The coal industry questions Recommendation 2.h. and states that OSM will likely oppose the technical team's attempt to maximize reforestation opportunities.

Response: This statement is unfounded. The proposed change to maximize reforestation opportunities does not violate the federal Office of Surface Mining's "no less effective" primacy clause. By this recommendation and associated rule change, the Agency does not intend to reject previously approved post-mining landuses, but recommends that areas not directly associated with a chosen landuse be reforested. The coal industry has indicated it is uncertain whether trees are superior to grasses in minimizing erosion and sediment problems and claims that bonds releases will likely be delayed while trying to meet tree survival standards. The intent is for trees to complement chosen post-mining landuses, not replace them.

ERRATA SHEET – PROPOSED RULE CHANGES

The following changes reflect comments that were received from both the public and FIAC. Most of the changes are made to provide clarity to the proposed rule and do not represent substantive changes.

Page 1, Item 3.7.d.

This item should state, "…storm runoff impacts **and siting considerations**." ADDED FOR CLARITY

Page 1, Item 5.4.b.4.

This item should state, "…for the entire disturbed fill acreage **contained** within the watershed…" ADDED FOR CLARITY

Page 1, Item 5.4.b.11.

This item should state, "… the post-mining configuration and **prevent watershed transfer.**" ADDED FOR CLARITY

Page 2, Item 14.14.a.8.

This item should state, "…durable rock fill must occur **in conjunction with** the developing…" and also "…from the sides of the valley **ahead of the actively developing face**." ADDED FOR CLARITY

Page 2, Item 14.14.g.9.

This item should state, "The durable rock fill shall be **designed and** constructed **from the bottom upwards with the face benches and drainage constructed progressively** from the toe upwards **or in lifts from the toe upwards**. The design plans and specifications shall specify the thickness of the lifts. **Provided, however, the lifts cannot exceed 100 feet in thickness.** The permittee shall provide certification from a registered professional engineer that such **design** will insure stability, **proper drainage** and meet all safety and environmental protection standards." ADDED FOR CLARITY

Page 4, Item 5.6.d.

This item should state, "After the first day of **October** two thousand **two**…" and should add "…date of the Secretary approval. **Active mining operations for the purpose of this subsection excludes permits that have obtained at least a Phase I release and are**

vegetated. Provided, however, permits or portions of permits that meet at least Phase I standards and are vegetated will be considered on a case by case basis." ADDED TO IDENTIFY THE AFFECTED PERMITS

ERRATA SHEET - FATT ANALYSIS

Page 73, Item B.1.b.

This item should state, "Revise BMPs to prohibit the use of lopped slash as a supplement for seeding on skid roads…"

Page 73, Item B.1.h.

This item should include landowners and state, "…increased technical assistance to timber operators and landowners…"

Page 73, Item C.

The FIAC recommends that the following two items be included:

- Sedimentation issues and their associated downstream effects.
- Scouring effects and the dynamics associated with repeated flooding making an area more flood prone. Possible remedial actions of dredging , floodwalls, stream bank restoration, etc., may lessen these dynamic effects.

WVDEP Proposed Rule Changes

Recommendation 2.c. Revise regulations to require the condition of the total watershed be reviewed prior to any approved placement of excess spoil material. Conditions that should be considered include the proximity of residents, structures, etc., to excess spoil structure.

3.7.d. A survey of the watershed identifying all man made structures and residents in proximity to the disposal area to determine potential storm runoff impacts and siting considerations. At least thirty (30) days prior to any beginning of placement of material, the accuracy of the survey shall be field verified. Any changes shall be documented and brought to the attention of the Secretary.

Recommendation 2.d. Revise regulations to require that valley fill designs minimize erosion within the watershed during precipitation. The permittee shall consider the total disturbance of the disposal area.

5.4.b.4. Have the capacity to store 0.125 Acre/ft. of sediment for each acre of disturbed area in the structures watershed; provided, that consideration may be given for reduced storage volume where the preplan and site conditions reflect controlled placement, concurrent reclamation practices, or use of sediment control structures; provided further, that reduced storage volume will be approved only where the operator demonstrates that the effluent limitations of subdivision 14.5.b of this rule will be met. The disturbed area for which the structure is to be designed will include all land affected by previous surface mining operations that are not presently stabilized and all land that will be disturbed throughout the life of the permit. All sediment control for valley fills, including durable rock fills, shall be designed for the entire disturbed fill acreage contained within the watershed of the fill and shall take into account the length of time the area is to be disturbed.

Recommendation 1.a. Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions.

Recommendation 1.b. Revise regulations so that the post-mining drainage design of all existing and future mining permits corresponds with the permitted post-mining land configuration.

5.4.b.11. Control discharge by use of energy dissipaters, riprap channels or other devices to reduce erosion, to prevent deepening or enlargement of stream channels and to minimize disturbance of the hydrologic balance. Discharge structures shall be designed using standard engineering procedures. The location of discharge points and the volume to be released shall not cause a net increase in runoff in a watershed when compared to pre-mining conditions and shall be compatible with the post-mining configuration and prevent watershed transfer.

Recommendation 2.f. Revise regulations to prohibit placement of windrowed material in areas that encroach into natural drainageways.

8.2.e. In order to promote the enhancement of food, shelter and habitat for wildlife, the practice of creating a timber windrow is encouraged. All unmarketable timber may be used to create a windrow within the permitted area as approved by the Secretary in the mining and reclamation plan. The windrow shall be designed and approved as part of a wildlife planting plan and authorized where the postmining land use includes wildlife habitat. In planning and constructing the windrow, care shall be taken not to impound water or and shall not be placed in such manner or location to block natural drainways. The windrow shall be placed in a uniform and workmanlike parallel line and located so as to improve habitat, food and shelter for wildlife. Areas in and around the windrow shall be seeded after construction with approved, native plant species to provide for erosion control and wildlife enhancement. Construction of the wildlife timber windrow shall take place within the permit area and should be placed immediately below or adjacent to the sediment control system, maintaining a sufficient distance to prevent mixing of spoil material with the selectively placed timber. The placement of spoil material, debris, abandoned equipment, root balls and other undesirable material in the windrow are prohibited.

Recommendation 2.e. Revise regulations to prohibit "wing dumping" of spoil in excess spoil disposal structures

14.14.a.8. All material placement into valley fills including durable rock fills must occur in conjunction with the developing face or be mechanically placed in lifts down the centerline of the valley. Under no circumstances shall material be placed in fills from the sides of the valley ahead of the actively developing face.

Recommendation 2.b. Revise regulations to require durable rock fills be limited to "bottom up or incremental lift construction" methods for enhanced runoff and sediment control.

14.14.g.9 The durable rock fill shall be designed and constructed from the bottom upwards with the face benches and drainage constructed progressively from the toe upwards or in lifts from the toe upwards. The design plans and specifications shall specify the thickness of the lifts. Provided, however, the lifts cannot exceed 100 feet in thickness. The permittee shall provide certification from a registered professional engineer that such design will insure stability, proper drainage and meet all safety and environmental protection standards.

Recommendation 1.a. Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions.

Recommendation 2.g. Revise regulations to limit areas allowed for clearing/grubbing of operations in excess spoil disposal areas.

5.6 Storm Water Runoff

5.6.a. Each application for a permit shall contain a storm water runoff analysis which includes the following:

5.6.a.1. An analysis showing the changes in storm runoff caused by the proposed operation(s) using standard engineering and hydrologic practices and assumptions.

5.6.a.2. The analysis will evaluate pre-mining, worst case during mining, and post-mining (Phase III standards) conditions. The storm used for the analysis will be the largest required design storm for any sediment control or other water retention structure proposed in the application. The analysis must take into account all allowable operational clearing and grubbing activities. The evaluation points will be selected on a case-by case basis depending on site specific conditions including, but not limited to, type of operation and proximity of man-made structures.

5.6.a.3 The worst case during mining and post- mining evaluations must show no net increase in runoff compared to the pre-mining evaluation.

Recommendation 2.i. Revise regulations to require rain gages be located on all mine sites and that monitoring and reporting schedules be developed.

5.6.b. Each application for a permit shall contain a runoff-monitoring plan which shall include, but is not limited to, the installation and maintenance of rain gages. The plan shall be specific to local conditions. All operations must record daily precipitation and report monitoring results on a monthly basis and any event of one (1) inch or greater must be reported to the Secretary within twenty-four (24) hours and shall include the results of a permit wide drainage system survey.

Recommendation 2.a. Revise regulations to require that each application for a permit contain a sediment retention plan to emphasize runoff control and minimize downstream sediment deposition during precipitation events.

5.6.c. Each application for a permit shall contain a sediment retention plan to minimize downstream sediment deposition within the watershed resulting from heavy precipitation events (over 0.30 inch per hour). Sediment retentions plans may include decant ponds,

secondary control structures, increased frequency for cleaning out sediment control structures, or other methods approved by the Secretary.

Recommendation 1.a. Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions.

5.6.d. After the first day of October two thousand two all active mining operations must comply with the requirements of this subdivision. The permittee must demonstrate in writing that the operation is in compliance or a revision shall be prepared and submitted to the Secretary for approval within 180 days. Full compliance with the permit revision shall be accomplished within 180 days from the date of the Secretary approval. Active mining operations for the purpose of this subsection excludes permits that have obtained at least a Phase I release and are vegetated. Provided, however, permits or portions of permits that meet at least Phase I standards and are vegetated will be considered on a case by case basis.

Recommendation 2.h. Revise regulations to maximize reforestation opportunities for all types of post mining land uses.

9.1.a. Each surface mine operator shall establish on all regraded areas and all other disturbed areas a diverse, effective and permanent vegetative cover of the same seasonal variety native to the area of disturbed land, or introduced species that are compatible with the approved postmining land use. Reforestation opportunities must be maximized for all areas not directly associated with the primary approved post mining land use. All revegetation plans must include a map identifying areas to be reforested, planting schedule and stocking rates.

Recommendation 1.c. Revise regulations to enhance contemporaneous reclamation requirements to further reduce surface water runoff.

14.15.a.2. All permit applications shall incorporate into the required mining and reclamation plan a detailed site specific description of the timing, sequence, and areal extent of each progressive phase of the mining and reclamation operation which reflects how the mining operations and the reclamation operations will be coordinated so as to minimize the amount of disturbed, unreclaimed area, minimize surface water runoff, comply with the storm water runoff plan and to quickly establish and maintain a specified ratio of disturbed versus reclaimed area throughout the life of the operation.

14.15.c. Reclaimed Area. For purposes of this subsection, reclaimed acreage shall be that portion of the permit area which has at a minimum been fully regraded and stabilized in accordance with the reclamation plan, ~~and~~ meets Phase I standards and seeding has occurred. The following shall not be included in the calculation of disturbed area

14.15.g. Variance – Permit Applications. The Secretary may grant approval of a mining and reclamation plan for a permit which seeks a variance to one or more of the standards set forth in this subsection, if on the basis of site specific conditions and sound scientific and/or engineering data, the applicant can demonstrate that compliance with one or more of these standards is not technologically or economically feasible and demonstrate that the variance being sought will comply with section 5.6 of this rule. The Secretary shall make written findings in accordance with the applicable provisions of section 3.32 of this rule when granting or denying a request for variance under this section.

Instructions for obtaining part 3

To obtain part three of this study go to:

http://www.dep.state.wv.us/part%20III.pdf

Flood Advisory Technical Taskforce

Runoff Analyses of Seng, Scrabble, and Sycamore Creeks

June 14, 2002

EXECUTIVE SUMMARY

Background

The Flood Analysis Technical Team (FATT) in conjunction with the Flood Investigative Advisory Committee, both enacted by Governor's Executive Order No. 16-01, performed an investigation evaluating the hydrological aspects of the May and July, 2001, floods in southern West Virginia. The investigation focused on possible flooding impacts from logging and mining activities.

Model Development

The study concentrated on peak discharge runoff using comparative analyses. The results reached in this report provide an indication of the impacts of mining and logging practices and the consequent behavior of the watershed throughout the July 8, 2001, storm event.

Watershed Selection

Selection requirements for the study watersheds were based upon acreage, occurrence of flooding impacts, and industry intervention, i.e., logging and mining disturbances. Choosing watersheds of limited size reduced the complexity of the study, and more importantly, the time to completion. Study sites were required to have experienced flooding impacts from the July 8, 2001, event. Finally, to satisfy the executive order, logging and mining influences had to be present and quantifiable. From this selection process, Seng Creek in Boone County, Scrabble Creek in Fayette County, and Sycamore Creek in Raleigh County were chosen. Seng Creek and Scrabble Creek were analyzed using runoff comparison methods. Sycamore Creek, which had no significant logging and mining disturbances, served only as a perspective watershed.

Project Conclusion

Based upon the modeling results, mining and logging did influence the degree of runoff in the study watersheds. Seng Creek had mining impacts (measured in runoff volume – ft^3/sec.) ranging from -0.2% to 3.0% and logging impacts ranging from 3.9% to 5.9% at the various evaluation points. Scrabble Creek had mining impacts ranging from 9.3% to 21.1%, while logging impacts ranged from 0% to 4% at its evaluation points. With negligible logging and mining disturbances, Sycamore Creek experienced "out-of-bank" flows with extensive surface water impacts.

Recommendations to Reduce Flooding Impacts from Mining and Logging

Recommendations are proposed to minimize and limit runoff peaks from future logging and mining operations. These recommendations focus primarily on improvements relative to the following watershed characteristics:

- Terrain characteristics and slope of natural undisturbed ground
- Type of mining activity, e.g., Approximate Original Contour vs. Variance
- Extent of mining
- Degree of reclamation
- Extent and type of logging activity
- Degree of post-timbering regrowth

FATT Runoff Analyses

PART I

Project Narrative

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PART II

Data Input and Results Summary

PART III

FATT Project Analyses **(Refer to the attached CD)**

I. INTRODUCTION

On July 8, 2001, the southern portion of West Virginia experienced major precipitation events with rainfall totals that ranged up to 6.77 inches south of Beckley in Raleigh County. The result was disastrous flooding throughout the southern coalfields that devastated many communities causing widespread property damage. Many hundreds of homes were damaged or destroyed, as were many businesses. Counties particularly hard hit were Boone, Doddridge, Raleigh, Fayette, McDowell, Mercer, Summers and Wyoming. Most of these counties are in the heart of West Virginia's southern coalfields and have extensive underground and surface mining activities. Timbering is also prevalent in this region of the State. This region also experienced other substantial, yet more localized, flooding events in May, 2001, and on July 25, 2001. In the aftermath of these events there were many concerns raised by the public and other entities as to the extent that mining and timbering activities may have exacerbated flood damage. Consequently, Governor Bob Wise issued Executive Order No. 16-01 creating a Flood Investigation Advisory Committee and a Flood Analysis Technical Team to focus specifically on the impacts of the mining and timbering industry on the July 8th flooding.

II. OBJECTIVES AND COMMITTEE MISSIONS

The overall objective of the Governor's executive order and this undertaking is to investigate the scientific and hydrologic cause of the flooding events which occurred in May and July, 2001, and to further assess the impact on flooding from current and past methods of coal mining and timbering in the affected counties and watersheds.

The Flood Analysis Technical Team (FATT) is comprised of professionals within the Department of Environmental Protection (DEP), Division of Mining and Reclamation (DMR) and operates under the general guidance of the Director of DMR. Members of the technical team include: Jim Pierce, Mike Reese, John Vernon, John Ailes, and Ed Griffith. The Technical Team was given the mission to prepare a report for the Secretary of DEP addressing the cause of the floods of May and July 2001, and specifically tasked with the following duties:

- Provide technical assistance and research support to the Secretary
- Investigate alternative mining or forestry practices if such current practices are found to have had a deleterious impact on peak water flows in affected watersheds
- Propose recommendations to the Secretary of the Department of Environmental Protection

The Flood Investigation Advisory Committee was created through the executive order and consists of not less than sixteen members, twelve of which were appointed from the public. The Secretary of the DEP and the Administrator of the Division of Forestry or their designees serve in an ex-officio capacity. The Advisory Committee was assigned the following duties:

- Assist and support the investigation of the scientific and hydrologic cause for the flooding of May and July 2001
- Assist in the determination of the effect and, if any be found, the impact on the flooding from current or past methods of coal mining and timbering practices in the affected counties and watersheds
- Provide assistance to the Flood Analysis Technical Team
- Retain or hire such hydrological, forestry, mining, or meteorological experts, as it deems necessary to assist it in reviewing any draft technical assessment prepared by the Flood Analysis Technical Team
- All such other general powers deemed necessary and proper to assist it in carrying out its particular duties under Executive Order No. 16-01

III. WATERSHED ANALYSIS METHODOLOGY

A. Introduction

Immediately after the July 8, 2001, floods, DEP initiated reconnaissance investigations of all mining and mining related sites located in the southern counties of West Virginia that had been impacted by the July 8, 2001, flood event. In addition to documenting the flood damage and high-water marks, DEP contacted the following agencies and obtained pertinent information concerning the July 8, 2001, storm event:

- National Oceanic and Atmospheric Administration (NOAA)
- National Weather Service (NWS)
- U.S. Army Corps of Engineer – Huntington District (COE)
- Office of Surface Mining Reclamation and Enforcement (OSM)
- United States Geological Survey (USGS)
- United States Department of Agricultural (USDA) Natural Resources Conservation Service (NRCS)

DEP contacted the NWS and was informed that there were three separate storm events that entered the southern counties of West Virginia and caused the flooding of July 8, 2001. The unofficial, non-certified, precipitation measurements that had been gathered by NWS for the July 8, 2001, storms are shown in Table 1.

NWS noted that prior to the flood event of the July 8, 2001, rivers and small streams were at normal to slightly below normal flows. Antecedent soil conditions in the region were normal to dry. This information was verified by DEP communications with the COE, USGS, and NRCS West Virginia offices.

The NWS county flash flood guidance values for Boone, Fayette, Kanawha, McDowell, Raleigh, and Wyoming, from the morning of July 8, 2001, ranged from 1.8 to 2.9 inches of rain. These guidance values are the precipitation amounts that would cause flooding problems in three hours. Some rainfall amounts generated by the storm events exceeded, or were just under the rainfall total.

The COE, Huntington District, provided to the DEP a precipitation comparison chart of storm events for the Huntington district that included the counties of southern West Virginia. This precipitation data was from NWS cooperative observers and NWS stations, COE project gages, and satellite gages. The COE noted that some of the precipitation data was not verified and the flooding had impacted some gages and these values could not be verified. (Table 2).

The West Virginia Geological Survey and the USGS provided to the DEP provisional recurrence intervals of locations flooded by the July 8, 2001, storm event. (Table 3). They also informed DEP of their efforts to determine the peak discharges of the streams on July 8, 2001, where the flooding had compromised or destroyed their stream gaging stations.

Probably the most misunderstood term with regard to flooding or storm events is recurrence interval. The recurrence interval of a flood or storm is defined as the average number of years between a flood or storm event of a given magnitude and any equal or larger flood or storm event. For example, over a time period of a thousand years, the ten-year flood or storm event would be the flood or storm event which was equaled to or exceeded one hundred times, or an average interval of ten years. Some people erroneously believe that if a one hundred-year flood or storm event occurs this year, it will be a hundred years before another flood or storm event as large or larger occurs. Unfortunately this is not true. If a one hundred-year flood or storm event occurs this year, a larger flood or storm event may occur next year and a still larger flood or storm event the next. The point to remember is that the recurrence interval for flood or storm event is based on a statistical average of events that have occurred, not on advance knowledge of what will occur.

B. Determination of Watershed Study Areas

The first task assigned to FATT was to determine which watersheds to analyze. FATT determined that three watersheds that had been impacted by flooding should be studied. Of these three watersheds, two had to be representative of flood-impacted watersheds that contained surface coal mining and logging operations. The third watershed would be a watershed with no mining or logging operations within the last 10 – 20 years.

FATT determined from the beginning that the hydrologic modeling of the watersheds would be of same or similar types in order to obtain accuracy in the model similitude. This was to be achieved by comparing the watershed characteristics and only model the watersheds that were the same or similar in characteristics. The characteristics used to determine which watersheds to model were:

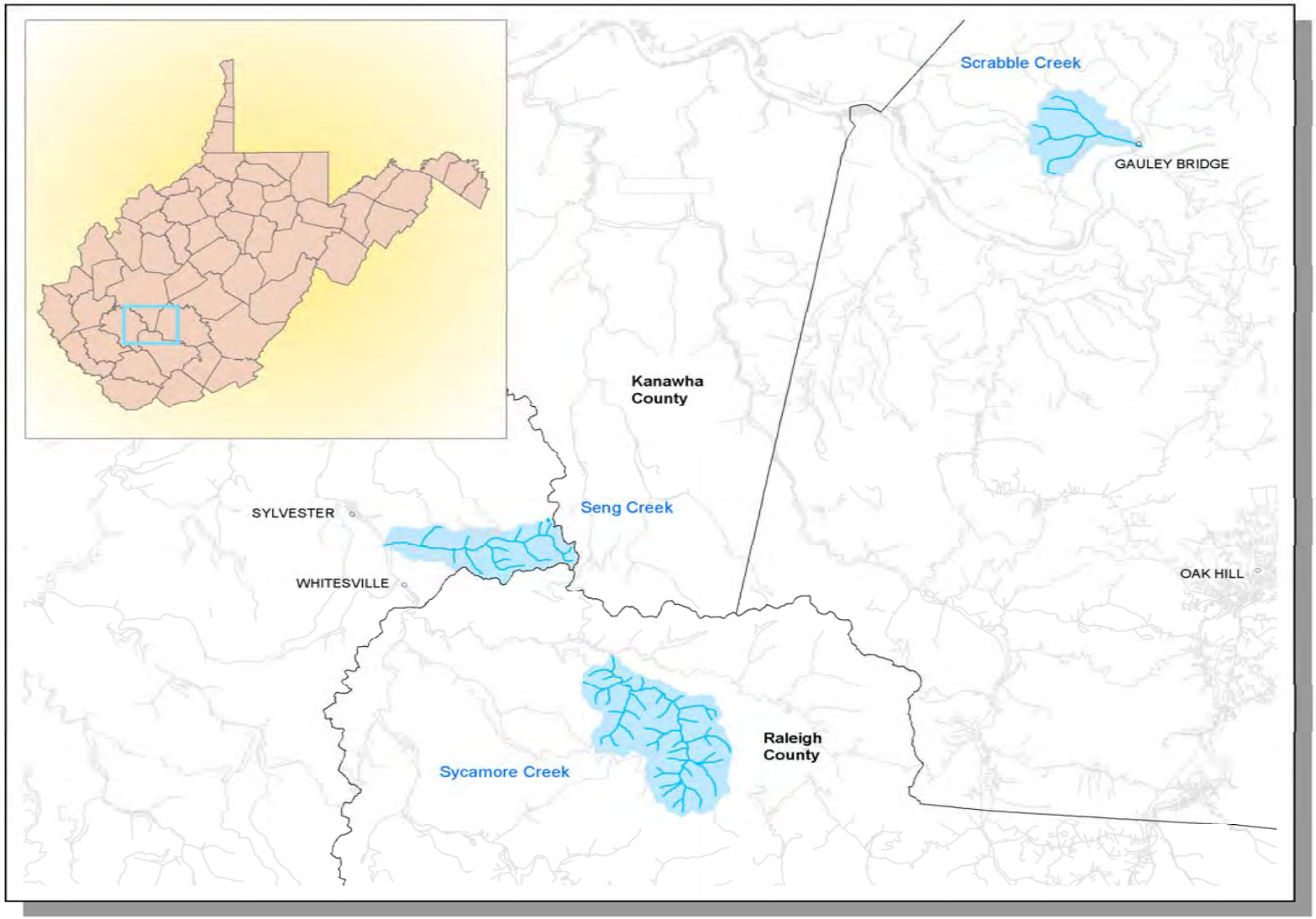
- Area or size (less than 5,000 acres)
- Topography (elevation and slope)
- Climate
- Meteorological event
- Vegetation type and density
- Soil type, soil depth, moisture content
- Watershed morphology and geomorphology
- Land use (urbanization, mining, logging, forest, etc.)
- Stream flood plain and floodway dimensions
- Stream profile
- Geology
- Stream roughness and characteristics
- Watershed elevation range
- Stream drainage networks or patterns
- Base flow characteristics
- Lithology of strata within the watershed
- Watershed aspect
- Watershed orientation
- Watershed shape
- Streams associated with heavy sediment transport
- Streams associated with frequent debris blockage
- Streams affected by back pooling of other streams
- Watersheds that had major forest fires within them in the last ten years

FATT reviewed relevant data available for watersheds impacted by the flooding on July 8, 2001, in the southern counties of West Virginia. After the data review and field and aerial inspections by DEP, a general list of watersheds that could be evaluated within the scope of the study was developed. Based on this information, FATT decided to isolate the

watershed modeling to the single storm event that developed and progressed through Boone, Clay, Kanawha, western Fayette, and western Raleigh Counties. This limited the hydrograph modeling to a single NRCS Type II storm front that could readily be delineated, measured, and accurately mapped by certified doppler radar images from the NOAA National Weather Service station at Charleston, WV. The certified doppler radar images had been “ground-proofed” and validated by the NWS, COE, USGS, and other authorized cooperative observation weather stations before NOAA would publish the certified precipitation measurements.

The other critical characteristics relative to runoff modeling were that the watersheds had to have current regulated mining and reclamation and logging operations within the watersheds. Included with this was the topography (elevation changes and slope), stream drainage network or pattern, geology and lithology of watersheds, watershed size, lack of frequent debris blockages and back pooling from other streams, soil types, soil depth, soil moisture content, and other parameters. FATT determined that the ability to achieve hydrologic model similitude would be achieved by modeling Seng Creek in Boone County, Scrabble Creek in Fayette County, and have a “control” watershed in Sycamore Creek in Raleigh County.

WATERSHED STUDY AREAS



One significant parameter noted in the hydrologic modeling of Seng Creek and Scrabble Creek was the different post-mining land configurations. Seng Creek's surface mine was a typical mountain top removal with an approximate original contour (AOC) variance and large excess disposal structures in the hollows. Scrabble Creek's mining operation was a mountain top removal operation with the topography restored to AOC with large excess disposal structures in the hollows.

C. Watershed Hydrologic Model Parameter Development

To develop the hydrologic model for each watershed, FATT interviewed residents at approximate 500' intervals along the stream from the mouth of Seng and Scrabble Creeks to the surface mine sediment control structure discharge outlets. These individuals denoted the highwater marks of the flood on July 8, 2001, at those locations. E. L. Robinson, Inc., surveyed stream channel cross-sections every 500' on the main stream reaches of Seng and Scrabble Creek up to and including the cross-sections of the primary mine sediment control structure outlet within the stream reach. All documented highwater marks of the July 8, 2001, flood were located and included in the survey. All permanent bridges and culverts in the watersheds that were not destroyed by the flooding were located and dimensions and elevations were obtained at the inlet, outlet, and a point approximately 200 feet upstream and downstream of the structures. E. L. Robinson, Inc., surveyed control sections at specified locations along Sycamore Creek.

In correspondence with the USDA NRCS West Virginia State Conservationist, Hydrologist and Soil Scientist, it was determined that prior to and including the day of the storm event (July 8, 2001) an antecedent moisture condition of II should apply and that the storm distribution event as determined by the NRCS Technical Reports was a normal Type II storm distribution. The NRCS established runoff curve numbers for surface mine areas in March of 1990 and these values are available to the public in the NRCS Engineering Field Manual. The soil scientist and hydrologist for the West Virginia NRCS recommended to FATT that the official published county soil survey and runoff curve numbers be used in the development of any hydrologic analysis of surface runoff in watersheds located in southern West Virginia. These published NRCS soil types and groups, values, runoff curve numbers, land classifications, and land use descriptions were used by FATT in its evaluation of the studied watersheds.

The land cover description, land cover type and hydrologic condition, hydrologic soil group, and the runoff curve numbers that were provided to DEP are included in Table 5.

D. Hydrologic Modeling Methods Evaluation

FATT, with consultation of Federal and State agencies, determined that two fundamentally different approaches have been developed and utilized to describe, analyze, and provide the basis of watershed hydrologic analyses. These are the unit hydrograph method and the variable source area concept.

1. Unit Hydrograph Method

   The classic approach to evaluating runoff in the short term is the engineering oriented unit hydrograph based on the relationship between precipitation intensity and infiltration during a storm. The unit hydrograph, focuses on the observation that the unit hydrograph is produced by surface runoff or overland flow that occurs because precipitation intensity exceeds infiltration capacity. Introduced first, the unit hydrograph and its attendant methods for hydrograph separation (into storm flow and base flow, primarily) currently dominate the engineering approach to watershed hydrology analyses. Based on several important assumptions, the unit hydrograph and its associated analytical methods have considerable utility in providing a means for precisely and in reliable replicated fashion analyzing assumptions themselves. It provides insight into the nature of the runoff process, as well as a means of evaluating and predicting stream behavior within the watershed with historic storm events and synthetic storm events.

2. Variable Source Area Method

   Here is where the distinction between storage and process begins to break down; this concept embraces both elements. Runoff is the result of interaction of a rainfall (or snowmelt) event and numerous different types of storage over the entire watershed. This gives rise to the variable source area concept, which recognizes the three-dimensional, dynamic nature of the runoff process, along with the knowledge that that process is in no way a simple one. The concept was initially named and presented by Hewlett and Hibbert who, after pointing out that “hydrograph separation is one of the most desperate analysis techniques in use in hydrology”, noted that:

   > Stream flow is generated chiefly by processes operating beyond perennial stream channels, [that] the yielding proportion of the watershed shrinks and expands depending on the rainfall amount and antecedent wetness of the soil, [and] the concept that stream flow from a small watershed is due to shrinking and

> expanding source area – the variable source area concept – grew out of studies of the drainage of sloping soil models at the Coweeta Hydrologic Laboratory.

Prior to that, Betson had reported that "runoff originates from a small but relatively consistent, part of the watershed," but that, in apparent contradiction thereof, there seemed to be variable portions of the watershed that contributed runoff at different times during storms. In a subsequent study, Betson and Marius (1969) had reported that the area contributing runoff was definitely not constant and the "variation in the depth of the topsoil caused a heterogeneous runoff pattern".

Variable source area is, in many ways, more difficult to comprehend than is the unit hydrograph method. It demands a conceptualization of the entire watershed. Ultimately, therefore, it demands synoptic, critical analysis of all the relevant factors affecting runoff from the drainage basin. Of special importance is consideration of the watershed's response to water input under a given set of antecedent moisture conditions. Essentially, all of the factors that affect the movement and storage of water must be within the conceptual boundaries for analysis of the watershed by the hydrologist. They are the underpinning of an ecological approach to the hydrologic analysis of the watershed.

E. FATT's Watershed Model Development Concepts and Concerns

1. Unit Hydrograph Method Development and Use by FATT

Introduced by Sherman (1932), the unit graph or unit hydrograph represents on paper the combined surface and subsurface runoff ("storm flow") from each separable segment of a watershed. It is a specialized case of the storm hydrograph, the pulse response of the watershed to the water input. This information was ascertained by field observations of hundreds of watersheds within the United States that resulted in the empirical equations that were used to develop the principles for the unit hydrograph and its associated equations relative to soil types and hydrologic soil conditions, land use, and land cover. This methodology led in the direct development by the Soil Conservation Service (SCS) of equations to determine curve numbers for defined soil types, soil hydrologic groups, land uses, and cover types within specific topography ranges. Wisler and Brater continued this work and provided a succinct statement of the principles of unit hydrograph theory:

- A unit hydrograph is a hydrograph of surface runoff resulting from a relatively short intense rain, called a unit storm
- A unit storm is defined as a rain of such duration that the period of surface runoff is not appreciable less for any rain of shorter duration. Its duration is equal to or less than the period of rise of a unit hydrograph, that is, the time of the beginning of surface runoff to the peak. For all unit storms, regardless of their intensity, the period of surface runoff is approximately the same.
- A distribution graph is a graph having the same time scale as a unit hydrograph and ordinates, which are the percent of the total surface runoff that occurred during successive, arbitrarily close, uniform time increments. Alternative and interchangeable units for the ordinates are cubic feet per second per square mile per inch of surface runoff. The most important concept involved in the unit hydrograph theory is that all unit storms, regardless of their magnitudes, produce nearly identical distribution graphs.

The basic assumptions underlying the unit hydrograph theory are:

- The contribution of each watershed segment does not interfere with the runoff from other segments
- That the runoff contributions from all the units are additive (Singh 1976). The unit hydrograph is a valuable analytical and educational tool. Its analytical value is particularly useful in determining storm-designed facilities such as culverts, reservoirs, and flood control works and analysis of small to medium watershed surface runoff response time (Dunne and Leopold 1978).

Linsley, Kohler, and Paulhus (1949) point out that consideration of the unit hydrograph "leads naturally to the hypotheses that identical storms with the same antecedent moisture conditions produce identical hydrographs." Proportionality exists between various measurable parameters of the hydrograph (e.g., height, length and rainfall duration) and, since the recession or falling limb is asymptotic to zero, and its rate of fall and duration are functions of its initial value (related or equal to the peak flow), the integration of the area under the hydrograph, which is volume of flow (cubic feet per second times time in seconds) will also be proportional to the storm's parameters.

Current watershed studies have shown that the ratio of storm hydrograph height to length is a constant, that peak flow is a function of rainfall excess, that the recession or falling limb has a characteristic and constant shape, and that the unit hydrograph may be used for

separating storm flow from base flow in order to achieve the foregoing measurements. In the event of accretion to groundwater during the storm, previous knowledge concerning the isolated runoff causing event's unit hydrograph may be useful in separating storm flow and base flow during these more complex periods as well. However, many times, it is necessary on ungaged watersheds for the hydrologist to calculate and determine the base flow using watershed modeling software. This watershed modeling methodology is comparative to the procedure that FATT used to analyze the ungaged study watersheds.

The unit hydrograph method works best for a relatively compact watershed with no major channel or groundwater storage, and hence may be used for watersheds under about 2000 square miles of area. It is best if the rainfall duration modeled for the watershed is approximately one-fourth the watershed basin lag (the time between the centroid of precipitation and the occurrence of the peak discharge) (Linsley, Kohler, and Paulhus 1949). On occasion, application of the unit hydrograph theory has been extended to larger and more complex watersheds and even to groundwater hydrographs. However, FATT chose watersheds that were less than 2000 square miles and did not have complex inter-basin water exchanges or complex groundwater situations contained within the watershed boundaries.

Smoothed, the plot of discharge (or head) over time is an oversimplified representation of a single storm event in a stream's history. In fact, a stream gage provides data to plot such a curve. Such plots of discharge versus time demonstrate the following:

- The curve assumes a characteristic shape for a given watershed, (i.e., delta shaped, linear, etc.)
- Further understanding of the runoff processes on that watershed becomes possible
- Runoff response is affected when land use, cover type, topography, stream alterations, or other runoff-affecting factors are altered

The hydrograph is a complex integration of runoff from each sub-basin or portion of the watershed that contributes to the peak flow, as well as an integrator of all the factors that affect it (American Society of Civil Engineers 1949). Violation of the assumptions underlying the hydrograph method provide the range of limitations of its use, the most common violations are:

- The storm does not uniformly, instantaneously, and completely cover a sub-basin and/or watershed analyzed

- The storm moves in an orientation to the watershed that will result in a considerable impact of the shape of the resultant storm hydrograph (i.e., moving at an angle greater to angle of 45 degrees to the main stream reaches of the sub-basins and/or watersheds, or up or down the main axis of the sub-basins and/or watersheds)
- The most commonly occurring natural violation is that the outflow from one watershed unit does not interfere with the outflow from another watershed unit nor does the pooling effect of one watershed unit impact another watershed unit

The measurements associated with the sub-basin and watershed hydrographs are empirical or incomplete approximations of the true and full relationships between many influencing parameters. However, there remains some very useful application of unit hydrograph theory in the hydrologic modeling of sub-basins and small to medium watersheds.

The DEP FATT used the unit hydrograph method in the hydrologic analysis and modeling of sub-basins and watersheds in order to predict peak flows of the historic storm event of July 8, 2001, and synthetic storm events based on a 25-year/24 hour and a 100-year/24 hour storm. FATT then compared the watershed hydrological modeling results with actual field surveyed high water marks of the July 8, 2001, flood in the watersheds studied.

F. Watershed Characteristics Used by FATT in Modeling of Watersheds

On an impervious watershed surface with constant slope, area, soil type and roughness (minute depression storage as well as resistances to surficial laminar flow), the peak flow will be a function of precipitation intensity and can be calculated. As with the situation with the unit hydrograph, one must make assumptions concerning the areal extent of the storm and the time-distribution of the precipitation. Normally, the hydrologist makes the assumption that the watershed is instantly, uniformly and completely covered by precipitation (rainfall) that has a constant rate from start to finish for the storm event. This modeling assumption makes the hydrologic model solution easier, and any deviation from such assumed uniformity complicates the solution.

Time of concentration is defined as the time necessary for a precipitation event to cause runoff in a given watershed. This is the period that is necessary for saturation of the surface in the sub-basin or watershed to occur.

Additional complicating hydrologic modeling factors include:

- Presence of groundwater storage
- Varying subsurface runoff
- Length of time between storms
- Nonuniformity of watershed
- Temperature
- Aspect
- Slope
- Type of vegetation
- Season
- Stream alteration
- High turbidity or excess sediment transport
- Channel scouring and associated sediment transport
- Stream alteration do to land mass slips into the stream
- Debris or damming of restrictions of flow with the stream reaches
- Climatic seasons

These factors influence evapotranspiration, stream reach discharge rates, peak discharges and the hydrologic season and the response of surface runoff to existing hydrologic conditions and their variables. The potential for variability in sub-basins and watersheds during storm events requires:

- The acceptance of unmeasureable influences
- The need for estimation by more than one technique, and/or
- The identification and elimination of the influence of minor or insignificant variables relative to the modeling of the sub-basins and/or watershed

Of primary importance is the presence or absence of groundwater storage and its possible contribution to peak discharge of surface runoff during storm events. This effect is important for hydrologic modeling of small to medium size watersheds, such as the watersheds chosen by FATT. For this reason, much of the early peak flow determination work as performed by other researchers was done with "small" sub-basins or watersheds; those that have, by definition (Chow, 1964), a drainage area of less than 100 square miles.

1. Base Flow Recession in Watershed Model

If, during the runoff event, there is an accretion to groundwater, or there are more than one-storm pulses, then a complex hydrograph will result. However, FATT was able to select watersheds in which

there was a single thunderstorm event that could be tracked over the watersheds, which resulted in the flooding, and the accretion was approximately equal to zero. Base flow recession analyses was carried out on clearly separate storms, therefore a more complete ability in the hydrologic analysis resulted in the protection of the base flow recession and storm flow. This resulted in FATT being able to clearly delineate the effects of base flow from the runoff resulting from the storm event.

2. Stream Behavior

   The parameters associated with a high intensity storm event or a flash flooding event have been modeled by researchers, but have yet to be refined and determined to be reliable. It is possible that select sections of a sub-basin or small watershed can be modeled that have limited impact from stream alteration, channeling, scouring, high turbidity, excessive sediment transport, debris blockage, damming of the stream reaches and other unknown parameters. FATT recognized and addressed these limitations of modeling of the sub-basins and watersheds chosen for the case studies in the early development of historic data for said sub-basins and watersheds. Subsequently, FATT determined and used only those stream reaches that had minimum impact by these and other factors that would influence the historic watermarks associated with the flood event that occurred during the flood events of July 8, 2001, to calibrate and validate the hydrologic models.

3. Watershed Morphology

   In southern West Virginia the watershed hydrology, in addition to natural geomorphology, is altered by man-made structures in the watersheds analyzed by FATT. Man-made structures that influenced the morphology of the watershed included:

   - Filling in of the natural flood plains and stream channels with material
   - Alterations of stream channel cross-sections
   - Removal of dense, deep-rooted vegetation from natural stream banks, making them easily erodible and subject to stream alteration and channel scouring
   - Removal of streambed gravel to use in construction
   - Construction of structures in the normal floodplains of the stream that were displaced by the flood waters and in many cases resulted in debris blockage and resulting in flooding of the streams

- Undersized culverts and bridges whose cross-sectional area did not allow for the adequate passing of the flood event stream discharge and thus caused flooding at that point and upstream of that point until said structures failed or were overtopped by the flood waters
- Trash, debris, and unwanted items (i.e., car parts, appliances, etc.), that were in the normal floodplain and when flooding occurred they were lifted up by the flood waters and were moved a point where they caused debris blockage and/or damming until the flood waters forced the blockage to break or the flood waters went over and/or around said blockage

4. Sedimentation

   In geomorphology, there are many theories, classification, and details of the aggradation and erosion processes that sculpt the sub-basin and watershed landscape. Major, broad-scale geologic processes are those by which the land surface is lifted and prepared for the processes that wear it down. Locally, aggradation occurs when the stream velocity is diminished such that the water can no longer carry large sized particles. This process is called sedimentation. The process where sediment is suspended in water is commonly referred to as sediment transport and is associated with many variables such as lithology, water temperature, stream velocity and other unknown factors. Due to these unknown variables, FATT chose not to include the analyses of sediment transport associated with the July 8, 2001, flood event.

5. Model Watershed Area or Size

   Past research has made numerous attempts to define a “small watershed”, either by actual size (e.g., 100 square miles) or function (e.g., response to precipitation inputs), or types of storage (e.g., no groundwater storage). Some runoff calculation formulas specify a watershed size limit.

   The Runoff Committee of the American Geophysical Union stated that:

   > From the hydrologic point of view, a distance characteristic of the small watershed is that the effect of overland flow rather than the effect of channel flow is a dominating factor affecting peak runoff. Consequently, a small watershed is very sensitive to high-intensity rainfalls of short duration, and to land use. On larger

> watersheds, the effect of channel flow or the basin storage effect becomes very pronounced so that such sensitivities are greatly suppressed. Therefore, a small watershed may be defined as one that is so small that its sensitivities to high intensity rainfalls of short duration and to land use are not suppressed by the channel storage characteristics.

Chow's (1964) definition is based upon a combination of the function and response concepts, specifically, the interaction of rainfall intensity and channel storage. This definition is fine in principle because it is a "floating" one rather than being specifically tied to some arbitrary, finite area. However, the definition is untenable in that it uses overland flow, which is runoff over the surface of the soil before becoming channelized. Generally overland flow is not a natural feature of non-urban hydrology.

Recognizing that there are broad groupings of factors that affect runoff and storage extending from the large-scale atmospheric and climatic factors, through weather, hydrographic, geomorphic/basin, soils-vegetation/land use, and channel/groundwater storage factors, FATT chose to define a small watershed as follows:

> A small watershed is one where channel and groundwater storage is not sufficient to attenuate or contribute to a flood peak primarily influenced by weather and land use.

6. Watershed Delineation

Watersheds are often not immediately discernible from a map or on the ground. The first step in watershed analysis is to identify the watershed outlet (lowest point or base level) on a map or computer model. Once the watershed has been identified, a number of parameters can be calculated that aid in describing and quantifying the characteristics of the watershed. The determination of several watershed parameters provides information that is useful in making decisions about how to manage the watershed in addition to simply describing it.

As implied in the definition of "watershed", the area of the drainage basin level can be identified on a topographic map. Most common of these maps are the quadrangle sheets and digital elevation models (DEMs) issued by the U.S. Geological Survey. These maps typically cover 7½, 15, or 30 minutes of arc (scale units 1 = 24,000, 62,500, and 125,000, respectively), and show streams,

wetlands, forest vegetation, and several cultural features in addition to the contours. Other sources of maps for modeling are those generated by aerial photogrammetry, remote sensing imagery, and **Li**ght **D**etection **A**nd **R**anging techniques, known as **LiDAR**. Cultural features, include useful surveying details, such as latitude and longitude, map names, and, where appropriate, boundaries that are marked on the ground, benchmark elevations, and elevations of peaks and water bodies, mine boundaries, logging boundaries, urbanization extent, etc., can be established by remote sensing imagery, airborne scanning laser altimetry (LiDAR), aerial photography, etc.

Unfortunately, the topographic boundary (divide) of the watershed as determined may not be the true hydrologic boundary. The watershed may be larger than indicated by the topographic divide because waters are diverted into it by a phreatic divide outside the watershed topographic boundary drawn on the map. The absence of non-conforming topographic and phreatic divides were field verified by FATT. Their determination resulted in FATT utilizing the topographic divides as the boundary for the watersheds studied.

FATT used various sources for watershed boundary delineation. LiDAR and USGS DEM sources with field verifications enabled proper watershed boundary delineation.

G. Watershed Modeling Parameters Evaluated and Utilized by FATT

Upon establishing the watershed boundary, several watershed parameters were determined by FATT. Those included watershed size with the associated feature aspects of elevation (maximum, minimum and mean values). Other watershed parameters considered were distribution of elevation, aspect, orientation, perimeter length, shape, and drainage network patterns. The following physical parameters were used in evaluating hydrologic characteristics.

1. Area or Size of Watersheds

Watershed area and size is important in order to estimate water resource parameters such as total annual yield and flood potential, and to evaluate land use measures that control water quality, quantity, or regime. Most importantly, size is an essential consideration in the initial evaluation of a watershed's hydrologic behavior. The hydrologic modeling analyses of the watershed by FATT were performed on watersheds of similar size.

The area of a watershed may be determined by any of several methods. FATT used a computerized area measurement system. While it is recognized that a good portion of the watershed is, in all likelihood, on a slope, the area that is reported is the horizontal projection of the watershed boundary.

FATT recognized the importance in differences in land use, land cover, topography, watershed area, and groundwater storage reservoirs. These parameters were tested for their sensitivities in the FATT models.

In terms of runoff per unit area, the peak flow is lower and later on larger watersheds. Small watersheds are said to have “flashy” hydrologic behavior, that is, they exhibit higher high flows and lower low flows. Calculation of the ratio of maximum to minimum flows reveals higher ratios on small watersheds, an interesting but unstandardized measure of “flashiness.”

2. Elevation and Slope of Watersheds

Elevations of specific points on a watershed may be read directly from a topographic map and interpolated/extrapolated for other points, or calculated by the modeling software. Slope is simply the gradient, or vertical difference between two points whose elevations are known divided by the horizontal distance between them. Elevation is important because precipitation generally increases with increasing elevation due to an orographic effect and slope is important because it is a prime factor in infiltration capacity. Combined with elevation, slope can be an important factor in orographic effects, and combined with aspect, slope is also important in insolation considerations that play a role in evapotranspiration. Generally, as slope increases, so does precipitation flow velocities.

3. Aspect and Orientation of Watersheds

Aspect is the direction of exposure of a particular portion of a slope, expressed in azimuth (0-369°, compass bearings (e.g., N 47°E) or the principal compass point (N, NE, E, SE, etc.). Orientation is the general direction of the main stem of the stream on the watershed. A watershed with an east-west orientation is likely to have slopes that are predominantly north and south in aspect.

Aspect is an especially important feature of the watershed in view of insolation. A 45-degree south-facing watershed at 45°N presents a surface that is parallel with a horizontal surface at the equator and perpendicular to incoming radiation. In most situations, the rays of the sun have a greater length of travel through the atmosphere which attenuates

their intensity. For example, at the summer solstice, with the sun at its maximum northerly declination of 23½°, the 45° south-facing slope at 45°N latitude and the horizontal surface at the equator receive nearly the identical amount of radiation. At certain times, the south-facing slope is certain to be a great deal dryer, have greater evapotranspiration, and therefore support more xerophytic vegetation than other nearby slopes. Conversely, north-facing aspects will tend to be cooler, have vegetation typical of more northern locations, yield greater annual runoff, and exhibit more flashy runoff behavior.

The overall effect of aspect is that highly insolated (exposed to sunrays) facets are likely to have lower average annual runoff than other portions of the watershed. Soils, if well developed, may increase water holding capacity, resulting in more sustained low flows, and have ample storage for attenuating flood peaks. Runoff will therefore tend to be less flashy as well. The reverse is likely to be true for aspects with lower isolation.

4. Watershed Shape

The shape of the watershed can have a profound effect on the hydrograph and stream behavior, particularly from small watersheds, and especially in relation to the direction of the storm movement. Watershed shape has a distinct influence upon the time of concentration. Consequently, time of concentration can be used to aid in studying the effects of watershed shape on the hydrograph and on stream behavior.

The combination of watershed shape and direction of storm movement is important. For example, if the rainstorm moves down the watershed over a 1-hour time period, the peak will be very high because the upper reaches of the watershed will be contributing runoff to the peak at the same time as the storm is over the outlet of the watershed. Conversely, if the storm moves up the watershed, the peak will be greatly attenuated.

Watershed shape has no obvious effect on average annual water yield. The primary effect of watershed shape appears to be its influence on the peak flow during a rainstorm on a small watershed. If storage on the watershed is limited, and there is considerable influence of shape on the magnitude of the peak, then the minimum flow might be affected as well. Such an effect is most likely in the extreme case, for example, where the watershed is long and narrow and exhibits little or no groundwater storage.

In extensive studies on models, watershed shape did not have as great an effect on peak flows as other characteristics such as slope or soil depth, and it may be dominated by direction of storm movement, antecedent moisture conditions, precipitation inputs, or other factors (Black 1972).

Time of concentration (in this case, time from start of precipitation until the peak flow occurs) was not affected by direction of storm movement, but the lag time (time from start of precipitation until stream starts to rise), and storm peak magnitude was affected dramatically.

Consideration of watershed shape is likely to be important when considering the effect on peak flows and regime from a portion of a watershed dependent upon its location in the larger watershed of which it is a part. Thus, for example, increased runoff from a small, logged watershed may have a different effect on the peak from a larger downstream watershed (within which the logged area is nested) dependent upon where the logged area is within the larger watershed.

5. Drainage Network of Watersheds

The drainage network of a watershed is the system that collects the water from the entire area and delivers it to the outlet. It includes the subsurface and surface drainage. In most cases, the entire drainage network is not revealed to the hydrologist, while the surficial stream drainage pattern is. The pattern of streams is only the surface manifestation of that larger system, and may carry a widely varying percentage of the total runoff. Most of the research into drainage networks has actually been directed at this surface portion; it is readily discernible on the map, can be measured and characterized, and can be described both numerically and verbally.

Initial evaluation of drainage networks was on the basis of stream order designated by 1, 2, 3, etc. A stream of order 1 has no tributaries; a stream of order 2 has tributaries of order 1, and so on. In the European system, a Class I stream is the main stem of the drainage, discharging directly to the ocean or a large water body. Class II streams are major tributaries to Class I, and Class II are minor tributaries discharging into Class II streams. Wisler and Brater (1959) point out that the original method of designation of using “I” for the smallest tributary, and working downstream assigning the next higher number when two tributaries of the like number join. The method is not conducive to comparative uses, or to calculations as shown. A major difficulty with stream order is that streams of different class may have different flow magnitudes because they have different tributary systems. Conversely, streams of the same class can drain watersheds that are considerably different in size dependent upon which magnitude of stream is designated “Class 1,” thus making it difficult to compare or generally inventory the classes. Horton’s system of stream order designation commenced at the tributary level (Class I) and the number increased as more and more tributaries were involved, thus, the higher the number assigned to the main stem, the larger the watershed and the greater the number and extend of its tributaries (Linsley, Kohler, and Paulhus 1949). Strahler (1957) modified the system to apply to

segments of streams between confluences. A great deal of research has been done on stream development theory, network evolution, bifurcation ratios, and relationships between drainage network and geology. While stream order has been shown to be related to other basin characteristics, no expression of stream order has been consistently or usefully related to runoff behavior.

Verbal description of the surface drainage pattern has not been formalized, but geomorphology tests typically refer to drainage patters in terms that are derived from describing leaf venation, fruit- or tree-forms, or other well-recognized formations. Thus the names: dendritic, palmate, pinnate, wye, trellis, radial, and annular are among those most often used. According to laboratory studies on watershed models, drainage pattern appears more important than drainage density in influencing peak flows and lag times (Black 1972).

Streams are classified in geologic texts as being influent, effluent, or intermittent. The influent stream provides water to the groundwater storage. The effluent stream conveys water from groundwater storage year round: this is the so-called permanent, or perennial stream. Ephemeral streams flow immediately following runoff-causing events, especially in arid climates; the bed may dry up rapidly, even following torrential runoff (Strahler and Strahler 1973). Intermittent streams, which also may flow immediately following a runoff-causing event, provide water to perched water table or to deep seepage. Standing on the bank of a stream that is flowing one moment and disappears into its bed the next, it is impossible to determine whether the stream is intermittent or ephemeral by its appearance. A watershed may exhibit any of these classes in different reaches of the stream.

Watershed characteristics have an effect on runoff behavior from small watersheds. An understanding of the impact of those characteristics on stream behavior is essential to successful hydrologic analyses and modeling of watersheds. These aspects were evaluated when choosing our study watersheds.

6. Watershed Geology

The most important geologic property in considering a watershed's hydrology is its soil. The type of soil determines its infiltration rate and its porosity; that is, how quickly the soil can absorb water and how much water the soil can hold per foot of depth, respectively. Sand, gravel, loam, and peat soils have high infiltration rate and high porosity, while rocky or clay soils have low ones. Those soils with high infiltration capacity and high porosity will contribute less to flooding, since they absorb and retain more rainfall than other soils. It should be noted here that since the

infiltration rate is usually a fraction of an inch per hour at most, neither infiltration nor porosity are significant factors except when discussing rainfalls of low intensity and long duration which are those that cause worse flooding on large watersheds.

Also important for soils of any given type is the depth of soil. The depth of soil determines the total capacity of storage available. This simply means that, for a given type of soil, a watershed where the soil is deep can hold much more moisture than one where the soil is shallow. The total moisture-holding capacity of a soil is important because when this storage volume has been filled with water, no further moisture falling on or running over the surface will be absorbed. This indicates that the potential decrease in floodwater volume is roughly proportional to the depth of the soil for a given soil type.

7. Watershed Lithology

Associated with a watershed's geology is the lithology of the strata in the watershed and its ability to resist erosion and thus decrease sedimentation. Sedimentation denotes the processes of erosion, transportation, and deposition. Erosion consists of detaching soil or rock particles and moving them to a channel in which they may be transported. Erosion may be caused by the impact of raindrops or by a combination of drag and lift forces on soil particles resulting from the fluids motion.

The regulated surface mining and logging operations likely minimized some sedimentation impacts in the watersheds by virtue of compliance with the rules and regulations enforced by that specific regulatory agency. The sediment and drainage control structures for mining and logging were not modeled with any attenuation in the structures. Readily available information relative to the storm volume attenuation in the structures was unavailable. Consequently, broad assumptions would have been necessary to model the effect of available storage volume upon the July 8, 2001, storm runoff. Therefore, FATT assumed that all sediment control structures were full of water and no attenuation occurred within the structures.

8. Watershed Sediment Transport

The topic of the influence of sediment transport was discussed in depth with the NRCS, COE and OSM. FATT and these agencies agreed that the sediment loading should be considered if the strata lithologic data, sediment load, and other sediment transport parameters are available. However, no reliable data of this nature was available for any of the watersheds studied. In addition, the NRCS, COE and OSM stated that time and budget constraints normally prevent detailed sediment transport

studies to be included in their hydrologic analyses of flood events. As a result, FATT decided to restrict its watershed hydrologic analyses to only the relationship of non-sediment laden water and its impact on the flood events of July 8, 2001.

H. Modeling Software Utilized by FATT

Once the watersheds were chosen by FATT for hydrologic analyses modeling, the FATT personnel investigated the most accurate and representative hydrologic modeling techniques and tools currently available. After consultation with Federal and State agencies, FATT determined that watershed hydrologic analysis is typically done using lumped parameter models such as the U.S. Army Corps of Engineers (CEO) HEC-programs, Natural Resource Conservation Service (NRCS) TR-20, and other models. FATT chose to use the HEC-1 model within BOSS International's suite of watershed modeling programs to model the hydrology of the watersheds.

BOSS Watershed Modeling System (WMS) is a comprehensive software environment for hydrologic analysis and modeling. The Engineering Computer Graphics Laboratory of Brigham Young University, in cooperation with the U.S. Army Corps of Engineers Waterways Experiment Station, developed it. The BOSS WMS software was used by FATT to model and develop the hydrologic models in the study watersheds. The computer results were used to determine the potential impact that mining and logging operations may have had on the flooding on July 8, 2001, in the studied watersheds.

Throughout this study, FATT periodically consulted BOSS International. BOSS provided a computer technical representative to discuss the limitations of the WMS program and the feasibility of our modeling approach. All recommendations offered by BOSS were evaluated by FATT. Boss International's involvement was solely at the discretion of FATT, but was thought necessary to assure a defensible modeling approach.

The WMS program is a broad-based hydrologic modeling system. Of the many available aspects of the program, FATT chose the most applicable features, based upon our available data. The following items highlight some of the program's features and source/input data requirements evaluated by FATT.

1. Watershed Software Modeling Capabilities and Limitations

   The distinguishing difference between WMS and other applications designed for setting up hydrologic models is its unique ability to take advantage of digital terrain data for hydrologic model development. WMS uses three primary data sources for model development:

- Geographic Information Systems (GIS) Data
- Digital Elevation Models (DEM's)
- Triangulated Irregular Networks (TIN's)

GIS data includes points, lines, and polygons to represent basins, streams, and key points such as outlets or culverts. In WMS, GIS data are called Feature Objects. Feature objects data can be used by itself to create a watershed models for hydrologic analysis or as a companion in the development of watershed models with DEMs.

With WMS, properly structured hydrologic models can be created automatically from points, lines, and polygons. This data was developed and stored in a GIS by DEP's Technical Applications and Geographic Information Systems (TAGIS) unit by importing from ArcInfo and ArcView, or DXF files. In WMS, lines used to define a stream network have direction. For each line (arc), there is a beginning and an ending node and "flow" along the line is defined in this direction.

In WMS there are three primary feature object types:

- Point data representing the watershed outlet and any sub-basin outlet or confluence points
- Arc (i.e., lines) data representing a stream network
- Polygons representing watershed boundaries, land use areas, and soil type areas

2. FATT Watershed Modeling Procedures

The FATT used BOSS International's WMS for defining models of the watersheds and developing hydrologic data, using digital elevation models (DEMs). A DEM is simply a two-dimensional array of elevation points with a constant x and y spacing. While a DEM results in data redundancy for surface definition, their simple data structure and widespread availability have made them a popular source for digital terrain modeling and watershed characterization. The DEMs used for modeling the three watersheds were based on USGS 30-meter (Seng Creek) and 10-meter (Scrabble Creek) models, and 3-meter airborne scanning laser altimetry (Light Detection And Ranging or LiDAR). LiDAR is increasingly gaining favor for accurate dense topographic mapping as it can penetrate the vegetation canopy and give actual ground elevations (Flood and Gutelius 1997). Topographic information developed with LiDAR can be generated over large areas at a horizontal resolution of 1 – 3 meter and a vertical accuracy of $\pm$ 15 cm. To increase the accuracy and speed of the development of the horizontal and vertical control for the watersheds being studied by FATT, DEP's Technical Applications and Geographic

Information Systems (TAGIS) unit met with FATT and strongly suggested that airborne scanning laser altimetry, more specifically, LiDAR, should be used to save both time and money in gaining the information needed to accurately model these watersheds. TAGIS arranged for several demonstrations of LiDAR's accuracy and project capabilities, and FATT members unanimously agreed that LiDAR was the only methodology that could be used for these specific watersheds for hydrologically modeling. TAGIS's personnel continued their strong support of the FATT project throughout its life and helped FATT by utilizing the state-of the art technology for the most accurate modeling methods currently available to the public. Without the assistance and direction of TAGIS's personnel, the progress and accuracy of these watershed analyses could not have been achieved to the degree of accuracy obtained and within the time frame mandated.

The primary data sets, which were obtained to perform watershed delineation with DEMs, were elevations, and flow directions. WMS can read digital elevation in standard USGS grids, Environmental Systems Research Institute (ESRI) ArcInfo grids, A(merican) S(tandard) C(ode for) I(nformation) I(nterchange) or ASCII grids, and Geographic Resources Analysis Support System (GRASS) grid formats. Flow direction data for DEM points were computed using the version of TOPAZ especially created for distribution with WMS. This version of TOPAZ, created for use with WMS, only requires an elevation grid as input and produces a flow direction grid as output. The TOpographic PArameteriZation program (TOPAZ) was developed by the USDA-ARS, Nation Agricultural Water Quality Laboratory. A modified version of the program is distributed with WMS for the purpose of computing flow directions for use in basin delineation with DEMs directions. TOPAZ is capable of DEM elevation processing, including raster smoothing, flow accumulation computations, basin and stream delineation and ordering, and development of other watershed parameters. TOPAZ uses a form of the eight-point pour model to determine the direction of flow. This model specifies that the flow will be directed toward the neighboring (in a structured grid there are eight neighbors for each point) DEM point with the lowest elevation. The algorithms typically include functionality for eliminating pits and resolving ambiguities with the lowest elevation is shared by more than one neighboring point.

With the flow directions assigned for each DEM point, the flow accumulation at each DEM point can be computed. The flow accumulation for a given DEM point is defined as the number of DEM points whose flow paths eventually pass through that point. With the aid of the flow accumulations, the location of the watershed outlet was determined and an outlet feature point created there. A minimum threshold is then defined and all of the DEM points "upstream" from the

defined outlet(s) are connected together to form a stream network of feature arcs lines.

The watershed was subdivided into sub-basins, and then nodes along the stream feature arcs were converted to “outlet” nodes. As these nodes are converted, the hydrologic modeling tree is automatically updated. Using the outlets on the stream network and the flow directions, the contributing DEM points for each outlet are assigned the proper basin ID.

As with the stream vectors, the boundaries between DEM points with different basin IDs were converted to feature polygons. Once the boundaries of the sub-basins were determined, geometric properties important to hydrologic modeling were computed from the DEM data.

WMS utilized DEMs to define watershed models. Developing watersheds from DEMs involves the use of both feature objects and DEMs. An elevation source is required for creating a model with WMS. The watershed outlets and streams were defined manually in order to confirm key drainage features, such as streams, to the watershed geometry. By default there may only be a single outlet point for the watershed defined, or perhaps only a portion of the stream network. WMS was used to add additional outlet points (representing sub-basin, culverts, etc.) and stream branches.

The watershed network and basin boundaries defined by FATT included several important watershed geometric parameters that were computed by WMS. These parameters (i.e., drainage area, slope, length, etc.) automatically tie into the HEC-1 hydrologic model by WMS. Along with the watershed definition on the DEM, an accompanying topologic model is created. FATT interacted with the model of the watershed to complete input for and begin the development of hydrologic analyses.

All gridded elevation data imported into WMS was in the ESRI ASCII grid format. Grid files were used as DEMs in WMS. Flow directions and flow accumulation grids were compiled by TOPAZ to define an elevation source within the watershed limits. After importing the computed flow direction and flow accumulation grids, all of the remaining watershed parameters were developed by WMS. The USGS and LiDAR elevation DEM or DEMs were used as the background elevation map when creating the watershed models.

Shape files created by DEP and the DEP TAGIS unit provided the method for FATT to import GIS data into WMS and create a watershed model directly.

In order to import shape files into WMS, the following conditions were met:

- A point coverage containing watershed and sub-basin outlet, with the appropriate type (outlet point) attribute defined must exist
- An arc (or line), coverage containing streams in the watershed with the appropriate type (i.e., stream) attribute defined must exist
- A polygon coverage containing watershed boundaries must exist
- There cannot be any overlapping arcs
- Stream arcs must be created from a downstream to upstream direction for all arcs

3. Feature Objects Used in the Watershed Modeling by FATT

   Feature objects in WMS have been patterned after Geographic Information systems (GIS) objects and include points, nodes, arcs, and polygons. Feature objects can be grouped together into coverages, each coverage defining a particular set of information. The use of feature objects is determined by the coverage, or attribute set, to which they belong, but were separated into three categories:

   i. Basin polygons and stream networks of pre-delineated watersheds as a shape file where the basin delineation and attribution has already taken place
   ii. A conceptual model or layout of features in the watershed, such as its rough boundaries and streams
   iii. Soil types, land use, or other data that can be used to define important hydrologic modeling parameters such as curve number (CN)

4. Development and Utilization of Hydrologic Modeling Techniques for Watersheds Used by FATT

   With GIS and other digital data, delineated stream networks and basin boundaries for a given watershed exist. FATT used WMS to build hydrologic models from three different features of the WMS map module: polygons representing basin boundaries, arcs representing stream networks, and nodes representing watershed and sub-basin outlet points.

   Data imported from a shape file was used to set up the hydrologic model in HEC-1. Attributes from the shape files were input and other hydrologic data developed with GIS was used to define input parameters of the given hydrologic model. A geo-referenced TIFF image map was used to establish the boundaries of the watershed at the proper scale so that lengths and areas determined from the feature objects were correct. The feature objects included the mine boundaries, timbering property, urbanized areas, etc.

A DEM was used as a background elevation map for interpolating elevation values to newly created vertices of the model.

5. NRCS Curve Numbers and Other FATT Model Analyses Input Parameters

Beside the creation of stream networks, and sub-basin boundaries, feature objects were used in WMS by FATT to define polygonal zones representing soil types, land use, etc. These polygons were then overlaid with the basin boundaries to determine composite curve numbers, pre-dominate soil type, and other parameters required by the supported hydrologic models. This information for soil types, land use, etc., was obtained from the NRCS publications and verified by correspondence with the NRCS soil scientists for each county that the watersheds were located. The NRCS land uses and their associated curve numbers were field verified by the DEP and the DOF personnel in each watershed subbasin by on-the-ground observation, aerial observation and mapping, and remote imagery techniques. The field information was categorized for each subbasin within each watershed. Then, the field verified land use categories and soil types areas were compared with the published NRSC (SCS) data. Utilizing published NRCS land use definitions, cover and treatment descriptions, and soil type data that matched the FATT field verified field data, allowed the curve numbers to be assigned for each specific area. FATT then used WMS and calculated a composite weighted runoff curve number for each site-specific subbasin within the watershed. The composite curve number that was calculated was then used in WMS in the development of the hydrological modeling of the watersheds.

6. Model Coverages

Feature objects can be grouped together into coverages. Each coverage represents a particular set of data. For example, one coverage, can be used to define line use, and another coverage can be used to define soil type. A common use for coverages is defining NRCS soil type and land use for NRCS (SCS) Curve Number (CN) computation from polygons. Separate coverages must be used for the land use and soil type polygons, since polygons may not overlap within a given coverage. (Table 5)

A common method for the determination of losses due to interception and infiltration makes use of the SCS curve number. Curve numbers were computed by FATT from a NRCS hydrologic soil group in combination with a specified NRCS land use. A hydrologic soil group was assigned to selected polygon(s) belonging to a soil type coverage. The soil group was specified as either A, B, C, or D. Once hydrologic

soil groups and land use definitions were assigned, composite curve numbers for each sub-basin were computed for the watershed.

Because of availability of elevation data in gridded format, gridded elevation data was used as a background elevation map when creating DEMs. The United States Geological Survey (USGS) 30 meter and 10 meter DEMs, and 3-meter grids processed from LiDAR data were imported from TAGIS and used as background elevation maps. DEMs were contoured and used as a guide for the placement of boundary, stream, and ridgelines. DEMs or grids were created from the feature polygons and arcs with elevation extracted from the background DEM.

7. Drainage Analysis Performed by FATT in Modeling Watersheds

A DEM was used to provide background elevation sources for the creation of feature objects and to perform drainage analyses using information derived from the elevation points. Data, such as flow directions, flow accumulations, and basin ID's were computed and stored as "attributes" of the DEM at the given location. Connected DEM points that comprised a stream branch were converted to arcs. Groups of DEM points that make a sub-basin within the watershed were converted to polygons for further hydrologic model definition. Beside the elevation DEM, flow directions for each elevation point in the DEMs were required in order to perform drainage analysis. Elevation and flow direction are the essential data from which all of the other drainage computations were made. Flow directions were computed with TOPAZ

A flow direction grid consists of a flow direction value for each DEM point. The flow direction identifies which neighboring point has the lowest elevation. A flow accumulation grid consists of an integer value for each DEM point that represents the number of "upstream" DEM points whose flow path passes through it. High accumulation values indicate points in the stream, whereas low values represent areas of overland flow. Flow directions and accumulations were determined by use of TOPAZ. Resulting grid files were imported into WMS.

If all DEM points had one and only one lower neighbor, the process of determining flow directions would be simple and the requirement to use other programs would not exist. However, there are many problems dealing with depressions and flat areas that make the algorithm for determining flow directions complex. Computations of flow accumulations were fairly straightforward once the flow directions were determined within the watershed. At this point, computations of flow directions cannot be done directly by WMS. A version of the TOPAZ program, modified specifically to work with WMS, creates as

output the flow direction and flow accumulation grids. These grids were then imported as DEM attributes and used for basin delineation. FATT used TOPAZ for computing flow direction and flow accumulation grids. Once flow directions had been imported into WMS, flow accumulations were computed. Flow accumulations were computed by counting, for each DEM point, the number of DEM points whose flow paths pass through the DEM point. Streams were identified by large accumulation values since the flow paths of many points pass through the stream points.

The elevation and flow direction values for each DEM point are the primary data required for performing basin delineation and watershed characterization with DEMs. Once these data are imported and flow accumulations computed, stream networks and basin boundaries are defined with the aid of feature objects. Arcs representing streams and feature points or nodes representing basin outlets must be present in order to define basins. Once basins were defined, watershed and sub-basin boundaries were converted to feature polygons. All of the ties to the hydrologic models are made available through these feature objects with geometric values such as area, slopes, lengths, etc. being populated from the DEM data.

An arc vertex is created for each DEM point that has a flow accumulation value greater than the threshold entered. Consecutive stream DEM points are then joined together as arcs with nodes created at junction points where the stream splits. By default, stream arcs are created for all DEM points that have a flow accumulation larger than the threshold. Outlet feature points/nodes are created at DEM points, which pass the accumulation threshold and do not have a neighboring point with a higher accumulation. The stream is “traced” upstream by noting the neighboring DEM point with the next highest accumulation. This process was repeated until no neighboring point had an accumulation larger than the threshold. Outlet points were created at specified DEM points. The outlet point or node has a high enough flow accumulation to pass the threshold.

Each time a feature outlet point is created a sub-basin for each upstream feature arc is created for the hydrologic modeling tree. This means that the stream arcs themselves are associated with a basin. The DEM points intersected by the stream arcs are assigned the basin ID already given to the arcs. The procedure continue by tracing the flow paths of the remaining DEM points until a point which had already been assigned a basin ID was intersected. The result was that each DEM point was assigned the ID of the sub-basin it belongs to within the watershed.

Once the desired sub-basin delineation from the DEM points had been defined, the basin boundaries were converted to feature polygons. This was done by tracing the boundaries between sub-basins to generate arcs. After all of the boundaries had been defined the arcs were converted to polygons and the polygons assigned the appropriate basin ID. After defining basin boundaries, attributes such as basin areas and slopes and stream lengths and slopes were computed. These are all geometric parameters used in defining basins and routing networks in HEC-1 made within WMS. If the basins are changed in any way, the drainage data must be recomputed. When computing basin data the model units and the parameter units must be specified.

The primary objective of WMS is to delineate stream networks and drainage basin boundaries using a DEM terrain model. Since the terrain model is an accurate geometric description of the watershed, parameters such as areas, slopes, and flow distances can automatically be computed. This terrain model then serves as a map to guide entry of all data necessary to run HEC-1.

The first process in performing drainage analysis is to edit the model where necessary. Flat triangles, flat channel edges, and flat ridge edges must all be eliminated before trying to delineate stream networks and basin boundaries. Filtering and removal of flat objects was used. Manual insertion of break lines, the addition of new points, and edge swapping aid in removing anomalies that are introduced into the model. With the model properly edited, stream networks and drainage basins defined in preparation for defining a complete hydrologic analysis are processed.

8. Lag Time and Time of Concentration Used by FATT in Watershed Modeling

Lag time (T_{LAG}) and time of concentration (T_c) are variables FATT used when computing surface runoff using unit hydrograph methods available in HEC-1. These variables indicate the response time at the outlet of watershed for rainfall event, and are primarily a function of the geometry of the watershed. Many different equations have been developed for different watersheds, and most of these equations are a function of the geometric parameters computed by WMS. WMS has implemented many of these equations and allows you to choose from the ones listed to automatically compute lag times / time of concentrations in HEC-1. By default no equations are defined, but once an equation is specified, the lag time and time of concentration will be computed automatically each time that basin data are computed, or when the curve number changes.

Because the equations were developed for specific watersheds (i.e., size, land cover, etc.) FATT considered the assumptions made about a given equation, and match identifies one that used watershed conditions similar to the ones, studied. The following was the WMS equation used by FATT to develop the hydrologic models for the watersheds. FATT chose to use the SCS equations. SCS found that from many field investigations and cases, the lag time of a specific watershed or basin could be related to the concentration time of flow by the following equation:

$$T_{LAG} = 0.6 * T_c$$

This relationship is always used by WMS to determine lag time when a method of computing time of concentration is chosen, or to compute time of concentration when a method for lag time is chosen.

The Soil Conservation Service (SCS, 1975) suggested that

$$T_c = 1.67\ T_{LAG}$$

Where T_{LAG} is defined with the peak discharge of direct runoff. When the other definition of T_{LAG} based on centroids is used, then

$$T_C = 1.42\ T_{LAG}$$

These equations are only valid when the time of concentration is reached.

The NRCS (SCS) (1972) developed an equation using the curve number method to estimate watershed lag time, T_{LAG} , (from the center of mass of the effective rainfall to the time of the peak runoff) that can be expressed as

$$T_{LAG} = (L^{0.8} (S_P + 1)^{0.7}) / (1900 * S^{0.7})$$

Where T_{LAG} is in hours, L is the hydraulic length of the watershed in feet, s is the average watershed landslope in percent, and S_P is the potential watershed storage in inches = 1000 / (CN –10), CN=hydrologic soil – vegetative cover complex number.

In modeling watersheds, WMS creates HEC-1 files compatible with any version of HEC-1. FATT computed the peak discharges and hydrographs with the HEC-1 module within WMS. Once an HEC-1 simulation had been run, FATT reviewed the resulting hydrographs.

After viewing the hydrographs, FATT repeated the previous steps in order to calibrate the watershed model and to look at different scenarios

In WMS an outlet point is used to represent locations where hydrographs are both combined and then routed. Precipitation, base flow, loss rates, and unit hydrograph methods for each hydrograph were specified before a complete HEC-1 file was created. Data for one or more basins was entered by selecting the basins, if no basins are selected, the information entered is applied to all basins.

9. Precipitation Patterns Within Watersheds Modeled by FATT

Precipitation patterns for the July 8, 2001, storm event, a 25-year/24-hour storm event, and a 100-year/24-hour storm event were assigned to basins. If multiple basins were selected then the defined parameters applied to all selected basins. If no basins are selected, the parameters were applied to all basins. FATT assumed uniform distribution of the precipitation for the time interval modeled.

10. Model Hydrology Loss Methods Considered by FATT

One of several different loss methods can be chosen when generating synthetic hydrographs. A loss method is assigned to a basin by first selecting the basin and then choosing the Loss Method.

FATT used the NRCS (SCS) (LS) Loss Method

The SCS curve number method uses the following parameters:

- Initial rainfall abstraction in inches for snow-free ground
- SCS curve number for rainfall/losses on snow-free ground. Note: Composite Curve Numbers were computed automatically when this method for computing losses was chosen.
- Percentage of drainage basin that is impervious

11. Unit Hydrograph Method Used by FATT in Watershed Modeling

One of several different unit hydrograph methods can be chosen when generating synthetic hydrographs. A method is assigned to a basin by first selecting the basin and then choosing the Unit Hydrograph Method in WMS. FATT used the SCS Dimensionless Unit Hydrograph Method. Parameters for generating a unit hydrograph using the SCS dimensionless method include:

- T_{LAG} = SCS lag time in hours

12. Stream or Drainage Routing Data Used by FATT

    Outlet points are used to define locations where hydrographs are combined and then routed downstream. The appropriate combined hydrograh stations are generated automatically when writing a HEC-1 file. Routing data was entered in order to simulate the movement of a flood wave through the river reaches. The effects of storage and flow resistance are accounted for in the shape and timing of the flood wave. In addition to these changes, volume may be lost due to channel infiltration. Routing methods available in HEC-1 are based on the continuity equation and the relationship between flow and storage or state.

13. Basin Outlet Names Used by FATT

    Outlets are used for both types (combining and routing) of hydrograph stations in the HEC-1.

14. No Routing at Basin Outlet Nodes Determinations by FATT

    By default there is no routing at an outlet point. This allows for hydrographs to be combined without considering routing effects.

15. Muskingum Routing Equation Method Used in the Watershed Modeling by FATT

    FATT chose the Muskingum routing method to be used in the HEC-1 module of WMS. The Muskingum method is dependent primarily upon an input-weighting factor. The Muskingum method is one of the most popular methods of channel-flow routing. The parameters along with a short description of their meaning are as follows:

    - The number of integer steps (equal to the number of subreaches for the stream or drainage area) for the Muskingum routing
    - Muskingum's k coefficient is the average reach travel time. Its dimension is in time.
    - Muskingum's x coefficient is a dimensionless coefficient used to weigh the relative effects of inflow and outflow on reach storage. x is known as a weighing factor. Theoretically, x can vary from 0 to 1 (Singh, 1992).

16. Storage Considerations Used by FATT

Storage-discharge routing can be used to define either channel or reservoir routing. The following parameters must be defined regardless of the storage routing option specified.

- Number of steps to be used in the storage routing
- Storage in acre-feet
- Discharge in ft^3/sec (cfs)
- Elevation in feet
- Storage, discharge, or elevation corresponding to the desired starting condition at the beginning of the first time period

17. Channel Routing Used by FATT

Channel routing used by FATT was with normal depths and methods. By using normal depth method, the following parameters must be defined:

- Manning's coefficient (n) - Manning roughness coefficients for the channel, and left and right overbanks
- Length - The length of the river reach
- Slope - The slope of the river reach
- Max Elevation - The maximum elevation for which storage and outflow values are to be computed

In addition to these parameters an eight-point cross-section was defined. The first two points define the left overbank, the third point defines the left bank, the fourth and fifth points define the channel itself, the sixth point defines the right bank, and the last two points define the right overbank.

18. Gages (PG) used by FATT HEC-1 Analysis Within the BOSS WMS Software

Gages can be used to establish the position and rainfall accumulation for rainfall gages. For all watersheds analyzed a uniform precipitation event over the watershed was assumed.

I. FATT's Utilization of HEC-1 Analyses with WMS Modeling

Before running an HEC-1 simulation, FATT ran the WMS model checker, which helped identify serious and potential problems that were corrected before a successful run of HEC-1 was made. Model Check in WMS reported any possible errors/inconsistencies in the model so that corrections were made prior to executing. Two types of information are provided as a result of this command. The first type is simply informational and provides things such as the starting time, time step, and total time of the simulation. The second

types of information messages are errors and were corrected before an accurate HEC-1 analysis was performed.

1. Computing NRCS (SCS) Curve Numbers and Runoff Coefficients

   NRCS curve numbers are typically determined by using an NRCS table relating land use to hydrologic soil type. The hydrologic soil type can be either A, B, C, or D, as defined by the NRCS country reports. Where the soils infiltration capacity decreases from A to D. The curve numbers for each soil group for a given land use are by the NRCS publications. (Table 1). A composite curve number for a basin can be computed by taking an area-weighted average of the different curve numbers for the different regions (soil type and land use) within a basin. The same thing can be done to compute a composite runoff coefficient, only in this case a table relating soil ID to runoff coefficient is used rather than a table for curve numbers.

   WMS defined a hydrologic soil coverage or grid, and land use coverage or grid that defined boundaries for the different soil types and land uses. These data were then mapped to drainage coverage polygons or TIN triangles and used in the computation of a composite curve number. The following data was used for computing composite CNs:

   - Basin boundaries were defined with feature objects (remember that boundaries defined from a DEM are converted to feature objects)
   - Land use IDs were supplied from land use coverage in the map module or as DEM (a grid) attribute
   - Soil type IDs were supplied from soil type coverage in the map module or as DEM (a grid) attributes

   Combinations of the different data required for computations were used (i.e., drainage coverage, land use grid, soil type coverage, etc.).

2. BOSS'S WMS Modeling Computation Method

   The computation method determines composite CN numbers or composite runoff coefficients. This affects the type of mapping table and also where results are stored. When computing CN's the values are automatically stored with HEC-1.

3. NRCS Soil Types as Published and used by FATT

   The soil type option within BOSS's WMS determines whether NRCS published soil type coverage or a soil type grid will be used. The soil data obtained from published NRCS (SCS) soil type reports for counties of West Virginia has a slightly different meaning depending on the use of CN numbers. For CN numbers the critical attribute is the hydrologic soil type (0-soil A, 1-soil B, 2-soil C, 3-soil D).

4. NRCS Published Land use Types or Classifications used by FATT

   The NRCS land uses as published determine the land use coverage that was assigned by FATT to specific areas within subbasins of each watershed studied. The critical attribute for land use is an ID that can be related to a table of curve numbers, one value for each of the hydrologic soil groups.

5. Channels and Channel Flows as Modeled by FATT

   FATT analyzed the conveyance and other properties of channels using Manning's equation. Channel calculation allowed for the definition of rectangular, trapezoidal, triangular, and circular cross-sectional channels. Once channel input geometry is specified, either depth or flow can be computed after supplying a value for the other. When a hydrograph had been computed using HEC-1, the peak flow for the hydrograph was used as the default flow value.

All calculations (except Froude Number) used Manning's Equation:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

Where:

Q = Flow in cfs
n = Manning's roughness
A = Cross-section area of stream flow
R = Hydraulic radius for stream
S = Slope of stream reach

The Froude number is computed from:

$$F = \frac{V}{g_{*}y}$$

Where:

F - Froude Number (if F<1 then the flow is subcritical, and if F > 1, then flow is supercritical)
V - Velocity
g – acceleration due to gravity
y – equivalent depth of flow for a rectangular channel.

The equivalent depth of flow for a rectangular channel is computed by dividing the cross-sectional area of flow by the top width of the water surface.

6. Precipitation Events Modeled within the Watersheds by FATT

Two different options for defining precipitation are available from the WMS interface. The first is uniform rainfall over the entire watershed and the second allows gage data at specified locations to be defined. Since the watersheds are ungaged watersheds, FATT chose to use a uniform rainfall distribution over the watersheds as derived from NOAA's National Weather Service doplar radar precipitation hourly data.

7. Uniform Rainfall concept used by FATT

The Uniform Rainfall option requires that a single rainfall intensity curve for the entire watershed to be defined. Rainfall intensity values were defined for the given intervals as derived from the National Weather Services radar ranges for the entire storm event on July 8, 2001. For other storm comparisons, FATT chose to use the 25-year/24 hour and 100-year/24 hour storm events evenly distributed over the watershed.

IV. WATERSHED MODEL CALIBRATION by BOSS RiverCAD SOFTWARE

One of the most important steps in any hydrologic modeling problem is calibration. During the calibration phase, an attempt is made to model a set of conditions that have been known to exist at a watershed and for which measured data (surface depth) was available. The geometry, resolution, and input parameters of the model are adjusted until the output computed by the model is reasonably close to the measured data. FATT used actual field surveyed highwater elevations created by the July 8, 2001, flood event to calibrate the HEC-1 model for each watershed.

A. Calibration of Watershed Models with RiverCAD by FATT

To calibrate the results of the hydrologic modeling of all watersheds, FATT used BOSS International RiverCAD software. BOSS RiverCAD (RCAD) incorporates all of the advanced technology available. There is no other river modeling software package with this much capability. Boss RiverCAD is a completely self-contained packaged, providing complete support for both the U.S. Army Corps of Engineers HEC-2 and HEC-RAS numerical flow analysis models. Boss RiverCAD computes water surface profiles for modeling bridges, culverts, spillways, levees, bridge scour, floodway delineations, floodplain reclamations, stream diversions, channel improvements and split flows. FATT utilized the HEC-RAS modeling software to model the watersheds due to the mixed flow variables in the watershed. The benefit of using HEC-RAS over HEC-2 is that it can accommodate mixed flow conditions, i.e., subcritical and supercritical, while HEC-2 cannot.

A BOSS RCAD HEC-RAS model was developed by defining cross-section locations and the corresponding ground geometry using digital contour maps, digital terrain models, XYZ field coordinate data, USGS DEM (Digital Elevation Map) data, on-screen digitizing, manual data entry, and the XYZ coordinate data obtain from LiDAR.

RiverCAD uses Manning's formula to compute the conveyance of each roughness subarea for the current cross-section. It then sums together all roughness subarea conveyances to determine the total conveyance for the cross-section.

In computing the normal or critical flow depth for a specified discharge, an iterative process is used to compute the flow depth to the specified accuracy.

In computing the average flow velocity, RiverCAD assumes a uniform velocity distribution across the entire cross-section. This value is determined by dividing the discharge by the total flow area. The velocity of each roughness

subarea is also determined. However, only the maximum velocity is reported to the user.

The program will automatically determine an energy gradient value to use when the program uses the minimum elevation at the current and adjacent upstream cross-sections and the channel flow length to compute an approximate energy gradient. The computed energy gradient is then checked to determine whether it is a reasonable value.

When computing normal depth or normal discharge, the reported critical slope is the channel bed slope that would cause critical depth to occur for the specified (or computed) discharge value.

RiverCAD considers the entire cross-section geometry as available for flow in its computations. RiverCAD cannot address ineffective flow areas, channel improvements, floodplain encroachments, split flow reaches, or overbank areas in which divided flow has been restricted.

If either the starting or ending cross-section stations is below the computed (or specified) water surface elevation, the program automatically extends wetted vertical walls to contain the computed flow. However, no attempt was made to adjust the wetted perimeter to account for the addition of these vertical walls.

A known water surface elevation corresponds to a known water surface elevation (i.e., high water mark) at the cross-section. This value is used to back-calculate a standard and a length-weighted Manning's roughness coefficient using the average friction slope equation. This entry must be specified in Manning's roughness coefficients are to be computed at every cross-section.

Note that an iterative method in determining roughness coefficients may be required due to the uncertainty sometimes associated with high water marks. The back-calculated roughness coefficients can be used with another friction loss equation to compute new water surface elevations. The validity of the computed roughness values can then be verified by comparing the computed water surface elevations with the originally specified high water marks. FATT utilized this technique to calibrate the hydrologic analyses of all watersheds.

B. HEC-RAS Methodology as Used in the Watershed Modeling by FATT

BOSS RiverCAD (referred to hereafter as BOSS RCAD) is based upon a highly optimized version of the U.S. Army Corps of Engineers Hydrologic

Engineering Center (HEC) water surface profile computation model HEC-RAS.

C. Hydrological Assumptions and Conditions Assumed by FATT in Watershed Modeling in RiverCAD Software

The current version of HEC-RAS only supports one-dimensional, steady flow, water surface profile calculations. This section specifically documents the hydrologic capabilities of the steady flow portion of the HEC-RAS. HEC-RAS is designed to perform one-dimensional hydraulic calculations for natural and constructed channels. The following is a description of the major capabilities of HEC-RAS as used or considered by FATT in the watershed analyses:

1. Steady Flow Water Surface Profiles

   This component of HEC-RAS is intended for calculating water surface profiles for steady gradually varied flow. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles.

   The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (i.e., Manning's equation) and contraction/expansion (i.e., coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (i.e., stream junctions).

   The effects of various obstructions such as bridges, culverts, weirs, and structures in the flood plain may be considered in the computations. However, whenever FATT did not have sufficient accurate data concerning the stream flow through the structure, then FATT did not model the structure as being in place during the flood. The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodplain encroachments. Also, additional special features include multiple profile computations, multiple bridge and/or culvert opening analysis, and modeling of levees.

   This component of HEC-RAS is capable of simulating one-dimensional unsteady flow through a full network of open channels. This unsteady flow component was developed primarily for subcritical flow regime calculations.

Note that this component of the HEC-RAS modeling system is currently being developed by the Army Corps of Engineers Hydrologic Engineering Center and is not yet available.

2. Sediment Transport and Movable Boundary Computations

   This component of HEC-RAS is intended for the simulation of one-dimensional sediment transport/movable boundary calculations resulting from scour and deposition over moderate time periods (i.e., typically years, although applications to single flood events are possible).

   Note that this component of the HEC-RAS modeling system is currently being developed by the Army Corps of Engineers Hydrologic Engineering Center and is not yet available.

3. Steady Flow Water Surface Profiles

   Calculations for steady gradually varied flow in natural or constructed channels. Subcritical, supercritical, and mixed flow regime water surface profiles can be calculated.

4. Cross-Section Subdivision for Conveyance Calculations

   The determination of total conveyance and the velocity coefficient for a cross-section requires that flow be subdivided into units for which the velocity is uniformly distributed. The approach used in HEC-RAS is to subdivide flow in the overbank areas using the input cross-section value break points (locations where values change) as the basis for subdivision. Conveyance is calculated within each subdivision.

   The program sums up all the incremental conveyances in the overbanks to obtain a conveyance for the left overbank and the right overbank. The main channel conveyance is normally computed as a single conveyance element. The total conveyance for the cross-section is obtained by summing the three subdivision conveyances (left, channel, and right). Field surveyed cross sections were acquired by FATT in order to more accurately represent the stream channel reaches and characteristics.

5. Basic Data Requirements Used by FATT to Model the Watersheds with RiverCAD

   The following sections describe the basic data requirements for performing the one-dimensional flow calculations within HEC-RAS. The basic data are defined and discussions of applicable ranges for parameters are provided.

The main objective of the HEC-RAS program is quite simple---compute water surface elevations at all locations of interest for given flow values. The data needed to perform these computations are divided into the following categories:

- Geometric data
- Steady flow data
- Unsteady flow data (unknown - not readily attainable)
- Sediment data (unknown - not readily attainable)

Geometric data are required for any of the analyses performed within HEC-RAS. The other data types are only required if you are going to do that specific type of analysis (i.e., steady flow data are required to perform a steady flow water surface profile computation). The current version of HEC-RAS is limited to steady flow computations, therefore, geometric data and steady flow data are the only available data categories.

The basic geometric data consist of cross-section data, reach lengths, and energy loss coefficients (i.e., friction losses, contraction and expansion losses). Hydraulic structure data (i.e., bridges, culverts, etc.), that are also considered geometric data, will be described in later sections.

Boundary geometry for the analysis of flow in natural streams is specified in terms of ground surface profiles (cross-sections) and the measured distances between them (reach lengths). Cross-sections are located at intervals along a stream to characterize the flow carrying capability of the stream and its adjacent floodplain. They should extend across the entire floodplain and should be perpendicular to the anticipated flow lines (approximately perpendicular to the ground contour lines). Occasionally it is necessary to lay out cross-sections in a curved or dog-legged alignment to meet this requirement. Every effort should be made to obtain cross-sections that accurately represent the stream and floodplain geometry. However, ineffective flow areas of the floodplain, such as stream inlets, small ponds or indents in the valley floor, should generally not be included in the cross-section geometry.

Cross-sections are required at representative locations throughout a stream reach and at locations where changes occur in discharge, slope, shape, or roughness, at locations where levees begin or end and at bridges or control structures such as weirs. Where abrupt changes occur, several cross-sections should be used to describe the change regardless of the distance. Cross-section spacing is also a function of stream size, slope, and the uniformity of cross-section shape. In general, large uniform rivers of flat slope normally require the fewest number of cross-sections per mile. The purpose of the study also affects spacing of cross-sections. For instance, navigation studies on large relatively flat streams may require closely spaced (e.g., 500 feet) cross-sections to analyze the effect

of local conditions on low flow depths, whereas cross-sections for sedimentation studies, to determine deposition in reservoirs, may be spaced at intervals on the order of miles.

The choice of friction loss equation may also influence the spacing of cross-sections. For instance, cross-section spacing may be maximized when calculating an M1 profile (backwater profile) with the average friction slope equation or when the harmonic mean friction slope equation is used to compute M2 profiles (draw down profile). The HEC-RAS provides the option to let the program select the averaging equation.

A stream station label identifies each cross-section in a HEC-RAS data set. The cross-section is described by entering the station and elevation (X-Y data) from left to right, with respect to looking in the downstream direction. The stream station identifier may correspond to stationing along the channel, mile points, or any fictitious numbering system. The numbering system must be consistent, in that the program assumes that higher numbers are upstream and lower numbers are downstream within a reach.

Each data point in the cross-section is given a station number corresponding to the horizontal distance from a starting point on the left. Up to 500 data points may be used to describe each cross-section. Cross-section data are traditionally defined looking in the downstream direction. The program considers the left side of the stream to have the lowest station numbers and the right side to have the highest. Cross-section data are allowed to have negative stationing values. Stationing must be entered from left to right in increasing order. However, more than one point can have the same stationing value. The left and right stations separating the main channel from the overbank areas must be specified. End points of a cross-section that are too low (below the computed water surface elevation) will automatically be extended vertically and a note indicating that the cross-section had to be extended will show up in the output for that cross- section. The program adds additional wetted perimeter for any water that comes into contact with the extended walls.

Other data that are required for each cross-section consist of downstream reach lengths, roughness coefficients, and contraction and expansion coefficients. This data will be discussed in detail later in this chapter.

6. Stream Reach Lengths

The distance between successive cross-sections is referred to as the flow length or reach length. There are two methods of defining flow length between cross-sections. The first method is to simply allow the program to use the difference in cross-section grid identifiers. The program will then

use this difference distance for the left overbank, right overbank, and main channel flow lengths.

A second method requires that individual flow lengths between successive cross-sections for the left overbank, right overbank, and main channel be specified. This method permits the user to use cross-section grid identifiers that do not necessarily reflect actual flow distances.

Channel flow lengths are typically measured along the channel centerline (sometimes called the thalweg). Overbank flow lengths should be measured along the anticipated path of the center of mass of the overbank flow. Often the channel and overbank flow lengths will be equal. There are, however, conditions in which they will differ, such as at river bends, or where the channel meanders considerably and the overbanks are straight. Where the channel and overbank flow lengths are different, the program based upon the discharges in the main channel and left and right overbanks determines a discharge weighted flow length. This discharge weighted flow length is then multiplied by the average conveyance in the energy loss computations for the reach being analyzed.

In a meandering stream, the channel's effect on flow direction and its contribution to total conveyance may lessen as flow depth increases. Once the channel is submerged and water is flowing in the floodplain, the majority of flow may travel along a shorter path. The amount of flow that becomes overbank flow depends upon many factors, including the channel size relative to the overbank area as well as the channel roughness relative to the overbank roughness.

7. Energy Loss Coefficients Used in the Modeling

Four types of loss coefficients are utilized by the program to evaluate energy (head) losses:

- Manning's roughness coefficients for friction loss
- Contraction and expansion coefficients to evaluate flow transition losses
- Bridge loss coefficients to evaluate losses related to weir shape, pier configuration, and pressure flow conditions
- Culvert entrance loss coefficients to evaluate losses due to flow entering a culvert

8. Manning’s Roughness Coefficients

When three Manning roughness values, n, are sufficient to describe the channel and overbank roughness, the Manning roughness data entries

were used. These values were changed at any other cross-section, when required, to reflect changes in roughness.

Often, three Manning roughness coefficients are insufficient to adequately describe the lateral roughness variation in a cross-section. The horizontal roughness data entries in can be used to describe roughness encountered by flow through defined cross-section subareas. These roughness coefficients remain in effect until changed at a subsequent cross-section. They should be redefined for each cross-section that has different ground geometry stationing specified.

Selection of an appropriate value for Manning's n is very significant to the accuracy of the computed water surface profiles. The value of Manning's n is highly variable and depends on a number of factors including:

- Surface roughness
- Vegetation
- Channel irregularities
- Channel alignment
- Scour and deposition
- Obstructions
- Size and shape of the channel
- Stage and discharge
- Seasonal change
- Temperature
- Suspended material and stream bed load

In general, Manning's n values should be calibrated whenever observed water surface profile information (gaged data, as well as high water marks) is available. When gaged data are not available, such as were all three studied watersheds, then values of n computed for similar stream conditions or values obtained from experimental data should be used as guides in selecting n values. Each stream cross section that was surveyed was documented with a digital photograph. These stream cross section photographs were compared by FATT with known Manning values for similar photographed streams by the USGS, and other agencies.

There are several references FATT modelers accessed that show Manning's n values for typical channels. An extensive compilation of n values for streams and floodplains can be found in Chow's book, Open Channel Hydraulics (Chow, 1959) or Singh’s book, Elementary Hydrology (Singh; 1992).

Although there are many factors that affect the selection of the n value for the channel, some of the most important factors are the type and size of materials that compose the bed and banks of a channel, and the shape of

the channel. Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of Manning's n of a channel.

A detailed description of Barnes' method can be found in Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (FHWA, 1984). This report was developed by the U.S. Geological Survey (Arcement, 1989) for the Federal Highway Administration. The report also presents a method similar to Barnes' for developing Manning's n values for flood plains, as well as some additional methods for densely vegetated flood plains.

Limerinos (1970) related n values to hydraulic radius and bed particle size based on samples from 11 stream channels having bed materials ranging from small gravel to medium size boulders.

Limerinos selected reaches that had a minimum amount of roughness, other than that caused by the bed material. The Limerinos equation provides a good estimate of the base n value. The base n value should then be increased to account for other factors, as shown above in Cowan's method.

V. AGENCY ROLE AND OBSERVATIONS

Information gained from first-hand observation and professional assessments of the impacts on and behavioral factors of watersheds during the July 8, 2001, event provided important input that enhanced the technically gathered data. Additionally, it is necessary to understand the fundamental regulatory framework that governs the activities of the coal and timber industry and the agencies that administer these laws. The combination of these factors provides a framework from which to draw conclusions about the event and recommendations to mitigate damage from future flooding.

A. Mine Drainage System Regulation Overview

The State of West Virginia has regulated the West Virginia coal industry since the 1930's. In 1977, the Federal Surface Mining Control and Reclamation Act, as amended (SMCRA), was passed by Congress and made law. This led all states, including West Virginia, to increase the regulation and enforcement of surface mining laws, as necessary, to be at least equal to the SMCRA laws and regulations. The West Virginia Legislature noted that the diverse terrain, climate, biological, chemical, and other physical conditions required laws and regulations that were specific to this State. Accordingly, the West Virginia Legislature developed and put into effect the West Virginia Surface Coal Mining and Reclamation Act (Act).

Surface coal mining, including the surface effects of underground mines, has many dynamic aspects that have the potential for causing adverse impact on the safety and well being of the public and the environment. The West Virginia DEP through its Division of Mining and Reclamation (DMR) is responsible for the administering the mandates of the Act, and the rules and regulations promulgated thereunder (Regulations).

One aspect of surface coal mining that may result in significant damage to the safety and well being of the public, and the environment is the unregulated discharge of water. The unregulated discharge of water can cause or contribute to the following:

- Channel scouring
- Stream alteration
- Erosion of soil
- Mass transfer of suspended solids
- Alteration of the chemical and physical characteristics of the receiving stream
- Flooding
- Change of water quantity and quality in watersheds impacted by mining

- Adverse impact to environmentally sensitive areas
- Adverse impact to private and public property, and the health and safety of the public

All applicants for mining permits are required to manage water discharge from the permit area through drainage control structures or systems. All systems or structures used in association with the mining operation shall be designed, constructed, located, maintained, and used in accordance with the Act and the Regulations, and in such manner as to minimize adverse hydrologic impacts in the permit and adjacent areas, to prevent material damage outside the permit area, and to ensure safety to the public. All water discharged from the permitted area is to comply with State and Federal water quality standards and meet effluent limitations as specified in a National Pollutant Discharge Elimination System (NPDES) permit.

The primary sediment and water control structures or systems currently used by the regulated surface coal mining industry in West Virginia are:

- Constructed impoundment structures (permanent & temporary)
- Sediment ditches (permanent & temporary)
- In-pit storage
- Diversion ditches, (permanent & temporary)

  (Note - Temporary impoundment structures or water control structures are structures/systems that are replaced by permanent structures and/or systems, or structures or systems that will be removed when the disturbed permitted area is reclaimed and the reclamation bond has been released by the DMR).

Current regulated surface coal mine water control and sediment control structures, or systems used in association with the regulated surface mine shall:

- Be constructed in accordance with the plans, design criteria, and specifications set forth in the approved and issued DMR permit
- Be located as near as possible to the disturbed mining area
- Comply with applicable State and Federal water quality standards
- Meet effluent limitations as set forth in an NPDES permit for all discharges
- Be designed to have a settling basin capacity designed to store 0.125 acre/ft. of sediment for each acre of disturbed area in the controlled watershed
- Be equipped with a non-clogging dewatering device
- Be designed, constructed and maintained to prevent short-circuiting

- Be cleaned out when the sediment accumulation reaches sixty percent (60%)
- All embankment type structures be designed to safely pass a twenty-five (25) year, twenty-four (24) hour precipitation event peak discharge. The combination of both the principal spillway and/or emergency spillway shall be designed to pass this same peak discharge event.
- Provide adequate freeboard to resist overtopping by waves or sudden increases in volume and adequate slope protection against surface erosion and sudden draw down
- Provide that an impoundment meeting the size or other criteria of 30 CFR 7.216(a) or W. Va. Code § 22-14 et seq., or located where failure would be expected to cause loss of life or serious property damage shall have a minimum safety factor of 1.5 for a normal pool, and a seismic factor of at least 1.2. Impoundments not meeting the size or other criteria of the aforementioned laws and regulations, except for a regulated coalmine waste impounding structure, and located where failure would not be expected to cause loss of life or serious property damage shall have a minimum static safety factor of 1.3 for a normal pool.
- Control water discharges by the use of energy dissipaters, riprap channels or other devices
- All embankment type water control or sediment control structures shall be designed, constructed and maintained according to the applicable State and Federal safety standards for such structure

Diversion and sediment ditches shall have the capacity to pass safely the peak discharge from a twenty-five (25) year, twenty-four (24) hour precipitation event. However, permanent diversion ditches associated with valley fill, side hill fills, and durable rock fills used in the disposal of excess spoil shall be designed and constructed to safely pass the peak runoff from a one hundred (100) year, twenty-four (24) hour precipitation event.

Another notable fact derived from the study was that the July 8, 2001, storm event approached, but did not exceed the 25 year / 24 hour design standard for sediment pond discharges commonly used in the mining industry. FATT observed that the emergency spillways of all the surface coal mine related sediment structures in both Seng and Scrabble Creeks accommodated the July 8, 2001, flows without overtopping. From this fact, FATT concluded that the 25 year/24 hour design standard was not exceeded. The primary purpose of sediment control structures is to treat sediment discharges from permitted areas. The design intent does not encompass flood control.

DMR reviews the Surface Mine Application (SMA) and determines if the SMA is accurate and complete and whether it complies with the Act and Regulations. The agency will also determine if the applicant has demonstrated in the SMA that reclamation as required by the Act and Regulations can be accomplished. The applicant will demonstrate this in the probable hydrologic consequences (PHC) analysis, the hydrologic reclamation plan, the drainage section, and other sections of the permit application.

The PHC is the applicant's statement describing the probable hydrologic consequences of the proposed mining operation with respect to the hydrologic balance, on both the permit area and the adjacent area. The PHC is based on baseline information developed from sampling and analysis of surface and groundwater at monitoring sites established both on the permit area and adjacent areas. The PHC will include findings on:

- Whether adverse impacts may occur in the hydrologic balance
- Whether acid-forming or toxic-forming materials are present that could result in the contamination of surface or groundwater, and whether the proposed operation may proximately result in the contamination, diminution or interruption of an underground or surface water source of water within the proposed permit or adjacent areas which is used for domestic, agricultural, industrial, or other legitimate purpose, and what impact the operation will have on:

    - Sediment yield from the disturbed area
    - Acidity, suspended and total solids, and other important water quality parameters
    - Flooding or stream flow alterations
    - Groundwater and surface water availability
    - Other characteristics as required by the Director of DMR

The applicant for a permit shall submit with the application, all available data and analysis described in the Act and Regulations for use in preparing the cumulative hydrologic impact assessment (CHIA). The DMR shall perform a separate CHIA for the cumulative impact area for each application. This CHIA shall be sufficient to determine whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

DMR then completes the facts and findings which shall include a CHIA of the hydrologic regime associated with the proposed coal mining permit. The Agency also determines if the applicant has demonstrated that reclamation as required by the Act and Regulations can be accomplished. Based upon those facts and findings concerning the proposed mining

operations, the permitting staff will recommend to the Director of the DMR that the application be approved or denied. After consideration of the facts and findings, public input, and recommendation of the DMR professional staff, the Director will make a determination to approve or deny the permit.

The permit contains all designs, construction details and specifications for the release or discharge of any water from the mine site. Using this data and making field measurements of water quality and discharge characteristics, the DMR inspector can monitor the permitted coal mine operation water discharges to ensure that they are in compliance with applicable laws, rules, and regulations.

B. Overview And On-Site Summary Of Inspection And Enforcement Program

DMR employs approximately 80 inspectors, inspector specialists and inspector supervisors that are responsible for enforcing the West Virginia Mining and Reclamation laws and rules at coal mining and non-coal mining operations throughout the State. During calendar year 2001, they conducted nearly 20,000 inspections on coal mine facilities and approximately 1,000 inspections on non-coal mining facilities.

DMR inspection staff necessarily become intimately familiar with not only the permitted areas they regularly inspect, but also with the watersheds and terrain in the vicinity of these permitted operations. In times of natural disaster such as the flood of July 8, 2001, they are called upon to immediately respond to their areas of responsibility. They evaluate the situation relative to the permitted facilities, render assistance as necessary and initiate remedial and enforcement actions as the conditions warrant. DMR's activities during and immediately after the July 8, 2001, flood resulted in 24 notices of violation issued for conditions the agency found were caused by or contributed to by mining operations. Firsthand observation from inspection personnel is an important element in analyzing the contribution of mining practices to flood damage.

The FATT conducted interviews of inspection personnel assigned to operations in the impacted regions. Questions asked during these interviews focused on observations made by these individuals both on and off permitted operations, as well as general observations involving the remainder of the watershed. They were asked to describe impacts from other non-mining related operations or facilities in the vicinity as well. They were also asked to provide recommendations relative to the conduct of existing and future mining operations that may minimize or prevent future problems related to precipitation events.

This information is noteworthy in that it reflects the observation and comments from trained personnel intimately familiar with the operations and watersheds in their assigned territories. Information was collected from nine individuals, including supervisory personnel. These individuals include those employees that had operational responsibilities in the most impacted regions of the State.

A general summation of information obtained during this process indicated that:

- Most damage that occurred regarding permitted mining facilities was confined within the permit boundaries and consisted of erosion on the faces of valley fills/unvegetated regraded areas and sediment clogging and filling sediment control structures
- Damage or problems observed off of the permitted area consisted of sediment deposition resulting from breached sediment ditches and sediment being pushed through ponds that were already full from the precipitation event
- Damage related to non-mining related facilities centered on debris clogging road culverts and bridge underpasses, material washing from logging operations and skid roads acting as a focal point for runoff
- Additional questions involved stream obstructions and the constituent make-up of flooding debris. Much of the material observed backed up against culverts and low bridges and consisted of assorted trash and debris, including woody material.

The remaining questions addressed recommendations that could minimize damage in future heavy precipitation events. These recommendations are contained in Section IX-A.

C. Overview of Division of Forestry Regulatory Program

West Virginia has been active in developing and applying practices designed to protect water quality on forestlands. A booklet titled “West Virginia Forest Practice Standards” was published in 1972 prior to implementation of the Federal Water Pollution Control Act. Guidelines to protect soil and water resources during harvesting operations were provided in this booklet. Since then, the West Virginia DOF has been publishing a manual titled “Best Management Practices For Controlling Soil Erosion and Sedimentation From Logging Operations in West Virginia” (see Appendices of Part III). Forest management practices designed to minimize or prevent non-point source water pollution are called Best Management Practices (BMP). Many of the practices outlined in the manual were developed by researchers working at the Fernow Experimental Forest located near Parsons, West Virginia. Best

Management Practices include topics related to streamside management zones, logging debris, road/log landing construction and maintenance, seeding, and pipe installation. The BMP are reviewed every three years by a committee convened by the DOF Director under West Virginia Code Section 19-1B-7(h). The Director of the DOF may then adjust BMP based upon suggestions of the committee.

In 1992, West Virginia moved from a voluntary program to a regulatory program with passage of the 1992 Logging Sediment Control Act (LSCA). The DOF was designated by the Legislature as the agency responsible for carrying out the mandates and provisions of the Logging Sediment Control Act.

The West Virginia Code Section 19-1B-4 requires that anyone, with certain exceptions, conducting a logging operation, buying timber or buying logs for resale is required to be licensed by the Division of Forestry. Acceptance of the license implies that the operator will protect environmental quality through the judicious use of silvicultural BMP.

According to West Virginia Code Section 19-1B-7(g), all timbering operations shall be guided by the silvicultural BMP in selecting practices appropriate and adequate for reducing sediment movement. Failure to use a particular best management practice which causes or contributes, or has the potential to cause or contribute, to soil erosion or water pollution constitutes a violation. West Virginia Code Section 19-1B-5(b) and (c) empowers the Division of Forestry to issue compliance orders to correct problems and, when necessary, to suspend a logging operation until specified corrections are made to bring the operator or operation into compliance with the law. Instances that may result in suspension include when human life is endangered, uncorrectable soil erosion or water pollution, an operation is not licensed, or when a certified logger is not supervising the operation. Licenses may be suspended if the person is found to be in violation twice in any two-year period, and they may be revoked if the logger is found in violation for a third time in any two-year period.

VI. Summary of Citizens Concerns and Observations

During November 2001, a series of public meetings were conducted in five counties with representation from both the Advisory Committee and FATT.

A. Public Meeting 1 – No vember 5, 2001, Whitesville Junior High School, Boone /Raleigh counties, WV.

The November 5, 2001, Boone/Raleigh combined public meeting was the first of a four-county tour. The meeting was held in Whitesville at the Whitesville Junior High School.

Those in attendance were asked to share with members of FATT and the members of the Advisory Committee what they saw and what they experienced during the flooding of July 8, 2001.

There were approximately eighty citizens at the Boone/Raleigh meeting and many shared their accounting of that July day. Many of the speakers spoke of a tidal wave-type wall of water with debris carried on top. Various residents spoke of living in their respective communities for twenty to thirty-plus years and never experiencing anything close to this magnitude of flooding. Additionally, numerous residents mentioned a diesel or gasoline odor and others just a strong stench to the waters. There was mention of the water being yellow then turning gray.

One resident of Whitesville commented, “there’s enough coal in my yard to heat the hollow for four years. I mean coal, lumps of coal, sludge and stuff in my yard.” The same resident spoke of logging trucks running in and out of the hollow, all day and all night, without resting at all. This went on for three years. She states: “To me, that’s what’s happened. They have logged and logged, and it’s not just them.” Many commenters spoke of seeing logs and boulders the size of cars washing off the hillsides.

Several residents from Round Bottom, in Sylvester, spoke about the “bridge” jamming up with rock and debris. The debris backed up from the dam causing an overflow onto residents’ property. The water could not get through and under the bridge nor through the dam but overflowed onto the banks of the river and onto residents’ property.

One resident of White Oak in the Clear Fork area spoke about logging and mining activity in June, 1997. He stated that there was an increase in water runoff after logging activity began on the right-hand fork of Clear Fork and mining activity began in the left-hand fork of Clear Fork. He also said that two of his neighbors had lost their lives. The resident said that of the three floods that took place in 2001, July 8th was the worst, with water coming out of the hollow just “black as black gets, and it was swift. It was capping up, real rough water.” The creek had been cleaned out three times this summer (2001), each time “they went in the creek and started digging them a little deeper.” “Then after July the 8th they took our creek bed down six foot, and everybody in the left-hand fork immediately we lost all of our water. We’re still using water out of tanks filled by the fire department.”

B. Public Meeting 2 – November 8, 2001, Falls View Grade School, Fayette County, WV.

The second public meeting was held November 8, 2001, in Fayette County at the Falls View Grade School with approximately eighty citizens in attendance.

Much like the residents of Boone and Raleigh counties, the committee heard more personal experiences from the Fayette county residents regarding the July 8, 2001, flooding. The majority of residents spoke of seeing a yellow thick mud. The yellowing is believed to be, by some residents, a result of mining. Many addressed logging activity and associated red water since logging began in their communities.

One speaker commented that oil and gas and utility companies were also responsible for the flooding as they have cut roads up and down the hillsides and across the roads.

Another speaker stated that the railroad was also responsible for the flooding. "Well, a lot of that problem was caused by the railroad not having adequate drains and the water came under the railroad, through the banks and washed out on the other side and washed into people's property, and if it had the right drains in there, a lot of that water wouldn't have done that." "There was drains that had been clogged up since I was a kid, and they finally come in there and halfway cleaned them out, the railroad did, after this flood."

One resident of the Charlton Heights area complained that the Department of Highways has inadequate drainage lines in that area. He said that he has been dealing off and on with the DOH since about 1986.

C. Public Meeting 3 – November 19, 2001, Mt. View High School, McDowell County, WV.

The third of four meetings was held November 19, 2001, in McDowell County at Mt. View High School with approximately 45 people in attendance.

Residents reported much the same damages and experiences as did other residents in the previous county meetings. Reports of the diesel smell and rainbow film in and on the waters, oil spots that had washed off the hill, tidal waves, black mud after the water subsided, heavy coal dust, trees washing down and clogging up drains and bridges and several references to a slate dump in Carswell Hollow and inadequate drain pipes

from the mine site nearby. There were many references to the flooding of 1986 but, according to the residents, this flood was much worse.

One resident of Welch commented that Welch got the rains and flooding later, mid to late afternoon, and that it took longer to rise, but within two to three hours, it was gone. "I had fifty-eight inches of water in my basement. Our flooding was caused by debris that floated down the river and lodged itself against the bridge that goes over to the city park, and that had that not occurred, most of our homes on Lake Drive would never have even been affected." "My observation was that most of that debris was natural debris. I didn't see any cars floating down there. It was tree limbs, you know, tree trunks and that sort of thing that lodged in the bridge and the water backed up from that."

D. Public Meeting 4 – November 26, 2001, Wyoming East High School, Wyoming County, WV.

The fourth and final meeting of the five county tours was held November 26, 2001, in Wyoming County at Wyoming East High School with approximately eighty people in attendance.

A resident of Mullens stated, "I'm a lifelong resident of Mullens. I've lived there for sixty years. I've been through floods there. I've got brothers and sisters there. We've never been flooded like we have this time. I've never seen water come so quick, come so high. I do know that all the mountains around Mullens have been logged out and I went back in those mountains and it looked like a bomb went off back in there."

Another resident said that, "there were no warnings of an anticipated flood. We had four very hard rains in a six hour period but no harder than we had many times in the past." "I heard something and looked, and it looked like a tidal wave coming. That thing was thirty feet high and looked like a surfer could be underneath it, an ocean wave."

This resident spoke of a chemical smell in the air and a sheen that could be seen on the water. The resident commented that she smelled this same chemical odor when they de-gassed the holes on her property and that it burned her throat and caused her difficulty with breathing.

The resident also stated that a "mine blowout right below the Hilton Strip caused a big tidal wave which never touched the ground until it hit the creek in Indian Creek. There it met one just like it coming down Indian Creek and it was just unreal, and it will happen again."

One individual stated that he has surveyed almost all of the watersheds affected. “We’re surveying these watersheds where there are disturbances such as mountaintop removal, valley fills, steep slope logging, old gob piles, old strip mines and possibly mine blow-outs maybe filled by water being gathered up by old strip mines. The old strip mines, particularly in this county, are everywhere.”

“Where you are closer to these disturbances the flooding is much, much, more severe, and that I think is just about unquestioned. I was at the 4-H camp on Glen Fork below some of the worst steep slope logging I can imagine. There is no question as to how and why logs ended up in the swimming pool of the 4-H camp, and ironically the cabin furthest up the hill, it was pointed out to me, had the worst damage because it was below logging and it came down a little hollow and bashed up the cabin.”

“On the other side of Clear Fork, the entire watershed of Sycamore has been totally clear-cut. Above Mullens, there is tremendous timbering in the Rhodell area, and that caused water to roar down the Guyandotte River.”

“I’d also like to comment about the watersheds that have been chosen for this study. There is more in common between the Scrabble Creek watershed and the Seng Creek watershed than there is the control. Seng Creek and Scrabble Creek are both long, rather somewhat short, narrow watersheds with steep headwater. Anyhow, those two watersheds are very similar.” The control watershed at Sycamore at Colcord is a large watershed and is shaped like a funnel. It does have steep headwaters, but it is a very large basin of water that converges to a very small point which is where the community unfortunately was located. I don’t know where, it’s so hard to find undeteriorated watersheds in southern West Virginia, I don’t really know where you look for a control, but you’re comparing two apples to one orange.”

Many of the residents at this county meeting spoke directly to timbering/logging issues associated with the flooding.

Residents at all the public meetings spoke of the devastation and loss of lives had this flooding occurred during the nighttime hours versus the daytime hours. Neighbors were able to warn and help each other and, in most cases, could see the flooding coming.

VII. FLOOD ANALYSIS TECHNICAL TEAM RESULTS

The results contained in this report can be applied throughout southern West Virginia's steep slope topography. While this report concentrated mainly on runoff analyses during the storm event, other issues of concern such as stream hydraulic jumps or energy transitions, stream constrictions, random stream blockages, stream bed loading and transport, sediment deposition, and sediment transport were considered based mainly on observation and/or comments. These issues are reflected in the recommendations to further protect these watersheds and others in the future.

The results reached in this report are based on proven scientific, engineering, and hydrological modeling techniques.

Through modeling calibration and validation of the physical and hydrologic characteristics in each studied watershed (i.e., Seng Creek, Scrabble Creek, and Sycamore Creek) FATT's watershed methodologies have proven to be accurate in establishing hydrologic modeling similitude. The accuracy standards are accepted in both scientific and engineering disciplines for model validation. Application of these validation techniques indicates that the characteristics of the watershed, as modeled, are sufficiently accurate to produce meaningful results.

Using this methodology, FATT determined the degree of impact from mining and logging activities under different scenarios for each watershed. FATT decided that only two watersheds would be analyzed to assess impacts associated with mining and logging, as present on July 8, 2001. For this modeling, Seng Creek and Scrabble Creek were chosen.

FATT determined that no current mining and/or logging industry activities had occurred in Sycamore Creek. Moreover, significant, observable, and measurable flooding had occurred in this watershed. Therefore, Sycamore Creek was chosen to be the control watershed. This watershed would be representative of a limited industry impacted area, and would serve as a comparative watershed for perspective purposes only.

Five scenarios were developed for the analyzed watersheds (Seng and Scrabble Creeks). These scenarios would include modeling specific types of mining and logging activities, as they existed in the watersheds on July 8, 2001. Due to the lack of relevant data, such as stream gage information, precipitation measurements and current industry data, certain conditions relative to the watersheds and the industry activities were assumed in the FATT models. These include:

- Existing urbanized areas would remain constant in cover type and area throughout each scenario for each watershed model.
- No industry impoundment and/or drainage structure were allowed to attenuate water flows. All water would flow through as though the structures were at their maximum storage volume.
- No forest areas were assumed to be “burned” or associated with any major forest fires within the last 10 years.
- No other industries (oil, gas, highway, power line, utility lines, etc.) activities were addressed as having any impact of the physical and/or hydrologic characteristic of each watershed.
- Bridges, low water crossings, stream crossing culverts that were known to allow the flood waters to pass through were included in the FATT hydrologic model. For those structures where it was not known how long, how much, or if all stream flow was blocked, it was assumed that the structure did not cause a constriction that would create a pooling effect and was not included in the model for the specific watershed.
- Back pooling from major tributaries that the modeled watersheds flowed into were not considered unless validated stream gages located on the main stream at the confluence were available. It was determined that no valid gaging stations were available at the confluence of any of the modeled watersheds and the next tier tributary into which it discharged. Therefore, the backwater effect of the next tier tributary was not considered as being of significance unless the model watershed validation nodes were influenced by this backwater or pooling. FATT determined that none of the validation nodes were impacted or influenced by such conditions.
- Based upon information obtained from the NWS and the NRCS, antecedent soil moisture condition II was used for all watersheds analyzed.
- Based on information obtained from NOAA’s NWS and NRCS, storm distribution Type II was used for all precipitation models.

The scope of this analysis is the determination of runoff volume differences of the mining and logging impacts versus those of a non-disturbed watershed condition. Although this study modeled stream flow differences to determine whether impacts occurred, the evaluation of water surface elevations relative to such impacts was not studied. To do so, would require extensive data collection and further study, including an investigation of every reach of stream in the impacted watersheds, the damaged residences and every natural and manmade stream constriction that could influence water level.

FATT established modeling scenarios for Seng Creek and Scrabble Creek to determine the potential impact of mining and logging industries that occurred on July 8, 2001. The scenarios are:

SENG CREEK WATERSHED MODELING SCENARIOS

- Scenario 1: All mining and all logging activities as existed on July 8, 2001, were modeled in the watershed. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified and validated by FATT. This data is inserted into the base hydrologic modeling methodology to model the watershed. LiDAR 3 meter x 3-meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet are used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 2: All mining activities but no logging activities were modeled in the watershed. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data was inserted into the base hydrologic model. LiDAR - 3 meter x 3-meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 3: All mining with all areas assumed to be reclaimed and bond released, the vegetation has matured for 40 years and is equal to that of the surrounding area. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base hydrologic model. LiDAR 3 meter x 3-meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 4: No mining and no logging were shown modeled in the watershed. All forest areas were assumed to be mature. However, the mine topography as created by the mining activities as of 2001, and mapped by the LiDAR data was maintained in this model. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base hydrologic model. LiDAR 3-meter x 3-meter grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 5: No mining and no logging activities were shown in the watershed. All forest areas were assumed to be mature. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

SCRABBLE CREEK WATERSHED MODELING SCENARIOS

- Scenario 1: All mining and logging activities as existed on July 8, 2001, were modeled in the watershed. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified and validated by FATT. This data is inserted into the base hydrologic modeling methodology to model the watershed. LiDAR 3 meter x 3-meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 2: All mining but no logging activities as existed on July 8, 2001, were modeled in the watershed. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT, This data is inserted into the base hydrologic model LiDAR 3 meter x 3 meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 3: All mining with all areas assumed to be reclaimed and bond released, the vegetation has matured for 40 years and is equal to that of the surrounding area. No logging activities were shown in the watershed. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base hydrologic model. LiDAR 3 meter x 3-meter horizontal grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 4: No mining and no logging were shown modeled in the watershed. All forest areas were assumed to be mature. However, the mine topography as created by the mining activities as of 2001,

and mapped by the LiDAR data was maintained in this model. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base hydrologic model. LiDAR 3 meter x 3-meter grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

- Scenario 5: No mining and no logging activities were shown in the watershed. All forest areas were assumed to be mature. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data is inserted into the base hydrologic model. USGS 10 x 10-meter grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at approximately every 500 feet were used to increase the accuracy of the stream cross-sections and stream profiles within the watershed.

SYCAMORE CREEK WATERSHED MODELING SCENARIO (CONTROL WATERSHED)

Scenario 1: No mining and no logging were shown modeled in the watershed. All forest areas were assumed to be mature. NRSC (SCS) soil groups and types, CNs, land types, land descriptions were identified by FATT. This data was inserted into the base hydrologic model. LiDAR 3 meter x 3-meter grid data was used to create the ground topography for this model. FATT surveyed stream cross-sections at specific locations in the stream necessary to calibrate and validate the model.

Because Sycamore Creek was designated the control watershed with no logging or mining influences, FATT modeled only one scenario, based upon the July 8, 2001, storm event. The model results concerning watershed performance was certified and then validated by FATT as being accurate and precise in its representation of the hydrologic and physical characteristics of the watershed during the storm event on July 8, 2001.

Certain physical conditions associated with mining and logging influences on runoff were input into the modeling analysis to ensure accurate depiction of these activities. Some of these conditions were:

- Type of terrain and slope of natural undisturbed ground
- Type of mining activity - Approximate Original Contour (AOC) versus Regrade Variance
- Extent of mining
- Degree of reclamation

- Type of logging activity – Select-cut or clear-cut methods
- Extent of logging activity
- Extent of post-timbering regrowth
- Location of industry activity within the watershed

Upon assembly of all pertinent research, data, and factors of influence concerning the subject watersheds, the modeling analysis was completed. After calibration and validation of model accuracy, the following results were obtained. For a more detailed comparison of watershed effects, refer to Parts II and III of this report.

The scenario comparisons yielded the following results. The results represent the percentage increases or decreases in flow volumes (ft^3/sec) at various locations within each study watershed.

Seng Creek

SENG CREEK WATERSHED - (July 8, 2001 event)								
PEAK DISCHARGE STREAM FLOW VALUES AND PERCENTAGE DIFFERENCES IN WATERSHEDS COMPARED WITH UNDISTURBED WATERSHED								
NODE LOCATION	Scenarios 1:2 Total Logging Influence		Scenarios 2:4 Total Mining Influence		Scenarios 4:1 Total Logging & Total Mining Influence		Scenarios 4:3 Mining with Reclaimed Topography Influence & No Logging	
Node 1C at mouth of watershed	144 cfs	5.9%	-6 cfs	-0.2%	138cfs	5.6%	-78 cfs	-3.3%
Node 2C	126 cfs	5.8%	-19 cfs	-0.9%	107 cfs	4.9%	-93 cfs	-4.4%
Node 3C	112 cfs	5.9%	55 cfs	3.0%	167 cfs	9.1%	-18 cfs	-1.0%
Node 4C	76 cfs	5.6%	-10 cfs	-0.7%	66 cfs	4.8%	-81 cfs	-6.3%
Node 5C near toe of Valley fill	27 cfs	3.9%	-19 cfs	-2.8%	8 cfs	1.1%	-87 cfs	-14.1%

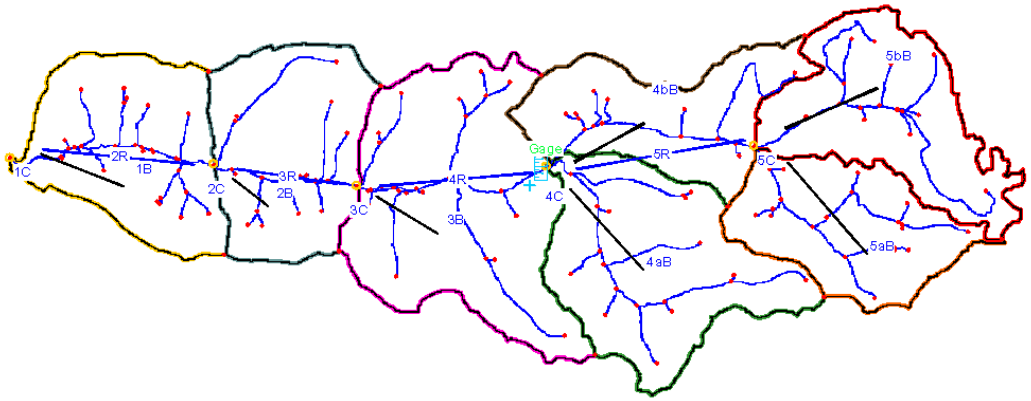
In the Seng Creek watershed at the 1C node (near mouth of the receiving stream), FATT determined that logging had a 5.9% flow increase and mining had a 0.2% flow decrease.

Logging in Seng Creek occurred fairly recently (within 1 – 5 years) and had minimal regrowth opportunity. Mining operations were ongoing and the actual regrade designs allowed a regrade variance from AOC. Specifically, the mined areas were regraded to a configuration having flatter slopes than the original pre-mining topography. This alteration of the topography by the surface mine to lesser slopes had a beneficial effect and produced less of an overall impact or influence outcome relating to surface runoff volumes and stream peak discharges.

Seng Creek Hydrology Analysis

Seng Creek Watershed Hydrology Analysis	Scenario 1 With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	Scenario 2 Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	Scenario 3 Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	Scenario 4 Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	Scenario 5 With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Watershed Delineation and Basin / Outlet / Routing Naming



Scrabble Creek

SCRABBLE CREEK WATERSHED - (July 8, 2001 event)								
PEAK DISCHARGE STREAM FLOW VALUES AND PERCENTAGE DIFFERENCES IN WATERSHEDS COMPARED WITH UNDISTURBED WATERSHED								
NODE LOCATION	Scenarios 1:2 Total Logging Influence		Scenarios 2:4 Total Mining Influence		Scenarios 4:1 Total Logging & Total Mining Influence		Scenarios 4:3 Mining with Reclaimed Topography Influence & No Logging	
Node 1C at bottom of Scrabble Creek	75 cfs	3.8%	168 cfs	9.3%	243 cfs	13.5%	-139 cfs	-8.4%
Node 2C	65 cfs	3.7%	205 cfs	13.4%	270 cfs	17.6%	-107 cfs	-7.5%
Node 3C	10 cfs	1.1%	110 cfs	13.4%	120 cfs	14.7%	-51 cfs	-6.6%
Node 4C Downstream of Valley Fill	0 cfs	0%	30 cfs	17.3%	30 cfs	17.3%	-2 cfs	-1.2%
Node 5C Downstream of Valley Fill	0 cfs	0%	59 cfs	21.1%	59 cfs	21.1%	-1 cfs	-0.4%
Node 6C Downstream of Valley Fill	0 cfs	0%	22 cfs	19.6%	22 cfs	19.6%	1 cfs	0.9%
Node 7C	23 cfs	4.0%	68 cfs	13.5%	91 cfs	18.1%	-33 cfs	-7.0%

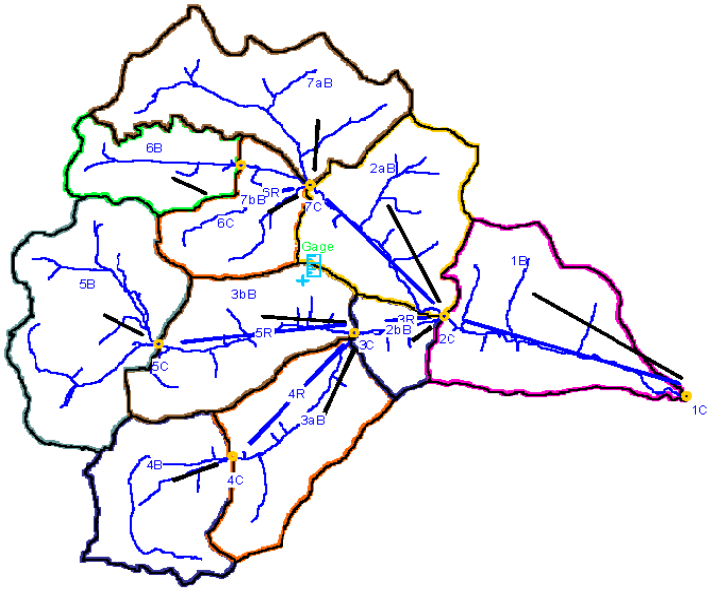
In the Scrabble Creek watershed at the 1C node (near mouth of the receiving stream), FATT determined that logging had a 3.8% flow increase and mining had a 9.3% flow increase.

In this study watershed, both current and recent logging occurred, but affected a lesser fraction of the watershed area than in Seng Creek. Much of the mining area was in some form of reclamation, but the average regrade slopes closely approximated those of the pre-mining topography when compared to Seng Creek. The mine reclaimed steeper slopes created faster surface runoff and retarded less flows than that of the surface mine in Seng Creek that had less reclaimed topographic slopes.

Scrabble Creek Hydrology Analysis

Scrabble Creek Watershed Hydrology Analysis	Scenario 1 With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	Scenario 2 Without Logging (CN 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	Scenario 3 Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	Scenario 4 Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	Scenario 5 With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Watershed Delineation and Basin / Outlet / Routing Naming



Sycamore Creek

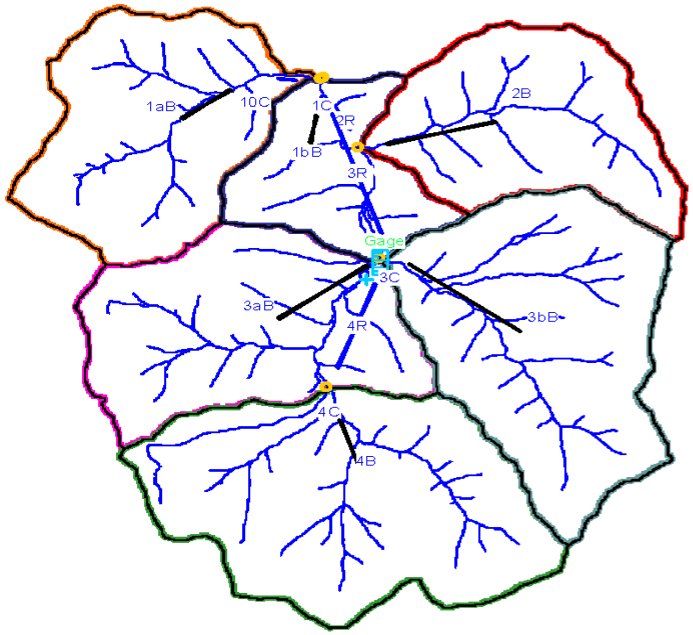
Sycamore Creek was observed to have extensive surface water runoff impacts with negligible logging and mining disturbances. No current logging or mining operations were identified in this watershed. Surface mining had been conducted many years ago (estimated 20 or more years) along a small contour operation near the head of the watershed. Over the years, natural revegetation of this mining disturbance had occurred. For modeling purposes, this watershed was assumed to be undisturbed.

The assimilated design storm in Sycamore Creek, representing the July 8, 2001, event consisted of 2.6 inches of rainfall over an approximate 5-hour period. This amount of rain was less than the 3.9 inches and 4.1 inches observed in Seng and Scrabble Creeks, respectively. Nevertheless, the impacts to the Sycamore Creek watershed by the “out-of-bank” flows were severe, especially when considering the damages caused to the community of Colcord, located near the mouth of Sycamore Creek. Because of these runoff impacts in the watershed, Sycamore Creek was chosen by FATT to provide a perspective analysis focusing upon the July 8, 2001, precipitation event and its associated surface water runoff effects in the watershed.

Sycamore Creek	LIDAR (wo Mining & wo Logging)		
Outlet Node	Event	25 yr	100 yr
1C	1211	4378	6078
2C	198	901	1255
3C	840	3374	4737
4C	333	1513	2109

9 fps

Watershed Delineation and Basin / Outlet / Routing Naming



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WMS Peak Discharge Values.xls

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VIII. FLOOD ANALYSIS TECHNICAL TEAM CONCLUSIONS

The Flood Analysis Technical Team in conjunction with the Flood Investigative Advisory Committee both enacted by Governor's Executive Order No. 16-10 undertook an extensive investigation into the scientific and hydrologic cause of the July 8, 2001 floods. The investigation focused on any impacts that current and past practices of the timbering and mining may have had or contributed to the aforementioned flooding events. The investigation made extensive use of information obtained from numerous Federal agencies, other West Virginia State agencies, and West Virginia University. Additional information was gained through agency consultations, individual interviews and public meetings.

The study concentrated on runoff analysis. The results reached in this report provide an indication of the impacts of mining and forestry practices and the consequent behavior of the watersheds throughout the July 8th storm event. This report may form the basis for more analyses in the future. Although time did not allow for additional watersheds to be studied, the results contained in this report are applicable to most steep slope topographic regions associated with most of southern West Virginia. While this study was based upon runoff analysis comparative methods, other issues of concern such as sediment deposition were considered based mainly on observation and/or comments. References to these types of issues are presented in the recommendations to provide further downstream protection.

In general, the percentage contributions of mining and timbering were relatively small when compared to the total stream flow volumes and the associated cross-sectional areas <u>at the mouths</u> of the selected watersheds, i.e., Seng Creek and Scrabble Creek. However, at evaluation points further upstream and closer to the industry disturbances, the calculated runoff volumes often increased and the associated effects became more pronounced. These effects intensified primarily because the topography is more restrictive and provides less cross-sectional area to accommodate flows and the closer proximity to industrial activities provides less runoff attenuation.

In the modeled watersheds, flows were "out-of-bank" for all scenarios, including the undisturbed scenario assuming no industry influences. Even without the exacerbating effects from the industry operations, significant "out-of-bank" flows would have resulted.

Any increase in runoff contributions must be considered potentially significant. However, it would be presumptuous of FATT to draw conclusions regarding significance without further long-term investigation and analyses, including (as previously mentioned) an investigation of every reach of stream in the impacted watersheds, the damaged residences and every natural and

manmade stream constriction in those watersheds that could influence water level. What can be concluded, however, is that mining and timbering impacts did influence the study watersheds by increasing surface water runoff and the resulting stream flows at various evaluation points.

IX. FLOOD ANALYSIS TECHNICAL TEAM RECOMMENDATIONS

These recommendations are meant to foster enhanced runoff control for logging and mining operations. Most of the recommendations contained herein will have to be implemented through rulemaking or, in the case of forestry, formal changes to the Best Management Practices, while others pertaining to forestry can be implemented through policy or programmatic development, as indicated.

As noted below, a number of these recommendations are the result of the technical analysis conducted for the development of this report. Others came as a result of field observations made by agency professionals and information developed from the public meetings that were conducted as part of this effort.

A. FATT RECOMMENDATIONS FOR MINING AND RECLAMATION OPERATIONS

1. Recommendations Resulting from the Technical Analysis

a. Revise regulations to enhance Hydrologic Reclamation Plans for all existing, pending and future permits to prohibit any increase in surface water discharge over pre-mining conditions.
b. Revise regulations so that the post-mining drainage design of all existing and future mining permits corresponds with the permitted post-mining land configuration.
c. Revise regulations to enhance contemporaneous reclamation requirements to further reduce surface water runoff.

2. Recommendations Resulting Primarily from Observations

a. Revise regulations to require that each application for a permit contain a sediment retention plan to emphasize runoff control and minimize downstream sediment deposition during precipitation events.
b. Revise regulations to require durable rock fills be limited to “bottom up or incremental lift construction” methods for enhanced runoff and sediment control.

c. Revise regulations to require the condition of the total watershed be reviewed prior to any approved placement of excess spoil material. Conditions that should be considered include the proximity of residents, structures, etc., to excess spoil disposal structures.
d. Revise regulations to require that valley fill designs minimize erosion within the watershed during precipitation. The permittee shall consider the total disturbance of the disposal area.
e. Revise regulations to prohibit “wing dumping” of spoil in excess spoil disposal structures.
f. Revise regulations to prohibit placement of windrowed material in areas that encroach upon natural drainageways.
g. Revise regulations to limit areas allowed for clearing/grubbing of operations in excess spoil disposal areas.
h. Revise regulations to maximize reforestation opportunities for all types of post mining land uses.
i. Revise regulations to require rain gages be located on all mine sites and that monitoring and reporting schedules be developed.

B. FATT RECOMMENDATIONS FOR FORESTRY OPERATIONS

Agency observations and comments by the public indicated substantial movement of logging debris and sediment from logging operations into streams during the flood event. Transport of this material was caused in part by concentration of flow by logging and skid roads. In addition, disposal of slash near streambeds also contributed material that may have increased flood damage. Erosion of material from roadways was evident from aerial overflights after the July 8 storm.

FATT recommends that the forestry oversight committee, established under the Logging Sediment Control Act, W.Va. Code 19-1B-7, include the foregoing recommendations as revisions to the West Virginia Best Management Practices to enhance sediment and runoff control. We further recommend increased staffing to aid in: forest fire prevention and suppression, forest hydrology, and field inspection and verification of the use of existing and proposed BMPs. While research shows the value of using BMPs, close field verification and vigorous enforcement are necessary to provide the benefits associated with proper timbering methods.

1. Recommendations

a. Revise BMPs to limit logging activities within the total area of a watershed based upon acreage, basal area removed, silvicultural methods or any combination so as to minimize runoff velocities and channelization of flows due to total watershed disturbance.

b. Revise BMPs to prohibit the use of lopped slash as a substitute for seeding on skid roads, require out-sloping and seeding of all roads prior to a post-operational site inspection or within sixty days of the end-date in the timber harvesting notification.
c. Revise BMPs to require a slash disposal plan be included in all timber harvesting notifications to provide for the removal of slash from roadways and landing areas. The BMPs should be revised to prohibit placement of large woody vegetation in intermittent and perennial stream channels.
d. Revise BMPs to require that the past history of uncontrolled burning in the watershed be taken into account in designing timbering operation plans to reduce runoff from these areas. The committee should investigate increased staffing for forest fire prevention and suppression with the long-term goal of eliminating forest fires as a contributor to increased runoff.
e. The Division of Forestry should conduct pre-operational site inspections to review proposed timbering operation plans, sediment control practices, and BMPs to be used by operators.
f. The Division of Forestry should implement a routine inspection regime to monitor and enforce BMPs and timbering notification requirements during active operations.
g. The Division of Forestry should conduct a post-operational site inspection at the end-date of the timbering operation to insure that all BMPs and sediment control practices have been met prior to removal of equipment from the site.
h. The Division of Forestry should provide increased technical assistance to timber operators in training and field verification, specifically with regard to road construction, stream-crossing construction, log landing location, and sediment control measures.

C. ADDITIONAL AREAS OF CONCERN EXPRESSED BY THE GENERAL PUBLIC AND RECOGNIZED BY FATT

FATT recognizes the following areas as appropriate for study to prevent or minimize storm-related flood damage. While assessments of these issues were beyond the scope of the instant analysis, FATT understands that most, if not all, of these matters are being addressed by the statewide flood protection task force.

1. Undersized road culverts in streams.
2. Inadequate flow areas under bridges and failure to maintain the bridge stream flow area.
3. Stream encroachment from land development.
4. Littering and placement of debris into streams and their flood plains.
5. Oil, gas, and other large scale earth disturbance projects.

D. FATT RECOMMENDATIONS FOR FURTHER STUDIES

1. Follow-up studies on any implemented recommendations resulting from this report to analyze effectiveness.
2. Additional studies to determine effectiveness of current logging BMPs and possible enhancements.

Table 1

Nation Weather Service precipitation measurements on July 8, 2001

Location	Amount of Precipitation
NWS Charleston station	1.87” of precipitation
Clay	2.33” of precipitation
Madison	0.65” of precipitation
Tornado	0.80” of precipitation
South of Beckley	6.77” of precipitation
Beckley	4.56” of precipitation
Dry creek	3.91 of precipitation
Babcock	3.26” of precipitation
Hawks Nest	5.12” of precipitation
Oak Hill	4.78”of precipitation
Page	5.00” of precipitation

National Weather Service Rainfall Data

LOCATION	COUNTY NAME	NORMAL JULY RAINFALL	RAINFALL ON JULY 8TH
Mullens, WV Oceana, WV Pineville, WV Kopperston, WV Wolf Pen, WV Clear Fork, WV	Wyoming	4.80 inches	5.32 inches 5.19 inches 4.79 inches 3.49 inches 2.56 inches 1.53 inches
Hawks Nest SP, WV Page, WV Oak Hill, WV Gauley Mountain, WV Mann Lookout Tower	Fayette	4.80 inches	5.02 inches 5.00 inches 4.78 inches 3.78 inches 2.38 inches
Beckley VA, WV Crab Orchard, WV Dry Creek, WV Grandview, WV Beckley AP, WV	Raleigh	5.50 inches	4.56 inches 4.05 inches 3.91 inches 3.42 inches 2.64 inches
London Lock, WV Marmet Lock, WV Latuna, WV Charleston AP, WV Charleston RLX, WV	Kanawha	4.80 inches	4.02 inches 2.49 inches 2.15 inches 2.05 inches 1.87 inches
Elkhorn, WV War, WV Welch, WV	McDowell	4.60 inches	4.05 inches 3.07 inches 1.20 inches
Elk Run, WV Williams Hill, WV Madison, WV	Boone	4.60 inches	1.88 inches 1.79 inches 0.65 inches

Table 2

U.S. ARMY CORPS OF ENGINEERS RAINFALL COMPARISON 2001

Gage	July 8th Storm (4 hour event)	July 27th (24 hour event)
Beckley, WV	4.56 inches	5.31 inches
Pineville, WV	4.75 inches	1.30 inches
Oceana, WV	5.19 inches	1.15 inches
Mullens, WV	5.37 inches	2.36 inches
Oak Hill, WV	4.78 inches	2.81 inches
Hawks Nest, WV	5.72 inches	2.38 inches
Wolf Pen, WV	2.56 inches	1.51 inches
Kopperston, WV	3.49 inches	1.74 inches

U.S. Army Corps of Engineers – Huntington District
Precipitation Comparison - 2001

Gage	May 16-18**	July 8*	July 26	July 29	July 30	Total all Storms
LOCATION						
Bartlick, VA	NA	0.41”	2.45”	0.25”	1.53”	4.64”
Beckley, WV	NA	4.56”	5.31”	1.28”	0.96”	12.11”
Beech Fork Lake, WV	3.10”	0.14”	1.43”	0.81”	0.84”	6.32”
Bluestone Lake, WV	3.55”	1.55”	3.48”	1.52”	1.29”	11.39”
Clintwood, VA	NA	NA	2.86”	NA	NA	2.86”
Craigsville, WV	NA	1.49”	3.74”	3.20”	2.03”	10.46”
Dewey Lake, WV	1.44”	0.58”	2.82”	2.12”	0.95”	7.91”
East Lynn Lake, WV	4.05”	0.32”	2.15”	0.94”	1.39”	8.85”
Frametown, WV	NA	2.38”	0.42”	0.63”	1.04”	4.47”
Georges Fork, VA	NA	0.65”	3.00”	0.41”	0.54”	4.60”
Grayson Lake	2.05”	0.40”	0.39”	1.19”	1.49”	5.52”
Hawks Nest, WV	NA	5.72”	2.38”	2.00”	NA	10.10”
Haysi, VA	NA	0.42”	3.13”	0.27”	1.67”	5.49”
John Flannagan Lake	2.23”	0.44”	4.00”	0.30”	1.90”	8.87”
Kopperston, WV	NA	3.49”	1.74”	0.88”	0.92”	7.03”
Madison, WV	NA	NA	3.80”	NA	NA	3.80”
Mt. Lookout, WV	NA	1.82”	3.22”	2.07”	2.34”	9.45”
Mt. Nebo, WV	NA	NA	2.75”	2.08”	NA	4.83”
Mullens, WV	NA	5.37”	NA	0.92”	1.51”	7.80”
Oak Hill, WV	NA	4.78”	2.81”	1.10”	NA	8.69”
Oceana, WV	NA	5.19”	NA	1.27”	NA	6.46”
Pikeville, KY	NA	NA	2.26”	0.47”	0.81”	3.54”
Pineville, WV	NA	4.75”	1.30”	0.63”	NA	6.68”
Queen Shoals, WV	NA	2.47”	0.69”	1.04”	0.70”	4.90”
R. D. Bailey Lake, WV	2.18”	0.62”	1.77”	0.74”	1.47”	6.78”
Richlands, VA	NA	NA	3.25”	NA	NA	3.25”
Summersville Lake, WV	3.30”	1.09”	4.18”	2.83”	2.96”	14.36”
Sutton Lake, WV	2.26”	0.44”	1.06”	0.77”	2.01”	6.54”
Wayne, WV	NA	NA	2.22”	0.88”	1.66”	4.76”

*July 8, 2001– an estimated 4-hour storm event
** May storms - all observed values from COE projects.

Table 3

USGS Provisional recurrence interval of July 2001 flood in West Virginia from High Water Marks compared to Flood Insurance Study

Location	Elevation	Recurrence Interval
Tug Fork at mile 153.1 (Downtown Anawalt)	1686.9	50
Tug Fork at mile 151.8 (West side of Anawalt)	1653.7	>500
Tug Fork at mile 150.2	1603.6	100
Tug Fork at mile 145.2	1471.7	100
Tug Fork at mile 141.4 (Downtown Gary)	1404.9	10
Tug Fork at mile 136.3 (East side of Welch)	1317.4	10-50
Elkhorn Creek at mile 13.7 (East of Keystone)	1664.4	10
Elkhorn Creek at mile 8.25 (East of Kimball)	1491.0	10
Elkhorn Creek at mile 7.0	1465.6	10-50
Elkhorn Creek at mile 0.5	1307.5	50
Browns Creek at mile (North side of Welch)	1448.0	
Guyandotte River at mile 167.2	1567.2	>500
Guyandotte River at mile 159.7 (Mullens)	1427.8	>500
Slab Creek at mile 0.3 (Mullens)	1423.3	100
Guyandotte River at mile 157.5	1408.3	>500
Guyandotte River at mile 149.1	1338.9	100-500
Guyandotte River at mile 147.6	1330.1	100
Guyandotte River at mile 143.8 (approximate)		>100
Pineville Upstream of Park Street	1288.3	
Pineville Downstream of Park Street	1286.3	
Guyandotte River at mile 142.6 (In loop of river)	1272.0	>500
Guyandotte River at mile 138.5	1224.2	500
Guyandotte River at mile 131.7	1171.25	>500
Clear Fork at Oceana (2.8 miles above State Route 10)	1257.6	50
Clear Fort at mile 12.3	1238.1	100
Paint Creek 14,200 ft. above confluence of town of Pax	1629.8	100

Table 4

Provisional discharge of the July 2001 flood in West Virginia and estimated recurrence interval from USGS gaging stations
[Drainage area in square miles, peak stage in feet, peak discharge in cubic feet per second, and recurrence interval years.]

USGS station number and name	County	Drainage Area	Peak Stage	Peak Discharge	Recurrence interval
03177100 Payne Branch near Oakvale	Mercer	8.64	2.86	--	--
03178000 Bluestone River near Spanishburg	Mercer	199.00	18.30	6,000	2
03178500 Camp Creek near Camp Creek	Mercer	32.00	7.15	4,800	25-50
03179000 Bluestone River near Pipestem	Summers	395.00	11.44	9,110	2-5
03185000 Piney Creek at Raleigh	Raleigh	52.20	9.40	--	--
03190100 Anglins Creek near Nallen	Nicholas	23.50	No HWM	--	<2
03190500 Meadow Creek near Summersville	Nicholas	4.22	No HWM	--	<2
03191400 Laurel Creek near Summersville	Nicholas	4.28	No HWM	--	<2
03198350 Clear Fork at Whitesville	Raleigh	62.80	28.47	--	--
09199300 Rock Creek near Danville	Boone	12.20	6.45	380	<2
03200500 Coal River at Tornado	Kanawha	862.00	18.83	15,400	<2
03202245 March Fork at Maben	Wyoming	4.85	15.38	Indirect Q	--
03202400 Guyandotte River at Baileysville	Wyoming	306.00	31.25	Indirect Q	--
03202480 Briar Creek at Fanrock	Wyoming	7.34	No HWM	--	<2
03202490 Indian Creek at Fanrock	Wyoming	40.70	17.11	4,940	50
03202750 Clear Fork at Clear Fork	Wyoming	126.00	15.60	Indirect Q	--
03212750 Tug Fork at Welch	McDowell	174.00	19.77	Indirect Q	--
03212980 Dry Fork at Beartown	McDowell	209.00	10.13	7,180	5-10
03213000 Tug Fork at Litwar	McDowell	505.00	13.17	19,000	5
03213620 Tug Fork at Vulcan	Mingo	778.00	17.00	19,500	--
03213700 Tug Fork at Williamson	Pike (Ohio)	936.00	20.01	13,000	<2

Table 5

NRCS Runoff Curve Numbers (ref. TR-55 Appendix) for Cultivated Agricultural Lands[1]

			Curve numbers for			
Cover type	**Treatment[2]**	**Hydrologic Condition[3]**	**A**	**B**	**C**	**D**
Fallow	Bare soil	-	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + (CR)	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	68	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	88
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded	Straight row	Poor	66	77	85	89
or broadcast		Good	58	72	81	85
legumes or	Contoured	Poor	64	75	83	85
rotation		Good	55	69	78	83
meadow	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition.

[2] Crop residue cover (CR) applies only if residue is on at least 5% of surface throughout the year.

[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including:
(a) density and canopy of vegetative areas

(b) amount of year-round cover
(c) amount of grass or close-seeded legumes in rotation
(d) percent of residue cover on the land surface (good > 20%), and
(e) degree of surface roughness.

Poor: Factors impair infiltration and ten to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 5, con't – NRCS Runoff Curve Numbers for other Agricultural Land[1]

Cover Description		**Curve numbers for hydrologic soil group**			
Cover type	**Hydrologic Condition[3]**	**A**	**B**	**C**	**D**
Pasture, grassland, or range – continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay.					
	-	30	58	71	78
Brush – brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	88
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads – building, lanes, driveways and surrounding lots.					
	-	59	74	82	86

[1] Average runoff conditions.
[2] Poor: < 50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
[3] Poor: < 50% ground cover.
Fair: 50% to 75% ground cover.
Good: > 75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.
[5] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover.
Other combinations of conditions may be computed from the CNs for woods and pasture.
[6] Poor: Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 5, con't. - NRCS Runoff Curve Numbers for Arid and Semi-Arid Rangeland[1]

Cover Description		Curve numbers for hydrologic soil group			
Cover type	**Hydrologic Condition[2]**	**A**	**B**	**C**	**D**
Herbaceous – mixture of grass, weeds, and low growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak–aspen – mountain brush mixture or oak brush, Aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper –pinyon juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	72	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub – major plants include saltbrush, greasewood, creosotebruse, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	88	79	84

[1] Average runoff conditions. For rangelands in humid regions, use table 2-3b.
[2] Poor: < 30% ground cover (litter, grass, and brush overstory).
Fair: 30% to 70% ground cover.
Good: > 70% ground cover.
[3] Curve numbers for group A have been developed only for desert shrub.

Table 5, con't. – NRCS Runoff Curve Numbers for other Urban Areas[1]

Cover Description		**Curve numbers for Hydrologic soil group**			
Cover type and hydrologic condition	**Average percent Impervious area[2]**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, etc.)[3]**;**					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right of way).		95	98	98	98
Streets and roads;					
Paved; curbs and storm sewers (excluding-right-of-Way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, dessert shrub with 1 – 2 inch sand or gravel mulch and basin borders.)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
¼ acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
½ acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no Vegetation)[5]		77	86	91	94
Idle lands (CNs are determined using cover similar to those in table 2-2a)					

[1] Average runoff condition

[2] The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

[3] CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.

[4] Composite CNs for natural desert landscaping should be computed based on the impervious area (CN = 98) and the previous area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CNs to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CNs for the newly graded pervious area.

Table 5, con't. – NRCS Runoff Curve Numbers for Porous Pavement & Surface Mined Areas[1]

Cover Description		**Curve numbers for hydrologic soil group**			
Cover type and hydrologic condition	**Gravel Subbase Thickness**	**A**	**B**	**C**	**D**
Porous pavement					
Properly maintained	10 inches	57	66	69	75
Properly maintained	12 inches	56	64	68	74
Properly maintained	14 inches	55	63	67	72
Properly maintained	16 inches	54	62	65	70
Properly maintained	18 inches	53	61	64	69
Properly maintained	20 inches	52	60	63	68
Properly maintained	24 inches	52	58	61	66
Properly maintained	30 inches	49	55	57	61
Properly maintained	36 inches	47	52	55	58
Not properly maintained	10-36 inches	98	98	98	98
Disturbed surface mined areas					
Raw spoils (gob piles)		88	88	88	88
Graded spoils		84	84	84	84
Top-dressed spoils		82	82	82	82
Vegetated spoils		75	75	75	75

[1] Average runoff conditions, $I_a = 0.2S$.

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Peer Review Addendum

As provided by the executive order, the Flood Advisory Committee recommended that this study be evaluated by impartial experts. Consequently, the committee chose Dr. Rhett Jackson and Dr. Wayne Swank to perform independent peer reviews of the FATT study. Their comments/recommendations and corresponding FATT responses are as follows:

Comments from Dr. Rhett Jackson

MEMORANDUM

To: Jim Pierce, John Ailes, and the West Virginia Flood Analysis Technical Team (FATT)

From: Rhett Jackson, P.E., Ph.D., Assistant Professor of Hydrology, Warnell School of Forest Resources, University of Georgia

Date: May 29, 2002

RE: Review of Draft Flood Analysis Technical Team Report

Introduction:

This memorandum provides a summary of my comments, observations, and suggestions regarding the draft flood analysis technical team report. Due to perceptions that mining and timber management activities may have contributed to the magnitude of the summer 2001 floods experienced in southern West Virginia, the Governor of West Virginia commissioned the Flood Analysis Technical Team (FATT) to assess the floods and the contribution of mining and timber management to these floods. The FATT has produced a draft report and has contracted for external review of the report before it is released to the public. This memorandum documents the findings of the review I have performed. The draft report is a substantial and important contribution to the understanding of the summer 2001 floods, and my comments are meant to help improve the document as a resource for the public and for State agencies.

Recommendations for Direct Analysis of Flood Related Data:

It is my opinion that the report in its current form relies too much on the hydrologic/hydraulic modeling to characterize the floods and their causes. Although the observational data is probably insufficient to support rigorous statistical analysis of the floods and their causes, the observational data can be better used to understand and explain the floods of summer 2001. It is my experience that the public and agency personnel will be more receptive to conclusions or inferences drawn from raw data than to conclusions drawn from modeling. It is best when data

analysis and modeling are complementary. I have a number of suggestions for direct analysis of flood related data.

Land use in the study area, and the relationship of land use to flood magnitude, need to be explored in maps and tables. I suggest creating a map, or possibly a series of maps, illustrating the hydrography and land use in the study area as well as the spatial distribution of available data. An ideal map would show:

- stream network,
- land use roughly categorized as forest, recent harvest, active mine, closed mine, agricultural, and residential/commercial,
- locations of flood damage,
- rain gages and precipitation amounts on the day in question,
- USGS flow gages and recurrence interval of flow on the day in question, and
- locations and recurrence intervals of flows estimated from high water marks.

I suggest supporting this map with a land use table for each basin where flow has been measured or estimated. The table should include the following information:

- location,
- basin area,
- percent of basin in forest cover,
- percent of basin recently logged,
- percent of basin mined,
- percent of basin developed,
- precipitation depth during the storm, and
- recurrence interval of resulting flow.

From the map and the table, readers can infer whether mining and timber mangement appear to be correlated to flood magnitude, or whether flood magnitude seems to be independent of these land uses. The map and the table would also allow technical reviewers to understand what data are available and what data analysis is possible. For instance, one question that occurred to me while reviewing the report was why there were so few large flows reported at the existing USGS gages? Where are these gages located with respect to the high precipitation amounts experienced in the summer of 2001?

If there are enough locations in the study area where flood flows were measured or estimated from water levels, I suggest running a multiple regression of flow recurrence (or the ratio of the peak flow to the basin's mean annual flow) against basin area, precipitation depth, percent of basin recently logged, and percent of basin mined. The regression would discover whether there are significant relationships between the logged and mined areas and the magnitude of the resulting floods. If there are insufficient data for a multiple regression, I suggest grouping basins by basin size, and conducting a graphical analysis of mining and timber harvest. Specifically, create graphs of relative flood magnitude versus

percent of area mined, percent of area recently harvested, and the summation of the area mined and recently harvested. The problems with such an analysis are that each basin received a different amount of precipitation, the amount of precipitation received often must be estimated based on spatial extrapolation, and the antecedent moisture conditions for each basin were different. That is why a regression analysis would be better. If there is a strong relationship to precipitation depth, it might be possible to conduct a simple graphical analysis of the residuals from the precipitation relationship versus mined and logged areas.

Another possible avenue for addressing the effects of logging and mining is analysis of long-term peak flow time series from the USGS gages. If there are gages on streams with little or no influence of mining and logging, these stations can serve as controls. Then, the ratios of peak flows in logged and mined basins to the peak flows in the control basins can be analyzed over time, and the pattern can be compared to the time series of logging and mining activities. There are established procedures for this type of analysis.

A literature review on the hydrologic effects of timber management and mining would also help support this analysis. There is a lot of scientific literature on the effects of timber harvest and management on stream flows. I would be happy to provide a short review of the literature on timber harvest and hydrology, and I could also provide a bibliography of such literature. I am not familiar with hydrologic literature concerning coal mining, but if any such studies exist, they should be described in the report as well.

I also suggest analyzing the types of damages that occurred during the flood. How were people killed? Were flooded structures within the mapped 100-year floodplain? Were they new structures built in areas where flooding was previously experienced? The types and mechanisms of flood impacts might guide policy changes to help minimize the damages incurred in future floods.

Comments on the flood modeling:

There is nothing inherently wrong with the analysis that was conducted, but the presentation suggests that the modeling effort was something more than it was. In essence, the SCS Curve number model has been run under various logging and mining scenarios to estimate the relative impact of these activities on the floods experienced in the summer of 2001 based on the principles of the SCS model. This exercise allows the comparison of predicted storm runoff for a hypothetical fully forested condition and the actual land use composition of 2001, as well as other scenarios that allow the predicted effects of logging and mining to be separated. If the proportion of land in these activities is relatively small, or if the post-mining topography temporarily captures stormflow, then the SCS method will not predict a major change in downstream flows. If the proportion of land in these activities is large, the SCS method will predict major changes in downstream flows. This is basically a way of filtering a land use analysis through a hydrologic model. The

argument would be much stronger, however, if a graphical and tabular land use analysis accompanied the effort (see comments above).

Throughout the report there are comments that the BOSS modeling system provides accurate and precise results. Actually, the SCS method that is the basis for HEC-1 and BOSS modeling is inherently inaccurate. There is a very good reason that the textbooks and guidance documents for the SCS method do not show the original scatter plots from which the curve numbers were derived - such plots would erode the user's confidence in the results of the model. While the curve number for a mature forest on a certain type of soil may be 70, the actual runoff behavior of such a land/cover combination is actually quite variable due to differences in soil depth, bedrock conditions, topography, landscape position, and landscape history. For these reasons, uncalibrated hydrologic models, including the SCS model and others, are notoriously inaccurate. They may do a good job of predicting average relative differences between land uses, but describing them as accurate is not a fair statement, and if they are not accurate, their precision is basically meaningless. The models should simply be described as representing standard practice in the engineering and hydrologic communities, and that experience has shown these models represent the relative effects of land use change reasonably accurately.

There are other reasons that the BOSS modeling system cannot be described as accurate without more verification data. The input data itself is not highly accurate. The soil maps have precise lines showing where one soil ends and another begins, but these maps are developed from spot checks and aerial photographs, and while they are generally accurate, the errors in these maps may exceed the scale of the effect being modeled. Furthermore, the SCS method is not well suited for describing the hydrologic behavior of the highly modified landscape of a mine or a closed mine. Finally, the precipitation data put into these models is not very accurate. The high spatial variability of convective rainfall makes it very difficult to accurately assess how much rainfall fell on a basin during a single storm.

These qualifications about the accuracy of the model do not mean that the modeling effort is not worthwhile, but they should affect how the modeling is presented and how it is supported by other direct analysis of available data (see comments above).

Another caveat about the modeling is that the calibration that was conducted was not a true calibration as hydrologists use the term. The available data are not extensive enough to support a true calibration. A calibration data set must include a large number of different types of storms so that model parameters can be developed to provide robust simulation over a broad range of hydrologic and flow conditions. Matching a single peak from a single storm does not constitute a calibration.

Comments on the Organization and Content of the Report:

I am not sure what audience is being targeted with this report, but I think the report needs to be reorganized and shortened in order to reach a larger and more relevant audience. Much of the information on the details of the SCS, HEC1, and BOSS modeling belong in an appendix. This information is not informative to engineers and hydrologists familiar with the workings of these models, and it is not interesting to non-engineering audiences. The details need to be included in an appendix, so the analysis could be reproduced by others, but the details do not belong in the report.

I suggest restating the objectives (Section II) as follows:

1. Conduct a general hydrologic and hydraulic analysis of the floods of May and July 2001.

2. Determine the extent to which timber management and mining contributed to the magnitudes of these floods.

3. If the effects of timber management and mining on these floods is found to be unacceptable, explore how such effects could be reduced or managed in the future.

4. Make hydrologic policy recommendations to the Secretary of the DEP.

These objectives are more specific and better guide the analysis.

I would give section III a title such as, **Public and Agency Perceptions of the 2001 Floods**, and I would move much of the current section V into the new section III. This section would describe how the public viewed the floods and how the agencies have responded to the floods. This would help motivate the analysis.

I would create a new section IV, **Current Hydrologic and Water Quality Regulation of Mining and Timbering**. This section would describe current mitigations required or suggested of these activities. I would pull the appropriate material from the current section V into this section.

I would create a new section V, **Hydrologic and Hydraulic Review of the 2001 Floods**. In this section I would present the map discussed in my comments, the land use assessments, and any direct data analysis of flood flows or precipitation.

Section VI would be **Analysis of Flood Scenarios Using Hydrologic and Hydraulic Modeling**. This section would describe what models were use, why these models were run, and what the models indicated. This section would have a brief summary of how the models were set up. The vast majority of the supporting information in the current section III would be moved into an Appendix.

The PDF file for the supporting information needs to be split into two smaller files for easier access. Once I acquired the file, I had no trouble using it, but accessing a file of this size via email or via the web is problematic. Since many computers have 128 Megs of RAM or less, and since the operating software and Adobe must use a part of the RAM, a 98 Meg file is too large to be accessible to many potential users.

I hope these comments are helpful and useful to the FATT. Please contact me if you have questions, comments, or concerns regarding this review.

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FATT's Responses to Dr. Jackson's Comments

Dr. Jackson stated, "It is my opinion that the report in its current form relies too much on the hydrologic/hydraulic modeling to characterize the floods and their causes."

FATT from the onset recognized the weaknesses associated with hydrologic modeling of natural, open systems (watersheds) and worked diligently to identify any and all key parameters that could not be accurately modeled for the storm event. These unknown parameters were documented and are available if additional in-depth flood routing analyses are required for these watersheds.

The FATT model input parameters were developed by FATT by field collecting data, recording site specific soil, land uses, cover types, geology, geomorphology, vegetation type and density, reviewing various types of remote images, personal interviews with flood victims, and many other pertinent data for each watershed evaluated in the FATT study. This information was complemented with many hours of telephone and personal conversations with hydrologists, hydrologic engineers, civil engineers, mining engineers, soil scientists, research scientists, and other professionals concerning the methodology of modeling and the importance of gathering actual field observation data and interviews of the flood victims. This wealth of information specific to the watersheds assisted FATT in the choice of the modeling technique and the importance of specific parameters critical to the development of an acceptable method to model the July 8, 2001 flood event and quantify its associated effects.

Because of these conversations, review of different modeling techniques, and personal accounts of the flood event by victims of the flood, FATT's hydrology model for each watershed relied on accurate site-specific empirical data to enter in the watershed models. Later, the results were calibrated and validated for each watershed model.

Jackson suggests that land use in the study area and the relationship of land use to flood magnitude needs to be explored in maps and tables. He further suggests creating a map, or possibly a series of maps, illustrating the hydrography and land use in the study area…

The information Dr. Jackson is seeking is available in the contents of the detailed FATT modeling input, output parameters, and is associated with maps and other illustrations within the detailed FATT study. This information was specifically developed by FATT based upon a sub-basin spatial distribution of all certified data collected for analyses of the watershed and the events of July 8, 2001. This information is found within and throughout the many sections of the FATT report. Additional maps have been included in the narrative report showing the land use patterns used by FATT in the analysis.

Dr. Jackson states, "I suggest creating a map, or possibly a series of maps, illustrating the hydrography and land use in the study area as well as the spatial distribution of available data. An ideal map would show:

Stream network, land use roughly categorized as forest, recent harvest, active mine, closed mine, agricultural, and residential/commercial, locations of flood damage, rain gages and precipitation amounts on the day in question, USGS flow gages and recurrence interval of flow on the day in question, and locations and recurrence intervals of flows estimated from high water marks.

The FATT watershed report and study addresses all available information for the determination of the input parameters for each watershed modeled. FATT recognized from the beginning that these were ungaged watersheds with no site-specific meteorological stations, stream gaging stations, etc., in existence within the near proximity to the study watersheds. The concept of modeling the watersheds with a modeling technique based upon spatial variable distribution of its input parameters was not possible due to the lack of information.

Jackson suggests supporting this map with a land use table for each basin where flow has been measured or estimated. He also suggests that the table include the following information:

location,
basin area,
percent of basin in forest cover,
percent of basin recently logged,
percent of basin mined,
percent of basin developed,
precipitation depth during the storm, and
recurrence interval of resulting flow.

The information requested by Dr. Jackson is included within the FATT watershed detailed study. The necessary information to develop any tables necessary for presentation can be achieved with minimal efforts by the members of FATT, or other parties, if so desired.

Dr. Jackson states, "…I suggest running a multiple regression of flow recurrence.…That is why a regression analysis would be better."

FATT does not totally agree with Dr. Jackson's suggestion of utilization of regression analyses for these ungaged, rural watersheds to be "better". Several studies were conducted by qualified professionals of similar ungaged, rural watersheds in West Virginia utilizing several different regression techniques for the determinations for peak discharges for the small watersheds. In almost every watershed evaluated with or by the regression analyses the accuracy associated with the results were less than acceptable. In one specific report, the range of "acceptable values" generated by regression modeling resulted in values that the authors stated were at least plus

or minus 150% of actual data when compared to actual measured field data. This high degree of inaccuracy is totally unacceptable to FATT for their modeling results, and as such, FATT could not support the utilization of algorithms, processes of parameters, and modeling techniques which did not yield an acceptable degree of accuracy for the watersheds studied. FATT's input parameters, modeling algorithms, modeling processes, and model results were continually certified, calibrated against actual documented and observed data, and the modeling results were verified or validated by different techniques to maintain modeling accuracy.

Jackson suggests analyzing the types of damages that occurred during the flood.

FATT fully appreciates the concern of Dr. Jackson as to the magnitude of the flood events. However, this type of data collection was not necessary to certify and calibrate the data and results of the FATT watershed models.

Jackson states, "…the SCS method that is the basis for HEC-1 and BOSS modeling is inherently inaccurate".

To a limited degree we [FATT] agree with Dr. Jackson's comments concerning the SCS modeling technique. The SCS technique when used by individuals not familiar with its limitations or with its principles, can create results that are inaccurate and misrepresentative of the watersheds modeled. However, SCS modeling methods, as well as many other modeling techniques, when used by qualified professionals knowledgeable of the particular models algorithms and limitations, strengths and weaknesses, can provide very good results of watershed hydrology. Any modeling technique is only as accurate as the input parameters, the model algorithms applications to the characteristics of the watershed, and the validation methodology of any results calculated by said modeling technique.

Comments from Dr. Wayne Swank

Review of Draft, Flood Advisory Technical Taskforce (FATT)

Detailed Report (May 17, 2002)

Submitted By:

Dr. Wayne T. Swank

Scientist Emeritus, Coweeta Hydrologic Laboratory

Adjunct Professor, University of Georgia

Adjunct Professor, Clemson University

Introduction

The purpose of this document is to provide a summary review of the draft report prepared by FATT as requested by staff of the Department of Environmental Protection, Division of Mining and Reclamation. The draft report addresses the scientific and hydrological causes of flooding events in southern West Virginia in May and July 2001 with a specific focus on assessing the impact of coal mining and timbering practices on flooding in the region. I was requested to focus my review on the hydrologic modeling approach and techniques used in the assessment. Background material was derived from 1) a site visit on May 22-23 to Seng Creek and Scabble Creek, two of these watersheds used in the study, to obtain on-the-ground familiarity with the topography, soils, vegetation, land use practices, and streams; 2) discussions with Jim Pierce, John Vernon (visit hosts), and Mike Reese of DEP and 3) a complete copy of the draft report comprised of three large volumes

containing narrative, data output, photographs, and copies of some source materials used in the assessment. Clearly, I was not able to digest and comprehend in detail all of this information within the time frame available for the review.

Hydrologic Modeling Approach & Techniques

A variety of rainfall-runoff models have been developed over the past several decades and a brief description of approaches is appropriate. In general, hydrologic models can be classified as physics-based, conceptual and metric (Beck 1991). Physics-based models utilize mathematical representation of real processes to mimic hydrological behavior of a watershed. The Institute of Hydrology Distributed Model (IHDM) (Beven et al. 1987) is a recent example of this class of model, which is characterized by requiring massive amounts of site-specific data. Conceptual models describe the component hydrological processes perceived to be of importance as simplified conceptualizations. System stores are linked and are recharged and depleted by appropriate hydrological processes. The Stanford Watershed Model (Crawford and Linsley 1966) is an early example of this approach and subsequently, numerous versions of conceptual models have been developed. IHACRES (Jakeman and Hornberger 1993) is an example of a later lumped conceptual model. Parametric uncertainty and over parameterization are risks associated with conceptual of models.

Metric models are constructed with little consideration of hydrological processes and characterize system response by extracting information from existing data. The unit hydrograph theory (Sherman 1932) is the basis of metric rainfall-runoff models and

assumes linearity between rainfall excess and streamflow. A major strength of methods using the unit hydrograph is their minimal data requirements.

The FATT team selected the unit hydrograph method and NRCS runoff curves numbers (CN) as defined by soil hydrologic groups, land uses, and cover types to predict peak flow rates for the ungaged study watershed. Given the time and resource constraints, this approach is probably the best available and most tractable method for you to use for the task. Alternative approaches are too data intensive or require extant discharge data which are not available for the study region.

There are important limitations associated with the application of the NRCS CN method as given in Technical Release 55. One critical consideration is that NRCS runoff procedures apply only to direct surface runoff and not conditions of large sources of subsurface flow. Surface or overland flow seldom occurs on undisturbed forested watersheds since infiltration capacity exceeds precipitation intensity. Thus, in forests, subsurface flow is linked to the variable source area to generate channel flow as you note on p.8 of the draft report. Apparently some consideration is given to this condition by assigning lower CN's to forest areas and the user has the option to adjust table CN's based on stream gage records (TR-55). The use of CN's for mining conditions is perhaps more straightforward since surface runoff from diversion ditches & ponds is a dominant process.

A critical question arises: is CN 70 an appropriate index for predicting peak discharge for "pristine" forests? Probably the best approach in addressing this question is to apply the NRCS procedure to experimental forested watersheds with long-term discharge records and compare predicted values with observed values. I

am not aware of any citeable reference where this is documented. However, Hewlett et al. (1977) developed simple nonlinear equations (R-Index Method) for predicting stormflow and peakflow for small-forested basins based on data from 11 watersheds from New Hampshire to South Carolina. Tested against the SCS runoff curve method used at that time (SCS-TP-149) on four independent basins, the R-index method was judged considerably more accurate. The runoff curve method gave quite wild predictions and largely over predicted stormflow volumes and peakflow discharge.

A very rough measure of overall basic model performance is a comparison of simulated peakflows with long-term baseline data for gaged forested watersheds. For the pristine scenario (no logging, no mining, i.e., undisturbed forest) simulated unit area peakflows at the outlets of Seng, Scabble, and Sycamore Creeks were 455, 429, and 237 $ft^3/sec/mi^2$ (CSM) respectively. The nearest long-term record of discharge for forested watersheds is the Fernow Experimental Forest in north central West Virginia. The four largest storms during 50 years of research ranged between 4.4 and 5.8 inches of precipitation and average peak discharge from three control (undisturbed) forested watersheds for these storms was 136 CSM with a range of 115-170 CSM (personal communication, James Kochenderfer). Thus, peak discharges simulated for the FATT watersheds are 2-3 fold greater than documented at Fernow. Discharge has been measured from 17-forested watersheds for 68 years at the Coweeta Hydrologic Laboratory in the Nantahala mountains of western North Carolina, including seven control watersheds. The maximum peak discharges recorded for the largest storms (15-20 inches in 7 days) averaged 132 CSM for five

of the control watersheds (3125-4056 ft. max. elevation), 450 CSM for two of the control watersheds (4770-5250 ft. max. elevation) and 189 CSM for the two fourth-order streams (average area of 2.9 mi.^{2}) which drain a mix of disturbed and undisturbed forest land (Swank et al. 1988). Peak discharge rates for two of the FATT watersheds are very similar to values for the two high elevation Coweeta watersheds with steep slopes (70% average) and thin soils. However, storm events were more than 3-fold greater for Coweeta than for the study area.

Of course, in the above comparisons, there are many differences between sites in watershed attributes which control peak discharge. From a perspective of the large body of knowledge about peak discharges for forested watersheds in the central and southern Appalachians, those simulated for the FATT study sites are among the maximum recorded. If you have any field estimates of peak discharge for the study watersheds (you mentioned a culvert site), it is important to show a comparison with simulated values. Although the study site streams show evidence of high hydrologic response, it is my feeling that CN 70 is somewhat high for the forested condition.

With regard to techniques and modeling software used in the hydrologic analyses, FATT employed current, state-of-the-art methods used by other hydrologic modeling groups. This appears to provide an excellent data base of watershed attributes and techniques used in the modeling effort.

Streamflow Responses to Disturbance

Decades of research on experimental forested watersheds provide a large body of knowledge on the effects of management on the quantity, timing and quality of streamflow. In particular, a wealth of information is available for the Appalachian

mountain range (see Appendix I for a brief historical background of forest hydrology). Based on these carefully conducted long-term panel watershed experiments, several common threads of information relevant to interpretations of the FATT simulation results may be helpful. Some summary references are Hewlett and Helvey (1970); Hewlett (1982); Kochenderfer et al. (1997); Hornbeck (1973); Swank et al. (1988); Lull and Reinhart (1972); Swank et al. (2001).

- On a given watershed, at least 25% of the forest stand basal area must be cut to measure significant changes in annual water yield and even larger harvests are required to measure changes in parameters of the storm hydrograph.
- Hydrologic recovery from forest cutting occurs quickly (4-5 years) due to rapid regrowth of natural regeneration.
- Overland flow seldom occurs in undisturbed forests. Roads, landings or other compacted features are the primary source of surface runoff associated with logging activities. As road density increases, the potential for altering storm hydrograph parameters increases.
- The beneficial effects of forest cover on reducing peak discharge and stormflow volume have been documented over a range of storm events. During major flood-producing storm events the effects of a forest cover on peak discharge are minimal.

Summary & Recommendations

I feel your modeling approach is appropriate in view of the time/resource constraints and mixed land-use associated with the task. These models provide a first approximation for the effects of land use on peak flows for the July 2001 storm. My

primary concern is with the CN's used for the undisturbed and logged forest scenarios. I recommend collaboration with Fernow scientists to validate the use of these procedures in predicting peak discharge from forests. You already have excellent techniques available and much of the required data input is available on the Fernow. Of course, this cannot be done prior to the report deadline but I feel your modeling effort is a work in progress. I highly recommend additional follow-up analyses/studies and can suggest some additional approaches that would support this effort. I feel the FATT group should be commended for your efforts on a complex issue.

Appendix I

Historical Background

The roots of forest hydrologic investigations are embedded in basic questions of the relationship between forests and runoff (Swank & Johnson 1994). Forest hydrologic research extends over more than a century with the establishment of two experimental watersheds in Czechoslovakia in 1867 with the purpose to examine the role forests play in surface runoff. Research on the effects of deforestation on flood flows in Switzerland began in 1902 using paired experimental watersheds. In the United States, concern about soil erosion, flood control, sustained flow of streams, and future timber supplies led to establishment of national forests from the public domain lands in the West. The role of forests in regulating the flow of navigable streams was the basis for enactment of the Weeks Act of 1911, which allowed the Federal government to purchase private lands for national forests in the East. Concurrent with these enactments there was considerable debate, but no scientific

evidence, concerning the influence of forests upon streamflow regulation and flooding. Thus, the first paired forested watershed experiment in the U.S. was initiated in Colorado in 1909.

Subsequently, the need for scientific studies of factors controlling floods and erosion was accelerated by the disastrous 1927 flood in the Mississippi River Basin. This led to the formal establishment of watershed research by the USDA Forest Service. Three forest hydrology laboratories were established in the east within the Appalachian Highlands Physographic Division: Coweeta Hydrologic Laboratory (1934) in the Nantahala Mountains of western North Carolina; Fernow Experimental Forest (1948) in the Allegheny Plateau of north central West Virginia, and Hubbard Brook Experimental Forest (1955) in the White Mountains of New Hampshire. The research approach at these laboratories has encompassed the hydrologic cycle with studies of basic hydrologic processes on individual experimental basins to determine the principals underlying the relation of forests and their management, to the supply and distribution of water. A large body of knowledge and understanding now exists on the basic hydrologic functions of forested watersheds and responses to management.

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FATT's Responses to Dr. Swank's Comments

Dr. Swank commented that the unit hydrograph theory, of which HEC-1 is an example and used by FATT, is probably the best available and most tractable method to use. However, he questions whether a runoff curve number (RCN) of 70 is appropriate for "pristine" forest areas.

FATT considered the actual forest conditions in the studied watersheds. In reality, much of the forested areas have been previously harvested. In southern West Virginia, an NRCS runoff curve number of 70-77 best reflects the conditions associated with the determination of surface runoff. Such range of curve numbers represents standard engineering practice in this locality.

We feel that a RCN of 70 is appropriate for the "pristine" undisturbed forest areas that we studied. This is primarily due to minimal forest litter, shallow depth of soil, bedrock exposure, forest floor characteristics, and other land alterations caused by previous logging activities or coal prospecting.

Also, it should be noted that the runoff curve numbers used in the FATT watershed models were determined by field investigation of the previous logged and undisturbed forest areas. Before making a final RCN choice, FATT used research and communication with professional foresters to determine appropriate site-specific runoff curve numbers for the study areas. Information relating to the runoff curve number determinations and the delineations of the timbering and undisturbed forest areas was provided by the personnel of the West Virginia Division of Forestry. FATT members certified these runoff curve numbers in conjunction with the efforts and with agreement by the professional foresters within the West Virginia Division of Forestry.

Dr. Swank commented that from a perspective of the large body of knowledge about peak discharges for forested watersheds in the central and southern Appalachians, those simulated for the FATT study sites are among the maximum recorded. He further recommended the use of any field estimates of peak discharge for the study watersheds to compare with simulated values.

For the July 8th event, the peak discharges per area (CSM) are on the high range of what Dr. Swank has experienced in other areas. However, the peak discharges in the subject watersheds represent the actual peak discharges at the watershed evaluation node as determined by indirect measurements from certified field surveyed high water marks produced by the actual flood event. Our data sets are not uncalibrated, unvalidated watershed model simulations, but are certified, calibrated, validated results at specific nodes throughout the study watersheds. The FATT model results agree with numerous field certified and verified observed high water points and flood water boundaries within each specific watershed as documented for the July 8, 2001, flood event in the specific geographic regions of West Virginia.

It should be noted that the NOAA National Weather Service has identified various meteorological regions throughout West Virginia. Also, the United States Geological Survey (USGS) in performing their water research projects have divided West Virginia into two climatic regions. Therefore, the meteorological events and climatic characteristics in the regions studied by FATT are characteristically different than those associated with the forest research centers referenced by Dr. Swank (Fernow in West Virginia and Coweeta in North Carolina). As a result, any research comparisons between those of the Forest Service Research centers and those studied by FATT could only be generalized due to these and other differences. The correct modeling solution would be to include the personnel of the Forest Research Center in a long-term evaluation of the specific watersheds evaluated by FATT. Subsequently, a true comparison of the Forest Research methodology could be applied to the specific watersheds evaluated by FATT. The Forest Research Center personnel then could accurately evaluate the modeling results of FATT for the specific watersheds studied in southern West Virginia for the flood events on July 8, 2001.

Swank references, "The FATT team selected the unit hydrograph method and NRCS runoff curves numbers (CN)…to predict peak flow rates for the ungaged study watershed(s)."

FATT chose to use BOSS international's software to model the watersheds to determine the impact of mining and timbering on the July 8, 2001, flood event. BOSS International's software provides many variations of modeling techniques to use. The software chosen by FATT was BOSS's Watershed Modeling Software (WMS) and RiverCAD. The reasoning that FATT members used for these choices were that the available data required for modeling was limited, the watersheds were ungaged, and the model results would have to be very accurate relative to the FATT evaluation. BOSS's software modules that were used by FATT to model the watersheds were those developed with the U.S. Army Corps of Engineers (COE) Hydrologic Engineering Center (HEC) HEC-1 and HEC-RAS hydrology and hydraulic modeling software. These HEC programs are accepted internationally, and have been proven to yield accurate results such as was required by FATT for their watershed modeling.

FATT and other qualified professionals made extensive field investigations and research of the specific watershed characteristics and meteorological events of July 8th. Only certified data that FATT or recognized qualified professionals contributed were used to input in the BOSS WMS (hydrology modeling software) for the watersheds. This information was certified by FATT and the associated qualified professionals for these specific watersheds prior to any of the modeling computer hydrology runs. Upon completion of the hydrology runs, FATT ran the hydrologic results through the BOSS RiverCAD software utilizing the COE HEC-RAS software and all certified observable field surveyed highwater marks of the July 8th flood event to calibrate the hydrologic modeling results. This reiteration of the watershed's hydrologic model results continued until the hydrology results for the watershed

agreed with the historic field surveyed highwater marks throughout the watersheds. This hydrology model calibration technique utilizing the more advanced hydraulic engineering algorithms and accurate field data is an acceptable technique whenever there are sufficient observed and field surveyed elevations and boundary limits of the actual event to calibrate the hydrologic model.

There were many dynamic parameters associated with the flood event of July 8, 2001, that made the hydrology and hydraulic modeling of the watersheds complex and could possible bias or cause inaccuracy in the results. Therefore, FATT insured that all field surveyed calibration points and boundary limits of the flood event were not unduly influenced by any of these parameters or any model input parameters that could not be certified. After the certified data was input into the computer program and the watersheds modeled, each watershed model was accurately calibrated with numerous field-surveyed points and elevations of the certified highwater marks utilizing certified parameter input into the hydraulic program. When these models were completed, FATT verified the results with all known certified observations. By this process, FATT validated the hydrology modeling of the July 8th flood event in the study watersheds.

Dr. Swank states, "The runoff curve method gave quite wild predictions and largely over predicted stormflow volumes and peakflow discharge."

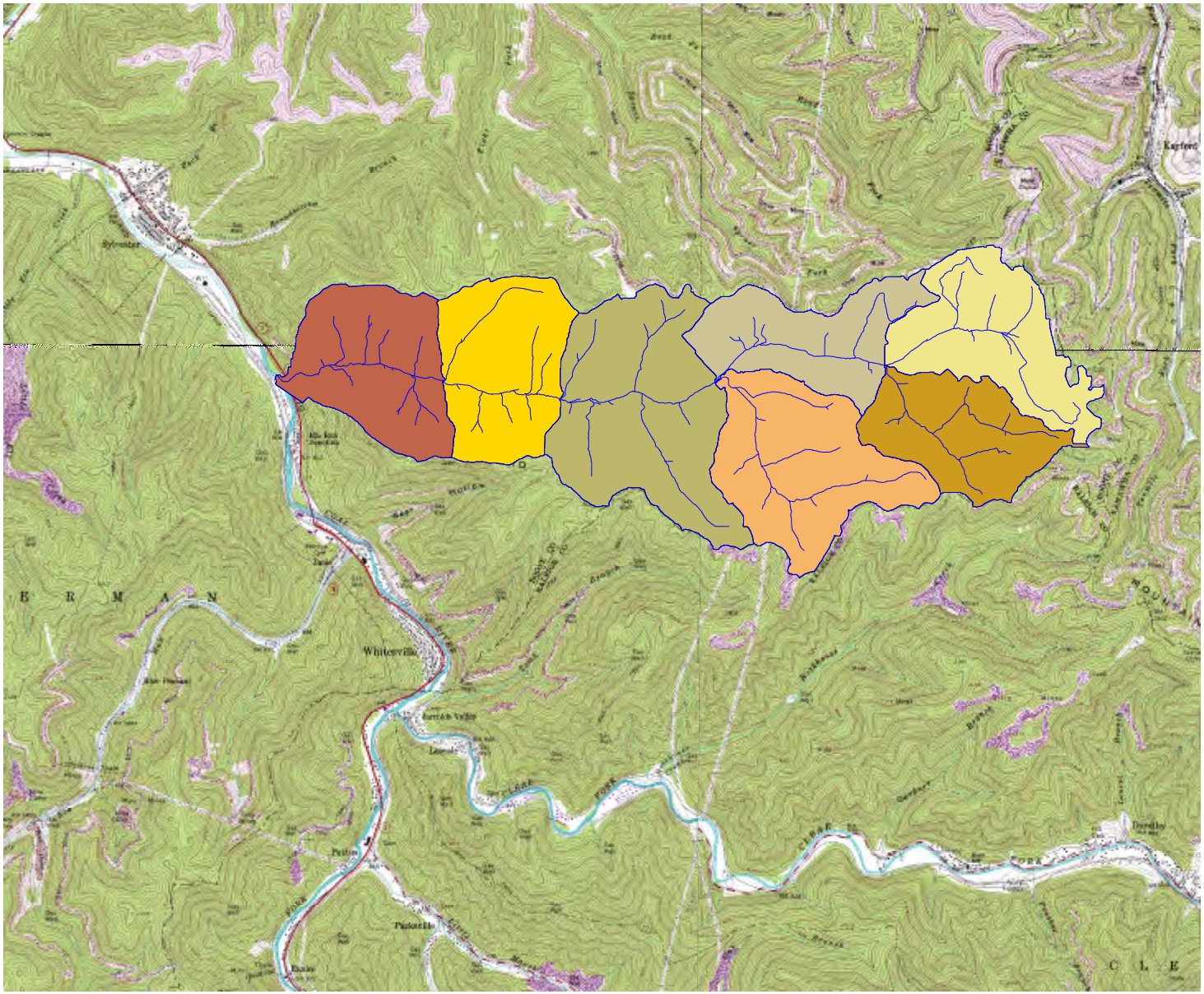
FATT agrees with Dr. Swank's introduction of the possibility of "wild predictions and largely over predicted stormflow volumes and peak flow discharges." It was for this specific reason that FATT took great care in the certification of all parameters used to determine the curve numbers, and chose modeling techniques to reduce the influence of the possibility of erroneous curve numbers. FATT realized that many research studies incorrectly used the curve numbers and caused erroneous results in their studies. FATT chose to use the curve number method because there are many other studies that have successful results in modeling the hydrologic events. FATT achieved its accuracy in its watershed models by its modeling methodology, parameter certification, model calibration, and model validation. FATT chose a modeling methodology that subdivided the watershed into many sub-basins that would not allow the influence of a singular curve number for an entire watershed to be introduced in the watershed model program. The use of the FATT certified data in the models, such as: soil types and characteristics, antecedent soil moisture, stream roughness and characteristics, stream flow conditions, subsurface flows, base flows, vegetation types and maturity, geologic character, geomorphology, stream and flow networks, precipitation variability, extent of urbanization, extent and type of industry disturbance, and many other measured and quantified observed data for the watershed model, allowed FATT to accurately model the specific watersheds utilizing the NRCS curve number method with the COE software within the BOSS modeling programs. In addition, FATT utilized certified data in their calibration process and FATT was therefore able to not only calibrate the watershed hydrology models within acceptable limits of modeling accuracy, but were also able to validate the subsequent hydrologic results for the watershed study.

FATT Runoff Analyses

PART II

Data Input and Results Summary

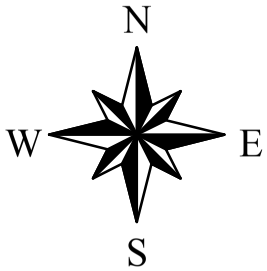
Seng Creek Watershed



Streams

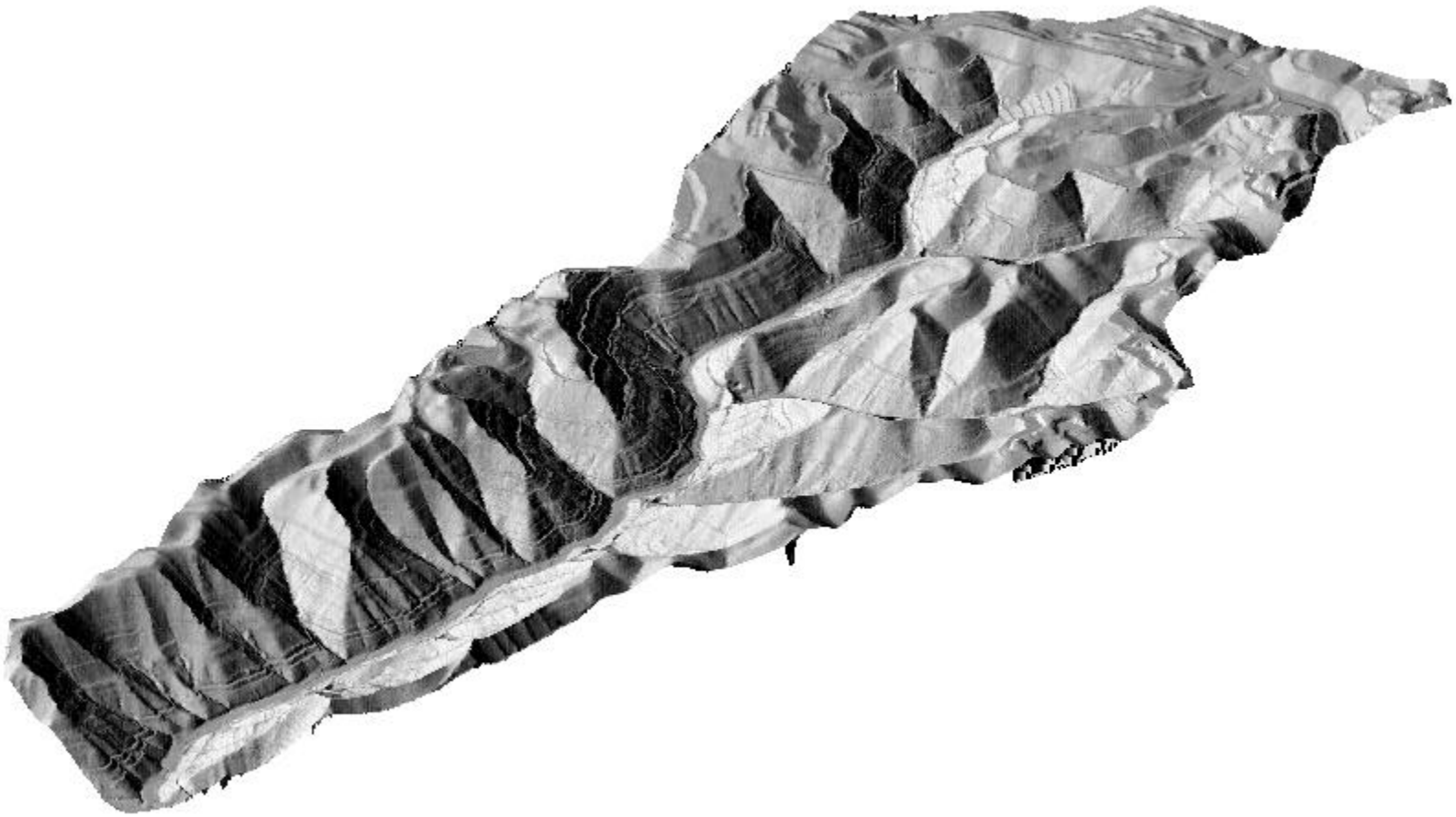
Drainage Areas

- 1B
- 2B
- 3B
- 4aB
- 4bB
- 5aB
- 5bB

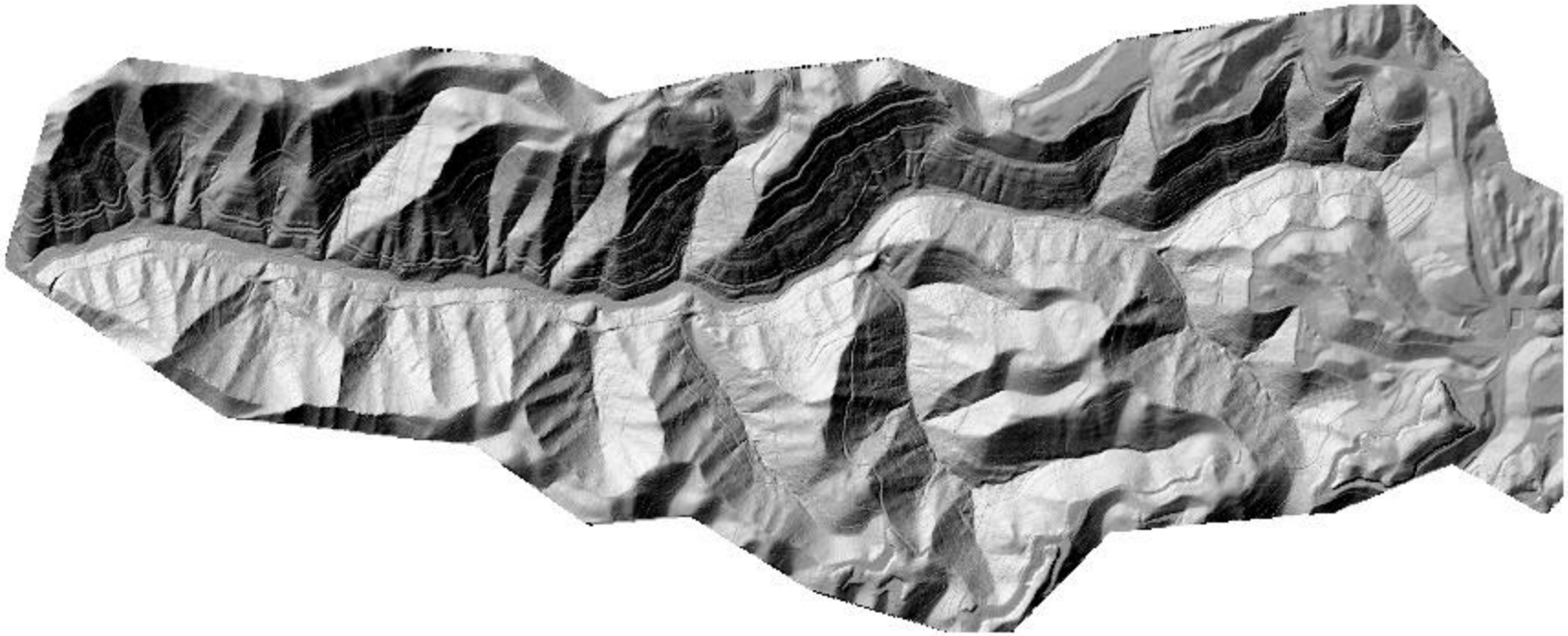


Printed March 27, 2002

Seng Creek LIDAR
3D View
Watershed Delineation



Seng Creek LIDAR
Plan View
Watershed Delineation



Seng Creek Study Area

Legend

Seng Creek Watershed Boundaries

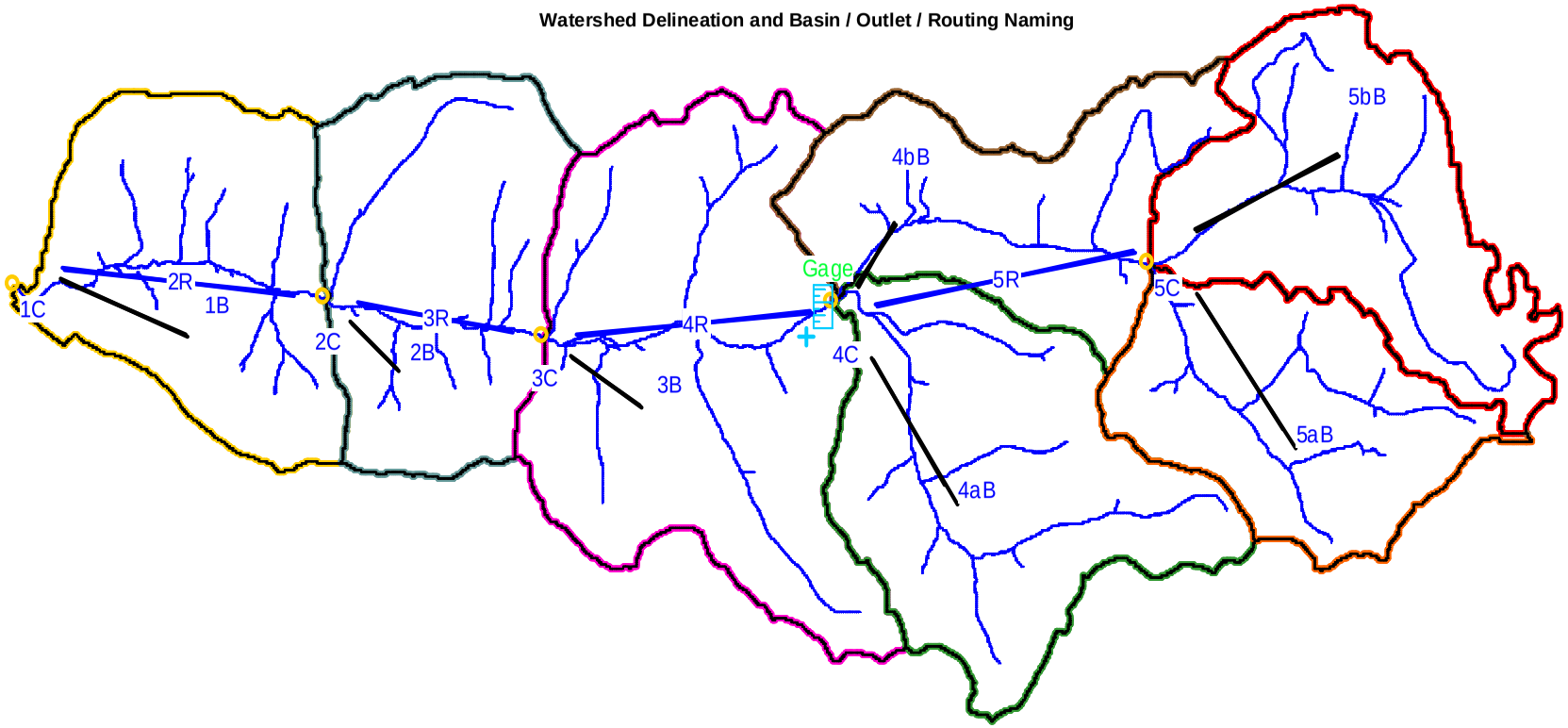
N
W E
S

3000 0 3000 6000 Feet

TAGIS

Seng Creek	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5			
	With Logging (CN 70 & 73)			Without Logging (CN 70)			Without Logging (CN 70)			Without Logging (CN 70)			With Logging (CN 70 & 73)			
	With Mining (CN 75 & 87)			With Mining (CN 75 & 87)			Reclaimed Mining (CN 70)			Without Mining (CN 70)			Without Mining (CN 70)			
	Topography w Mining (LIDAR Data)			Topography w Mining (LIDAR Data)			Topography w Mining			Pristine Topography (USGS DEM Data)			Pristine Topography (USGS DEM Data)			
Outlet Node	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	14 fps
1C	2595	3467	4622	2451	3224	4350	2379	3118	4230	2457	3265	4431	2609	3545	4751	
2C	2297	3209	4255	2171	2986	4008	2097	2861	3867	2190	3005	4065	2322	3243	4339	
3C	1995	2816	3722	1883	2622	3507	1810	2490	3359	1828	2534	3418	1942	2733	3641	
4C	1440	2155	2872	1364	1991	2689	1293	1864	2545	1374	1941	2654	1452	2112	2847	
5C	713	1145	1511	686	1092	1452	618	961	1306	705	1078	1465	732	1131	1524	

Watershed Delineation and Basin / Outlet / Routing Naming



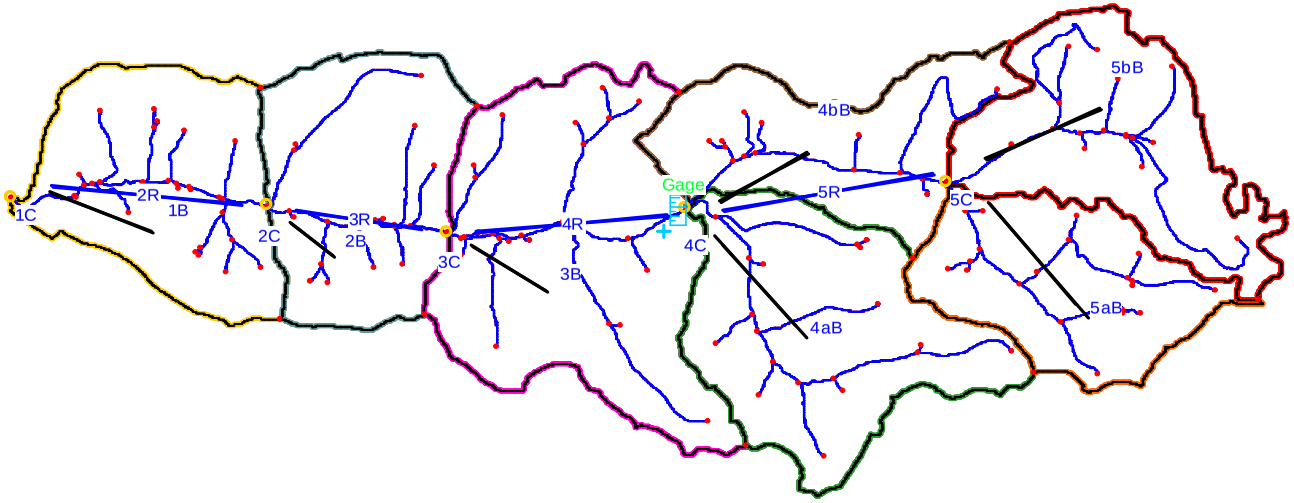
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)			**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)			**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)		
Bottom of Seng Creek at Node 1C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*2595*	*3467*	*4622*	*2451*	*3224*	*4350*	*2379*	*3118*	*4230*	*2457*	*3265*	*4431*	*2609*	*3545*	*4751*
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	*216*	*349*	*392*	*72*	*106*	*120*				*138*	*202*	*191*	*152*	*280*	*320*
% Difference	*9.1%*	*11.2%*	*9.3%*	*3.0%*	*3.4%*	*2.8%*				*5.6%*	*6.2%*	*4.3%*	*6.2%*	*8.6%*	*7.2%*
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	*144*	*243*	*272*	*-6*	*-41*	*-81*				*-78*	*-147*	*-201*			
% Difference	*5.9%*	*7.5%*	*6.3%*	*-0.2%*	*-1.3%*	*-1.9%*				*-3.3%*	*-4.7%*	*-4.8%*			
At Node 2C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*2297*	*3209*	*4255*	*2171*	*2986*	*4008*	*2097*	*2861*	*3867*	*2190*	*3005*	*4065*	*2322*	*3248*	*4339*
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	*200*	*348*	*388*	*74*	*125*	*141*				*107*	*204*	*190*	*132*	*243*	*274*
% Difference	*9.5%*	*12.2%*	*10.0%*	*3.5%*	*4.4%*	*3.6%*				*4.9%*	*6.8%*	*4.7%*	*6.0%*	*8.1%*	*6.7%*
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	*126*	*223*	*247*	*-19*	*-19*	*-57*				*-93*	*-144*	*-198*			
% Difference	*5.8%*	*7.5%*	*6.2%*	*-0.9%*	*-0.6%*	*-1.4%*				*-4.4%*	*-5.0%*	*-5.1%*			
At Node 3C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*1995*	*2816*	*3722*	*1883*	*2622*	*3507*	*1810*	*2490*	*3359*	*1828*	*2534*	*3418*	*1942*	*2733*	*3641*
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	*185*	*326*	*363*	*73*	*132*	*148*				*167*	*282*	*304*	*114*	*199*	*223*
% Difference	*10.2%*	*13.1%*	*10.8%*	*4.0%*	*5.3%*	*4.4%*				*9.1%*	*11.1%*	*8.9%*	*6.2%*	*7.9%*	*6.5%*
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	*112*	*194*	*215*	*55*	*88*	*89*				*-18*	*-44*	*-59*			
% Difference	*5.9%*	*7.4%*	*6.1%*	*3.0%*	*3.5%*	*2.6%*				*-1.0%*	*-1.8%*	*-1.8%*			

Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)			**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)			**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)		
at Node 4C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*1440*	*2155*	*2872*	*1364*	*1991*	*2689*	*1293*	*1864*	*2545*	*1374*	*1941*	*2654*	*1452*	*2112*	*2847*
										Total Influence			Logging Influence Cross Check		
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	*147*	*291*	*327*	*71*	*127*	*144*				*66*	*214*	*218*	*78*	*171*	*193*
% Difference	*11.4%*	*15.6%*	*12.8%*	*5.5%*	*6.4%*	*5.7%*				*4.8%*	*11.0%*	*8.2%*	*5.7%*	*8.8%*	*7.3%*
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	*76*	*164*	*183*	*-10*	*50*	*35*				*-81*	*-77*	*-109*			
% Difference	*5.6%*	*8.2%*	*6.8%*	*-0.7%*	*2.6%*	*1.3%*				*-6.3%*	*-4.1%*	*-4.3%*			

Downstream of Valley Fill at Node 5C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*713*	*1145*	*1511*	*686*	*1092*	*1452*	*618*	*961*	*1306*	*705*	*1078*	*1465*	*732*	*1131*	*1524*
										Total Influence			Logging Influence Cross Check		
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	*95*	*184*	*205*	*68*	*131*	*146*				*8*	*67*	*46*	*27*	*53*	*59*
% Difference	*15.4%*	*19.1%*	*15.7%*	*11.0%*	*13.6%*	*11.2%*				*1.1%*	*6.2%*	*3.1%*	*3.8%*	*4.9%*	*4.0%*
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	*27*	*53*	*59*	*-19*	*14*	*-13*				*-87*	*-117*	*-159*			
% Difference	*3.9%*	*4.9%*	*4.1%*	*-2.8%*	*1.3%*	*-0.9%*				*-14.1%*	*-12.2%*	*-12.2%*			

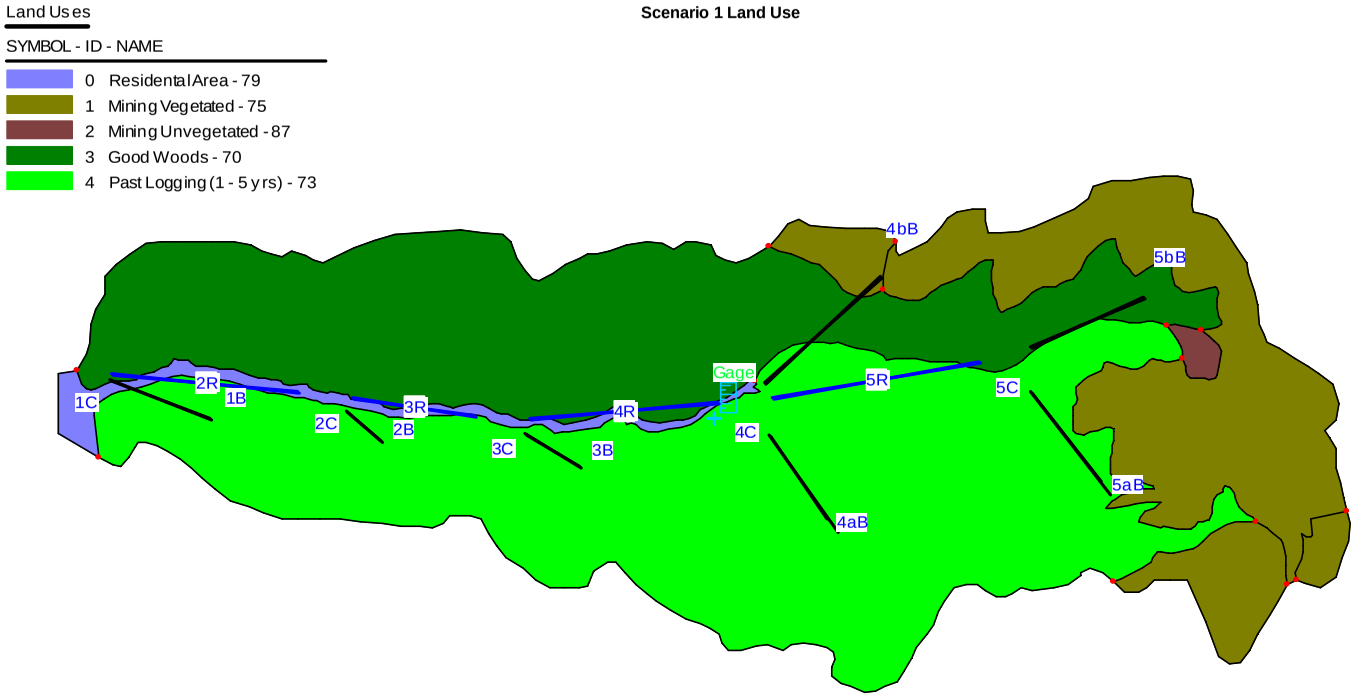
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Watershed Delineation and Basin / Outlet / Routing Naming



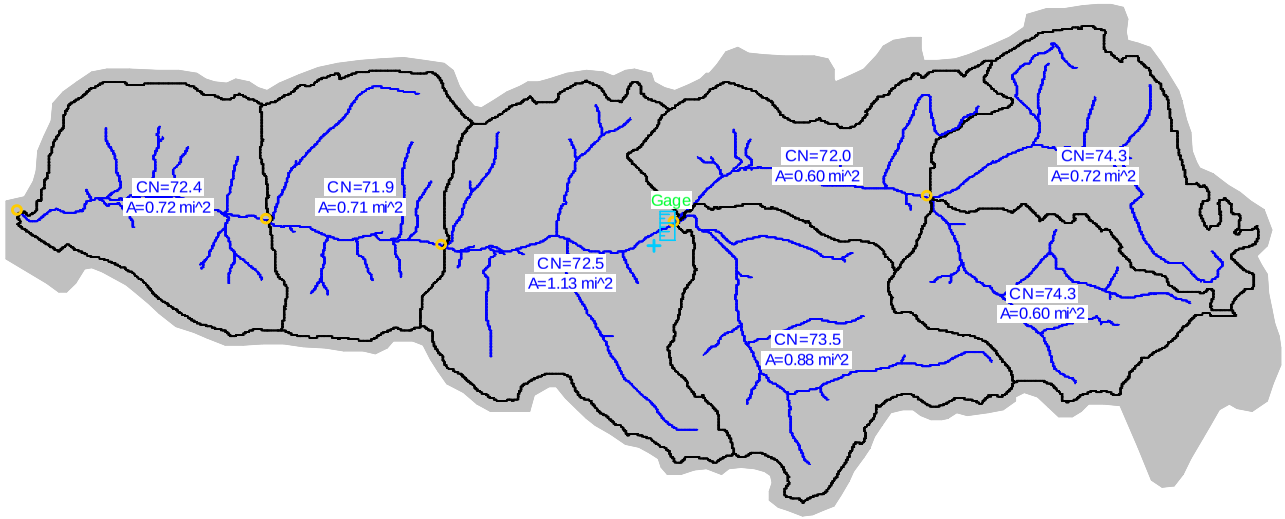
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 1 Land Use



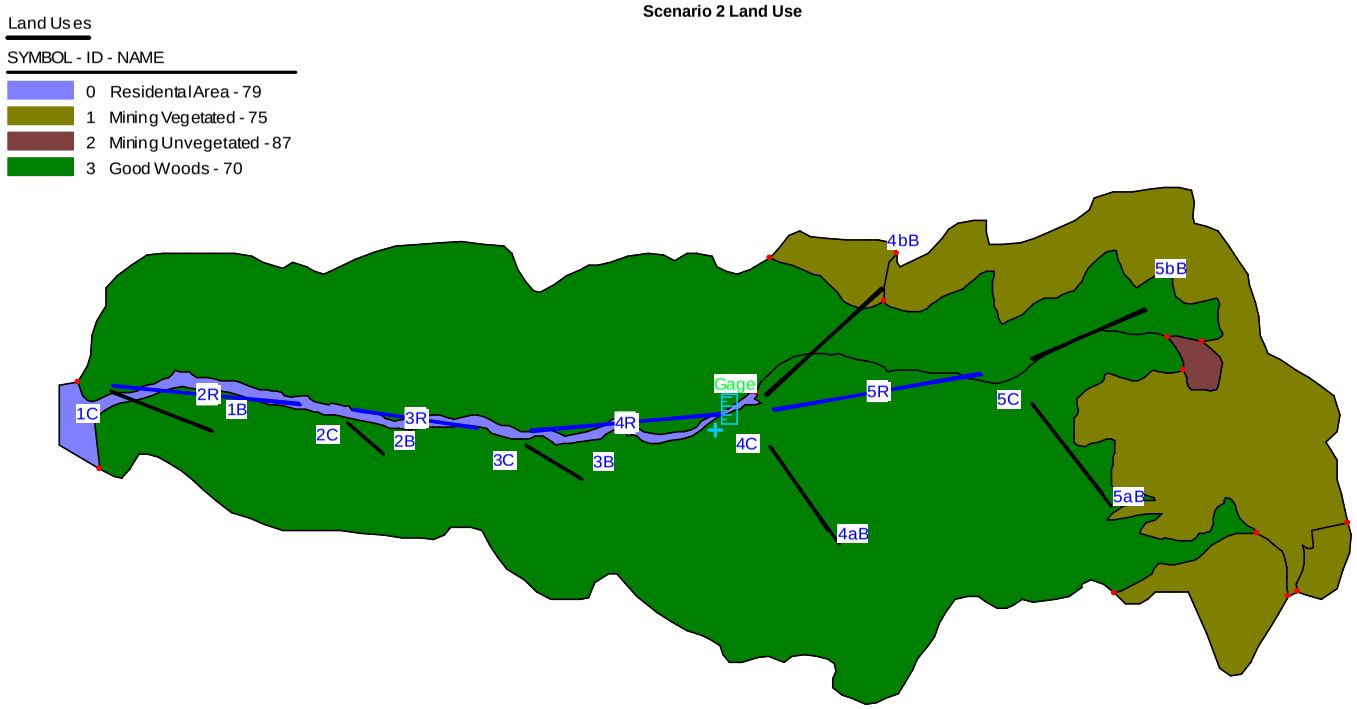
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 1 Watershed Boundaries
and Composite CN and Computed Areas



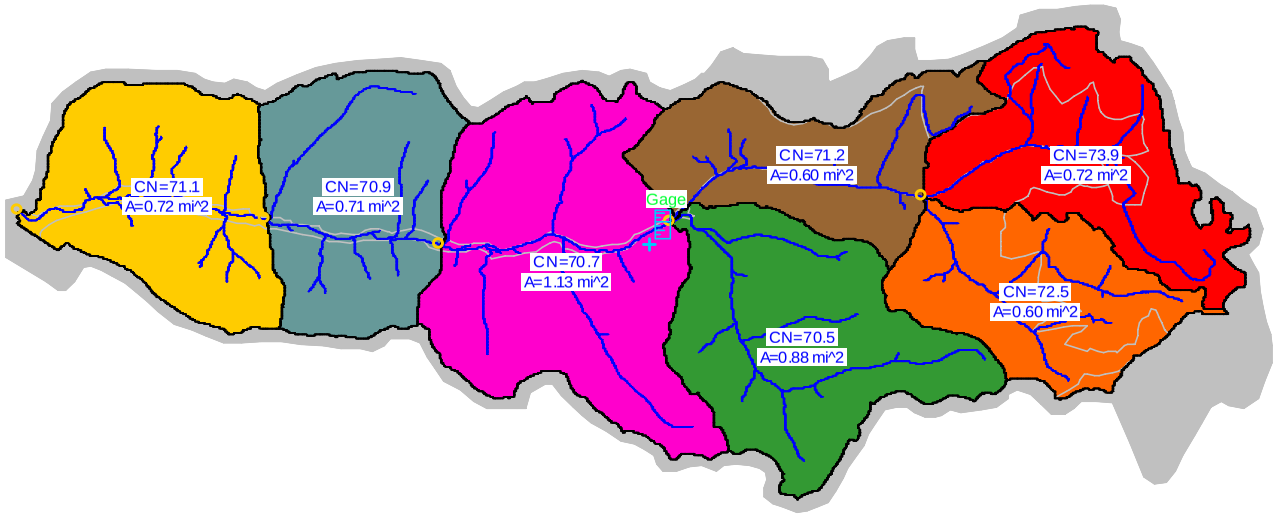
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 2 Land Use



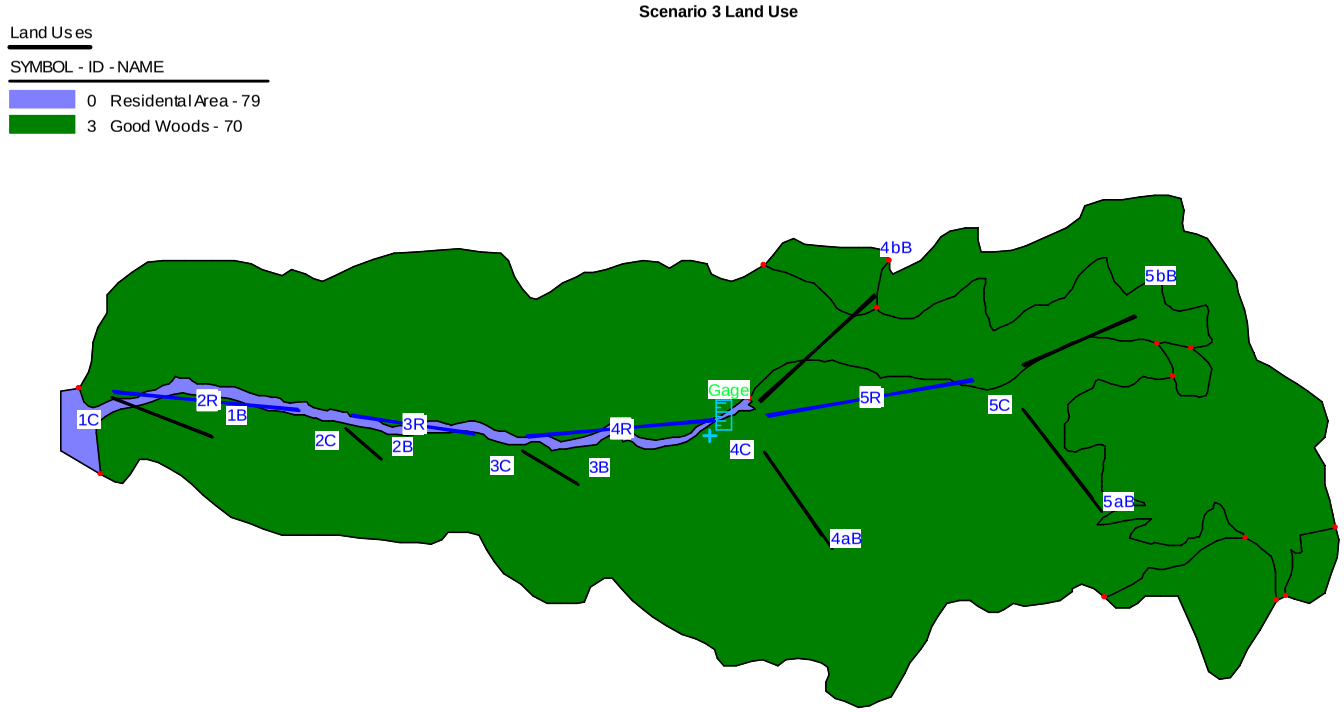
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 2 Watershed Boundaries
and Composite CN and Computed Areas



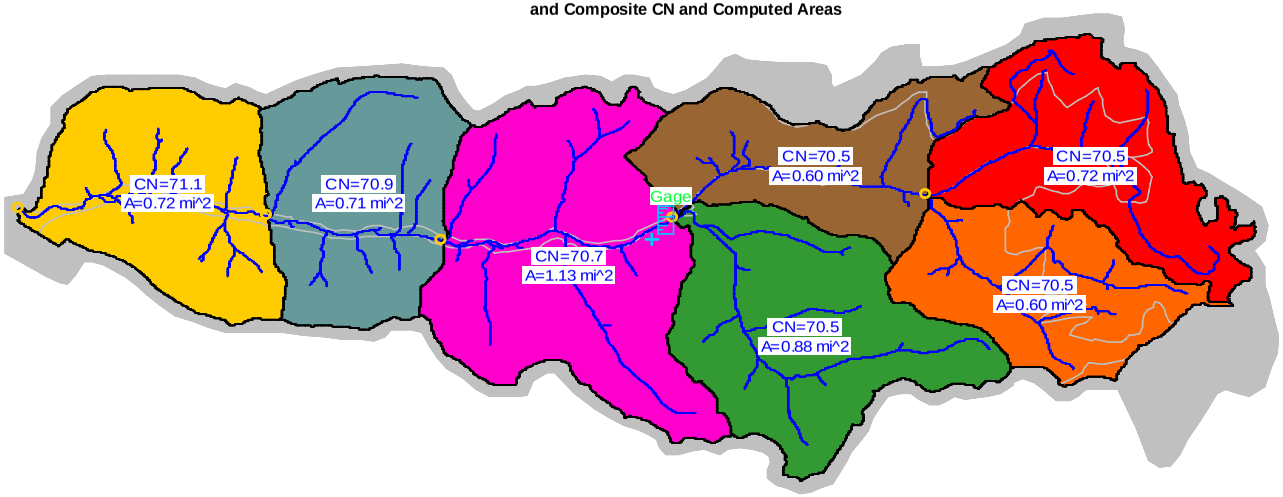
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 3 Land Use



Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 3 Watershed Boundaries
and Composite CN and Computed Areas



Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

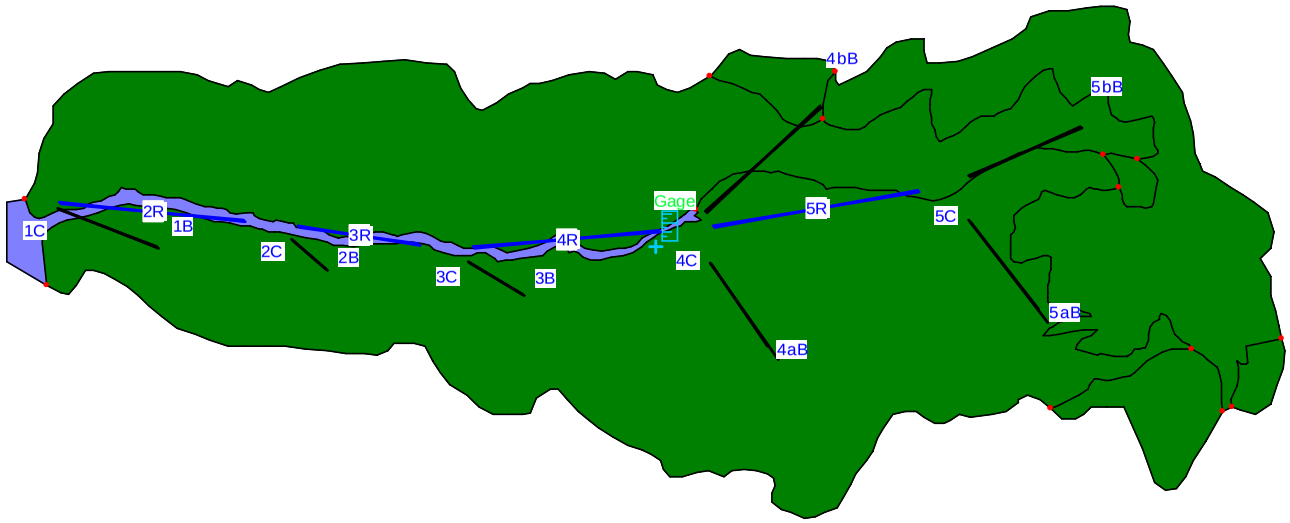
Scenario 4 Land Use

Land Uses

SYMBOL - ID - NAME

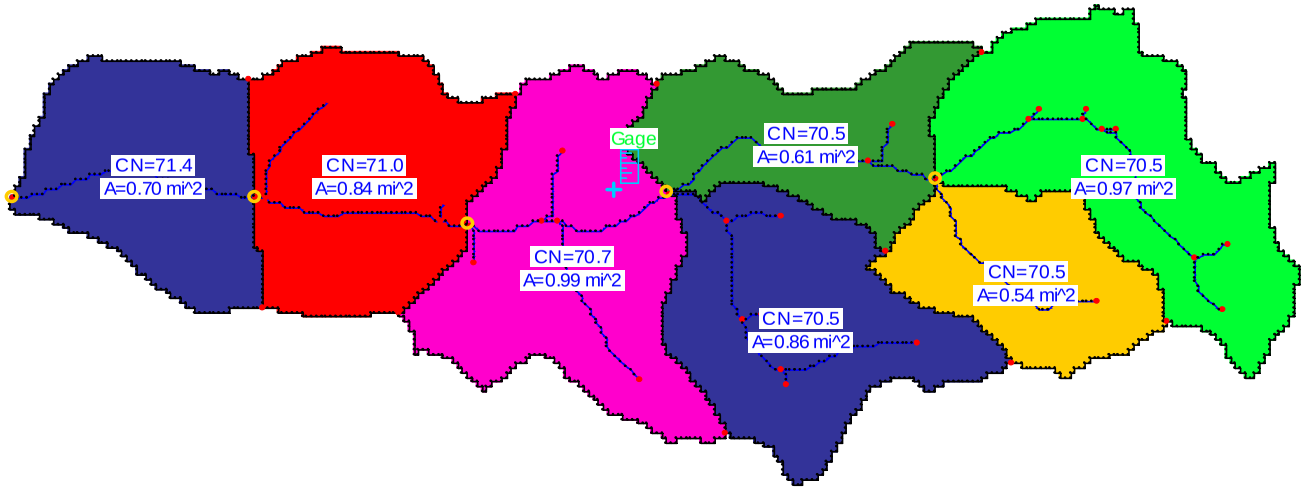
0 Residental Area - 79

3 Good Woods - 70



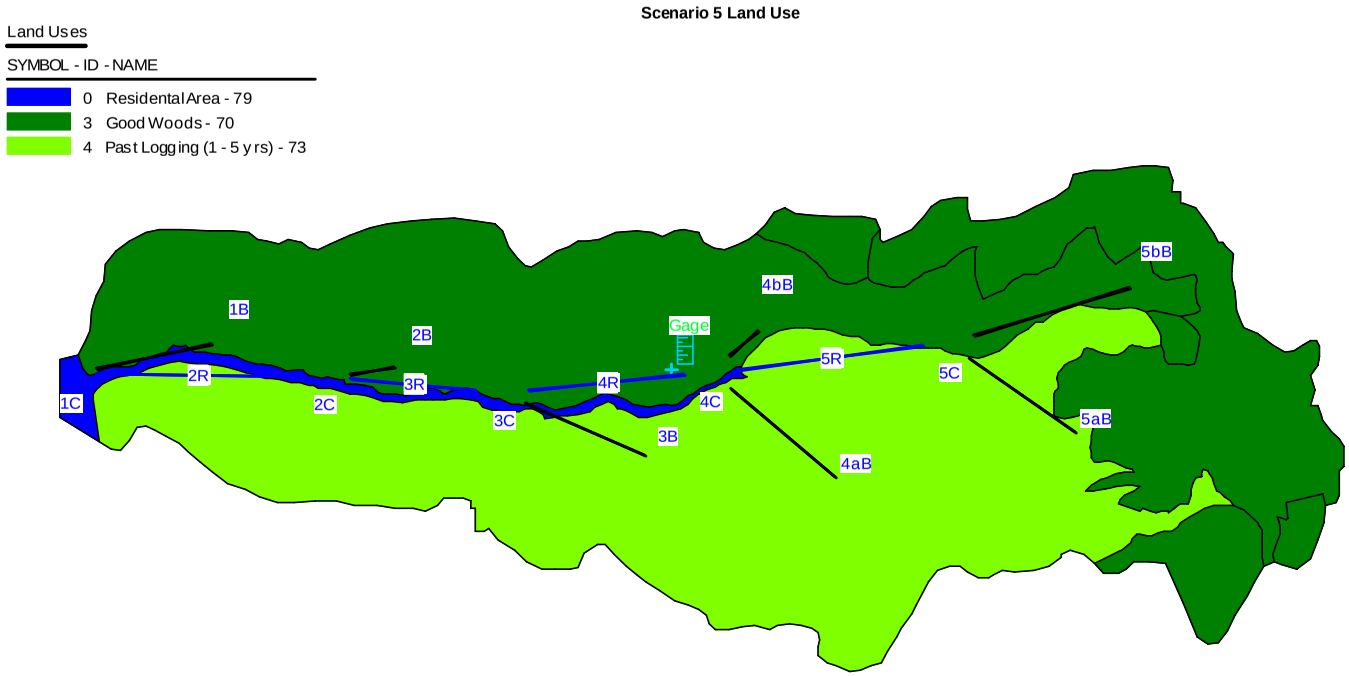
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

Scenario 4 Watershed Boundaries
and Composite CN and Computed Areas



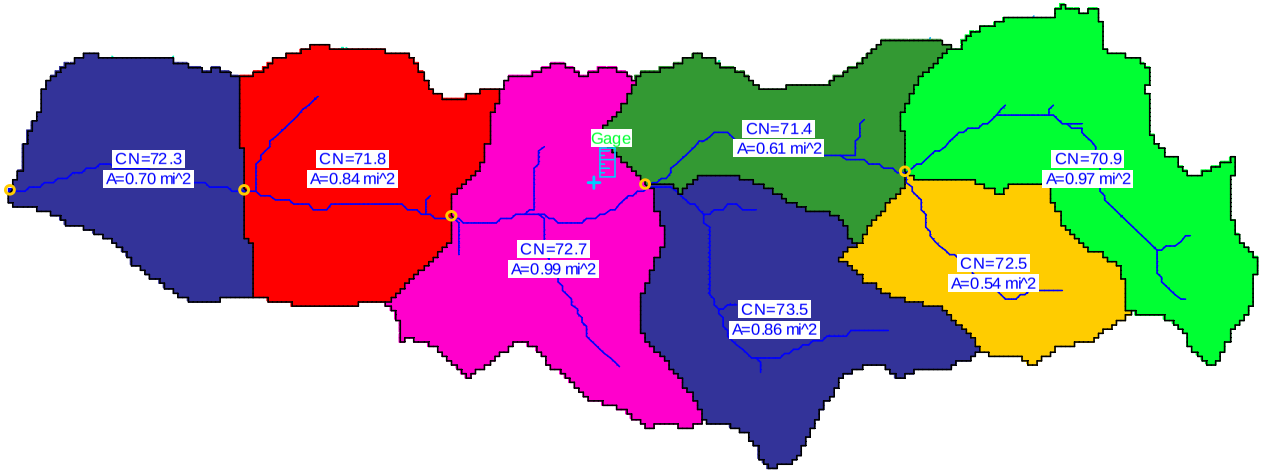
Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

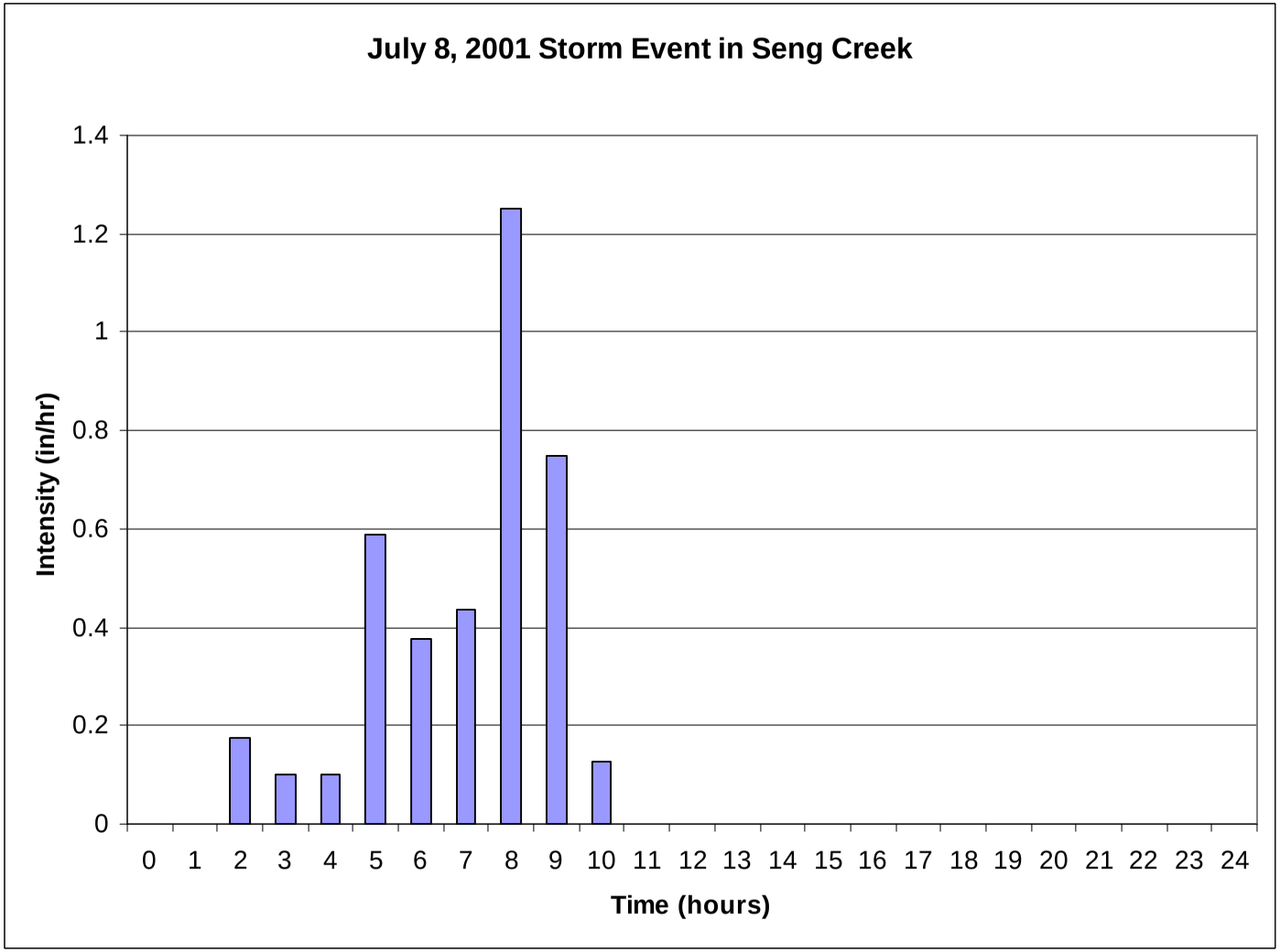
Scenario 5 Land Use

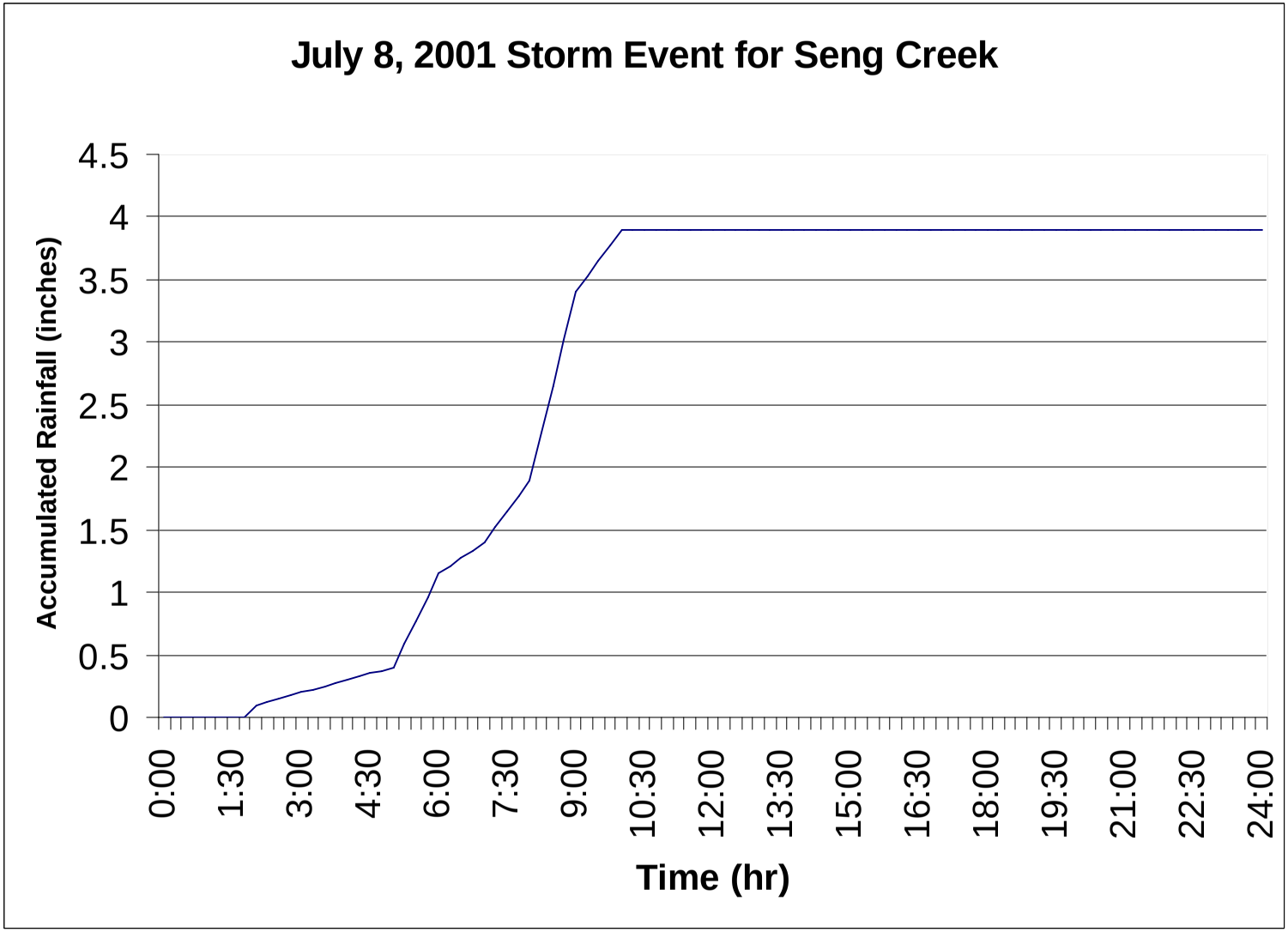


Seng Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (USGS DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (USGS DEM Data)

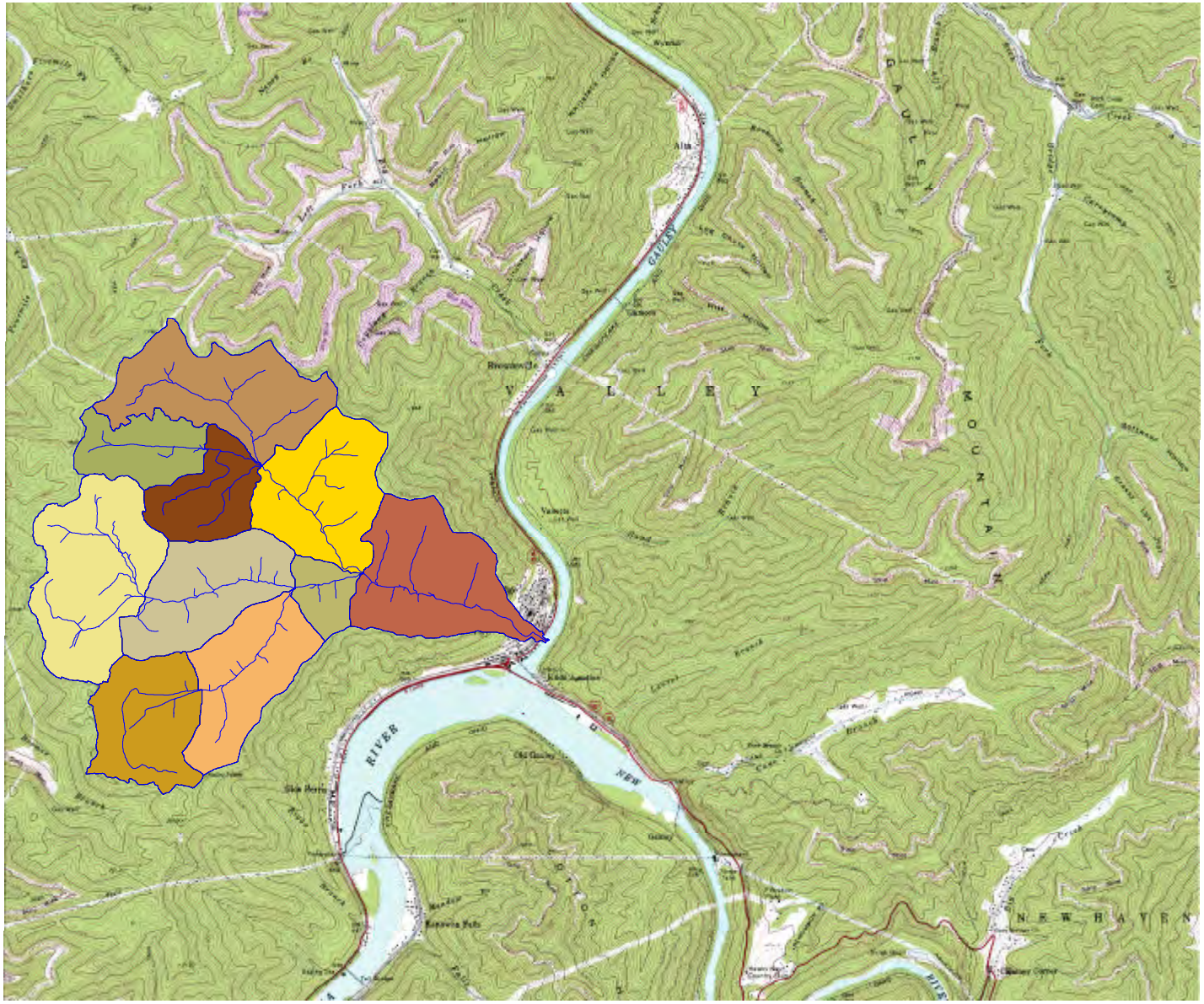
Scenario 5 Watershed Boundaries
and Composite CN and Computed Areas




July 8, 2001 Storm Event in Seng Creek
Intensity (in/hr)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)


July 8, 2001 Storm Event for Seng Creek
Accumulated Rainfall (inches)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0:00
1:30
3:00
4:30
6:00
7:30
9:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
24:00
Time (hr)

Scrabble Creek Watershed



Streams

Drainage Areas

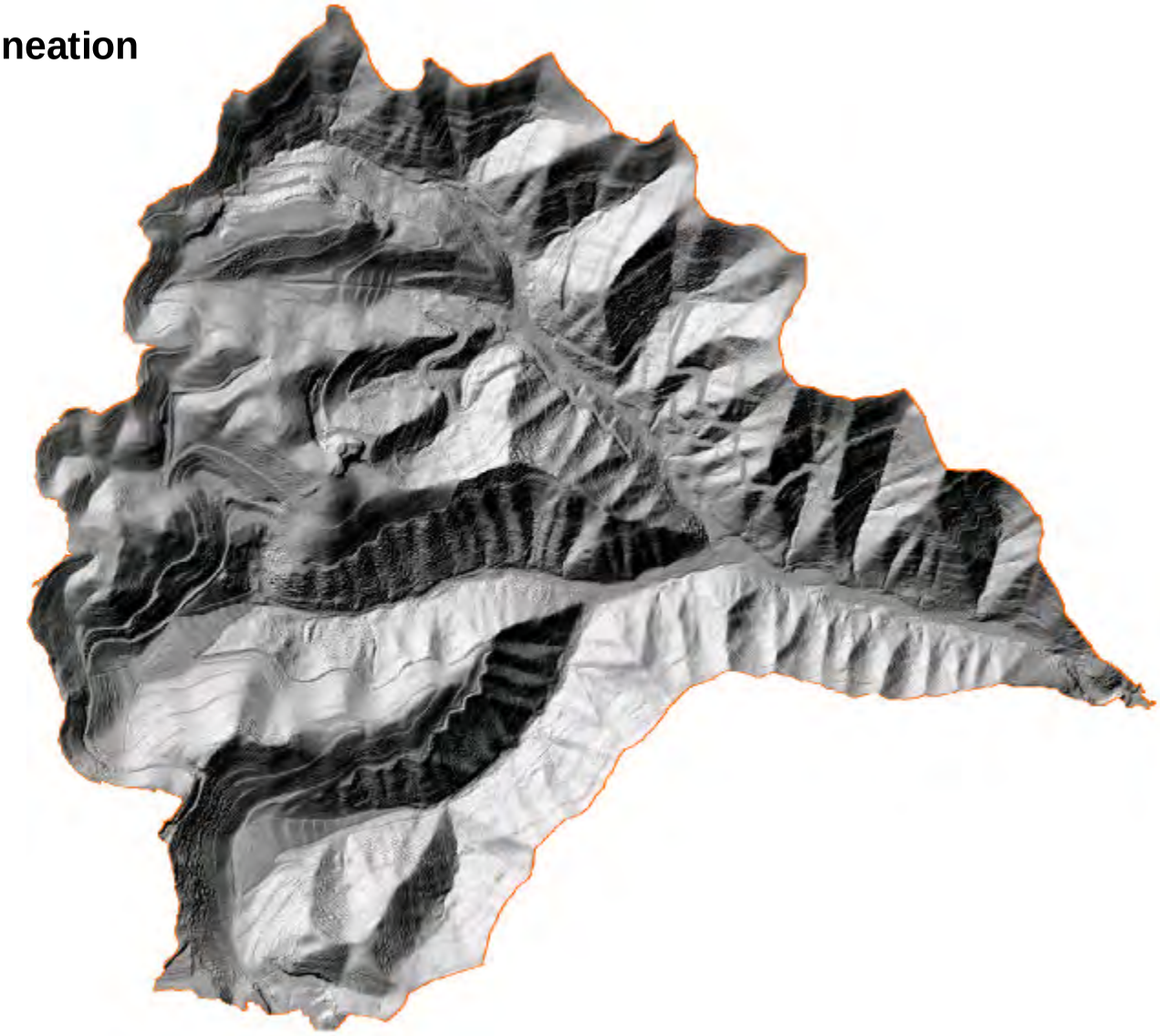
- 1B
- 2aB
- 2bB
- 3aB
- 3bB
- 4B
- 5B
- 6B
- 7aB
- 7bB

N
W E
S

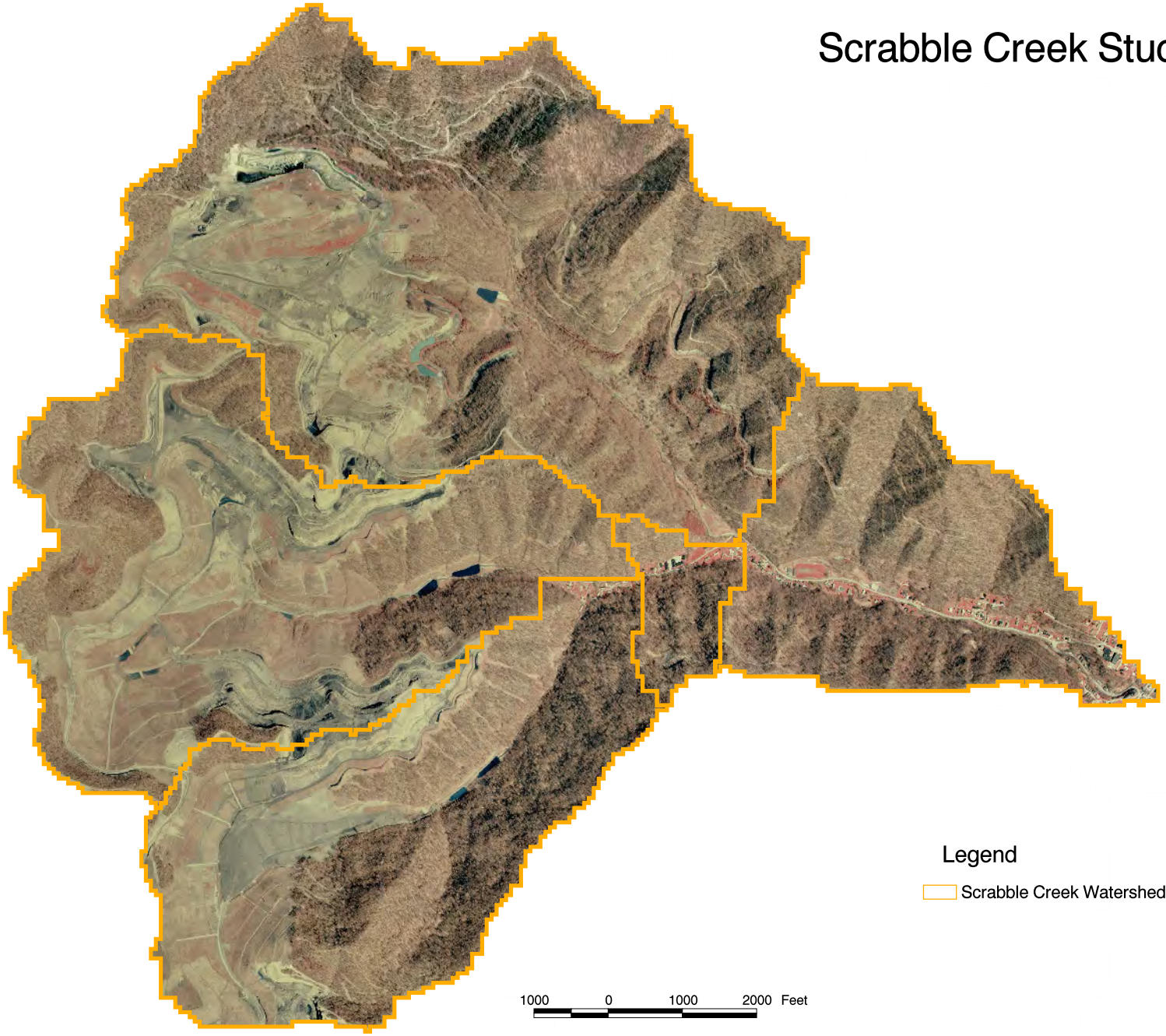
Printed March 27, 2002

Scrabble Creek LIDAR
3D View
Watershed Delineation

Scrabble Creek LIDAR
Plan View
Watershed Delineation



Scrabble Creek Study Area

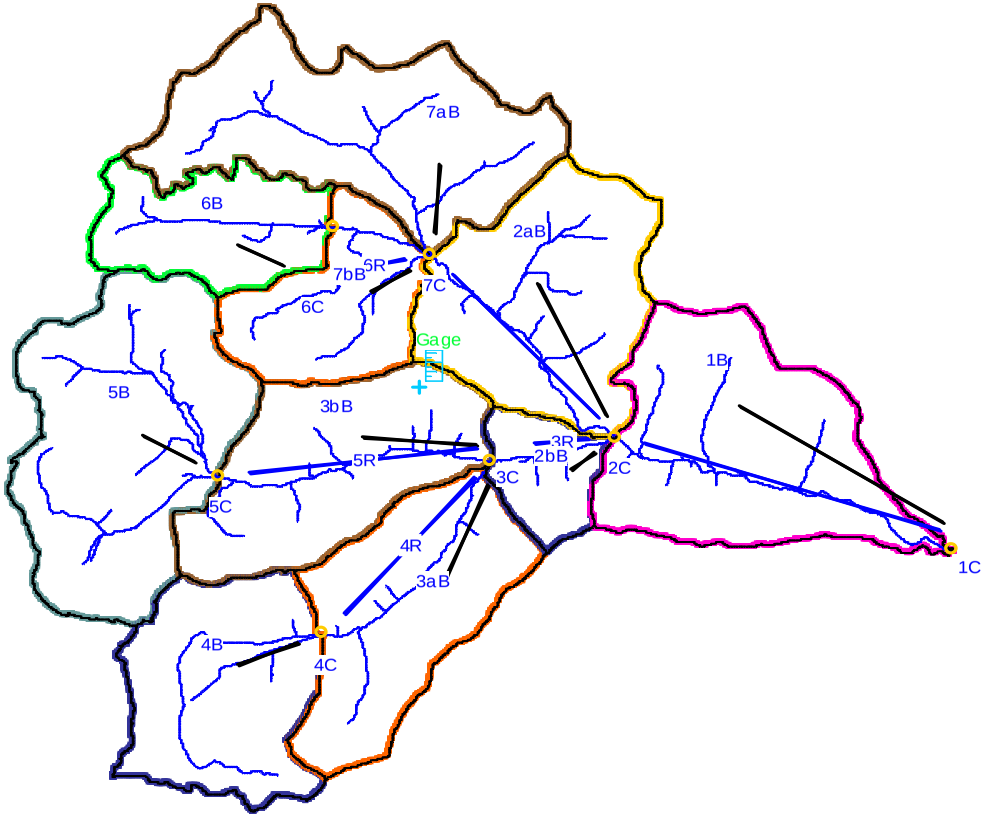


Legend

Scrabble Creek Watershed Boundaries.

Scrabble Creek	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5			
	With Logging (CN 70 & 73)			Without Logging (CN 70)			Without Logging (CN 70)			Without Logging (CN 70)			With Logging (CN 70 & 73)			
	With Mining (CN 75 & 87)			With Mining (CN 75 & 87)			Reclaimed Mining (CN 70)			Without Mining (CN 70)			Without Mining (CN 70)			
	Topography w Mining (LIDAR Data)			Topography w Mining (LIDAR Data)			Topography w Mining			Pristine Topography (USGS DEM Data)			Pristine Topography (USGS DEM Data)			
Outlet Node	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	Event	25 yr	100 yr	14 fps
1C	2045	3760	5165	1970	3595	4980	1663	2745	3879	1802	3242	4573	1877	3405	4755	
2C	1803	3621	4926	1738	3515	4808	1426	2004	2848	1533	3041	4254	1586	3143	4368	
3C	938	1886	2568	928	1867	2547	767	1320	1864	818	1634	2294	827	1654	2316	
4C	203	395	535	203	395	535	171	336	470	173	341	477	173	341	477	
5C	338	682	932	338	682	932	278	552	785	279	530	747	279	530	747	
6C	134	286	392	134	286	392	113	238	337	112	228	324	112	228	324	
7C	594	1489	2032	571	1422	1958	470	1108	1560	503	1241	1748	525	1307	1821	

Watershed Delineation and Basin / Outlet / Routing Naming



Scrabble Creek Watershed Hydrology Analysis	Scenario 1 With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			Scenario 2 Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			Scenario 3 Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)			Scenario 4 Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)			Scenario 5 With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)		
Bottom of Scrabble Creek at Node 1C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	2045	3760	5165	1970	3595	4980	1663	2745	3879	1802	3242	4573	1877	3405	4755
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	382	1015	1286	307	850	1101				243	518	592	75	163	182
% Difference	23.0%	37.0%	33.2%	18.5%	31.0%	28.4%				13.5%	16.0%	12.9%	4.2%	5.0%	4.0%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	75	165	185	168	353	407				-139	-497	-694			
% Difference	3.8%	4.6%	3.7%	9.3%	10.9%	8.9%				-8.4%	-18.1%	-17.9%			

At Node 2C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	1803	3621	4926	1738	3515	4808	1426	2004	2848	1533	3041	4254	1586	3143	4368
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	377	1617	2078	312	1511	1960				270	580	672	53	102	114
% Difference	26.4%	80.7%	73.0%	21.9%	75.4%	68.8%				17.6%	19.1%	15.8%	3.5%	3.4%	2.7%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	65	106	118	205	474	554				-107	-1037	-1406			
% Difference	3.7%	3.0%	2.5%	13.4%	15.6%	13.0%				-7.5%	-51.7%	-49.4%			

At Node 3C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	938	1886	2568	928	1867	2547	767	1320	1864	818	1634	2294	827	1654	2316
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	171	566	704	161	547	683				120	252	274	9	20	22
% Difference	22.3%	42.9%	37.8%	21.0%	41.4%	36.6%				14.7%	15.4%	11.9%	1.1%	1.2%	1.0%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	10	19	21	110	233	253				-51	-314	-430			
% Difference	1.1%	1.0%	0.8%	13.4%	14.3%	11.0%				-6.6%	-23.8%	-23.1%			

Downstream of Valley Fill at Node 4C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	203	395	535	203	395	535	171	336	470	173	341	477	173	341	477
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	32	59	65	32	59	65				30	54	58	0	0	0
% Difference	18.7%	17.6%	13.8%	18.7%	14.9%	13.8%				17.3%	15.8%	12.2%	0.0%	0.0%	0.0%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	0	0	0	30	54	58				-2	-5	-7			
% Difference	0.0%	0.0%	0.0%	17.3%	15.8%	12.2%				-1.2%	-1.5%	-1.5%			

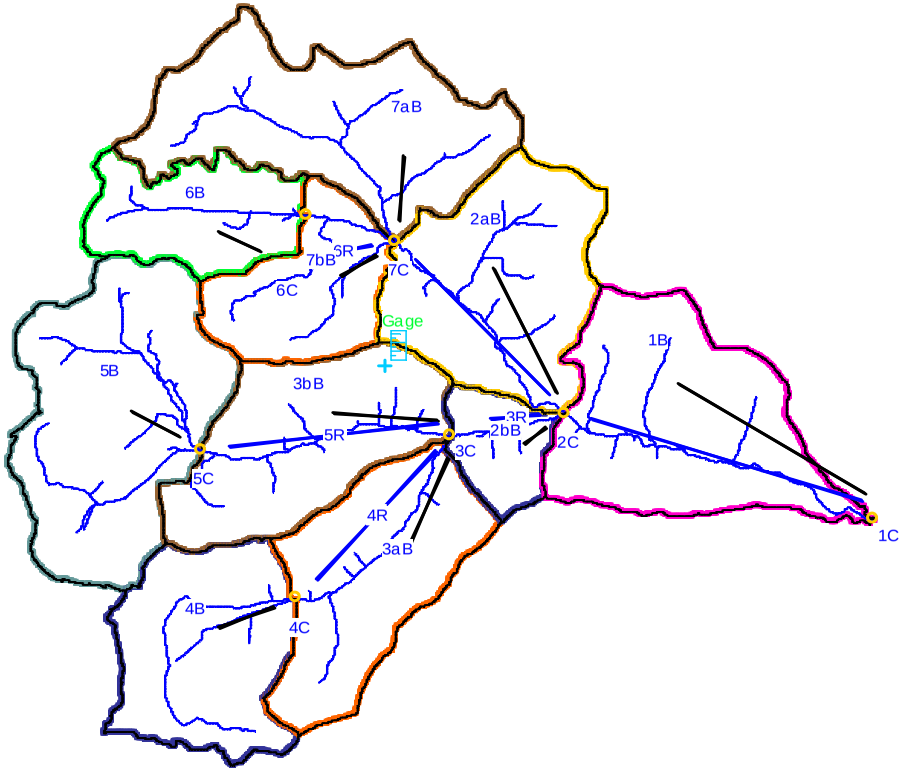
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)			**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)			**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)			**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)		
Downstream of Valley Fil at Node 5C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	338	682	932	338	682	932	278	552	785	279	530	747	279	530	747
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	60	130	147	60	130	147				59	152	185	0	0	0
% Difference	21.6%	23.6%	18.7%	21.6%	23.6%	18.7%				21.1%	28.7%	24.8%	0.0%	0.0%	0.0%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	0	0	0	59	152	185				-1	22	38			
% Difference	0.0%	0.0%	0.0%	21.1%	28.7%	24.8%				-0.4%	4.2%	5.1%			

Downstream of Valley Fil at Node 6C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	134	286	392	134	286	392	113	238	337	112	228	324	112	228	324
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	21	48	55	21	48	55				22	58	68	0	0	0
% Difference	18.6%	20.2%	16.3%	18.6%	20.2%	16.3%				19.6%	25.4%	21.0%	0.0%	0.0%	0.0%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	0	0	0	22	58	68				1	10	13			
% Difference	0.0%	0.0%	0.0%	19.6%	25.4%	21.0%				0.9%	4.4%	4.0%			

Node 7C	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	594	1489	2032	571	1422	1958	470	1108	1560	503	1241	1748	525	1307	1821
											Total Influence			Logging Influence Cross Check	
	Comparison with Scenario 3			**Comparison with Scenario 3**						**Comparison with Scenario 1**			**Comparison with Scenario 4**		
Difference	124	381	472	101	314	398				91	248	284	22	66	73
% Difference	26.4%	34.4%	30.3%	21.5%	28.3%	25.5%				18.1%	20.0%	16.2%	4.4%	5.3%	4.2%
		Logging Influence			Mining Influence						Topography Influence				
	Comparison with Scenario 2			**Comparison with Scenario 4**						**Comparison with Scenario 3**					
Difference	23	67	74	68	181	210				-33	-133	-188			
% Difference	4.0%	4.7%	3.8%	13.5%	14.6%	12.0%				-7.0%	-12.0%	-12.1%			

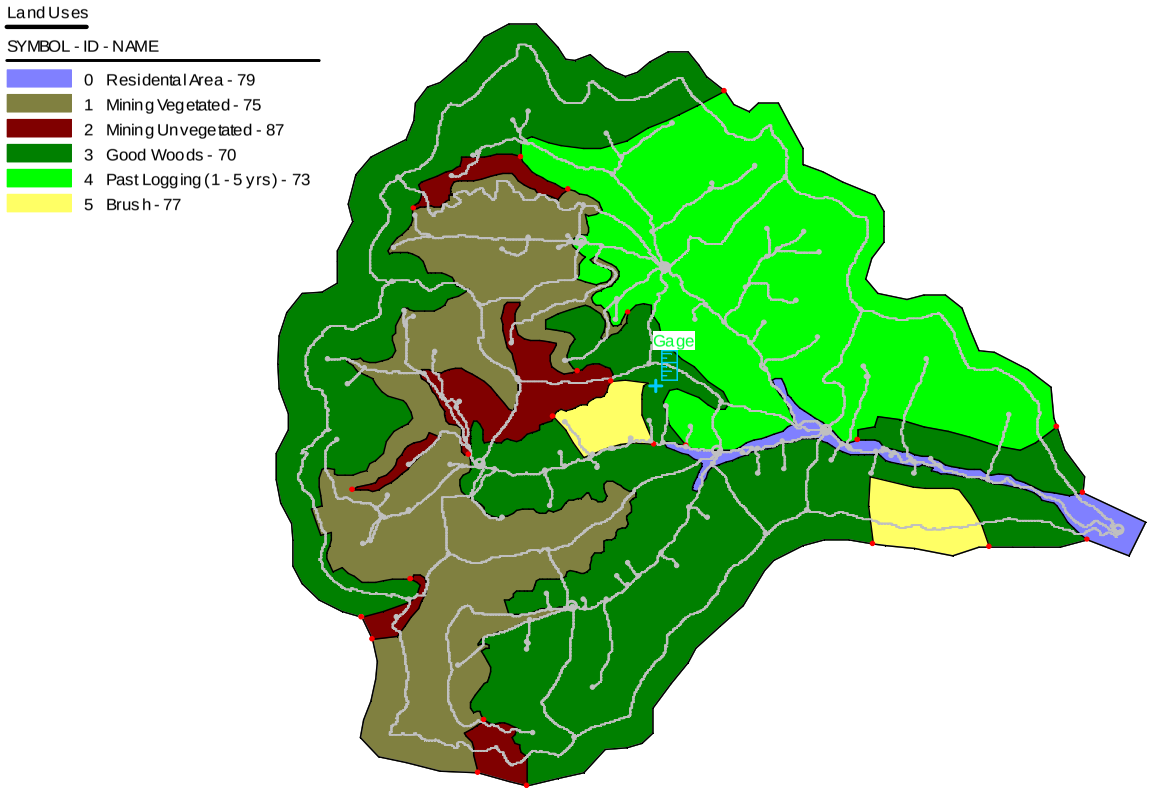
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Watershed Delineation and Basin / Outlet / Routing Naming



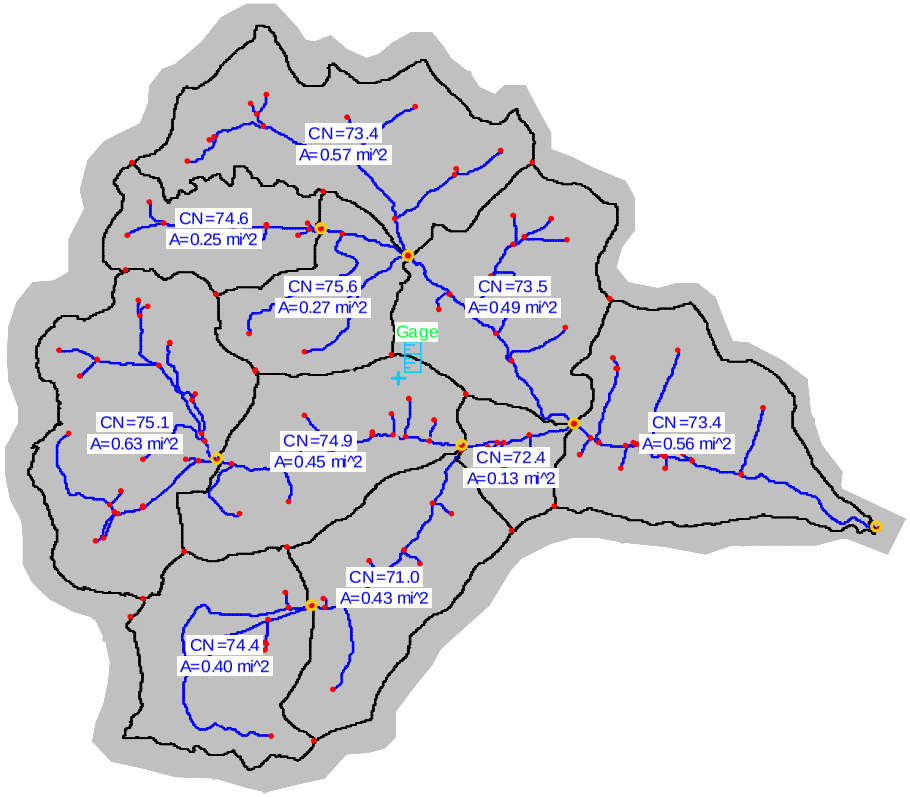
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 1 Land Use



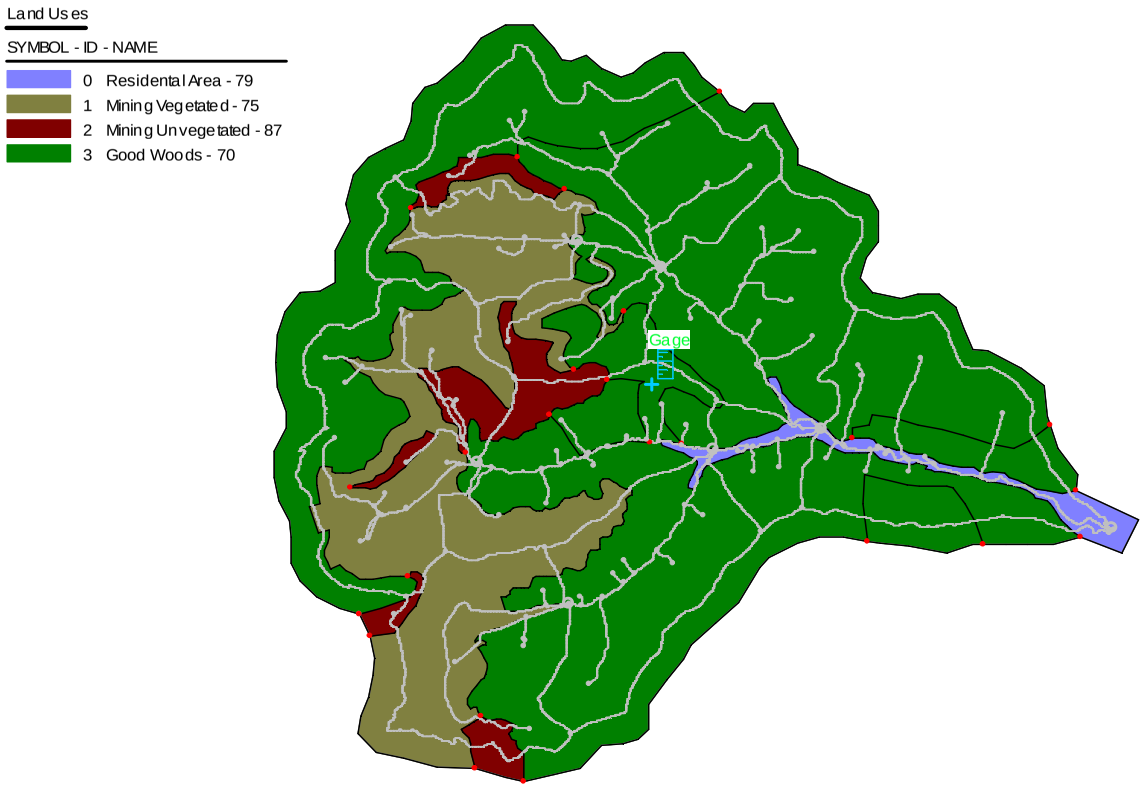
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 1 Watershed Boundaries and Composite CN and Computed Areas



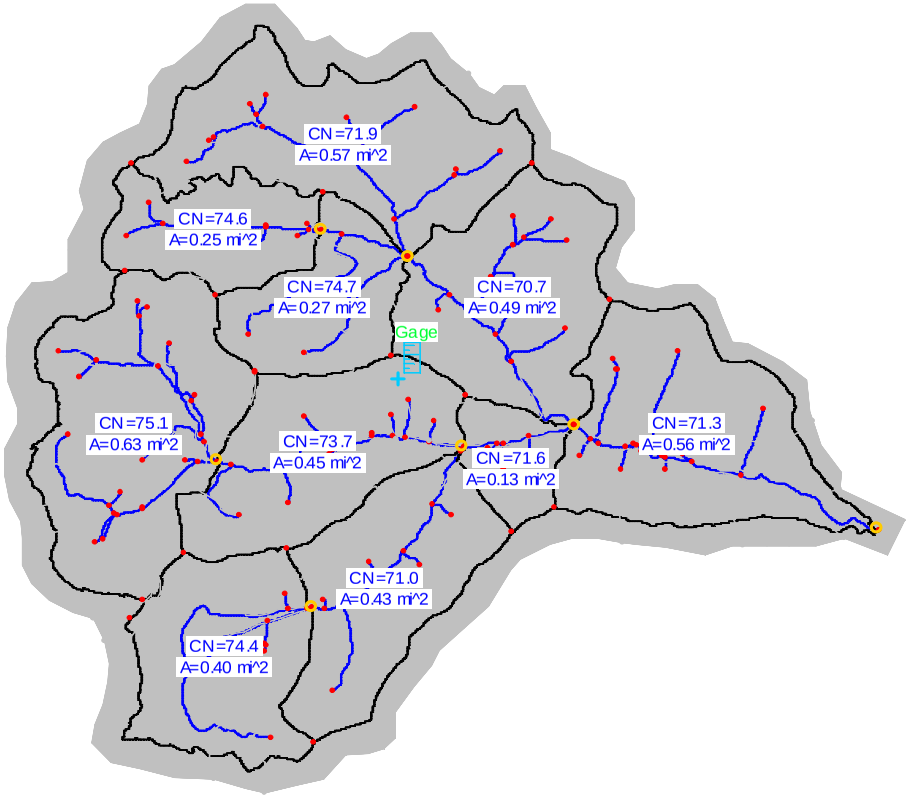
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 2 Land Use



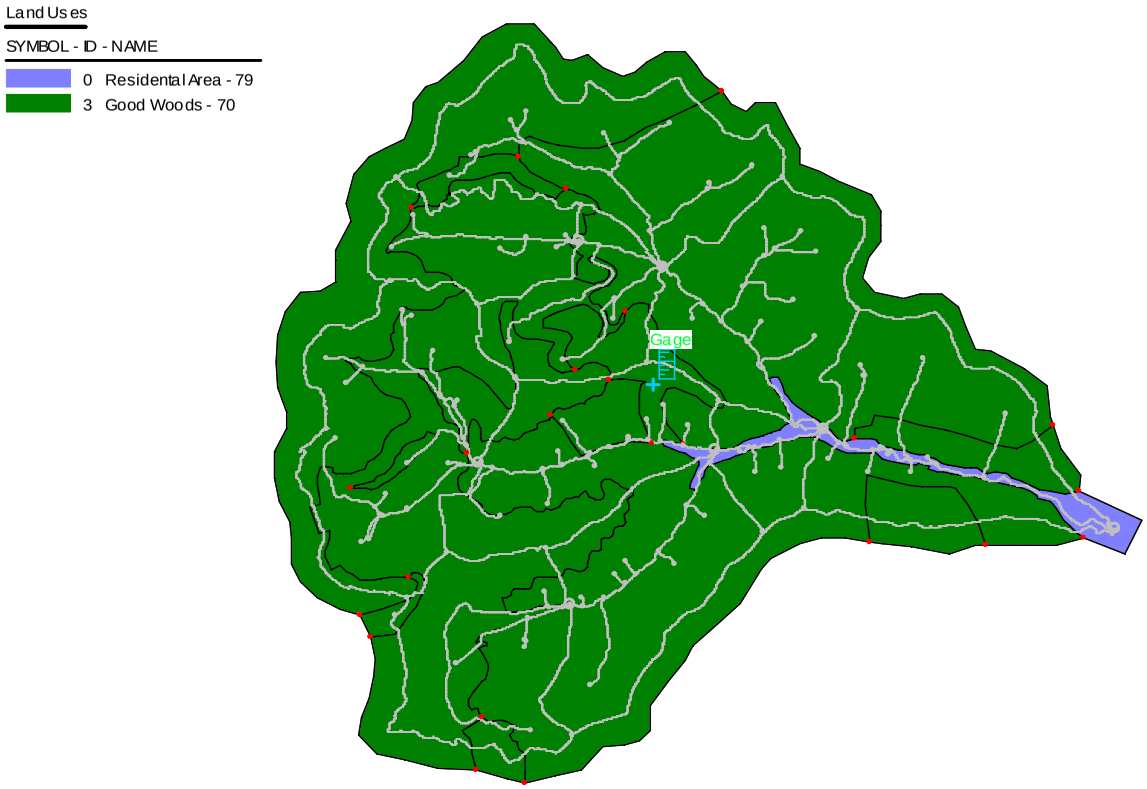
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 2 Watershed Boundaries
and Composite CN and Computed Areas



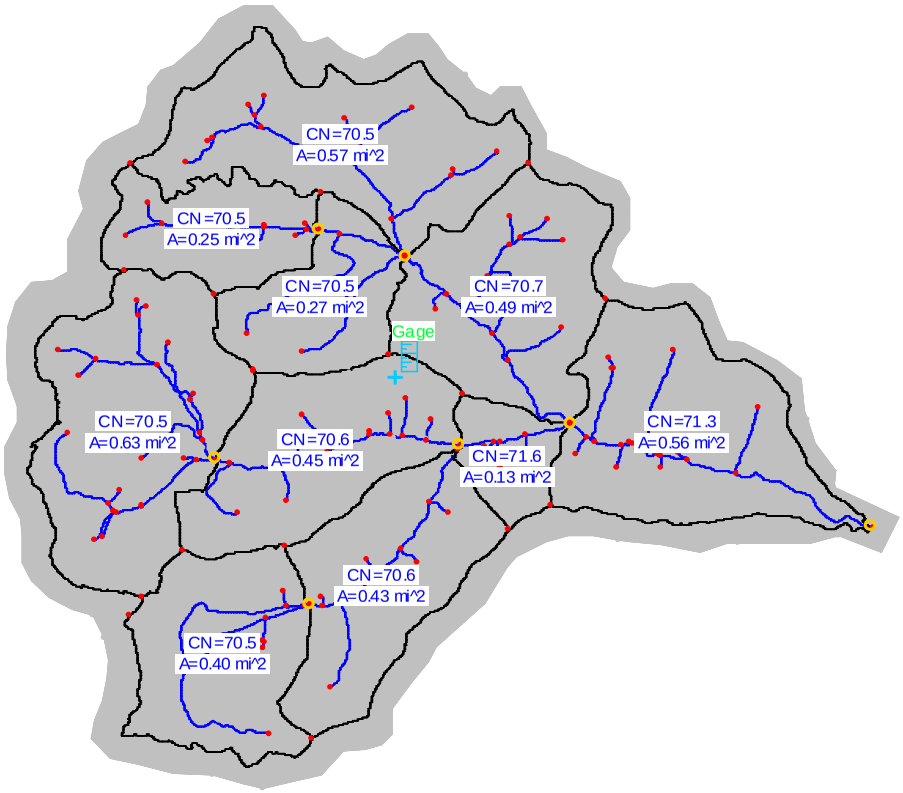
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 3 Land Use



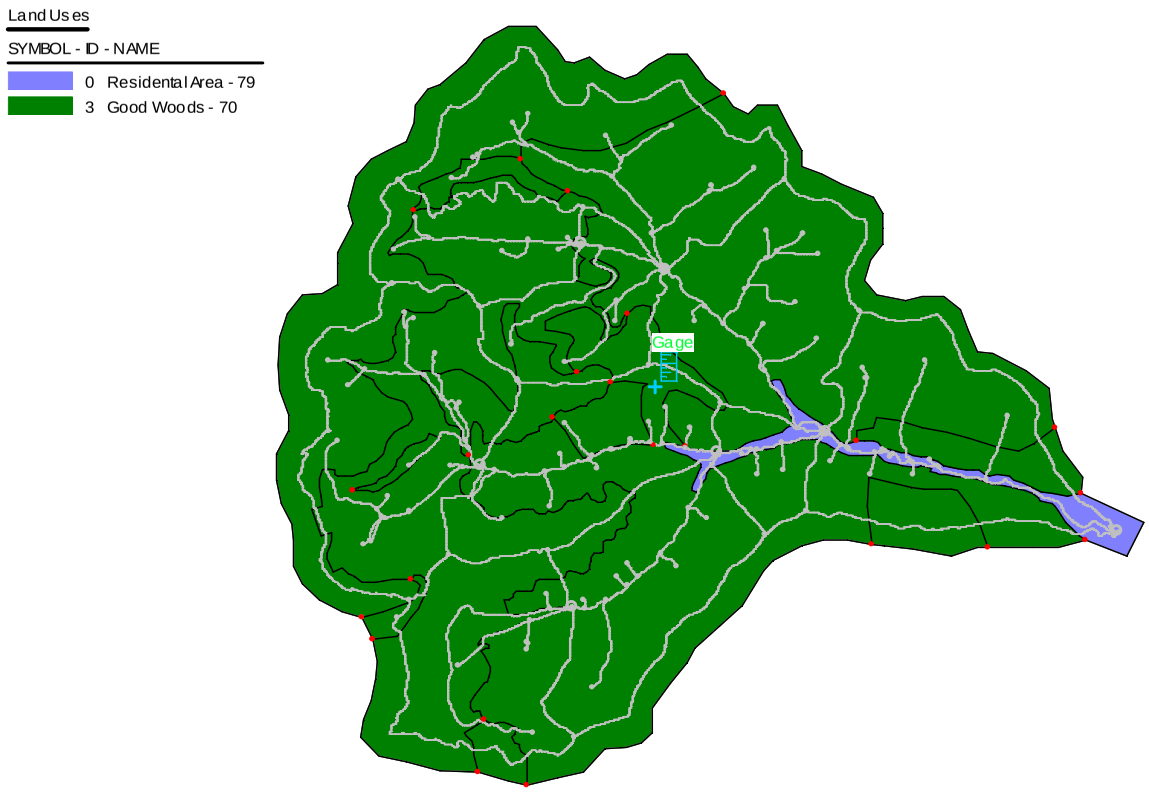
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 3 Watershed Boundaries
and Composite CN and Computed Areas



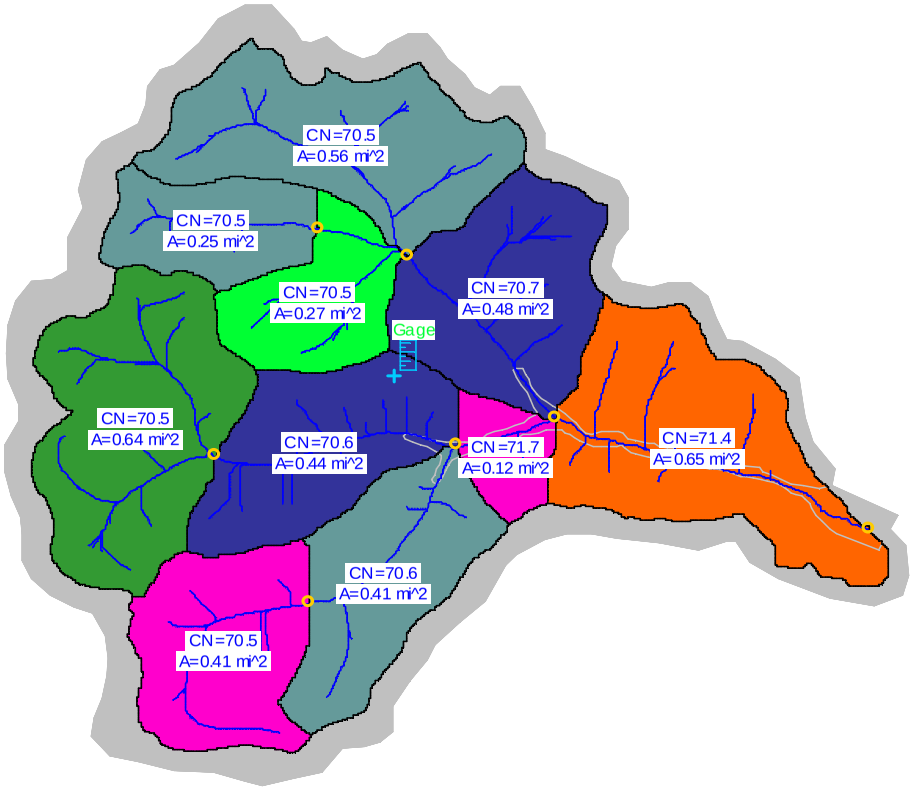
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 4 Land Use



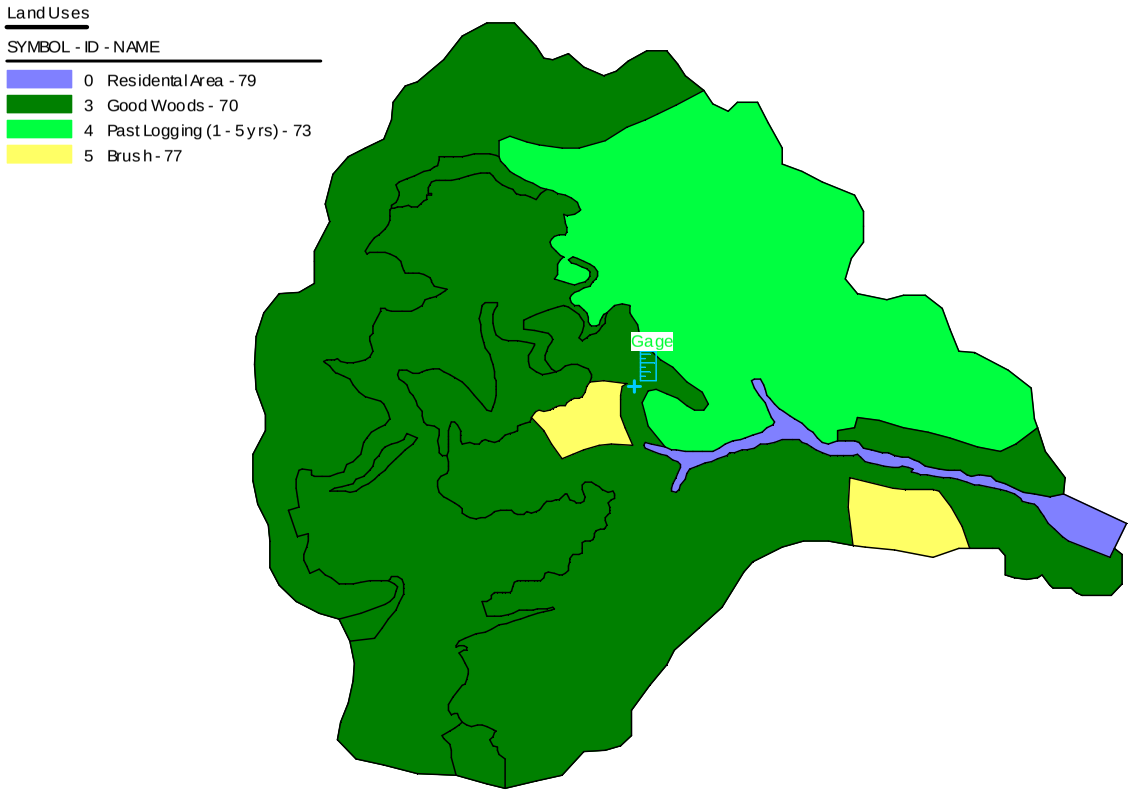
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

Scenario 4 Watershed Boundaries and Composite CN and Computed Areas



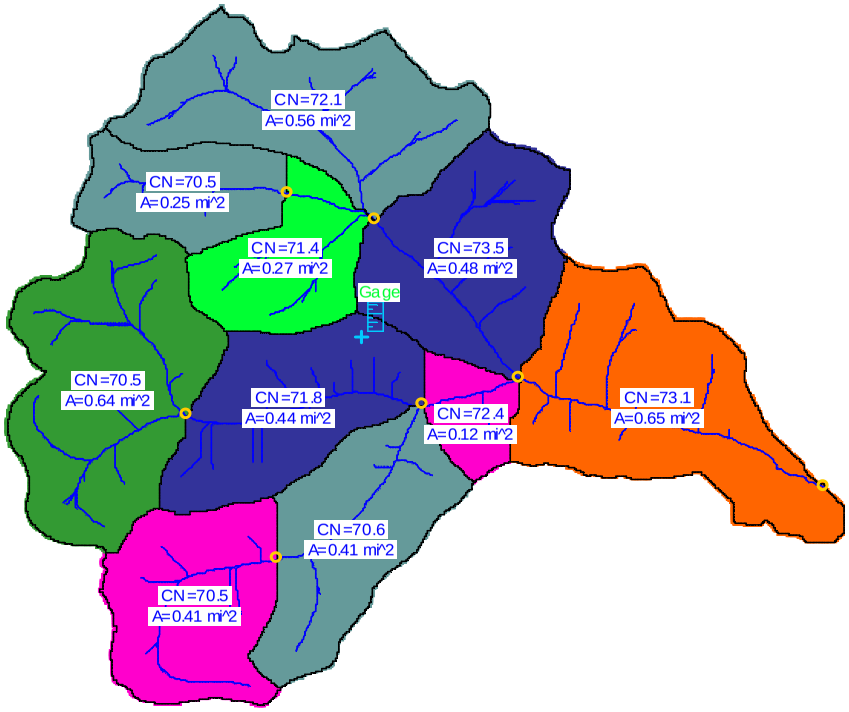
Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

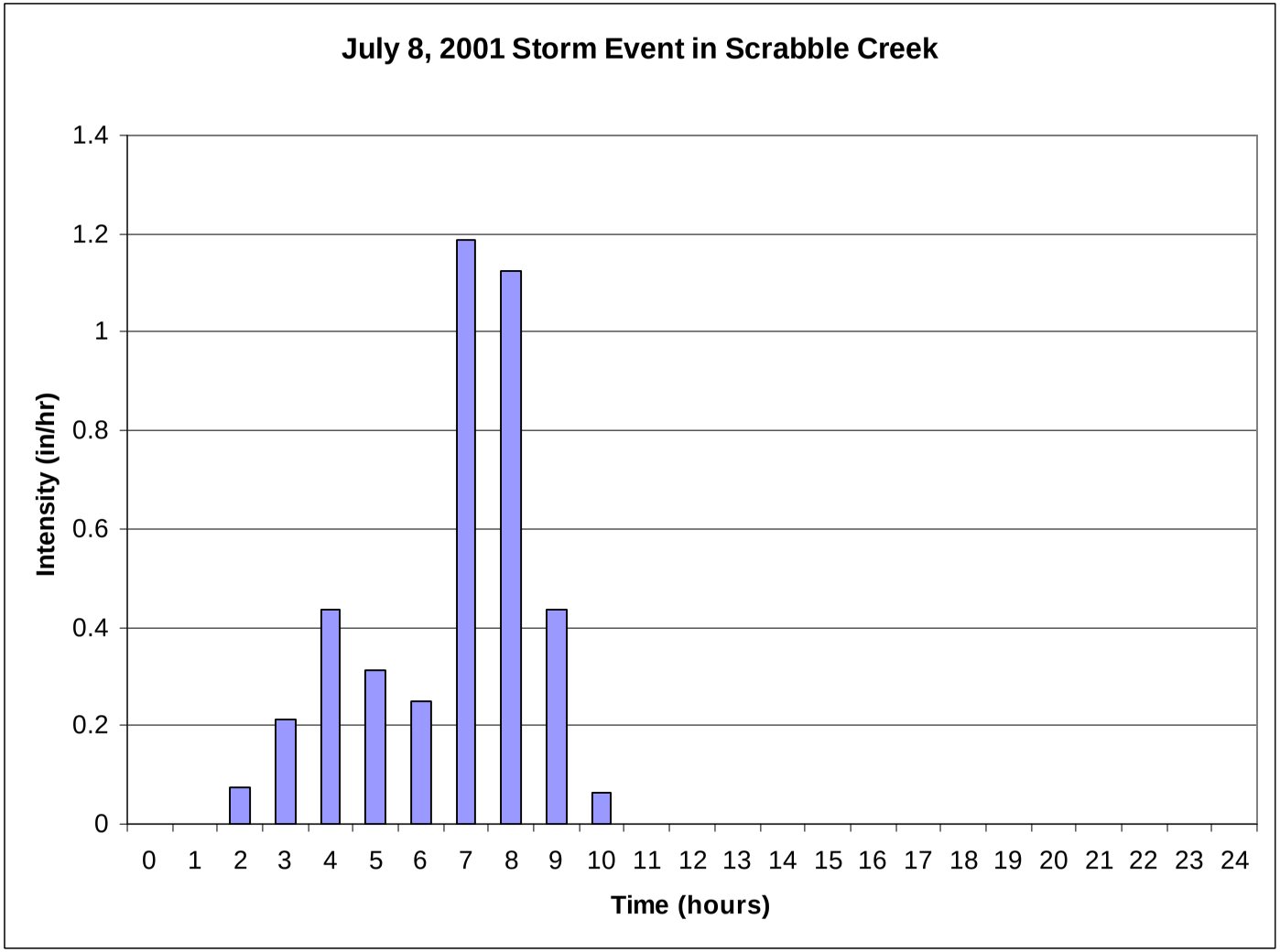
Scenario 5 Land Use

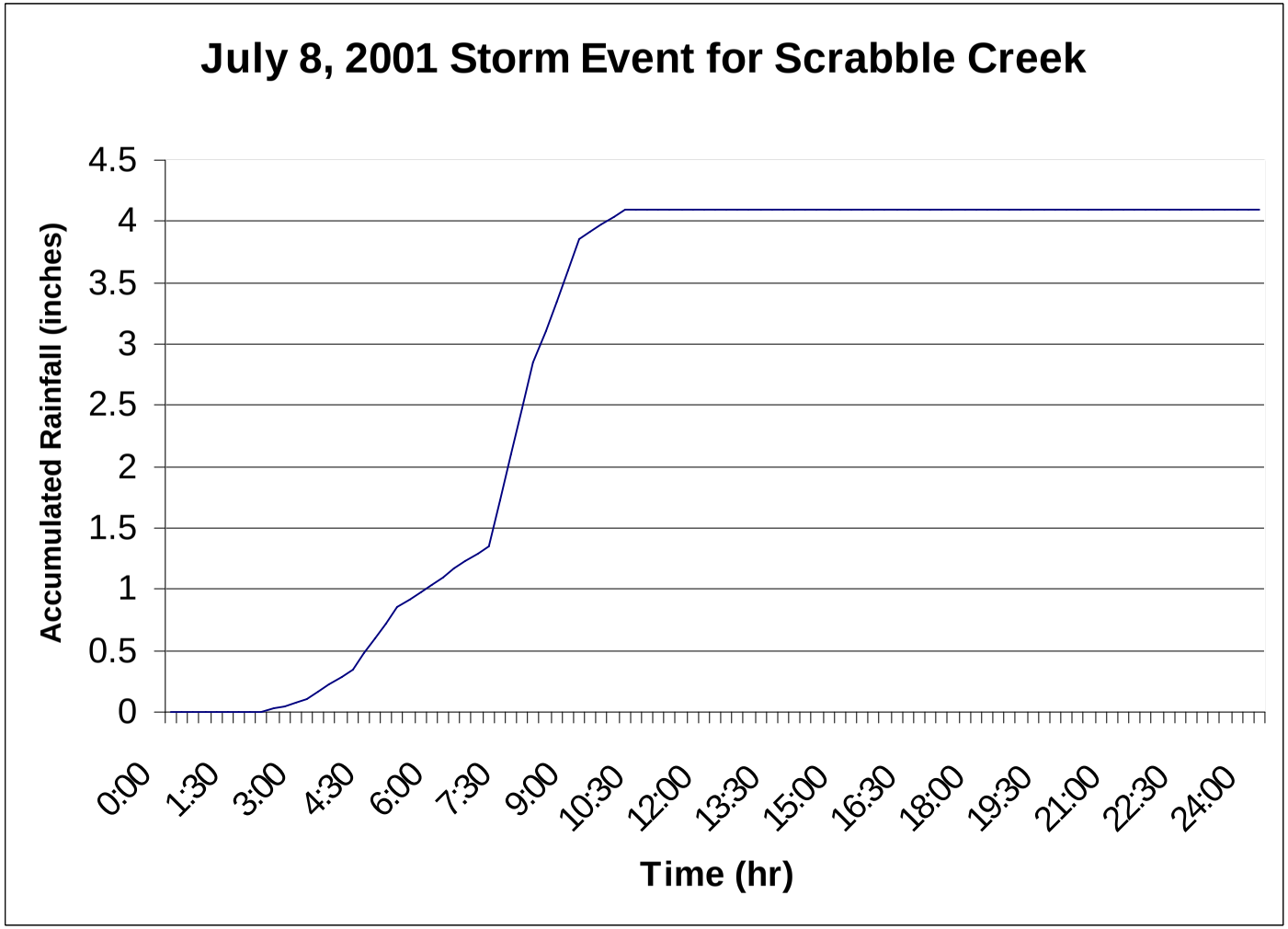


Scrabble Creek Watershed Hydrology Analysis	**Scenario 1** With Logging (CN 70 & 73) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 2** Without Logging (CN 70) With Mining (CN 75 & 87) Topography w Mining (LIDAR Data)	**Scenario 3** Without Logging (CN 70) With Reclaimed Mining (CN 70) Topography w Mining (LIDAR Data)	**Scenario 4** Without Logging (CN 70) Without Mining (CN 70) Pristine Topography (10m DEM Data)	**Scenario 5** With Logging (CN 70 & 73) Without Mining (CN 70) Pristine Topography (10m DEM Data)

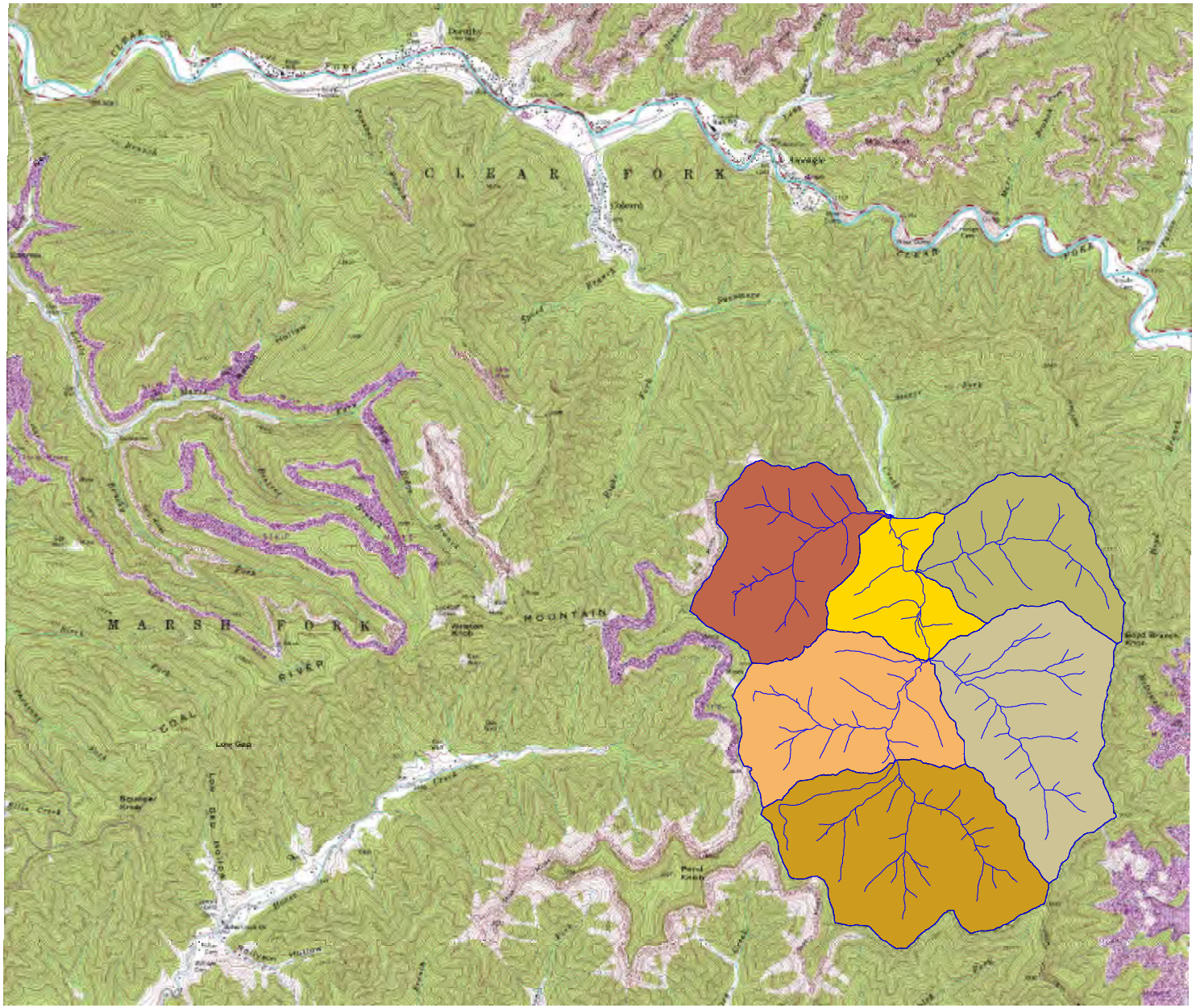
Scenario 5 Watershed Boundaries and Composite CN and Computed Areas




July 8, 2001 Storm Event in Scrabble Creek
Intensity (in/hr)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)


July 8, 2001 Storm Event for Scrabble Creek
Accumulated Rainfall (inches)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0:00
1:30
3:00
4:30
6:00
7:30
9:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
24:00
Time (hr)

Sycamore Creek Watershed



Streams

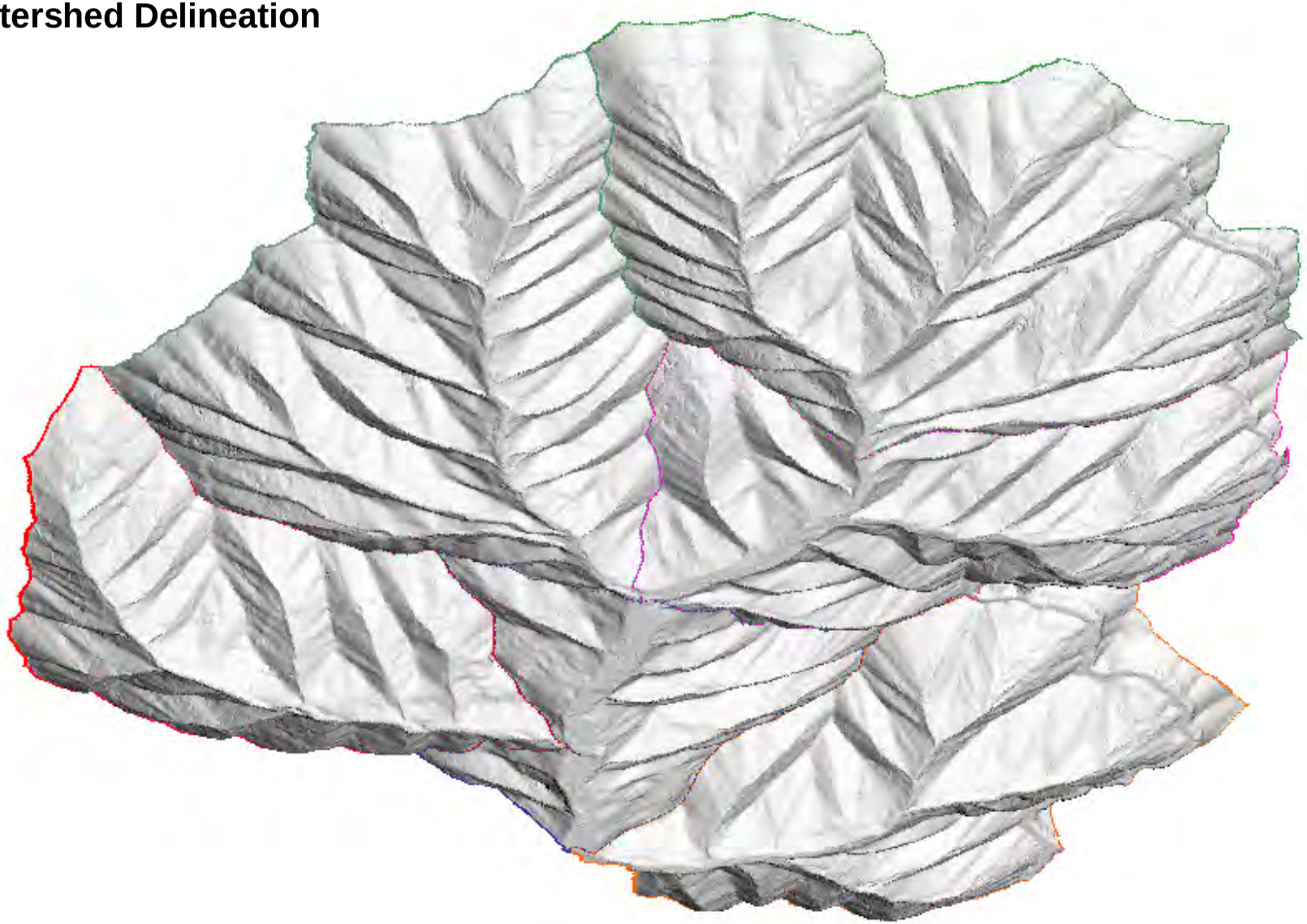
Drainage Areas

- 1aB
- 1bB
- 2B
- 3aB
- 3bB
- 4B

N
W E
S

Printed March 27, 2002

Sycamore Creek LIDAR
3D View
Watershed Delineation



Sycamore Creek LIDAR
Plan View
Watershed Delineation

Sycamore Creek Study Area

Legend

Sycamore Creek Watershed Boundaries

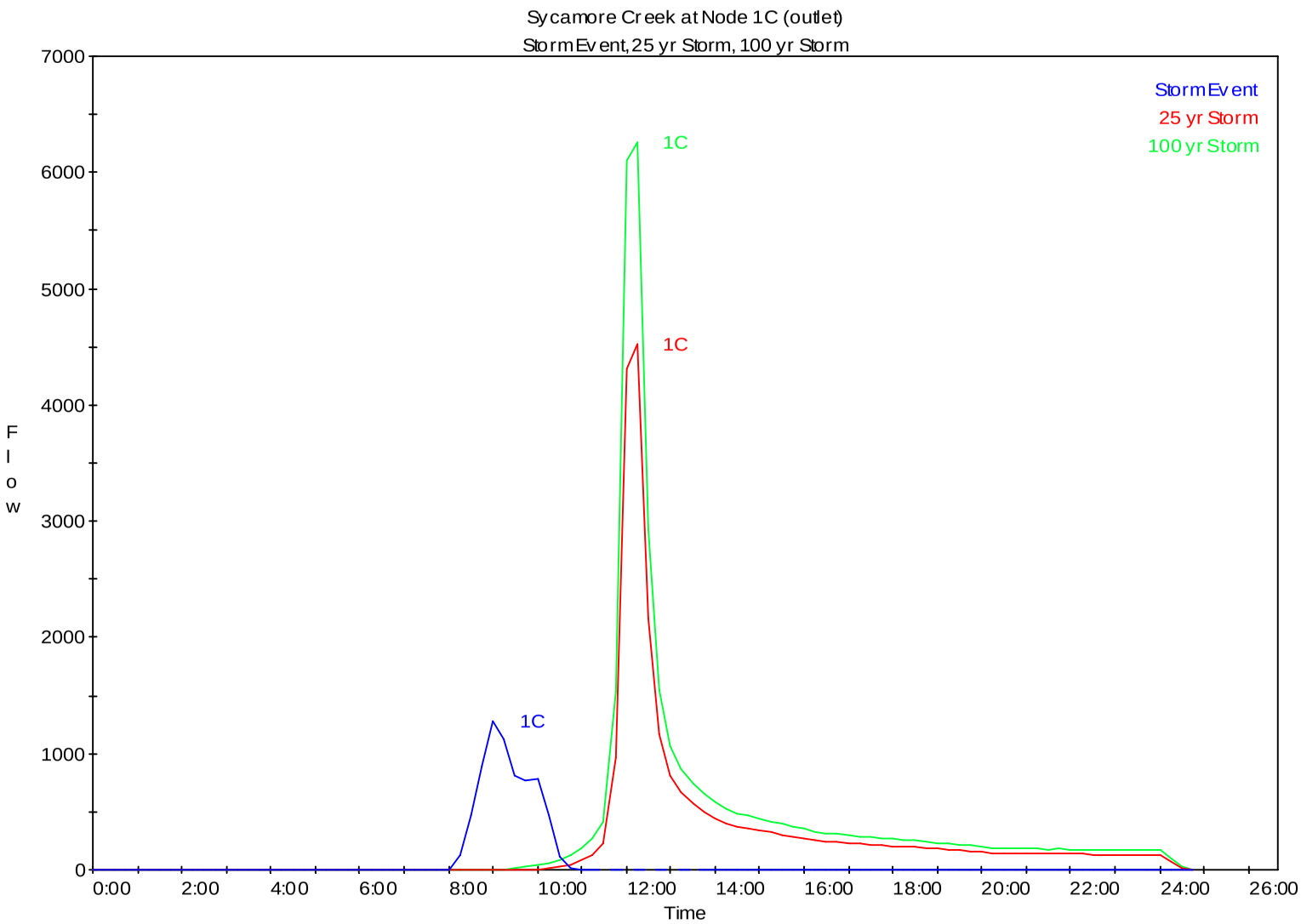
N
W E
S

3000 0 3000 6000 Feet

TAGIS

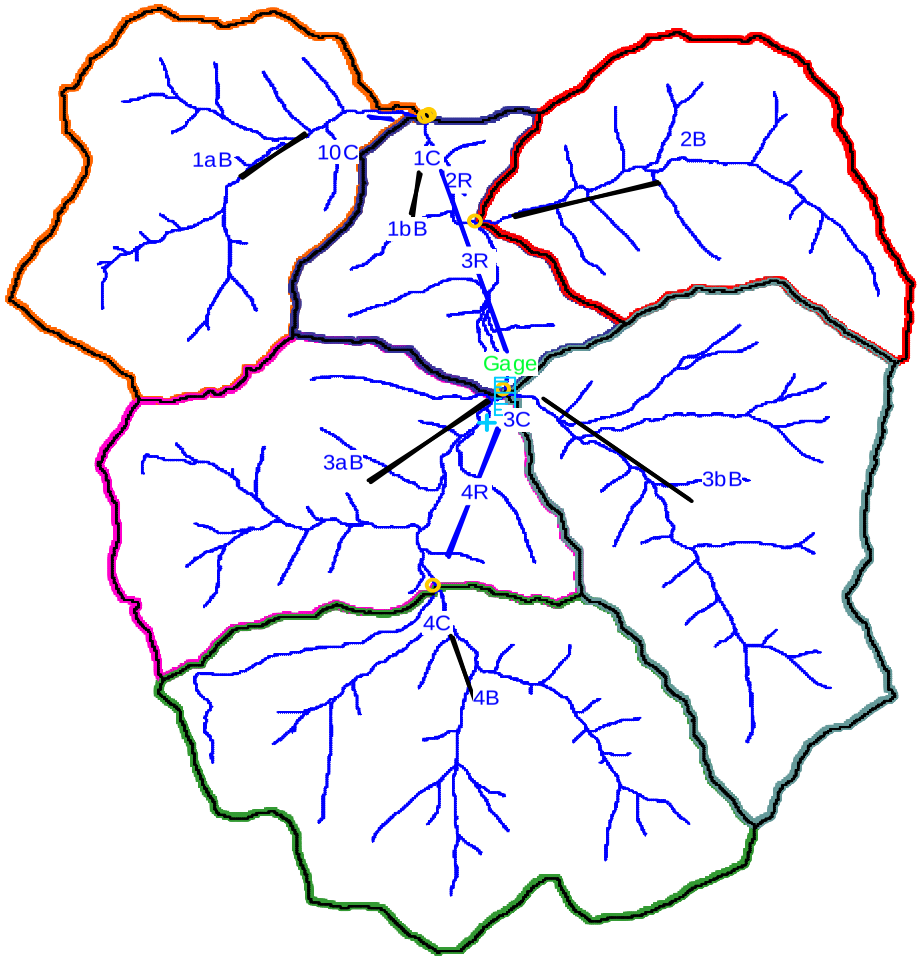
Sycamore Creek Hydrology Analysis

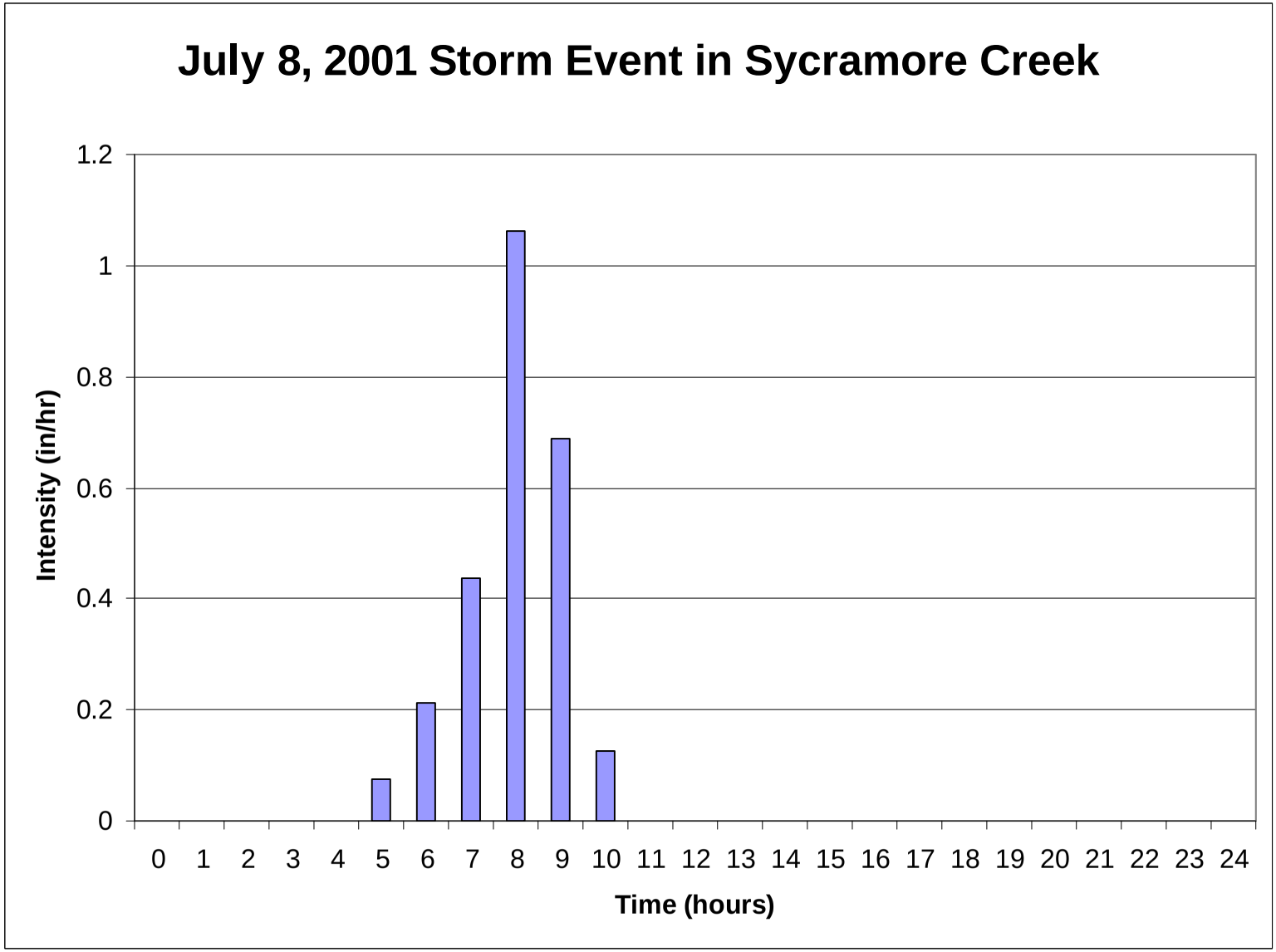
Bottom of Sycamore Creek	Storm Event	25 Yr Storm	100 yr Storm
Max Flow	*1211*	*4378*	*6078*

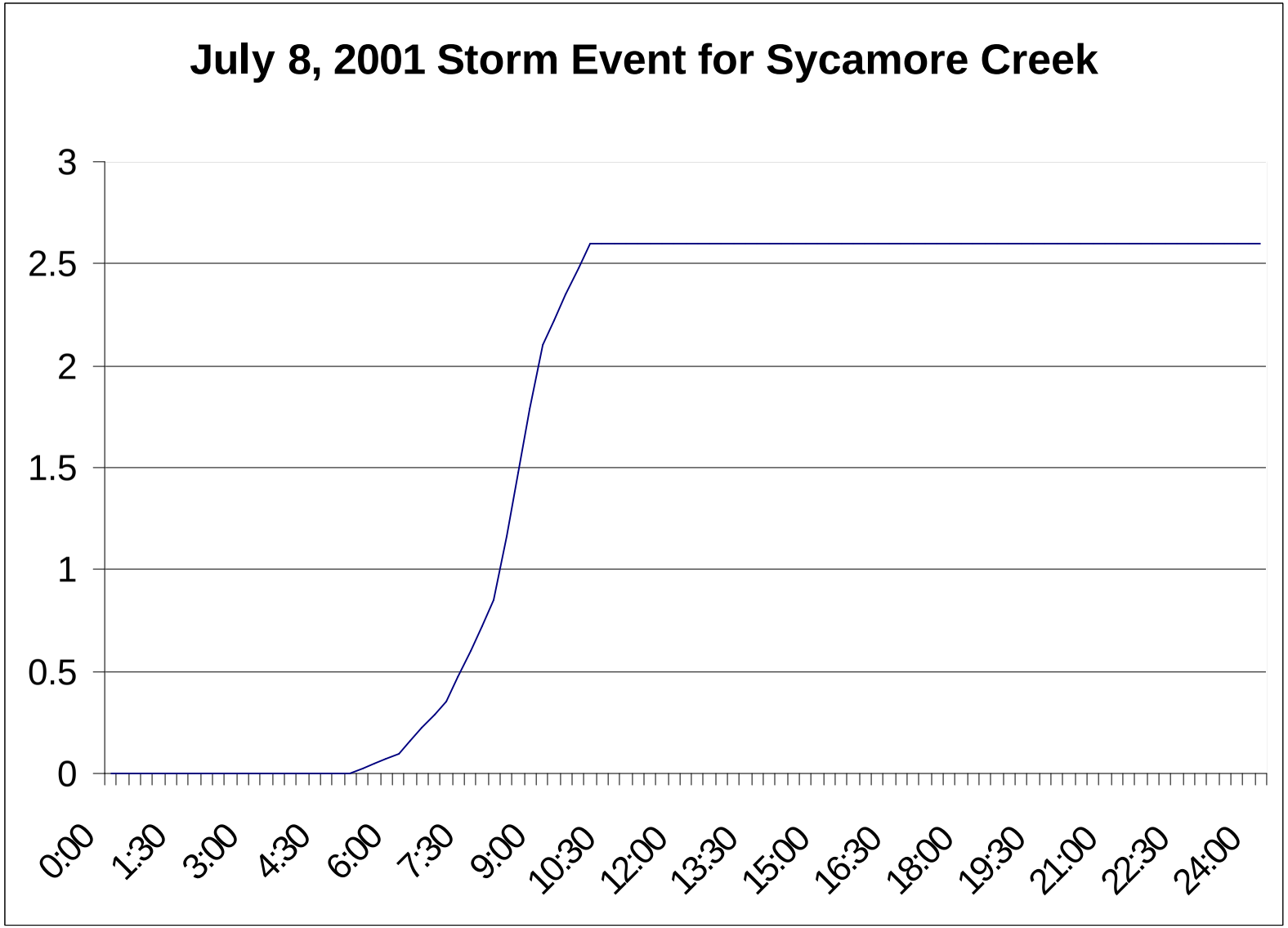


Sycamore Creek Outlet Node	LIDAR (wo Mining & wo Logging)			
	Event	25 yr	100 yr	9 fps
1C	1211	4378	6078	
2C	198	901	1255	
3C	840	3374	4737	
4C	333	1513	2109	

Watershed Delineation and Basin / Outlet / Routing Naming




July 8, 2001 Storm Event in Sycramore Creek
Intensity (in/hr)
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (hours)


July 8, 2001 Storm Event for Sycamore Creek
3
2.5
2
1.5
1
0.5
0
0:00
1:30
3:00
4:30
6:00
7:30
9:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
24:00

LONG-TERM STABILITY OF VALLEY FILLS
FINAL REPORT

March 2002

PREPARED BY

U.S. Department of Interior
Office of Surface Mining

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SYNOPSIS OF FINDINGS

During the outreach and scoping process for the programmatic environmental impact statement (EIS) on mountaintop mining and valley fills, comments received suggest that valley fills might pose a threat to downstream areas due to mass instability. The perception that looming fill failure potential, with consequences similar to a dam or an impoundment failure, had not been addressed by a comprehensive regional assessment of valley fills--although several past oversight analyses of excess spoil disposal practices have occurred in each state. The sense within the regulated community prior to this study was that occurrences of valley fill instability (i.e., landslides or land slips on fills) were isolated and infrequent; and, that properly constructed valley fills are well-engineered and stable structures. The EIS Steering Committee chartered a study of fill stability to provide regional empirical information addressing this issue.

A review and analysis of the data indicates that significant slope movements on valley fills are neither commonplace nor widespread. As of the completion of this study in November, 2000, only 20 occurrences of valley fill instability are recorded out of more than 4,000 fills constructed in the past 23 years. While these instances of fill instability might have been "major" as regards the cost of re-engineering and corrective action to mitigate the mass movement, the consequences were not loss of life or significant private property damage. Another important finding of the study was that all of the fill movement occurred during the mining and reclamation phase of the permits; thus correctable prior to bond release. Conversely, no records of instability were discovered on valley fills after final bond release. The twenty slope movements reported appear to result from improper construction or design practices or inadequately-investigated foundation conditions.

The regulations under the Surface Mining Control and Reclamation Act require geotechnical investigation of fill sites, foundation preparation, controlled placement of material, as well as surface and subsurface drainage control. Slope movements and other events symptomatic of potential fill instability were identified in the study, but all of them reflect site-specific problems that can be corrected, or could have been avoided, under the current regulatory framework. This investigation has found no systemic failings in the regulations ensuring valley fill stability.

While the study found only a very small percentage of excess spoil fills that experienced instability over the past 23 years, there are areas of fill design, construction, and documentation that could be improved to better ensure long-term stability. Some of the following recommendations have already been implemented by state regulatory authorities: (1) more discriminating methods for determining rock durability; (2) consideration of alternative fill construction techniques to assure optimal foundation and drainage control; (3) better guidance on requirements for foundation investigations and stability analyses; (4) better documentation and record keeping for critical construction phase certifications; (5) prohibition of, or limitations to, "wing dumping" for excessive distances beyond the fill face; (6) additional assurances for fill foundations on steep slopes; (7) consideration of limits on fill construction temporary cessation periods before requiring face completion; (8) additional studies of completed fills; and, (9) diligence in assuring a prohibition of impoundment construction on fills.

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APPENDICES

Appendix A: Workplan Approach for Fill Stability

Appendix B: Permit and Field Data from Valley Fill Samples

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I. Introduction

A typical mountaintop mining/valley fill operation in the Appalachian coalfields removes overburden and interburden material to facilitate the extraction of coal seams. Inadequate storage within the mine site requires placement of excess spoil into adjacent valleys. The valley fills that result vary greatly in size. Fills evaluated in this study range in volume from 0.2 to more than 200 million cubic yards (mcy); and in length from 300 to nearly 10,000 feet. Concerns have been expressed that instability of a fill could endanger life, property, and the environment downstream.

The purpose of this investigation under the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS), and as an OSM oversight special study, is to assess the effectiveness of current regulatory and policy-driven safeguards against future fill instability that may negatively affect public safety. The scope of the study includes the identification and analysis of past and existing cases of valley fill instability in steep-slope Appalachia. It also includes the collection and analysis of indicator data relating to fill designs, present-day construction practices, and the existing conditions of as-built embankments. This study also evaluates the current State and Federal regulations, policies, and practices; government documents that identify and discuss issues related to fill stability; and pertinent geotechnical literature. The procedures undertaken by the United States Office of Surface Mining (OSM) include: (1) discussions with State/Federal inspection and enforcement (I & E) and permit-review personnel and Federal geotechnical experts; (2) review of permits, inspection reports, and other relevant documentation; and (3) aerial and ground-level site inspections. This report presents conclusions concerning the adequacy of the current safeguards and recommends improvements, where appropriate.

II. Background

A. Nature and consequences of valley fill instability

Data analysis pertaining to occurrences of fill instability are presented in section IV, E, 3. For the purposes of this study, fill instability is defined as any evidence that: (1) part of the fill's mass has separated from the rest of the fill; (2) the separation occurs along a continuous slip surface, or continuous sequence of slip surfaces, intersecting the fill's surface; and (3) some vertical displacement has occurred. Cases of instability, or "slope movement," identified with these criteria are further distinguished between "major" and "minor" occurrences. Major slope movements are those judged to occur over a large fraction of the fill face (e.g. over at least a few outslope benches) and/or require a major remediation effort (redistribution of the spoil from one part of the fill to another, construction of rock-toe buttresses, extensive reworking or augmenting of the drainage systems etc.). Minor slope movements are those that occur over a small area on the fill (e.g. not more than one bench on the fill face) and only necessitating minor reworking of the fill material (i.e. without significantly changing the original fill configuration).

The word, "instability," is a general term used in science and engineering when a material or structure fails to remain intact or "hold up" under stress. For valley fills, commonly-used terms descriptive of slope movement include landslide and land slip. These are distinguished according to distance and rapidity of material transport. The more dangerous of these is the landslide, which involves sudden, rapid, and relatively distant movement of material. A land slip has many features that are similar to a landslide, but is characterized by a gradual movement over a shorter distance. Although this kind of slope movement is at first less of a safety hazard compared to a landslide, it can turn into a slide if left unremediated. Both landslides and slips can be considered major slope movements if they are large enough and costly to remediate. Relatively small events, i.e. minor occurrences of instability, are simple to repair. However, if left unattended to, they can grow into major events.

Although most valley fills occur in relatively remote areas, some of them are above or adjacent to buildings (primarily residential) and public roads. Structures at these locations risk severe damage, if not total destruction, if the fill is not stable. People in or on these structures during a landslide may experience injury.

It is important to note that the danger posed by a potential fill instability is limited in areal extent. Those people or structures on or very close to the site of a slope movement can be affected. However, catastrophic impacts over a great distance down-valley, such as occurred during the Buffalo Creek coal waste dam failure (Logan County, West Virginia, 1972) or the 2000 Martin County, Kentucky, coal waste impoundment breakthrough into an underground mine working, should not occur. An unstable valley fill would not be expected to impact distant areas because:

- Fill designs build in a substantial, long-term factor of safety against instability and have specific drainage control measures.

- No large quantity of water should be present in properly designed valley fills to "lubricate" the fill material into a flowing mass that could transport for any great distance. The regulations prohibit ponds on fills or fills impounding water behind them. Even improperly-designed fills should have minimal impounding potential.

- Dam failures may release large volumes of water with little or no warning. Slope movements on fills can also be sudden, but are often characterized by the presence of warning signs of instability (cracks, increased seepage, etc.) and a slow creep.

Although this study is primarily concerned with possible injuries and property damages directly resulting from fill instability, it is noteworthy that there are other potential environmental consequences as well. Exposure of rock fragments and soil along the scarps and ground cracks of a landslide or slip may increase erosion and stream sedimentation. Accelerated erosion can lead to the partial or total filling of sedimentation ponds and/or stream channels beyond the fill

toe, thus reducing the water-retention capacity of the ponds or streams, and possibly accentuating floods during unusually high precipitation events.

B. Methods of valley fill construction

The predominant valley fill construction technique is the durable rock fill method. Because of this, the proper design of stable excess spoil fill structures is dependent upon accurate characterization of rock strength and durability [30 Code of Federal Regulations (CFR) §816.73]. Excess spoil consists of overburden or interburden (soil and rock excavated during the mining operation) not needed to reclaim the disturbed area to the approximate original contour of the land. The excess spoil material forming the rock fill is generally made up of angular blast rock. Before the enactment of the Surface Mining Control and Reclamation Act of 1977 (SMCRA), excess spoil disposal structures were generally constructed with minimal engineering guidance. Often these structures were placed at locations selected merely for the convenience of the mining operation. Since the passage of SMCRA, regulations require increased engineering efforts directed toward design and construction of excess spoil disposal areas to improve safety.

In general, methods of excess spoil placement in valleys that are recognized by the State and Federal regulations include: (a) the 'conventional' lift-type construction method (Figures 1 and 2); (b) the head-of-hollow fill method (Figures 3 and 4); and, (c) the durable rock (gravity segregated) fill method (Figure 5). Each type is described below.

In the lift method, excess spoil is usually deposited in uniform and compacted horizontal lifts or layers (four feet or less in thickness). Prior to placement of the spoil, the foundation (i.e. valley floor and sides where the spoil will be placed) must be prepared and rock underdrains installed to accommodate groundwater seepage and surface-water infiltration. OSM regulations at 30 CFR §816.71(f)(3), require that the rock underdrain be durable (rock that will not slake in

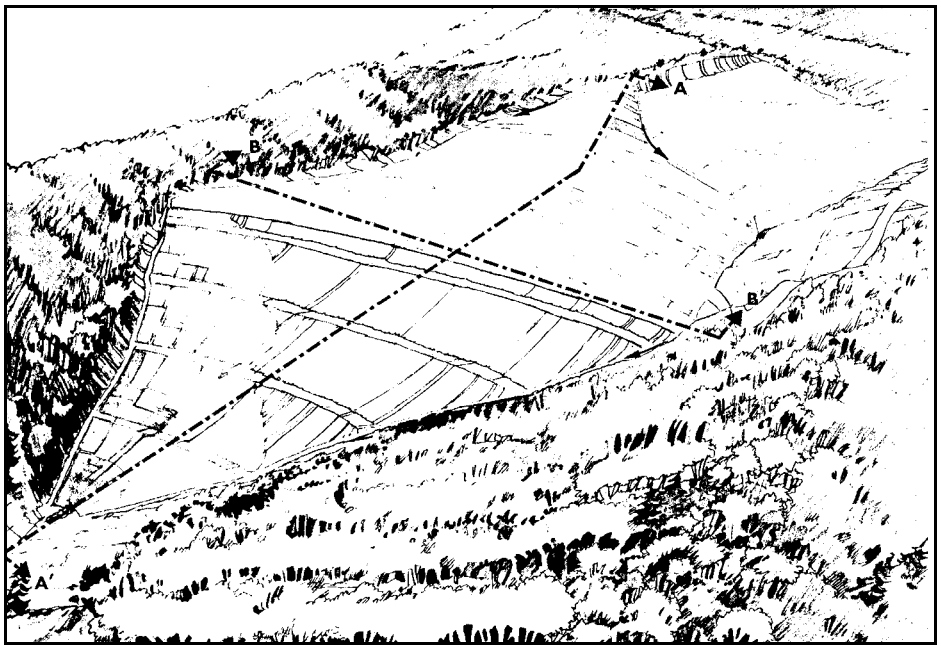

Figure 1: Typical Conventional-Lift Valley Fill (after Loy, Leroy D., Jr. et. al., 1978)

water nor degrade to soil material); non-acid or toxic forming; and free of coal, clay or other non-durable material.

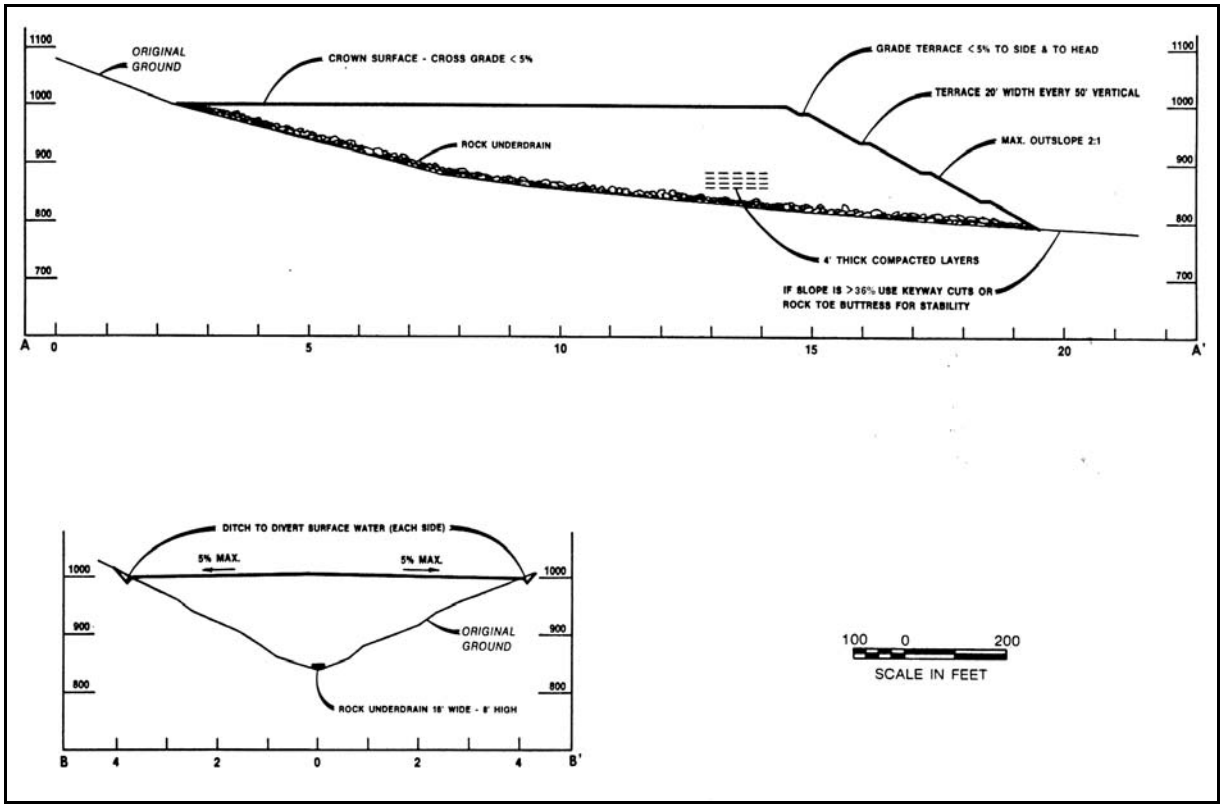

Figure 2: Sections of Conventional-Lift Valley Fill (after Loy, Leroy D., Jr. et. al., 1978)

The Federal regulations [30 CFR §816.72(b)(1)] also provide for another method for excess spoil disposal, which involves the placement of spoil in lifts at the valley head, i.e. at elevations approximating the adjacent ridge lines of the watershed. This "head-of-hollow fill" method originated in West Virginia in the early 1970's, and

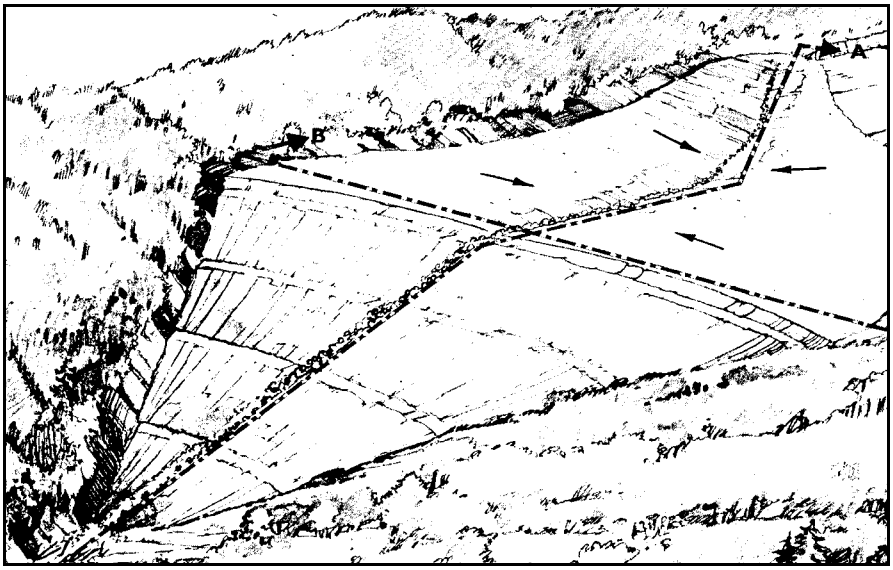

Figure 3: Typical Chimney-Drain Valley Fill (after Loy, Leroy D., Jr. et. al., 1978)

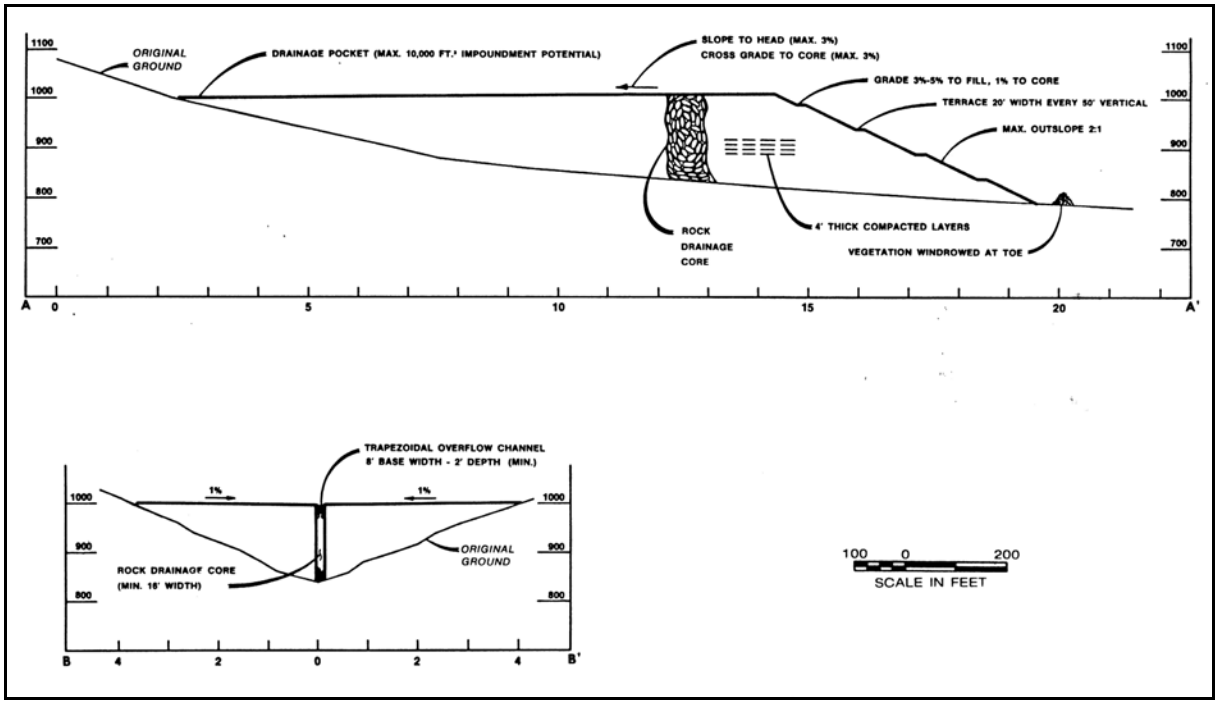

Figure 4: Sections of Chimney-Drain Lift Valley Fill (after Loy, Leroy D., Jr. et. al.., 1978)

combines the lift-placement technique described above and a rock chimney drain in the center, or core, of the fill. The "rock core chimney drain" results from mechanical segregation of larger, durable rock during spreading of spoil material and lift compaction. All surface and subsurface drainage is to be controlled by this rock core to minimize the phreatic surface or water level within the fill mass. This type of fill must crest as close as possible to the ridge line to minimize the surface drainage entering the rock core. The chimney drain can also be used in lift fills lower in the watershed, provided the fill volume does not exceed 250,000 cubic yards (cy) and upstream drainage is diverted around the fill.

The durable rock fill method (30 CFR §816.73) consists of end-dumping spoil into valleys in a single lift or multiple lifts. The fill construction begins at an elevation where the crown or top of the completed fill will occur. Dump trucks haul spoil to the center of the hollow and dump

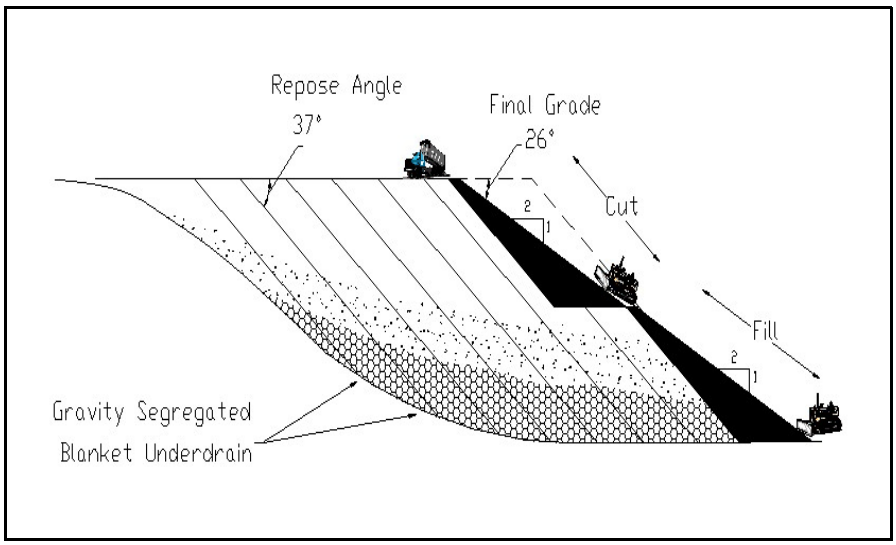

Figure 5: Diagram of Durable-Rock Fill

the material downslope. This continues to take place, allowing a platform of spoil to lengthen down the hollow, and ends when the toe or bottom of the fill approaches its as-designed final location. This study has found the lifts of existing fills to range between 30 to over 400 feet in thickness. At the completion of spoil placement, the face of the fill is graded from its dumped angle of repose (the natural slope of spoil material under its own weight) into a less steep, terraced configuration. The durable rock fill method can only be used if durable rock overburden is present and will comprise at least 80 % (by volume) of the fill[1]. A designed rock drain is not required for this type of fill, since the gravity segregation during dumping forms a highly permeable zone of large-sized durable rock in the lower one-third of the fill.

Among these different methods of valley-fill construction, end-dumping to build a durable rock fill has been, by far, the most commonly applied since 1980. It is less expensive than lift construction; and, with the sampling and testing practices commonly in use, most permits demonstrate excess spoil volumes of at least 80 % durable rock.

C. Valley fill construction and inspection issues

The literature reveals that numerous technical and regulatory issues have arisen concerning the stability of valley fills since before the enactment of SMCRA. These include the following:

- Testing rock durability. There is no consensus among geotechnical experts working for the industry, environmental groups, and government as to what constitutes rock durability testing protocol (i.e. to determine whether or not a material is durable enough to be used in an underdrain, chimney drain, or durable rock fill) that represents the conditions rocks are subject to by excavation and placement during mining, and as long-term residence within a fill. The rigor of various testing techniques proposed varies widely.

- Sampling to determine volume of available durable rock. Accepted standards do not exist for the frequency of rock sampling prior to mining and a methodology for ensuring that 80 % (by volume) durable rock is being placed during durable rock fill construction.

- Plugging of durable rock fill underdrains during regrading. Following the end-dumping of spoil, the mine operator is required to regrade the face of a durable rock fill from the angle of repose to a more stable, 2:1 slope. This regrading is commonly accomplished by grading spoil from upper sections of the fill outslope towards the toe, thus extending the toe downstream. This reworked spoil is finer-grained than the gravity-segregated underdrain material. The placement of the fines downstream of the terminus of the

[1]The 80 percent durable rock standard was first proposed to OSM by Dirk Casagrande in October, 1978, in comments on proposed rule making following the passage of SMCRA (Casagrande, 1978).

blanket underdrain can retard free drainage from within the fill, and consequently increase pore pressures in the spoil, reducing fill stability.

- Surface drainage control on durable rock fills. Durable rock fills in most states are constructed with perimeter or groin drains to control drainage from sources on and above the fill (Figure 6). However, the current approved West Virginia regulations allow for

Figure 6: Durable Rock Fill with perimeter drains.

Figure 7: Durable Rock Fill with center surface drain.

the use of drainage structures located on the top and face of the fill surfaces [38 Code of State Regulations (CSR) § 2-14.14(e)(6)] (Figure 7). These center drains result in increased contact between running water and the fill. Whether or not this significantly influences the stability of valley fills remains in question. Some geotechnical experts recommend allowing all drainage to run through the fill mass (Terra Engineers, Inc., 1993).

- Wing dumping. A common problem in mountaintop mining concerns the dumping of spoil across the valley from the mining bench at points down-valley of the toe of a developing fill. Ideally, all spoil is first transported up the valley and then dumped from the top of the fill in the down-valley direction. In this way, the end-dumped face of an advancing fill progresses uniformly down the valley and parallel to the fill face. This preferred procedure maximizes gravity segregation of competent (unweathered) rock for underdrain development; and minimizes spoil exposure, and consequent breakdown and stream sedimentation. Presently, wing dumping is expressly limited in West Virginia [(State Directive Series 14 (effective October 1992)]. Kentucky has also adopted procedures for restricting wing dumping. OSM will evaluate the Kentucky procedures after two years of implementation.

- Effect of spoil settlement on pore-water pressures and stability. Government and academic studies have documented the expected occurrence of surface settlement on constructed excess spoil fills (Wunsch et. al., 1996) and have evaluated effect of settlement on pore-water pressures and fill stability, using a matric-stress critical state model (Rohlf et. al., 2000). Settlement of spoil fills results from spoil fragments or particles gradually coming closer together (consolidating) under the influence of gravity (i.e. the weight of the spoil). Pore water in the fill is located within spaces between the spoil particles. Below the phreatic surface or ground-water table, the weight of the pore water produces forces that press against the spoil particles. The work suggests that a fill can become either more or less stable with spoil consolidation, depending on a variety of factors related to the depth of the ground-water table in the fill and characteristics of the fill mass itself. Presently, there is very little, if any, empirical data about the internal conditions of completed fills.

- Differences between as-built and as-designed fill configurations and their effects on stability. Regulatory staff say it is a common occurrence that as-built fills often have very different configurations than those approved in the original permit. As-built fills are often much smaller than as-designed. Building a fill that is smaller or larger than planned can impact long-term stability. Smaller fills could end up higher in the watershed where the natural ground could be much steeper. Consequently, fill stability is more difficult to maintain. Larger fills can extend the toe area into zones of thicker, less stable, foundations soils (that may not have been investigated in the permit application).

- Timeliness in fill completion. Sometimes durable rock fills are abandoned for long periods of time following partial construction. Long exposure of spoil to the elements without the benefit of revegetation could accelerate rapid spoil degradation and erosion. This can lead to rapid in-filling of sedimentation ponds (which the permittee is required to repair) and significant stream sedimentation; and can also result in instability in the completed fill from internal weak zones parallel to the face of the completed fill.

- Effectiveness of I & E protocol to ensure sound fill-construction practices. Specific concerns related to this issue have included the frequency of inspections at fill-construction sites, adequate pre-mining site inspections, and protocols for verifying the stability of completed fills.

In addition to evaluating other concerns pertinent to the question of valley-fill stability, this study addresses the issues above with one exception: There are insufficient subsurface data to support consideration of spoil settlement and its effect on fill stability. However, properly-installed underdrains and surface diversions should limit pore-water pressures to a low level within the fill–and, thus, not impact stability adversely.

III. Investigative Approach

SMCRA led to regulations containing permitting, design, and construction requirements intended to implement state-of-the-art engineering standards for excess spoil disposal. The regulations and engineering standards were tailored to ensure excess spoil disposal practices were meeting the SMCRA goals of long-term stability and, hence, public safety and environmental protection.

A retrospective study definitively evaluating the mass stability of large earth and rock structures requires extensive knowledge of the in-situ engineering properties of the fill and foundation materials, as well as the phreatic surfaces within the fills. The limited funds and time available for this study made it impractical to accurately establish the geotechnical condition of the thousands of fills on the Appalachian mine sites. This investigation utilizes information and data from permit files, interviews, and field observations, which serve as indicators of regulatory program effectiveness in assuring long-term stability of fills. The adopted approach focuses on problematic fills. The team is using these sites, along with fills randomly selected, in the evaluation of valley fill performance.

Scope of Investigation

The tasks undertaken to determine the effectiveness of regulatory programs with respect to fill stability include:

- Assemble all available literature on excess spoil disposal practice evaluations and compare the conclusions and recommendations with known current practices.
- Examine the feasibility of documenting that 80% durable rock (by unit volume) is attained during construction and in final fill configurations.
- Evaluate the effectiveness of current sampling and testing protocols for establishing representative rock durability of excess spoil.
- Establish the effectiveness of current methods utilized in I & E of excess spoil disposal.
- Determine the population of documented fill instability since the permanent regulatory program, and the causative factor(s).
- Review strength parameters, phreatic surfaces, and analysis methods used in stability analyses in the approved permit.
- Evaluate state surface mining information systems (SMIS) data and compile violation data relative to excess spoil disposal.

- Review documentation, certification of critical construction phases, and quarterly certification.

- Establish if foundation conditions for fill placement are as defined in the approved permit.

- Aerial reconnaissance of a sampling of completed and fills under construction in WV, KY, and VA to visually assess stability, drainage control, and related features.

- On-the-ground visits to selected sites identified in 10, above to further assess stability, drainage control, and related features.

- Compare as-built fill configurations with as-designed.

- Assess if proper surface and subsurface drainage controls are installed.

A full description of each of these tasks is provided in the workplan as Appendix A. The workplan also identifies the principal participants in the study (hereafter identified as "the team") and principal State and Federal contacts. Task 1 entailed a document and literature search. Tasks 2 through 5 are interviews with Federal geotechnical experts and state regulatory agency inspection staff. Tasks 6 through 13 entail permit and field reviews of selected fill samples. The approximate location of the fill samples are shown in Figure 8. Data and photographs for each fill are presented in Appendix B. The selection and utilization of samples in each state are summarized in the table below:

State	Total # of fills	Durable rock fills	Reclaimed fills	Aerial inspection	Ground inspection	Spoil Volume (mcy)	Construct-ion dates (yr)
WV	49	34	35	49	19	0.2-201.1	78-98
KY	48	46	6	0	48	0.2-90.9	87-00
VA	25	24	10	25	13	0.3-16.8	90-99
TN	6	4	0	0	1	0.2-7.5	86-98
Total	128	108	51	74	81	0.2-201.1	78-00

West Virginia: The West Virginia sample list was derived from a list of problem fills identified by the West Virginia Department of Environmental Protection (WVDEP) in a 1994 inventory study of inspectable fills (i.e., fills in active permits). This list was augmented by OSM personnel from the Charleston Field Office from personal experience with valley fill investigations. The study database includes 49 West Virginia fills. All of the fills were observed

from the helicopter. From the document review and helicopter surveillance, 19 sites were selected for ground-level inspection. These sites include two adjacent unstable fills initially not included in the sample list, one of which was detected from the helicopter.

Among the West Virginia samples, fill construction began between June 1978 and September 1998. Thirty five of these had been reclaimed as of 1999. The recorded size of the fills range from 0.20 to 201.10 mcy. Fill lengths range from 490 to 9,900 ft. Thirty four were proposed as durable rock fills in the permit, the rest conventional-lift, chimney-drain, or (in the case of two

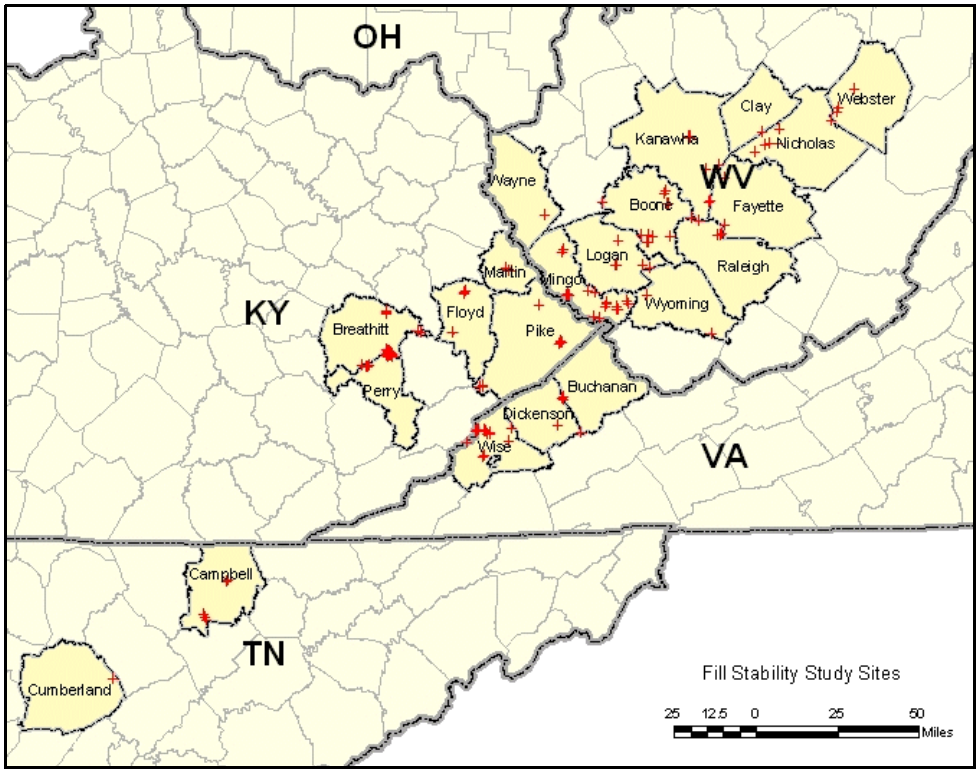

Figure 8: Locations of valley fill samples.

fills) unknown types of construction. Twenty one of the sampled durable rock fills use center surface drains, which are unique to the state (the durable rock fills in the other states use perimeter surface drains).

Kentucky: The elements of the study in Kentucky were completed as part of a durable rock fill oversight study by the Kentucky Department of Surface Mining Reclamation and Enforcement (KYDSMRE) and OSM. Since the state agency conducts routine overflight and video-documenting of permits, aerial reconnaissance under this study was unnecessary. Also, the oversight workplan requirements of the durable rock-fill study included ground-level visits of all sites.

For the most part, the samples were randomly selected--with a few known problem fills added. The study database includes 48 Kentucky valley fills. Construction start dates range from March 1987 to September 2000. The recorded fill sizes range from 0.20 to 90.90 mcy; and fill lengths vary from 300 to 8,800 ft. All but two samples are durable rock fills. The two exceptions were conventional-lift fills. All include perimeter surface drains. At the time of the site visits, only six of the sample fills had been reclaimed. For this broader study, the list was supplemented with four more completed fills for ground-level inspections and permit reviews. OSM had identified stability problems on these additional fills during oversight of the Kentucky program between 1986 and 1990. The final bonds on the permits of all four of the fills had been released before the inception of this study.

Virginia: The team developed a 25-fill sample list from the Virginia Department of Mine Land Reclamation (VADMLR) fill-inventory database. Thirteen fills were visited at ground level. Construction start date ranges from August 1990, to December 1999. The fill volumes range from 0.30 to 16.80 mcy; and the lengths vary from 390 to 4,300 ft. All but one are durable rock fills, the exception being of the conventional-lift type. All of the fills include perimeter surface drains. Ten were reclaimed at the time of the helicopter survey.

Tennessee: The Tennessee sample list includes six fills that are still under an active permit. The construction start dates range from January 1986 to June 1998. Recorded volumes range from 0.20 to 7.50 mcy. Fill lengths varied from 350 to 3,300 ft. The team conducted a ground-level visit of the largest fill. Four of the samples are durable rock fills and two are conventional-lift fills. All of them include perimeter surface drains.

IV. Findings

A. Durable rock fills

1. Background

The successful long-term performance of excess spoil structures is directly related to the strength and durability of the rock in the fill mass and rock drains. Rock materials removed from their in-situ condition during the surface mining of coal exhibit changes in physical integrity. Such changes are caused by physical and chemical mechanisms induced by variations in moisture and stress regimes. The rock in fills has been subjected to blasting, handling, compaction, and weathering–and continues to be subjected to overburden pressure and weathering after fill emplacement. Generally speaking, a sedimentary rock that can withstand these processes without rapidly breaking down into smaller-sized, soil-like, weaker material can be classified as a durable rock.

Durable rock is defined in Federal regulations at 30 CFR §816.73(b) as rock which does not slake in water and will not degrade to soil material. The regulatory intent is to selectively obtain rock that can withstand surface mining conditions, and natural forces affecting the fill mass after

final placement, without significant degradation. The intent is that, over the long term, the durable rock fill behaves as a mass of broken rock and not as soil. A rock mass is inherently more stable than soil with similar volume, geometry, and foundation conditions because rock has much greater load-carrying capacity. Rock has more resistance to both consolidation and displacement along planes of weakness. Durable rock fill or underdrain material has this greater strength because of strong friction between the particles (quantified as the angle of internal friction) and greater resistance to forces promoting shear (shear stress). A rock mass is also free-draining because of its high permeability. Weak, nondurable rock will degrade into finer soil-like particles as a result of the weight of the material above it (overburden pressure) and moisture absorption. The drainage system provided by the void space between the rocks may become clogged. The clogging may cause excess pore water pressures to develop that will cause a decrease in the shear resistance or shear strength of the fill material. A decrease in shear strength can cause instability in the excess spoil structure. Another concern is that the uneven settlement of the fill (differential settlement) resulting from the breakdown and excessive consolidation of non-durable rock can disrupt surface drainage structures, including diversion channels on terraces. Failure of drainage diversions leads to increased water infiltration and promotes fill mass instability. Therefore, the correct assessment of the strength and durability of the rock is a critical design factor.

The Kentucky, Virginia, and West Virginia definitions of durable rock are similar to the Federal definition. The Kentucky and West Virginia definitions are, in fact, more specific. The Kentucky regulations require a Slake Durability Index (SDI) of at least 90 %, or similar result using another test that's equivalent to the SDI to the KYDSMRE's satisfaction [405 Kentucky Administrative Regulations 16:130 § 4 (1)(a)2]. The West Virginia regulations reject soil-like material in the durable rock definition: rock capable of degrading to a material, of which at least 50 % is finer than 0.074 millimeter, has plasticity, and is classified as ML, CL, OL, MH, CH, or OH (under ASTM D-2487), is considered to be soil [38 CSR § 2-14.14(g)(1)(B)].

In all states, the industry and state agencies have relied upon the SDI as the primary method to evaluate rock durability. However, early OSM special studies and inspection reports indicated that weak, non-durable rock was being used in durable rock applications. Consequently, the agency undertook a major study that developed an alternative testing protocol and classification system (called the "strength-durability classification") and examined the results of applying it and the SDI test to116 overburden samples collected from 61 mine sites in the same four states covered by this study (Welsh et. al. 1992). The study concluded that the strength-durability classification was significantly more effective than the SDI in discriminating weak, non-durable rock[2]. OSM emphasized that the recommended protocol was not only effective, but also simple and inexpensive.

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[2]Subsequent, independent analysis of the data used in the 1992 study confirms this conclusion, with the notable exception of rock samples obtained from West Virginia, in which the SDI test was more discriminatory than the OSM classification (Rohlf, 2001).

The proposed strength-durability classification utilizes a phased approach. The initial phase consists of soaking rock samples in water for 24 hours to identify very low-durability rock by its short-term slaking behavior. Samples passing this phase are then subjected to a second phase of free-swell and point-load tests. In the free-swell test, a rock sample is immersed in water and the degree of its expansion or swelling is measured over a 12-hour period. Rocks tend to weaken with swelling. Thus, rocks that tend to swell less have a greater chance of being classified as durable. The point-load test is a relatively inexpensive procedure for measuring a rock's shear resistence. The sample is placed between two metal cones. The cones are then pressed into the specimen with increasing force until the sample fails. The point-load strength and swell-test data are plotted on a graph, and the points are compared to "zones" on the same graph representing the acceptable value ranges for durable rock classification.

Since this OSM study was published, the strength-durability system has received both support and criticism. There seems to be a broad consensus among the state and Federal regulatory agencies that the SDI does not adequately discriminate non-durable rock for surface coal mining and excess spoil fill construction. Some comments against the strength-durability classification protocol have asserted that its requirements for durability are far too stringent (Casagrande, 1991). For example, the ASTM procedure for the 24-hour soak test includes oven drying the samples before and after soaking; but temperatures as high as 105 degrees Centigrade do not occur in a valley fill. Also, critics contend that the free swell test is unnecessary. The tendency of rocks that do not readily slake to swell in an unconfined state does not indicate a significant loss of strength; and the swelling should be resisted to some degree by the confined conditions (from contact with other rock particles) within the spoil fill. Finally, the minimum point-load strengths required for rock to be classified as durable are claimed to be unreasonably high, considering the range of fill thicknesses and, therefore, the limited compressive force a rock endures. A counter argument supportive of the strength-durability is that the purpose of oven drying is not to replicate the temperature regime in a fill. Its intent is to simulate drying. Rocks do, in fact, experience significant drying and air slaking from excavation to placement during the mining process (Farrar, 1999). Further, the stress concentrations from point-to-point contacts between the rock particles in the finished fill can result in forces much stronger than those associated with simple vertical compression (Farrar, 1999). It is noted herein that a rock durability test must conservatively account for a valley fill's <u>long-term</u> stability. The stability of valley fills are not monitored or maintained by the mining industry or government following final bond release. Steps in a testing procedure that may subject a sample to extreme environments over a very short time period <u>may</u> help to account for the effect of milder environments over an indefinite period of time. They may also account for short-term events not easily captured in the lab, such as the effect of blasting and severe impact and abrasion among boulder-size particles during the spoil-handling process.

A review of technical literature shows progress in rock durability research. However, many of the classification systems discussed relate to rocks unlike those encountered in coal mining, e.g. rocks of the igneous and metamorphic variety which are heavily influenced by chemical weathering of constituent minerals. Hudec (1997) points out that shales have the most rapid weathering rates of all rock types, but also that their weathering is almost entirely physical in

nature. Weathering of shales occurs through water-pressure build up in small pores during wetting and drying, or through ice expansion and contraction during the freeze-thaw process. Dick and Shakoor (1997) compared various geologic characteristics of mudrocks (claystones, shales, and mudstones) to their durability as measured by the SDI. They proposed that some of these geologic properties (e.g. percent water adsorption for shales and micro-fracture density for mudstones) may be useful durability indicators. The team did not find any other work that provides a relevant alternative to either the SDI or OSM classification.

2. Interviews

The team interviewed a number of WVDEP staff members from the Nitro, Logan, Oak Hill and Phillippi regional offices. In general, the durability observations of inspectors and their supervisors partly depend on which part of the state they are working in. Inspectors working in the southern part of the state are relatively confident that the fills have about 80% durable rock thanks in part to the presence of massive sandstones in the overburden and interburden. This confidence does not seem to be mirrored among those working further north. This may be a reflection of a lesser occurrence of sandstone in the geologic section in that part of the state. A related contrast in topography was observed from the helicopter between these two regions: The landscape to the south is more rugged with weathering-and-erosion-resistant sandstones capping the ridges. The mountains of the north are lower and more rounded, suggesting the predominant influence of weaker rock types. Still, all of the inspectors seem to feel that the durable rock fills in their areas are stable based on their record to date (i.e. the lack of slope-movement events). One comment advocated a standard for particle-size distribution in durable rock fills under construction in order to ensure the formation of an adequate underdrain. There is a broad consensus among the WVDEP inspectors that the SDI is not an adequate test for durability. This latter opinion seems to be shared by the inspection staff of the KYDSMRE based on draft findings of their joint oversight study with OSM.

Discussions with VADMLR staff indicate that durable rock fills in the state are stable due to the availability of hard sandstone in the overburden and interburden and the absence of any record or recollection of fill instability. The agency has not made a call on the reliability of SDI as a test for rock durability for excess spoil construction. Use of the test among permit applicants is accepted because of its broad use as a standard for a wide variety of engineering applications.

The team contacted with members of the U.S. Bureau of Reclamation, Corps of Engineers, Federal Highway Administration, Mine Safety and Health Administration, Bureau of Land Management, and Department of Energy. The first four agencies deal with structures in which the durability of construction material is important. However, large earthen structures constructed or inspected by these organizations tend to be composed of selected off-site materials and to be constructed by other than the end-dumping method. An interviewee with the Bureau of Reclamation familiar with the SDI would like to see the current ASTM protocol supplemented with some sort of measure of specimen break-down following the regular testing procedure and suggested that this may make the technique more applicable to the durable rock fills.

3. Data analysis

The issues described above relating to rock durability testing and placement of 80 percent durable rock in a durable rock fill have largely resulted from subjective observations by state and federal inspectors, engineers, and geologists of fills under construction. The investigators of this study recorded their own observations using the sample valley fills. During initial site visits, the percent durable rock estimates of several fills were compared to assure consistency. The remaining valley fills in the sample were then individually evaluated. The use of this visual technique for purposes of this study should not be construed as an endorsement by OSM for use in regulatory programs.

Figure 9: Durable Rock Fill under construction.

Figure 10: Shale breakdown in fill under construction.

Using on-site visual observations and photographs of the fill samples, the team made subjective judgements on whether sampled durable rock fills were being constructed with at least 80 percent durable rock (Figures 9-12); and whether a discernable underdrain was being formed via

Figure 11: Degraded shale boulder in a completed valley fill.

Figure 12: Non-durable sandstone in a durable rock fill under construction.

gravity segregation (Figures 13-14). The photographs used were primarily those taken from the helicopter, but also included some color certification photographs. Possible responses to the two questions (when visual data was available) included *yes*, *no*, or *no response* (i.e. when there was too much uncertainty). The criteria employed for the first question included the perceived particle-size distribution on the advancing face of the fill, the amount of sandstone versus shale in the dumped spoil,

Figure 13: Note gravity segregated underdrain.

Figure 14: Lack of gravity segregation in a durable rock fill under construction.

and (for ground-level site visits) the degree of particle breakdown occurring in the exposed portion of the spoil. Subjective judgements were made for 44 durable rock fills. Of these, 28 appeared to have less than 80 percent durable rock and 5 were considered to lack discernable gravity-fed underdrains. The percent durable rock estimates for those under 80 percent range from 20 to 70 percent.

West Virginia's definition of soil for durable rock classification purposes highlights how rock-overburden and interburden lithology can influence the effectiveness of a durable rock fill's underdrain system. Even if gravel-to-boulder size particles break down into their unit grain sizes, the resulting material would possibly still be permeable enough to act as an effective underdrain. Some of the sandstones in the region may fit this condition. Shale fragments, on the other hand, result in relatively impermeable material when decomposed. In general, sandstones also have the added advantage of being harder and more resistant to impact, abrasion, and weathering; and thus more likely to preserve large and porous particle-size distributions in the fill underdrain. To document the variation in lithology among the sample mine sites, the team measured the % sandstone from drill logs in the permit files down to the lowest coal seam mined. In all, 117 recordings were made. It is important to note that the data do not accurately represent site-specific volumes of sandstone available for excess spoil fill construction. For instance, the volume of a 10-foot thick sandstone bed forming a ridge crest may be markedly less

than that of 10 feet of sandstone immediately overlying the mined coal seam. This is a result of the geometric effects of topography. Nevertheless, the data should be a fair indicator of general variability with respect to the rock type's occurrence. The measured column-weighted amount of sandstone ranged from 6 to 97 percent. The percentages most commonly fall in the 50 to 70 percent interval and are relatively high in West Virginia and Kentucky. Based on this information, it may be both technically and economically feasible to incorporate volume-weighted rock/lithology distribution as a partial indicator for the designation of durable rock fills[3]. Justification for this approach, especially for sites where available sandstone may be weak and/or non-durable, may require research that identifies the permeability ranges of regional sandstone-derived soils and compares them to the subsurface drainage discharges of typical valley fills.

An apparent contradiction within the durable rock classification issue occurs where the same layers of rock (rock strata) in a permit area are designated as both durable and suitable for topsoil substitution. A rock is designated as suitable for topsoil substitution (in the absence of sufficient quantities of natural topsoil) if it can sustain revegetation on spoil fills. To support freshly planted vegetation on a reclaimed surface, the rock must rapidly decompose into soil-like material. This requirement appears to directly contradict what is expected of durable rock (i.e. that it will not slake into a soil-like material). The occurrences of this phenomenon among the fill samples of the study was not systematically recorded and, thus could not be queried from the database; but the permit review has identified several samples that fit this category. This apparent dichotomy of properties is partly explainable by the nature of the lab tests performed: tests for topsoil substitution directly measure the organic chemistry of the samples, whereas those for rock durability test the specimen's mechanical behavior. However, the problem may also be symptomatic of the inadequacy of the SDI test for durability. It is noted that the spoil at the surface of a valley fill is used as a soil-substitute as a matter of course, due primarily to the lack of in-situ natural soil available. Even in a durable rock fill, however, this may be acceptable if the end-dumping has effectively segregated the durable material towards the bottom of the fill.

Another observation made (but not recorded from the permit review) concerns the representative sampling of the overburden and interburden for the purpose of determining % durable rock by volume. The frequency of sampling relative to the thickness of the rock section above the lowest mined coalbed (or sampling density) varies significantly. Whether or not a realistic rock durability testing protocol is used, the results are not meaningful if the tests are applied to only a few specimens. For this reason, it is recommended that regulatory authorities develop standards or guidelines pertaining to the density of sampling for rock durability testing.

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[3]The concept of applying percent sandstone to valley fill design was previously proposed by Robins and Hutchins (1979): Fills with greater than 65 percent sandstone would not require compacted lifts; and fills in steep terrain with more than 90 percent sandstone could use gravity segregated underdrains. This present report, however, does not recommend specific, numeric percentages; nor does it recommend that percent sandstone necessarily be the sole basis for fill-design considerations.

4. Discussion

The subjectivity some of the work described herein and the general lack of consensus on what test(s) are appropriate for determining rock durability in valley fills, underscores the absence of empirical data on subsurface conditions in valley fills. Resolution of this issue may not be possible without critical information about (1) what is the typical geochemical environment or the range of environments inside a fill mass and (2) how do different materials (affected by mining) hold up under these conditions over time. In addition to or in lieu of an agreed-upon testing protocol for durability, the team recommends consideration of in-situ sandstone % as a contributing (but not stand-alone) parameter for the designation of durable rock fills. It is noted that any requirements based on this parameter would be relatively easy to enforce. Further, the team suggests that estimating or even quantifying particle-size distributions at different elevations on an advancing fill face may be an effective, quantitative way to evaluate gravity-fed underdrain formation. The application of scaled, electronic photography in conjunction with a computer-enhanced counting-and-measuring procedure might turn out to be a useful quality-control tool. For purposes of enforcement, where the effectiveness of blanket-drain formation is suspect, a representative number of measurements by the regulatory authority would be necessary.

As an alternative approach to resolving these difficult issues concerning durable rock fills, a standard construction method could be adopted that combines end-dumping following placement of carefully constructed underdrains. This would limit the need for strength and/or durability testing (with the possible exception of the underdrain material) and for developing a representative test-sample collection procedure. The underdrains would be constructed to effectively capture all sources of seepage and to extend an adequate distance beyond the final toe position of the fill. Stability analyses would assume soil-like properties (with minimum or no compaction) in the spoil above the underdrain. Compacted lift requirements would only apply to sites where the mine operator or regulatory authority judged the spoil properties to be such that long-term stability would not be obtainable otherwise. The study team believes that this may be the most cost-effective approach available.

B. Effectiveness of I & E programs

The WVDEP inspection report form includes two questions per excess spoil fill construction. These are paraphrased as follows: (1) Is the fill being constructed in accordance with the specifications of the permit; and (2) have all the appropriate construction certifications been provided? The KYDSMRE inspection form includes “disposal of excess spoil” as part of a compliance/non-compliance check list. The VADMLR form is electronic and includes two spaces for identifying compliance and violations of unspecified performance standards. The Federal form includes a compliance/non-compliance check list under “excess spoil disposal” for “placement,” “drainage control,” “surface stabilization,” and “inspections and certifications.” All of these forms are general and must assume that the inspectors using them are fully

knowledgeable of the regulatory standards and permit specifications applicable to the construction of an excess spoil fill.

Some insight into the state staffs' experience with the I & E programs were obtained from the interviews with WVDEP inspection personnel and a review of the joint KYDSMRE-OSM durable rock-fill study. WVDEP interviewees did not have any significant issues with their I & E program vis a vis assurance of fill stability, or with fill stability in general. Specific comments include the following:

- The program has significantly improved over last six or seven years, thanks to increased resources and more and better-trained people;

- Three inspections of a permit (one full, two partial) are required per quarter. One inspection per week often occurs. One interviewee indicated that this may be enough, i.e. if anything is wrong, it will be wrong during an inspection. Another cautioned, however, that some mines are in operation for 24 hours (i.e. thousands of cy's can be placed between inspections–even at this inspection frequency);

- Sampling for durability testing and other parameters should be more thorough. One sample per stratigraphic unit (such as a 50 ft. thick sandstone bed) is not sufficient.

- People conducting the lab testing, collecting samples for the lab testing, or directing the handling of spoil in the mining operations should be better trained.

The joint KYDSMRE-OSM study has produced draft recommendations reflective of the State staff's perspective on its I & E program. Some of the recommendations are related to: increasing the frequency of inspections during critical construction phases; requiring more detailed information in the critical-phase certifications; requiring a more thorough analysis of coal seams and coal mines in permit-application foundation investigations; and requiring new spoil-balance calculations when a permittee changes the method of mine operation or does not generate the amount of excess spoil originally estimated.

C. Valley fill design

1. Foundation investigations

Review of the foundation investigations in the permit applications of the fill samples resulted in three categories: (1) reports that reference test pit(s) and/or test hole(s); (2) reports limited to narrative; and (3) no reports of foundation investigation found in the permit file. The permit data analysis indicates that there were 25 out of 129 fills for which the team was unable to find even a narrative of foundation conditions. Fill foundation reports for 55 of the fill samples appeared to be limited to narratives that generally (1) state that a foundation investigation was performed, (2) identify the underlying bedrock, (3) report the soil depth to be shallow, and (4) claim that springs

or seeps or signs of instability were not found. Test pits and/or test holes drilled in the foundation areas were found in the permits for 48 fills. Again, where test pits or holes were included in the permits, soil depths were generally reported as shallow.

The study also included a limited in-field and photograph assessment on the fill foundation conditions based on: (1) the occurrence of springs or seeps on the fill; (2) fill instability attributable to uncontrolled subsurface drainage or thick soil foundations; and (3) mass movements in the hollow surrounding the valley fill. Clear cases of seeps or springs were identified on 11 fills. Some of these seeps occurred near the fill toe (Figure 15). These may be reflective a generally high phreatic surface in the fill, if not a natural ground-water discharge point from underlying bedrock near the toe. Other seepages occurred higher in the fill outslope; and can result from local ground-water discharges from the underlying strata and/or highly-permeable zones in the fill material. Some additional fills with possible seeps or springs, as observed the helicopter photographs, were noted but not digitized. Seventeen of 20 cases of fill instability in the database are connected to inadequate underdrains or thick foundation soils. Signs of instability in natural slopes adjacent to the fill were noted for nine of the samples (Figure 16).

Figure 15: Seepage at toe of valley fill.

Figure 16: Landslide into side of valley fill.

An important foundation issue identified during this investigation pertains to the presence of abandoned underground or auger mines in the location of the valley fill, where the rock strata dip or are inclined towards the fill. Abandoned deep mines may result in ground-water discharge exceeding the capacity of the fill's drainage system--if they are not thoroughly investigated and accounted for in the fill design. Alternative solutions to presence of abandoned mine effluent include: (1) over design of the subsurface drainage system (to account for worst-case flow discharges); (2) sealing the mine effluent areas; and (3) relocating the proposed fill to another hollow.

2. Design parameters

Background: The unit weight (or density), angle of internal friction, and cohesion of a material comprising a valley fill are the engineering properties that affect the fill's stability. In the slope stability analysis of a proposed fill, the engineering factors of the material are assigned values assumed to be representative of the spoil properties. The analysis is applied to the steepest profile (side-view projection) of the fill. The procedure then calculates the safety factor (SF) for several two-dimensional curves which represent possible three-dimensional slip surfaces in the fill. In one type of analysis commonly used in permit applications, each curve is an arc of a circle defined by a center and radius. A grid pattern of circle centers and a range of radii delineate the potential slip surfaces in the fill (Figure 17). The curve with the lowest calculated SF is the end result of the analysis. An SF above 1.0 is the margin between instability and stability. That is, the higher the SF is above 1.0, the more stable the fill structure.

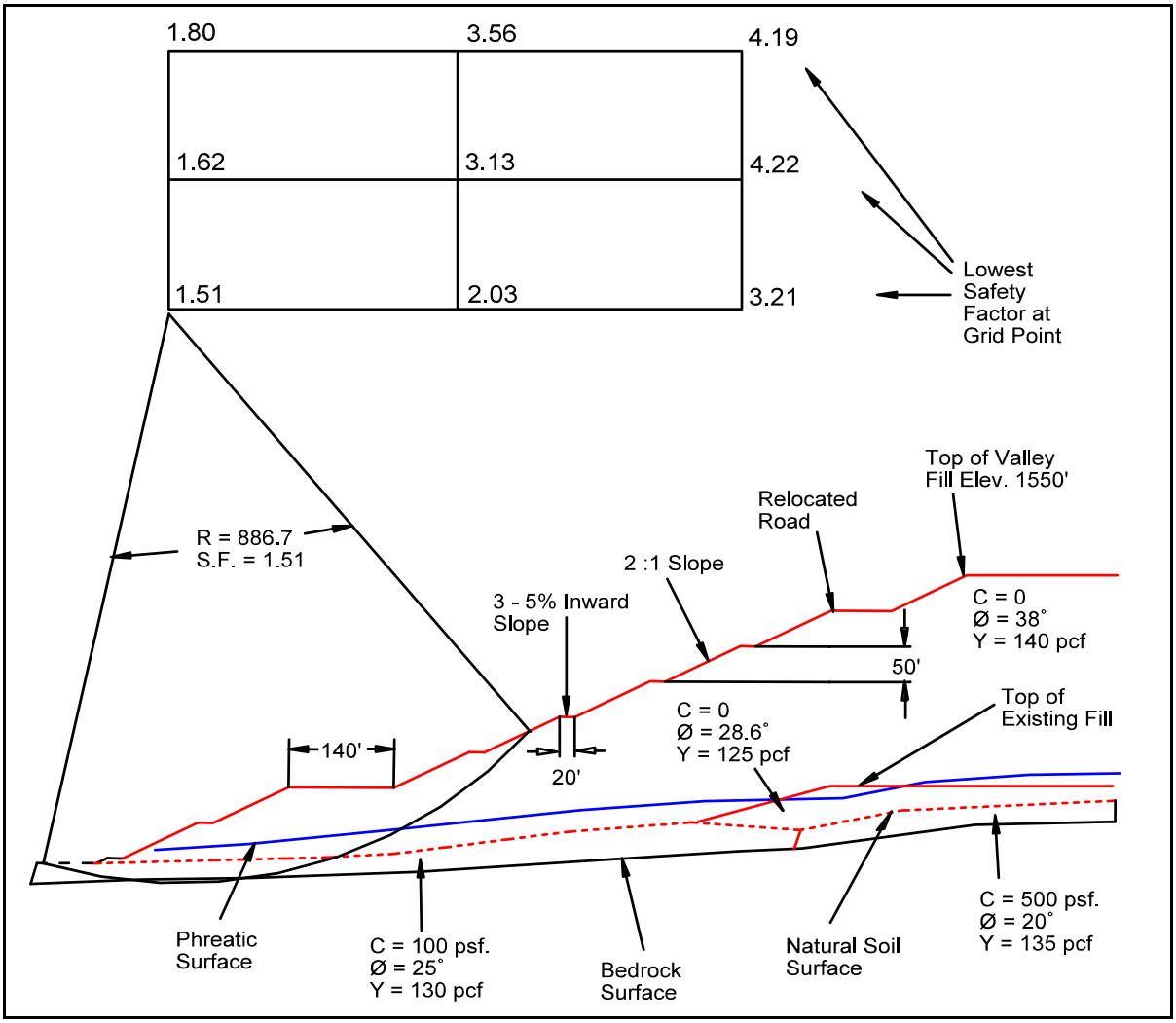

Figure 17: Example of a slope-stability-analysis profile.

The SF is a ratio between forces that resist slope movement (resisting forces) and those that can contribute to slope movement (driving forces). The regulations require the ratio of resisting to driving forces to be at least 1.5 for designed valley fills under static conditions (i.e., conditions which do not include the effects of vibrations from earthquakes, etc.). The total weight of the spoil (i.e. the spoil volume multiplied by the material's unit weight) above a potential slip surface contributes to both the resisting and driving forces. How much it contributes to each of them depends on the steepness of the underlying foundation slope. The material's friction angle and cohesion affect the resisting forces only. The higher the friction angle and cohesion, the stronger the resisting force and more stable the fill. On the other hand, the presence of pore water in the fill normally reduces the effect of the resisting forces. The higher the pore-pressure ratio, or the higher the phreatic surface in the valley fill profile, the lower the resisting forces and less stable the fill.

The regulations also require an SF of 1.1 for designed durable rock fills under dynamic conditions (conditions which include the influence of earthquakes and other sources of vibration). In general the dynamic SF is calculated the same way as the static SF, except that the driving forces are augmented with a horizontal load equal to a proportion, or fraction, of the total weight of the fill. The proportion is determined by a seismic coefficient which, in turn, is related to the seismic zone occupied by the site in question (Algermissen, 1969). The general area of interest in this study occurs within zone 1, characterized by Modified Mercalli earthquake intensities of V and VI and "minor damage."[4]

The team obtained typical engineering values for mine spoil and similar materials from the following sources: (1) text book engineering tables; (2) direct-shear and triaxial tests on several samples of surface-mine spoil (Superfesky et. al., 1978); (3) bench-scale tests for shear strength on durable and non-durable surface-mine spoil (Hribrar et. al., 1986); and (4) testing of samples obtained from 12 non-durable rock mine spoil embankments in Ohio (Shakoor et. al., 1989). The references indicate a unit-weight range of 100 to 125 pounds per cubic foot (pcf). Friction angle varies from 25 to 40 degrees for spoil (or like material); but, with respect to durable rock fills, has a narrower range of 30 to 40 degrees. Cohesion ranges from 0 to 400 pounds per square foot (psf) for spoil, but is assumed 0 psf for embankments similar to durable rock fills.

Permit data collection: Data recorded from stability analyses in the permit applications and some final as-built engineering certifications include: the analysis software employed; SF; the engineering properties of the spoil and foundation material (unit weight, angle of internal friction, and cohesion); and the phreatic surface. As for the phreatic surface, the team has distinguished the data into three categories: (1) pore pressure ratio given; (2) no pore pressure ratio given, but phreatic surface shown on the cross-section of the proposed fill; and (3) no phreatic-surface data provided. For all of the above parameters, the team recorded data for: the original permit applications; the latest permit-application revision that was approved prior to the

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[4]The discussion in this section relating to SF analysis is focused on the static case. However, since the factors in the static and dynamic analyses are almost identical, pertinent observations and conclusions in this report should be equally applicable to the dynamic case.

completion of the fill; and the fill's as-built condition. The purpose of this data collection was to: (1) observe the ranges of engineering values used in the stability analyses; and (2) compare these ranges to the accepted value ranges for spoil and similar materials to discern whether the numbers used in the fill stability analyses are consistently reasonable.

Permit data analysis: The primary slope-stability software employed by permit applicants is the Rotational Equilibrium Analysis of Multi-Layered Embankments (REAME). SB-Slope and STABLE have been used infrequently. A few of the original designs include hand calculations. All of these methods assume cylindrical, rotational landslides or land slips; and have been developed for slopes composed of unconsolidated material. In some cases, the Sliding Wedge Analysis of Side-Hill Embankments (SWASE) was also been used in conjunction with REAME. SWASE had been developed for blocky or wedge-type slope movements, such as in densely jointed, in-place, massive units of rock. Predominantly, if not in all cases, the application of SWASE results in higher minimum SF's than those of the rotational-movement analyses. No valley fill stability analyses were found in six original permit applications. All of the existing analyses resulted in minimum SF's of at least 1.5.

The spoil-related engineering data analyzed were collected from 119 stability analyses in original permit applications, 48 analyses in permit modifications, and 21 post-construction analyses in final certifications. The ranges of engineering values approximate those in the literature; and are roughly consistent among the original permits, permit modifications, and final certifications. Unit weight or density values for spoil vary from 95 to 165 pcf and concentrate between 120 and 130 pcf (Figure 18). Friction angles range from 21 to 50 degrees and are focused between 20 and 40 degrees (Figure 19).

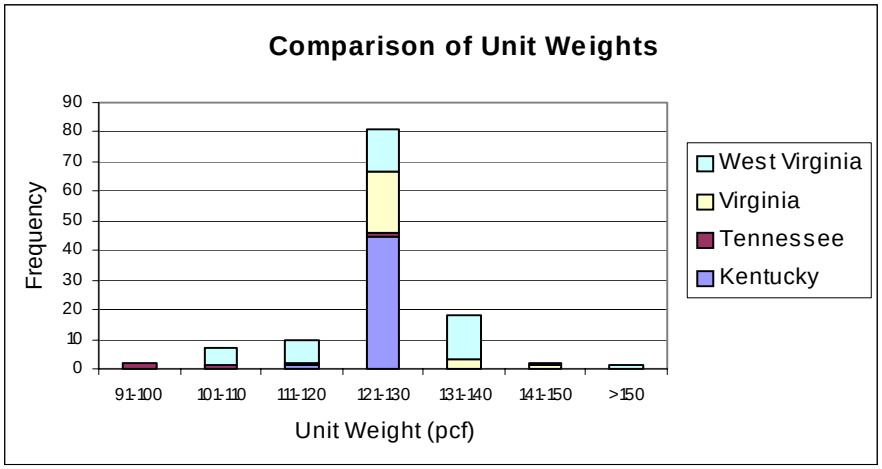

Figure 18: Frequency distribution of unit weight values.

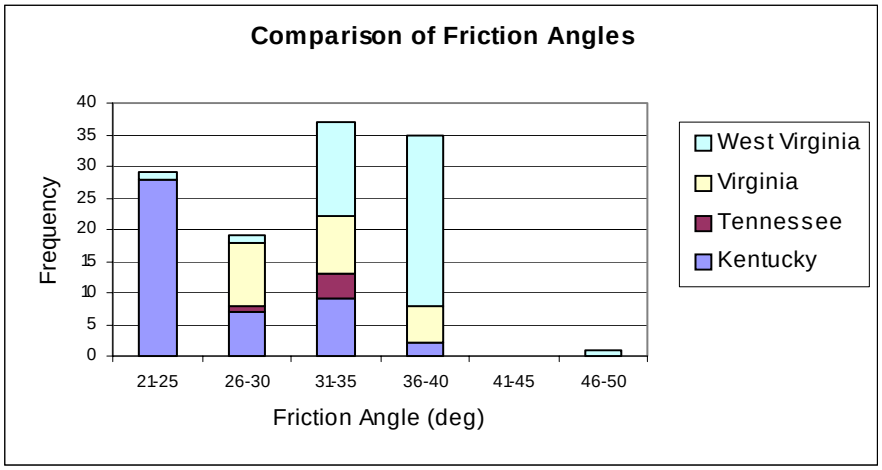

Figure 19: Frequency distribution of friction angle values.

However, there appears to be a bimodal distribution of these values. This is clear when one examines the Kentucky data for original permits and permit modifications. Friction angles cluster at 24 degrees, and between 30 and 35 degrees. The West Virginia data mostly falls within 33 to 39 degrees. Virginia and Tennessee have friction angles equal to or greater than 30 degrees. For spoil cohesion, Kentucy, Virginia, and Tennessee values are concentrated between 160 and 200 psf (Figure 20). Most of the West Virginia fills have zero cohesion, with a few occurrences of 100 psf.

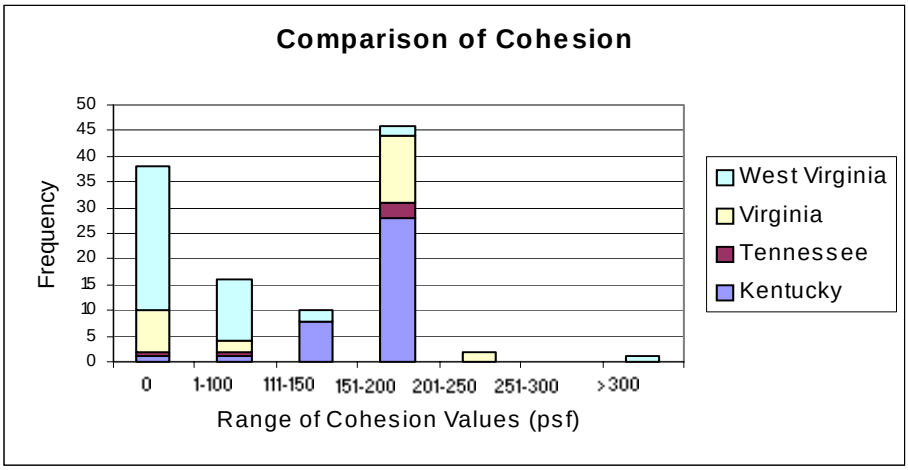

Figure 20: Frequency distribution of cohesion values.

Many stability analyses also include engineering values for the fill foundation. These values were not systematically recorded in the initial period of the investigation. The database includes 51, 13, and 9 sets of foundation values from original permits, permit modifications, and final certifications, respectively. Unit weight ranges between 90 and 130 pcf. Friction angle values vary from 22 to 45 degrees; 43 out of 51 original-permit values equal or exceed 30 degrees. Cohesion ranges from 0 to 2500 psf, but concentrates between 0 and 200 psf. Most of these numbers seem to reflect rock-like properties. This should be justified where soil cover is thin and discontinuous following foundation preparation.

The data analysis found 67 out of 121 stability analyses in the study database that use pore-water pressure ratios of 0.05. Nine analyses employ a ratio of 0.10. Twenty-six did not appear to present this ratio but did include a shallow phreatic surface in cross-section. Finally, there were 24 analyses in which the team did not find any phreatic-surface information.

During the permit reviews, the team did not systematically determine whether or not permit applications included specific justification for the engineering values. It was noted, however, that such justification was frequently provided. Commonly, these values were derived from the weighted average of typical shear-strength properties of the rock overburden and interburden. It is assumed that pore pressures and/or phreatic surfaces are sometimes applied to proposed valley fills to perform a conservative (i.e. cautious) analysis. A truly effective underdrain system should prevent any subsurface-water build up in the fill.

Parameter sensitivity analysis: In the interest of minimizing the impacts of valley fills on streams, the EIS is considering limiting the length of valley fills to above the reach of

intermittent and perennial streams. This could increase the foundation slope of fills at the toe (where most of the resisting forces to movement occur) and thus might impact their stability. To assess the significance of this quantitatively, the team selected a valley fill design profile and determined the maximum foundation slope at which a stability analysis resulted in a SF of 1.5. One of the West Virginia fills, specifically durable rock fill # 2 of permit # S-5027-89, was selected for the analysis. The slope was gradually increased by moving the fill toe to various elevations up-valley from its original location (where the slope is 7 percent). At each elevation, the profile of the fill face was adjusted to maintain 50-ft. vertical distances and 2:1 slopes between terraces. Fill volume decreased each time the toe moved up the valley slope. That is,spoil material was never added to the top of the top of the fill to maintain the original volume. The material input parameters of the stability analysis in the permit application were held constant:

Property	Spoil	Foundation
Unit weight (pcf)	129	125
Cohesion (psf)	40	200
Friction angle (degree)	38	30
Pore pressure	0	0.05

Using the SB-Slope computer program as the analysis method, the toe-foundation slope at which the SF dips below 1.5 occurs between 25 and 27 percent (14 and 15 degrees).

The team also assessed the sensitivity of SF to changes in spoil engineering properties, based on the ranges of values in the database. The same fill profile was employed. An estimated mean value and two representative end values for each engineering property were selected, with the exception of pore pressure, which was held to 0.05. The same foundation values as above were assumed for this analysis. The following spoil values were selected:

Property	Value 1	Value 2	Value 3
Unit weight (pcf)	95	115	135
Cohesion (psf)	0	100	200
Friction angle (degree)	20	35	50

The fill's toe foundation slope, and the location and depth of the circles defining potential minimum SF's, were also varied by modifying the grid of circle centers and range of circle radii.

Five scenarios were developed as follows:

Case	Toe foundation slope percent (degree)	Minimum SF circle
1	7 (4)	Through the toe
2	25 (14)	Through the toe
3	25 (14)	Shallow circle above the toe
4	25 (14)	Deep circle above the toe
5	25 (14)	Above the toe and through the foundation

Using the total of 27 combinations of spoil engineering values, stability analyses were run for the 5 scenarios (totaling 135 runs). Box-and-whisker plots were generated to show the variation of SF against the three engineering values. Example plots for a critical toe circle and 25 percent or 14 degree toe slope are presented in Figures 21-23. All of the plots (and an explanation of what they show) are provided in Appendix C.

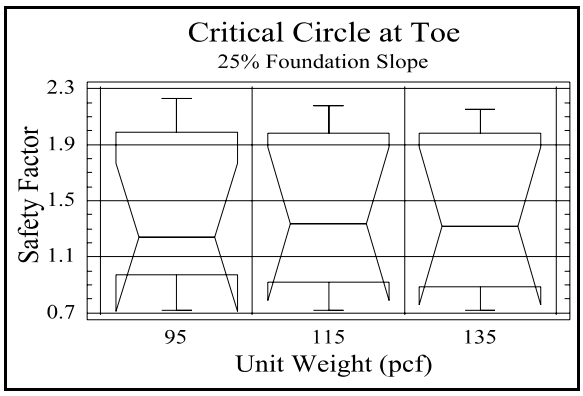

Figure 21: Notched box and whisker plot showing safety factor vs density.

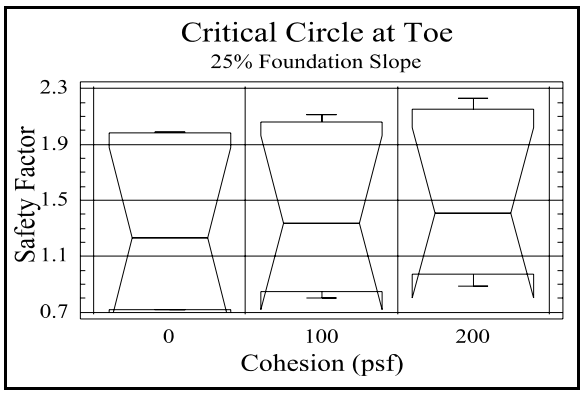

Figure 22: Notched box and whisker plot showing safety factor vs cohesion.

The following observations were made from the parameter analysis and other results of this study:

- Although the average toe foundation slope among the valley fill samples is 10 percent , 5 of them have foundation slopes at the toe of the fill that are greater than 25 percent. Four of these have experienced instability (see Section IV, E, 3 for discussion of

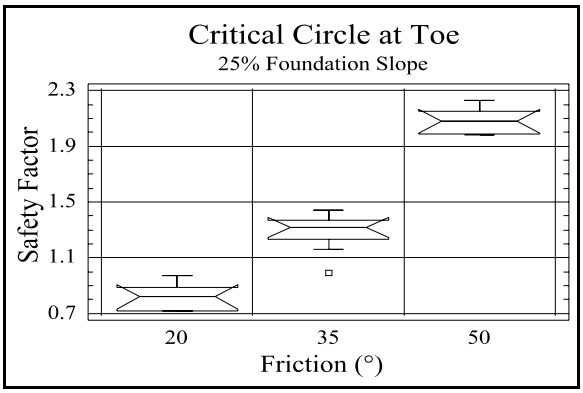

Figure 23: Notched box and whisker plot showing safety factor vs friction angle.

slope imovements), which corroborates the result of the toe-slope analysis discussed above. The result of the analysis would not, of course, be precisely replicated by a similar analysis of all other fill designs. However, the team believes that it is reasonably representative. It is important to note that the analysis may have resulted in an SF below 1.5 sooner (starting with a foundation slope less than 25 percent) if the spoil volume in the fill remained constant as the toe was moved upslope. A constant volume would have forced the placement of more spoil in the uppermost parts of the existing fills, i.e. those parts where the driving forces of instability are strongest and the resisting forces are weakest.

- The box-and-whisker plots of SF vs. the input engineering parameters show a similar pattern across most scenarios. SF is least sensitive to unit weight. The relationship is either nonexistent or statistically insignificant, and inconsistent.

- There is a relationship between SF and cohesion and SF that is consistently direct across the minimum-safety-factor cases. However this relation is also very weak to statistically insignificant.

- The influence of friction angle on SF markedly contrasts with that of the two other engineering parameters. The correlations for most scenarios are direct, statistically significant, and dramatic. The exception occurs in the shallow circle scenario where the sensitivity of SF to the three parameters are similarly low. This result underscores the importance of using the correct friction angle in a stability analysis. This concern especially applies to durable rock fills that may not, in fact, comprise 80 percent durable rock. Under such circumstances, rock-related friction angles are not justified.

- The results of this study's sensitivity analysis are similar to a sensitivity analysis for Ohio mine-spoil embankments conducted by Shakoor et. al. (1989). Their analysis included variations of the same input parameters (with similar value ranges); and also phreatic surface (0 to 40 ft. in elevation relative to the toe of the fill) and slope angle (from 20 to 34 degrees). Within these value ranges, the significance of the input parameters relative to SF, in descending order, are slope angle, angle of internal friction, phreatic surface, cohesion, and unit weight. Our own analysis assumed a constant slope angle between terraces of approximately 27 degrees, since this is the standard requirement of valley fills. The significance of the phreatic-surface effect on stability, as demonstrated in the earlier analysis, emphasizes the importance of accurate accounting of the ground-water conditions, as well as the amount of durable rock, in the design of a durable rock fill.

- The lowest SF's computed by this study's stability analyses occur at the fill toe. All of the SF's fall below 1.00 for the 20-degree internal friction angle (a soil-like property). Almost all are below 1.5 where the friction angle is 35 degrees (comparable to a strong shale or weak sandstone). Again, the dimensions and density of the circle-center grid, and the range and incremental lengths of the radii were adjusted to compute the minimum SF's at the toe and other locations on the fill. This study did not include an in-depth

study of grids and radii used among the sample permit applications; and, therefore, the team cannot state whether the stability analyses are usually adequate in assessing the proper circle radii and grid to compute the SF. Regulatory authorities should consider specifying the parameters required to set up stability analyses to assure the minimum SF is assessed under the proper circumstances.

Slurry impoundments on or below valley fills: During the course of this investigation, it has come to our attention that several permit applications are proposing the construction of large slurry impoundments on existing valley fills. It is inappropriate to place an impounding structure on top of a valley fill. The design standards for valley fills were developed to assure that permit applications and construction practices minimize the infiltration of water into the fill.

The Federal regulations prohibit the placement of permanent impoundment structures on all excess spoil fills [30 CFR §816.71(e)(4)]. This provision was intended to preclude mine planning that would allow impoundments to be designed or constructed on valley fills as part of mining or reclamation operations. However, the same logic applies to old fill sites which are contemplated to be "retro-fitted" with an impoundment. Even placing a dam downstream of a valley fill could cause the pool to envelop the fill toe and impede the free-flow of internal drainage. In the case an impounding structure built on the crest of a valley fill, internal drainage structures for the fill may not be adequate to handle the additional seepage that would result. The presence of such impoundments would add load to the fill and increase the effectiveness of driving forces; the possible influx of additional subsurface water into the fill material could decrease the effectiveness of resisting forces. While there may be engineering designs and analyses that could show it is possible to build an impoundment on a old valley fill, elaborate drainage controls and rigorous geotechnical evaluations would be required to demonstrate feasibility and safety. State regulatory authorities should exercise great caution in considering this type of permit and, as a general rule, disfavor such proposals. Future OSM oversight should focus on whether and how states considered these types of proposals.

An additional note of caution relates to the construction of valley fills above reclaimed coal-waste impoundments. The consolidated slurry typically comprising reclaimed impoundments: is fine grained; may still contain a significant amount of pore water; and, consequently, may have very low engineering strength. Unless measures are taken to prevent pore-water pressure build-up in the slurry and otherwise strengthen the waste material, the finished valley fill will rest on an unstable foundation. The effectiveness of impoundment-stabilization measures will depend on a thorough fill-foundation investigation. The study team recommends that the placement of fills above reclaimed impoundments be avoided as a matter of policy.

D. Valley fill construction

1. Critical-phase certifications

Based on the data collected on the construction certifications, the team distinguished three categories: (1) critical-phase certification provided; (2) no critical-phase certification, but

equivalent quarterly certification provided; and (3) no certification. These categories were applied to the critical phases of foundation preparation, placement of underdrains, construction of surface drains, grading and revegetation, and final certification. Photographic documentation was categorized into: (1) color photographs provided; (2) copies of photographs provided; and (3) no photographs provided.

Numerous fills have quarterly certifications without title- or narrative-reference to a specific critical phase. The team found many of these quarterly certifications to be applicable to one phase or another based on the text of the report and/or accompanying photographs. These were counted as critical-phase certifications. Still, only eighteen of the fills had certifications that covered all of the critical phases. Incomplete sets of certifications were found in the permits of 113 fill samples. Figure 24 shows the results of this analysis, specifically for completed fills.

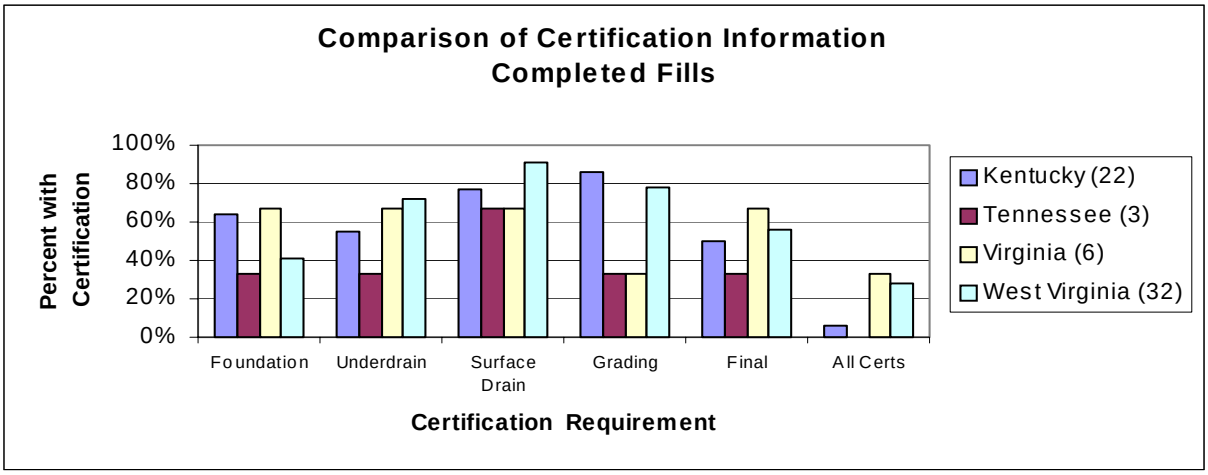

Figure 24: Frequency percent of completed valley fill samples with critical phase certifications.

A similar pattern was found with respect to photographs. No fills have a set of original color prints or copies of photographs that cover all critical construction phases. Original prints and copies of photographs for some, but not all, of the critical phases were found in the permits of 42 and 35 fill samples, respectively.

The team recognizes that the above results with respect to certifications are related, in large part, to where the files were reviewed. It is understood, for instance, that the most current and complete documents are usually in the possession of the field inspectors and not preserved in files available for public review. Where copies of photographs were available, it is assumed that color prints do exist elsewhere, or at least did exist at one time. In this case, the team recommends better public-record keeping. The regulatory authorities should take steps to assure that permit files available for public review are as complete as practicable. Where inspectors are routinely the source of the most recent certifications and it is difficult to maintain the latest copies in central files, the permit file should contain a notation explaining that missing data might be held by the field inspector or district office and can be requested for review, as necessary. If, upon request, the data is found to not exist, the state can take necessary

enforcement actions for failure to provide required information. Finally, it is recommended that construction certifications specifically reference the critical phases they are supposed to represent.

2. As-built versus as-designed volume/configuration/position

Many permit revisions and as-built certifications include changes in the fill's dimensions. Revisions that increased and decreased fill size were both noted. Size reduction may result in a stability concern if it significantly increases the toe-foundation and/or average foundation slope of the valley fill. Theoretically, this can occur in durable rock fills which are constructed by progressive end dumping of spoil in the down-slope direction. A reduction of available excess spoil during the mining operation may prematurely halt fill construction. This could cause the fill to toe out at a higher elevation and in a steeper part of the hollow than originally planned. Since most of the resistence to fill instability occurs in the toe area, a marked reduction in fill stability may result. In addition to potentially steepening the toe foundation, a change in fill length may result in an increase in soil thickness beneath the toe from what had been assumed in the fill design. This also may weaken the foundation conditions of the fill due to the low shear strength of soil (relative to the rock beneath it). The problem applies to increases as well as decreases in fill-size.

There seems to be agreement among State personnel that valley fills commonly decrease in size between the design and as-built condition. However, interviewees did not think that the size reductions posed a serious threat to fill stability. For instance, an inspector observed that the fills he worked with were large enough that, when they became smaller than planned, the foundation slope at the toe did not significantly change. Others inspectors pointed out that if the toe foundation slope did significantly change from the latest approved design in the permit, the operator may be required to push the spoil down-valley to a more gentle natural slope. Alternatively, the inspector may require a new stability analysis in the final certification, if not a complete permit revision. It is noteworthy that the West Virginia regulations stipulate a maximum toe-foundation slope of 20 % (approximately 11 degrees) for durable rock fills.

The study attempted to collect data on fill size changes through the permit-review process. Fill dimensions in length, area, and/or volume were recorded if available from original permit applications, permit modifications, and as-constructed certifications. Records were also made of fill-crown and toe-elevation changes. Unless final, as-built certifications were available, the study was unable to systematically assess the occurrence of size changes of finished fills in comparison with the latest documentation in the permit files. Limited field time precluded land-surveys or the application of the global positioning system. There were a few exceptions where a size change was significant enough to be visually apparent. In addition to querying this study's database, the team hoped to utilize the results of the EIS valley fill inventory to compare as-built and as-proposed footprints. Fill boundaries from aerial orthographic photography of finished fills and permitted as-designed fills had been digitized into a Geographic Information System database for Kentucky and West Virginia. While the valley fill inventory does not allow accurate comparison of the change in individual fill size, it did show considerable decrease in the

total number of fills built from those planned. For instance, in Kentucky, the original inventory of planned fills exceeded 4,000; however, the as-built data showed less than 2,000 on-the-ground fills.

Analysis of the study database identified 53 out of the 129 fill samples with at least one size change in the permit files. In terms of volume or length, permit modifications for 20 fills proposed enlargements and 24 proposed size reductions. A few fills have contradictory data between the volume and length changes. These may result from recording errors or represent changes in fill geometry, e.g. from flat to concave outslopes. This data is not included in the numbers above. The number of fills with recorded changes in toe elevation and foundation slope are 12 and 17, respectively. There are seven fills with documented increases in toe slope; the magnitude of the changes range from 4 to 27 percentage points.

In addition to identifying fills that have experienced size reductions, the database was developed to evaluate why the reduction occurred. Permit file and field reviews, and interviews with State and OSM inspectors, identified seven categories: (1) change in market conditions during the mining operation; (2) change in coal quality during mining; (3) pinch out of a coal seam; (4) interception with abandoned underground or auger mines; (5) inaccurate spoil volume calculations in the permit; (6) permit revocation; and (7) reason unknown. There is insufficient data to emphasize the influence of one or more of these factors on the size reductions.

A potential improvement in the mine operator's valley fill planning and construction process that may help to avoid undersized fills is more extensive exploration drilling of the coalbeds. Given an unavoidable margin of error of market forecasts, it may be recognized that some amount of size change is inevitable. From a regulatory perspective, methods of controlling this problem include policies that require the planned toe location to remain fixed, or more comprehensive foundation investigations and stability analyses that cover a realistic range of conditions that may represent different fill face locations up or down the hollow. In any case, effects on fill stability from changes in the proposed toe position should be fully evaluated in a permit modification prior to fill completion.

3. <u>The construction process</u>

A number of issues concerning durable rock-fill construction have been noted during the field review. These include (1) wing dumping, (2) fill outslope configuration, (3) inadequate gravity-placed underdrain formation, and (4) lack of timeliness in fill reclamation.

<u>Wing dumping</u>: The practice of wing dumping can lead to both stream pollution and eventual stability problems. In terms of stability, this technique potentially impairs formation of the rock underdrain system. Effective gravity segregation of the larger rocks is not as effective compared to end-dumping of the spoil by trucks from the head of hollow.This is further exacerbated by the fact that the material pushed downslope originates from the highly-weathered outcrop regions and is more soil-like in its characteristics. This material is generally not representative of the type of spoil material (1) required by the State and Federal programs for durable rock fills and

(2) portrayed in the stability analyses in the approved permit. There are some examples among fills under construction in which materials with varying properties are being placed on the different outslopes (Figures 25-26). Some spoil material may have been degraded to fine-grained soil-like properties at or near outcrops prior to its removal in the mining process (Figures 12 and 14).

Figure 25: Variation of spoil materials in a wing-dumped fill.

Figure 26: Contrast of segregated sandstone and poorly segregated shale in a wing-dumped fill.

Outslope configuration: Unanticipated reductions in excess spoil may result in a concave outslope on the completed fill (Figure 27). This can happen in durable rock fills, where "wing dumping" of spoil occurs on the hollow side slopes ahead of the advancing toe. With less-than-anticipated excess spoil, the face may be regraded to a concave configuration. This can lead to over-steepened slopes against the valley sides. A concave face can also result in longer and less-inclined terrace drainage channels. Increased water transport distances and diminished channel gradients can cause ponding on the terraces. Ponding, in turn, may promote water infiltration into the fill material, fluvial erosion, and consequent fill instability. It is also noted, however, that an argument in favor of the concave outslope with respect to a fill's mass stability has been made. It purports that stabilizing compression arches form on the concave face because the direction of driving forces influencing different parts of the face "collide." The database includes 27 cases of concavity from final-permit documentation and the team's field observations. Sixty eight of the fill outslopes are recorded as flat and

Figure 27: Comparison of concave (left) and flat (right) valley fill outslopes.

four convex. The database is insufficient to enable the team to discern any connections between fill-face configuration and fill stability in this study.

Gravity segregation: Inadequate gravity segregation during the end-dumping process is not unique to wing dumping. Among other factors, its effectiveness depends on the length (or height) and steepness of the outslope. A slope can be too short because the gravity transport distance does not allow sorting of larger from smaller particles in the spoil. This can occur in shallow fills in the headwaters of the hollow, or even in larger fills that are constructed in several end-dumped lifts. On the other hand, longer slopes may have enough fine-grained particles to affect the friction angle and cohesion of the spoil. In this situation the slopes may be too gentle and the material may cushion impact and thus reduce the momentum of the rolling rock, preventing the larger particles from rolling all the way to the base of the fill (Figure 28). Another factor is the shape of the larger spoil particles. Large rock fragments from thinly-bedded strata will be platy, and less disposed to roll all the way to the advancing toe than more spherical particles. Factors such as slope inclination and length, and particle shape, become less significant as % durable rock increases. For example, where excess spoil is comprised of 80 to 90 % hard sandstone, the formation of an effective underdrain via gravity segregation should depend little on the length of the outslope.

Figure 28: Limited gravity segregation on a long outslope of a developing durable rock fill.

Timely reclamation: This study also found eight cases of unreclaimed durable rock fills where end-dumping or regrading-and-seeding work had not occurred for a year or more (Figure 29). Severe erosion has resulted. The prolonged exposure of some of the material to the surface elements has also accelerated the weathering process and diminished the potential effectiveness of subsurface drainage control.

Figure 29: Spoil degradation and erosion on an unreclaimed durable rock fill.

Additional concerns about valley fill construction that were discussed by OSM and State personnel during the course of this study include: (1) plugging of durable rock fill underdrains during final regrading of the fill face; and (2) inadequate quality control. OSM could not evaluate either of those problems in the field, since each of the sample fills were visited only one or two times. However, the problem of underdrain plugging

during regrading has been expressed since well before this study. The proposed solution, which we support, is to require the mine operator to extend the underdrain system some distance down-valley of the final toe position prior to the regrading.

The assurance of proper valley fill construction requires adequate quality control, especially during the critical phases of foundation preparation and placement or formation of underdrain systems. The regulatory authorities should review their inspection policies and, wherever possible, increase the inspection frequency during the critical phases of foundation preparation and placement or formation of underdrain systems.

E. Valley fill performance (completed fills)

1. Previous work

Other studies related to the stability of existing valley fills include: (1) the 1994 WVDEP valley fill survey, used by this study for the selection of West Virginia fill samples; (2) the study of the interrelationship between fill settlement and pore-water pressures (Rohlf et. al., 2000); (3) an ongoing investigation of a durable rock fill near Prestonsburg, Kentucky (Bentler et. al., 2000); and (4) various State and Federal agency reports of fill instability. Other work that is less directly related to valley fill stability includes work on the stability and hydrology of mine-spoil backfills (Shakoor et. al., 1989; Hawkins et. al. 1992; and Hawkins, 1998). In general these studies emphasize the significance of subsurface drainage. For instance, Bentler et. al. are concerned with the effects of underground mine drainage entering a Kentucky fill experiencing local stability problems. They demonstrate that, under current estimated phreatic-surface conditions and assuming durable rock engineering properties of the fill material, a stability analysis results in a SF well less than 1.5. They further show that a potential increase in the water level controlled by the elevation of the underground mine could result in instability. Hawkins' findings on ground-water activity in mine backfills includes an apparent inverse correlation between a fill's age and the permeability of its material, i.e. the older the fill, the less permeable it tended to be. This may reflect the influence of particle breakdown into finer-grained, less porous material. Decreases in permeability may result in increases in pore pressure and, ultimately, fill instability. He also evaluated the potential role of the amount of sandstone in the contributing overburden and fill permeability. A general correlation was not found, with the exception of older fills (greater than 100 months old) for which there occurred a direct correlation.

The factor of fill age was also assessed by Shakoor et. al. with respect to backfill spoil engineering properties. A breakdown of spoil into finer-grained sediment theoretically results in lower friction angles and higher cohesion. A significant relationship in this regard was not found from their data, however.

2. Helicopter-survey and ground-level observations

The purpose of field-inspecting constructed fills was to observe their general condition and note any symptoms of instability or events that could result in instability. The team's database includes information on the occurrence and position of mass-movement events, tension and shear

Figure 30: Tension crack.

Figure 31: Depression

Figure 32: Seeps, ponding and erosion on fill face.

Figure 33: Erosion above seep area on right side of the fill toe.

cracks, depressions, erosion areas, hummocky or bulging ground, seeps or springs, and notable changes in vegetation and/or soil color (Figures 30-33). The analysis found a total of 42 fills exhibiting one or more of these symptoms. Most of them were recorded during ground-level inspections which permitted closer scrutiny of the fills than the helicopter surveillance. Twenty fills in this category have also been identified as experiencing, or having experienced, instability (see next subsection). Problems less severe than fill instability were regarded as fully repairable within the remaining time period of the permits. However, some of them could clearly result in instability if not properly remediated.

3. Identification and analysis of fill instability

OSM recognized that, in advance of identifying and characterizing instability on valley fills, a working definition was necessary. For the purposes of this study, fill instability is defined as any evidence that: (1) part of the fill's mass has separated from the rest of the fill; (2) the separation occurs along a continuous slip surface, or continuous sequence of slip surfaces, intersecting the fill's surface; and (3) some vertical displacement has occurred. The cases of instability identified with these criteria have been further distinguished between "major" and "minor" occurrences. Major slope movements are those judged to occur over a large fraction of the fill

Figure 34: Land-slip on valley fill.

Figure 35: Land-slip escarpment.

face (e.g. over at least a few outslope benches) and/or require a major remediation effort (redistribution of the spoil from one part of the fill to another, construction of rock-toe buttresses, extensive reworking or augmenting of the drainage systems etc.) (Figures 34-37). Minor movements are those covering a small area on the fill (e.g. not more than one bench on the fill face) and only necessitating minor reworking of the fill material (i.e. without significantly changing the fill's original configuration).

Using this definition, the team identified 22 cases of fill instability. Twenty of these were

Figure 36: Land-slip bulge near base of fill.

Figure 37: Signs of fill instability. Note arcuate crack and seepage pattern near toe, left of center drain.

reviewed in the permit files and inspected in the field; and thus are among the 128 fill samples in the database. Two cases of instability were not reviewed or inspected, but were noted from an OSM list of valley fill problems that had transpired between 1986 and 1990 in Kentucky (House, 1990). Four other cases on the list are part of the database. All six of these fills were stabilized and reclaimed; and the permit bonds were released.

Nine of the 22 slope movements are in West Virginia and 13 in Kentucky. The study did not find or learn of any occurrences of fill instability occurring post final-bond release. However, one major occurrence in West Virginia is located on a bond-forfeiture site and remains unrepaired at the time of the study. Fill instability had begun during the permit period and continued after the permit revocation. The WVDEP is presently looking at alternative methods for reclaiming the fill. As previously stated, this inventory included ground-level inspections and permit reviews of four out of six bond-released Kentucky fills that had experienced slope movement while the permits were still active. One of the fills could not be observed when field visited because it had been buried or removed by subsequent mining activity. The other three were found to be stable.

Of the 22 cases of fill instability, all but two were judged to be major events. The assignment of this classification to the six bond-released Kentucky fills is relatively uncertain, due to the presently stable condition of the inspected fills and lack of detailed documentation. The handwritten notes of an OSM civil engineer identify the events as “mass failure,” or “toe failure.” A recent personal conversation with the engineer indicated that the events were relatively large slides.

One of the minor slope movements in the database involves a set of tension cracks that appear connected to bulges and seeps on the next bench down. The other entailed the failure of a barrier near the top of a fill which led to severe erosion of the embankment. The small number of recorded minor events, relative to the number of major events, may not accurately reflect real field conditions for two reasons. First, the major slope movements were not discovered randomly, but resulted from our concerted effort to identify problem valley fills in fulfilment of one of the tasks in this investigation. There is high probability that most, if not all, major occurrences of valley fill instability are covered in this investigation. Second, minor slope movements, as defined herein, are small and their remediation is relatively simple, involving surficial reworking of the spoil. Normally, minor cases of instability can be corrected by the mine operator quickly, and without the need for documentation beyond normal enforcement procedures. Minor occurrences of slope movement on valley fills may be more numerous than major events, and therefore under-represented in the study since they are less well known.

The analysis indicates that all but one of the unstable fills in the database are small, ranging from 0.10 to 7.70 mcy, the exception being 53.0 mcy (one of the minor cases). However, neither the length nor volume frequency distributions of the unstable fills differ from those of general sample (Figures 38 and 39). Whereas the average foundation slope at the toe among all the fills in database is about 10 percent, that of the 20 unstable fills is approximately 16 percent. Twelve of the 20 unstable fills have toe slopes above the database average, and 6 have slopes greater

than 20 percent (Figure 40). The database also characterizes the slope movements in terms of: position of movement on the fill; dimensions of the moving material, scarp(s), and cracks; rate and extent of movement. Two of the fills were reported to have slope movements on at least three positions on the outslope. Four recorded lengths range from 35 to 900 ft. Four width recordings vary from 20 to 400 ft. Scarp heights are 8, 30 and 60 ft.

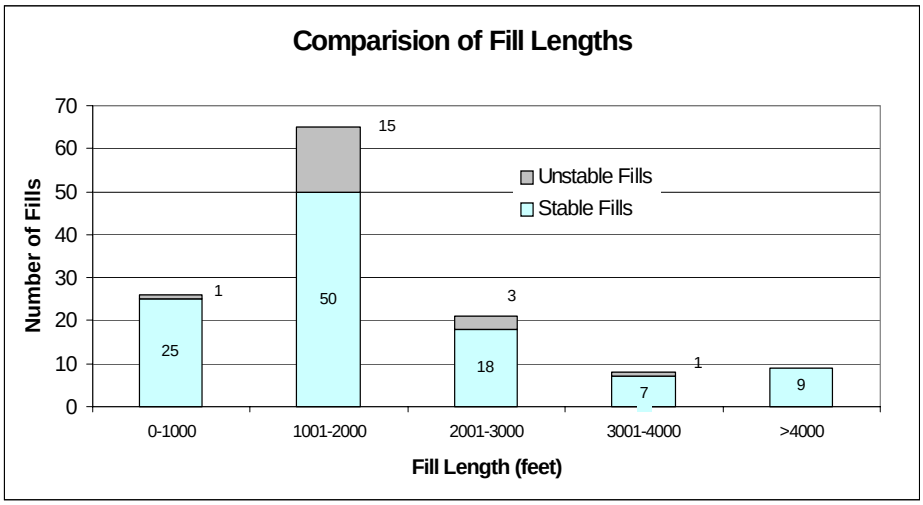

Figure 38: Frequency distribution of valley fill lengths.

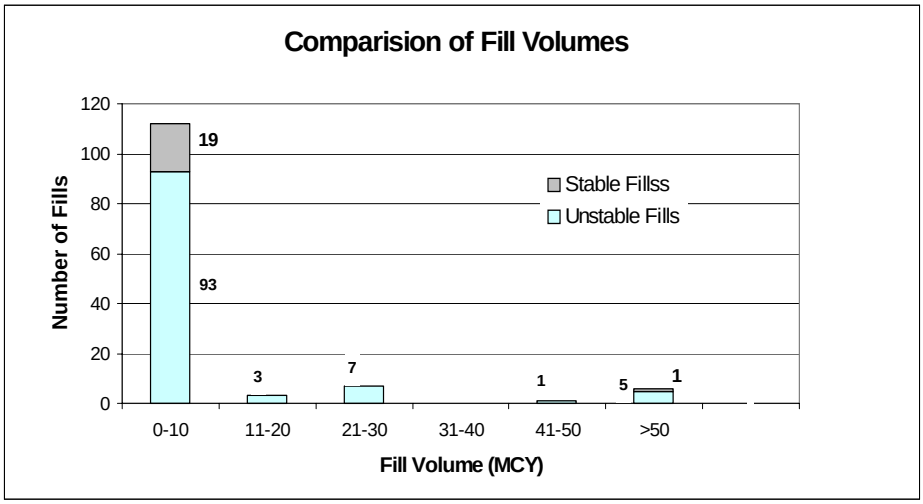

Figure 39: Frequency distribution of valley fill volumes.

The predominant causes of the slope movements were also assessed. Potential factors were identified from a review of the field notes and other information sources. Where the available data allowed, one or more factors were then selected as probable causes of fill instability. Probable causes were entered in the database for 17 fills that experienced instability (i.e., data

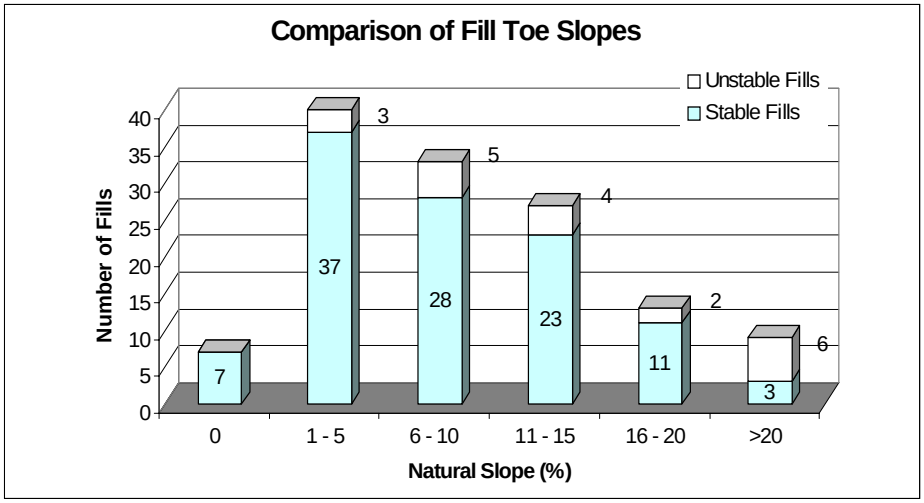

Figure 40: Frequency distribution of toe foundation.

were insufficient to determine causes for 3 fills). The causes are listed in descending order of selection frequency as follows: inadequate subsurface drains; non-durable rock; underground mine drainage; inadequate surface drains; steep foundation slope; and (interchangeably) thick soil foundation and construction in a landslide-prone area. It is important to note that, for any valley fill, these factors can be interrelated. For example, an underdrain system of a durable rock fill may be inadequate due to an insufficient amount of durable rock spoil and/or unaccounted-for underground mine drainage. A thick soil foundation can result from accumulations of colluvial sediment in landslide-prone topography.

V. Conclusions and Recommendations

A review and analysis of the data indicates that valley fill instability is neither commonplace nor widespread. Only 22 known cases of instability occurred (all during the mining and reclamation phase) out of more than 4,000 fills constructed in the past eighteen years. All reported slope movements appear to have resulted from improper construction or design practices or inadequately investigated foundation conditions.

The regulations under SMCRA require geotechnical investigation of fill sites, foundation preparation, controlled placement of material, as well as surface and subsurface drainage control. Slope movements and events symptomatic of potential fill instability were identified in the study, but all of them reflect site-specific problems that can be corrected, or could have been avoided, under the current regulatory framework. This investigation has found no systemic failings in the regulations pertaining to ensuring valley fill stability. The results of the study indicate that most reclaimed fills are evolving into stable landforms (Figure 41). Almost all slope movements documented herein have taken place during the permit period, either during or shortly following the completion of spoil emplacement. The permit of one unstable fill has been revoked. The team is unaware of any occurrences of instability in reclaimed valley fills post final-bond release.

Figure 41: Old valley fill in stable condition.

While this study found only a very small percentage of excess spoil fills that experienced instability over the past 23 years, there are areas of fill design and construction that could be improved. Implementing the following areas for suggested improvement would provide even greater assurance of minimized environmental and public safety concerns related to fill stability[5]:

[5]Recommendations presented below or elsewhere in this report should not, of course, be incorporated into regulatory programs without further thorough review and assessment.

1. **Fill Construction Methods:** OSM should consider establishing a different fill construction method that would replace the durable rock and lift-type fill techniques. The proposed new fill regulation would allow end-dumping of spoil, but only after the construction of an effective, conventional sandstone or limestone underdrain. The underdrain would extend downstream beyond the ultimate toe of the final regraded front face. End dumping would occur on top of the constructed underdrain, but would stop at a point where regrading the front face would not cover up the end of the drain. For stability analyses, the applicant would assume more conservative, soil-like shear strength and cohesion properties and configure the front face to an appropriately stable slope. To account for spoil with unusually weak engineering properties at some mine sites, the regulatory authority would still have the discretion of requiring compacted-lift construction above the underdrain. This hybrid fill construction technique would involve higher costs for underdrain installation, but those costs would be offset by the elimination of durability testing and the need to selectively handle spoil.

2. **Durable Rock Standards:** If the first recommendation above is not adopted (i.e. if the regulations will continue to recognize the durable rock fill as an option for excess-spoil disposal), a more discriminating rock durability test or testing protocol should be developed. OSM and the states should consider the strength-durability classification system proposed in OSM research and other sound, scientific alternatives. Criteria using a volume-weighted percent sandstone might be appropriate for assessing the presence of 80 percent durable rock above each coal horizon. To support this approach, regulatory authorities may need to establish: (1) the general durability of sandstones compared to shales in steep-sloped Appalachia; and (2) the permeability of slaked sandstones in comparison with typical subsurface drainage discharges in the fills. Guidelines for sample frequency should be recommended by OSM or developed by the state regulatory authorities to ensure representative geospatial distribution and establish the proper ranges of rock properties for fill design. Coupled with better testing, techniques for selective handling of mine spoil must used to assure no less than 80% of the durable portion of overburden is placed into end-dumped fills. Additional research could assist to set testing and placement standards for durable rock fills. The research should involve data collection at constructed fills and should establish typical material properties reflecting a range of subsurface conditions. This information would allow proper fill stability modeling based on anticipated rock behavior over time.

3. **Slope Stability Analyses:** The regulatory authorities should consider specifying grid, circle-radius, and/or other applicable parameters required to set up stability analyses to assure minimum SF is assessed under the proper circumstances.

4. **Foundation Investigations:** Regulatory authorities should specify the detail necessary to satisfy existing foundation investigation requirements for the proposed valley fill footprint. Foundation investigations, in addition to establishing the thickness and properties of residual, or colluvial soil deposits, should also determine the presence of underground workings, auger holes, or natural groundwater discharge points. Designs

and stability analyses should consider the maximum anticipated flows from these sources for underdrain sizing and setting pore water pressure ratios or phreatic levels. The ability of an underground mine to carry the added weight of a valley fill and the effect of collapse on stability should be analyzed.

5. **Critical Phase Inspections and Certifications:** Because the Federal provisions and state counterpart rules require greater levels of documentation by the permitee during critical phases of construction, state regulatory authorities should consider increased inspection frequency during these times–particularly during foundation preparation and underdrain installation. OSM inspector training could be enhanced in these areas. State programs should also require that each valley fill critical phase certification be clearly designated as to the type of critical phase being submitted. Public review files should contain up-to-date certifications or state that the most recent submissions can be requested from regional offices/inspectors for review. The absence of critical phase certifications in any state file locations is cause for enforcement action.

6. **Wing Dumping:** Regulatory programs should prohibit or limit wing dumping to a short distance beyond the advancing durable rock fill face.

7. **Fill Outslope Completion/Temporary Cessation:** Regulatory authorities should expand temporary cessation requirements to valley fill construction where durable rock fill faces have not been completed. Timely regrading of dumped-rock fills to a 2:1 slope should be required for sites anticipating temporary cessation for more than a few months. In addition, sites not in temporary cessation, where durable rock fill placement is completed, should initiate regrading immediately to achieve the long-term stable final fill slope.

8. **Long-term Stability Studies:** Additional study of long-term stability at completed fill sites should be periodically performed by OSM in cooperation with the states. Such studies should utilize aerial surveillance followed by ground-level inspection, where warranted. Consideration should be given to use of high resolution orthophotography, satellite multi-spectral imagery, or other remote sensing technology to establish where field visits should occur.

9. **Impoundments on Fills:** Regulatory authorities should discourage the construction of impoundments on completed valley fill structures and ensure impoundments are not placed on proposed valley fills.

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Acronym List

ASTM	American Standard Testing Methods
CFR	Code of Federal Regulations
CSR	Code of State Regulations
cy	Cubic Yards
EIS	Environmental Impact Statement
I & E	Inspection and Enforcement
KYDSMRE	Kentucky Department for Surface Mining Reclamation and Enforcement
mcy	Million Cubic Yards
OSM	Office of Surface Mining
pcf	Per Cubic Foot
psf	Per Square Foot
REAME	Rotational Equilibrium Analysis of Multi-Layered Embankments
SDI	Slake Durability Index
SMCRA	Surface Mining Control and Reclamation Act of 1977
SRA	State Regulatory Authority
SWASE	Sliding Wedge Analysis of Side-Hill Embankments
VADMLR	Virginia Department of Mine Land Reclamation
WVDEP	West Virginia Department of Environmental Protection

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APPENDIX A

PERMIT AND FIELD DATA FROM VALLEY FILL SAMPLES

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Mountaintop Mining/Valley Fill Environmental Impact Statement
Technical Study

WORK PLAN APPROACH FOR FILL STABILITY

I. Problem Statement

A typical mountain-top mining/valley fill (MTM/VF) operation in the Appalachian coalfields removes overburden and interburden material to facilitate the extraction of low-sulfur coal seams--requiring placement of excess spoil into adjacent valleys. These valley fills are some of the largest earth and rock fill embankments being built in the world today. Concerns have been expressed that mass movement or failure of a fill could endanger life, property, and the environment downstream.

This study plan will record instances of past fill failure as well as collecting indicator data regarding outward signs of fill instability. Geotechnical engineering assessments will be made on fill designs, construction practices, and as-built embankments.

II. Goals and Questions to be Addressed by This Work Plan

The steering committee for the Environmental Impact Statement (EIS) has adopted goals and questions to be addressed from several different perspectives: environmental, regulatory, and public service. This work plan, in conjunction with the other work plans and technical symposia that will be conducted during the preparation of the EIS, will attempt to address the following goals as adopted by the committee:

- Are fills adequately stable under the current regulatory scheme? If not, why and what alternatives are available?

III. EIS Team Members and Experts Consulted

Point of Contact: Peter Michael, OSM Appalachian Regional Coordinating Center, Pittsburgh, PA, (412) 937-2867, pmichael@osmre.gov

OSM Lexington, KY Field Office: Joe Blackburn
OSM Columbus, OH Field Office: Stephen Koratich
OSM Knoxville, TN Field Office : Jim Elder

Experts Consulted: KYDSMRE: Mark Thompson; WVDEP: Lew Halstead; VADMLR: Bill Bledsoe; COE: Mike Gheen, Bob Yost, Mike Spoor; Bureau of Reclamation: Jeff Farrar, Dave Gillette; OSM: Mike Superfesky, Dave Lane, Mike Robinson

IV. Study Approach

The Surface Mining Control and Reclamation Act of 1977 established general engineering requirements for valley fills to assure mass stability of valley fills. OSM regulations provide even more specific requirements that, if properly followed during design and construction, establish a high probability against failure.

The EIS will evaluate State and Federal regulations, policies, and practices; geotechnical literature; and the conditions of existing valley fills to assess the effectiveness of current safeguards against future fill failures that may negatively affect public safety. The OSM study team (team) will conduct: (1) discussions with State/Federal inspection-and-enforcement and permit-review personnel and Federal geotechnical experts; (2) review of permits, inspection reports, and other relevant documentation; (3) aerial and ground-level site inspections; and (4) test drilling. The team will reach conclusions per the adequacy of the safeguards and will recommend improvements, where appropriate.

It is impractical for this evaluation (i.e., cost-prohibitive and an inadequate period of time) to definitively establish the geotechnical condition of thousands of fills throughout Appalachian mine sites. In fact, the various state regulatory programs routinely evaluate the company submission of this type of information in permits, evaluate the adherence to approved plans in monthly inspections, and assess the fills for signs of incipient or actual failure prior to making bond release decisions after construction. Company engineers and consultants perform extensive tests, stake their professional reputation and licenses on fill designs, document/certify critical construction phases, and certify quarterly. Therefore, this evaluation limits its focus to various indicators of regulatory program effectiveness in assuring long-term stability of fills

To perform a retrospective study definitively evaluating the mass stability of large earth and rock structures would require detailed knowledge of representative shear strength parameters of the fill and foundation material, as well as ground-water activity within the fill. With reliable excess spoil geotechnical strength parameters and internal pore water pressure information (along with the dimensions of the fill, foundation, and bedrock) a stability analysis could provide accurate engineering estimates for the factor of safety of the fill.

The following descriptions of the approach for each task assume the completion of the inventory of fill types, sizes, and location proposed under a separate study under the EIS; or, the existence of other inventories. Based on these inventories, the team will select candidate fills for the study.

Task 1: *Assemble all available literature on excess spoil disposal practice evaluations and compare the conclusions and recommendations with known current practices.*

- Assemble and review documents and literature pertaining to the construction of excess spoil fills. This includes National Academy of Science reports, contract

research studies, oversight special studies, reports of investigation on specific fill problems, professional articles, regulation preambles, public hearing transcripts, court decisions, letters, memoranda, etc.

- Assess current Federal and State regulations as well as historic and current regulatory program policies and inspection practices.

- From the above reviews, develop an accounting of program-related problems and issues affecting fill construction and a historical perspective of the technical issues at hand.

- Compare issues and recommendations delineated in the reports to current day issues and practices for relevance. Use this information to guide data collection efforts for some of the other tasks outlined below.

Task 2: *Examine the feasibility of documenting that 80% durable rock (by unit volume) is attained during construction and in final fill configurations.*

The concept of 80% durable rock by unit volume is a valid one, theoretically--with respect to attaining long-term excess spoil fill stability. However, there is no known feasible representative sampling technique to evaluate a fill during or following construction to assess if the material placed meets the regulatory standard.

The team will consult with geotechnical experts throughout the Federal government for advice relating to:

- The "enforceability" of the current regulatory standard and the availability of alternative measurable standard(s).

- Possible use of a more rigorous durability classification system on overburden cores used in permit design.

- Greater controls on spoil selected for fill placement (e.g., selective handling controls to assure higher volumes of durable rock).

- Available techniques for in-pit sampling and testing of overburden to show that permit conditions are or are not field validated.

Task 3: *Evaluate the effectiveness of current sampling and testing protocols for establishing representative rock durability of excess spoil.*

OSM completed a comprehensive research study in 1990 that concluded the slake durability test is not particularly effective at discriminating rock durability. The study recommended a different testing protocol and rock durability classification system that

more closely evaluates rock durability under the excess spoil disposal conditions of slaking in water and under compression in a fill. Under this task the team will continue to evaluate the rock-durability question through the following activities:

- Document the rock durability observations of SRA permitting and inspection staff through (1) phone or in-person interviews with I&E and permitting supervisors and (2) discussions with available State inspectors, permit reviewers, and technical staff in the course of performing tasks 5-13.

- Document the rock durability information supplied within the approved permit and comparing it to field observations under task 11.

- Recommend whether or not the rock-durability classification system proposed in the OSM study should be put forward for rule making.

Task 4: *Establish the effectiveness of current methods utilized in inspection and enforcement of excess spoil disposal.*

- Determine if a fairly standard protocol for fill inspection is in effect in each state.

- Identify any issues or practices encountered about excess spoil disposal that concern the State staff.

Task 5: *Determine the population of documented fill failures since the permanent regulatory program, and the causative factor(s).*

- Assess any documented failures from reports gathered in Task 1 and failures known by the SRA to quantify the failure rate of permanent program fills.

- Compile a list of failure causes to see if any commonality exists. Use this information to guide survey and data collection efforts for other tasks.

Task 6: *Review strength parameters, phreatic surfaces, and failure analysis methods used in stability analyses in the approved permit.*

- Based upon existing SRA fill inventory data or results from Evaluation Topic 1, compile a sample of permits with excess spoil fills of varying type (post-SMCRA durable-rock and post-SMCRA non-durable-rock), size (small, <3 MCY; medium, 4 to 20 MCY, large, >20 MCY), and stage of construction (fills still under construction and fills completed). Apply the sample to this and tasks 7-14.

- Review the permit applications of sample fills to identify and record values for shear strength, phreatic surface, and failure method used to assess fill stability.

- Compile the data into a database and compare them with accepted ranges for shear strength; expected phreatic surface; and, appropriate failure type.

Task 7: *Evaluate state surface mining information systems (SMIS), environmental resource information networks (ERIN) or other similar databases and compile violation data relative to excess spoil disposal.*

- Using the sample of permits selected for task 6, document the types of violations written on excess spoil disposal sites and develop a database.

- Evaluate the potential impact of the violations on fill stability.

Task 8: *Review documentation and certification of critical construction phases and quarterly certification.*

- Using the sample of permits selected for task 6, review photos and certifications of critical fill construction phases.

- Assess on-site conditions and fill construction methods pertinent to stability concerns and record observations for comparison in the field.

Task 9: *Establish if foundation conditions for fill placement are as defined in the approved permit.*

- Using same sample as in task 6, review permits to compare fill foundation preparation and underdrain placement documentation (color photos and RPE certifications submitted by the company as required by regulatory programs) with documentation of foundation test holes.

- Assess whether or not foundation conditions comport with fill design.

Task 10: *Aerial reconnaissance of a sampling of completed and fills under construction in WV, KY, and VA to visually assess stability, drainage control, and related features.*

- Using the samples selected for task 6, perform aerial surveys of the fills.

- Develop an inspection checklist to document the condition of each fill, including signs of instability (e.g. seepage, drainage control failure, ground cracks).

- Make video recordings of observations for further analysis at the office.

- Use the results of the aerial inspections to select sites for Task 11.

Task 11: *On-the-ground visits to selected sites identified in 10, above to further assess stability, drainage control, and related features.*

- Conduct on-the-ground inspections of fills selected from Task 10 to confirm conditions observed in the air and obtain more detailed information on the condition of slopes, seepage, drainage control systems, etc.

Task 12: *Compare as-built fill configurations with as-designed.*

Regulatory staff say it is a common occurrence that as-built fills are often very different configurations than proposed and approved in the original permit. Situations have been described when fills are much smaller than planned, or the fill site is not used at all. Whether a fill is constructed smaller or larger than planned can have definite impacts on the stability analyses and long term stability. Smaller fills tend to be higher in the watershed–sometimes where the natural ground is much steeper and instability could be more problematic due to less friction counteracting sliding/driving forces. Using the sample from task 6, the team will:

- Review the permits--and evaluate the fills during the aerial reconnaissance and on-the-ground inspections--to compare fill designs with as-built configurations.

- Estimate the potential effect of as-built variance from design on fill stability.

- Evaluate overburden characterization and coal exploration thoroughness in the permit to see if the reason(s) for variance can be determined.

- Document permit revisions, including stability analyses, for changes in design.

- Make recommendations for improving the rate of as built = as designed, if appropriate.

Task 13: *Assess if proper surface and subsurface drainage controls are installed.*

- Using the same sample of permits as task 6, inspect the fills during the aerial overflight and on-the-ground site visit for the presence of seepage contrary to the expected subdrain performance (as shown in the stability analysis assumptions).

- Document the designed surface drainage control system in the permit applications and compare with aerial/field observations of the as-built system.

- Note significant differences between the as-built and as-designed systems, if any, and document evident flaws.

Final Report: The team will write a chapter to be incorporated into the EIS report. This chapter will provide an analysis of: technical and programmatic issues related to excess-spoil-fill stability; the results of the permit and inspection documentation review; and field inspections and testing. The chapter will also draw conclusions, where possible, on the long-term stability of the fills.

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APPENDIX B

PERMIT AND FIELD DATA FROM VALLEY FILL SAMPLES

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APPENDIX B

Explanation of Valley Fill Data Sheets

Two pages of data ("data sheets") are provided for each valley fill sample used in this investigation. The data is topically organized into boxes. Data collected from the permit files is included on the first page. Data obtained from the field is identified by an asterisk in the left margin of the data sheet; and begins at the bottom of the first page and continues on the second page.

Permit-application data is presented in the top 12 boxes; and is identified as to whether they were collected from the original application ("original design"), the latest valley fill modification to the application ("revision"), or the final certification on a completed fill ("as constructed").

The question as to whether **critical-phase certifications** were found on file is broached in two ways. First, the "yes" column is marked when a certification was found that clearly indicated that it was connected to a critical construction phase. Second, an "applicable" quarterly certification is recognized if it contains information or photographs showing a critical phase in the construction, even if it is not specifically connected to a critical-phase certification. This type of certification is identified by the year and quarter. For example, 92/2 represents the second quarter (January through March) of 1992. In the data analysis, credit for having a critical-phase certification was given if the "yes" column was marked and/or the year and quarter of an applicable quarterly certification was indicated.

A substantial part of the **field data** pertains to the identification and **location of potential symptoms of instability** on fills such as ground cracks, erosion scars and seeps. The location of these features, when identified, is presented in terms of bench level and "quarter." For perspective, the total number of benches on the fill outslope is given at the bottom of the first field-data box. Bench designations are numbered upwards from the toe to the crown. B 3, for instance, represents the third bench up from the toe of the fill. B 6-crown represents an area between the sixth bench and the crown of the fill. The quarters are identified from left to right when one faces the fill outslope from a position down-valley of the toe. Q 1 indicates left-most $1/4^{th}$ of the fill face. Q 2-3 represents an area crossing the boundary between the second and third quarter, i.e. centerline, of the outslope.

Explanation of Page Numbering

The pages in Appendix B are organized alphabetically by State and numbered Sequentially. The States represented and their respective abbreviations are: Kentucky (KY), Tennessee (TN), Virginia (VA), and West Virginia (WV). Pages are numbered using the State's abbreviation, a hyphen, and the sequential number. The pages for Kentucky are numbered KY-1, KY-2, KY-3, through KY-198. Pages for the other States are numbered as follows: Tennessee, TN-1 through TN-34; Virginia, VA-1 through VA-110; and West Virginia, WV-1 through WV-294.

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KENTUCKY

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KENTUCKY

Company	Mine	Permit	Fill
Addington Enterprises	Prater #1	813-0238	HF #8
Addiiigton Enterprises	Prater #1	813-0238	HF #10
Addington Enterprises	Prater #1	813-0238	HF #12
Addington, Iiic.	UK #1	813-0180	HF #3
Addmgton, Iiic	UK #1	813-0180	HF #7
Big Creek Mining, Inc	Hunt's Branch Strip	898-0490	HF #5A
Big Creek Mining, Iiic	Hunt's Branch Strip	898-0490	HF #5B
Big Creek Mining, Inc	Hunt's Branch Strip	898-0490	HF #6
Big Creek Mining, Inc	Hunt's Branch Strip	898-0490	HF #9
Big Creek Mining, Inc	Hunt's Branch Strip	898-0490	HF #10
Big Creek Mining, Inc.	Hunt's Branch Strip	898-0490	HF #11
Big Creek Mining, Inc.	Hunt's Branch Strip	898-0490	HF #16
Cheyenne Resources	Surface Mine Job k3	860-0377	HF #4
Coal Mac Mining, Inc.	No Mine Identifier	498-0204	HF #1
Coal Mac Mining, Iiic.	No Mine Identifier	498-0204	HF #2
CZAR Coal Corp.	Panther Fork Mine	880-0122	HF 112
EDCO Energy Coip.	EDCO Mine	836-0100	HF #1
Elkhorn Coal Corp	Homer Short Surface Mnie	880-0130	HF #1
Elkhorn Coal Corp	Homer Short Surface Mine	880-0130	HF #2
Elkhorn Coal Corp.	Homer Short Surface Mine	880-0130	HF #3
Elkhorn Coal Corp	Homer Short Surface Mine	880-0130	HF #4
Elkhorn Coal Corp	Homer Short Surface Mine	880-0130	HF #5
Elkhom Coal Carp	Homer Short Surface Mine	880-0130	HF #6
Elkhorn Coal Corp	Homer Short Surface Mine	880-0130	HF #7
Elkhorn Coal *Corp*	Homer Short Surface Mine	880-0130	HF #8

KENTUCKY

Company	Mine	Permit	Fill
Elkhorn Coal Corp	Homer Short Surface Mine	880-0130	HF #9
H & D Coal Co., Inc	Isom Branch	898-0440	HF #1
Lodestar Energy, Inc.	No Mine Identifier	836-0261	HF #3A
Lodestar Energy, Inc.	No Mine Identifier	836-0261	HF #4
Lodestar Energy, Inc.	No Mine Identifier	836-0261	HF K6C
Martin County Coal Corp.	No Mine Identifier	880-0103	HF #33
Martin County Coal Corp.	No Mine Identifier	880-0103	HF #34
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #13
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #14
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #15
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #16
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #17
Miller Brothers Coal	Wolf Creek #1	813-0207	HF #18
Mountain Clay, Tnc.	#32	518-0157	HF #3
New Ridge Mining	Road Fork of Big Creek	898-0415	HF #K
Pine Branch Coal Sales	Haddock Fork Mine	897-0271	HF #10
Pine Branch Coal Sale?	Hdddock Fork Mine	897-0271	HF #13
Pine Branch Coal Sales	Haddock Fork Mine	897-0271	HF #DD
Richardson Fuels, Inc.	Mine #2	836-0212	HF #1
Starfire Coals, Inc.	Skyline	060-0080	HF #1
Sunny Ridge Mining Co.	Jones Fork	898-0507	HF #9

Kentucky
Addington Enterprises
Prater #1

Permit: 813-0238

Fill: HF #8
Fill: HF #10
Fill: HF #12