OSM VALLEY FILL STUDY

HOBET MINE WESTRIDGE VALLEY FILL

Appalachian Regional Coordinating Center

US Army Corps of Engineers
Pittsburgh District

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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.

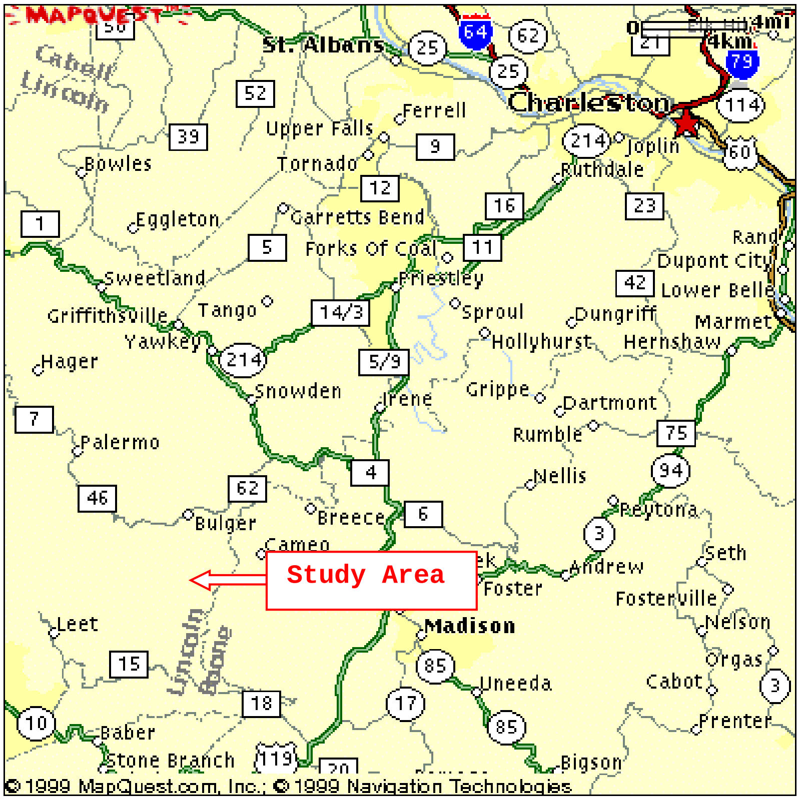
Topographic maps, aerial photographs and survey cross sections were used to formulate these hydrologic and hydraulic models.

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

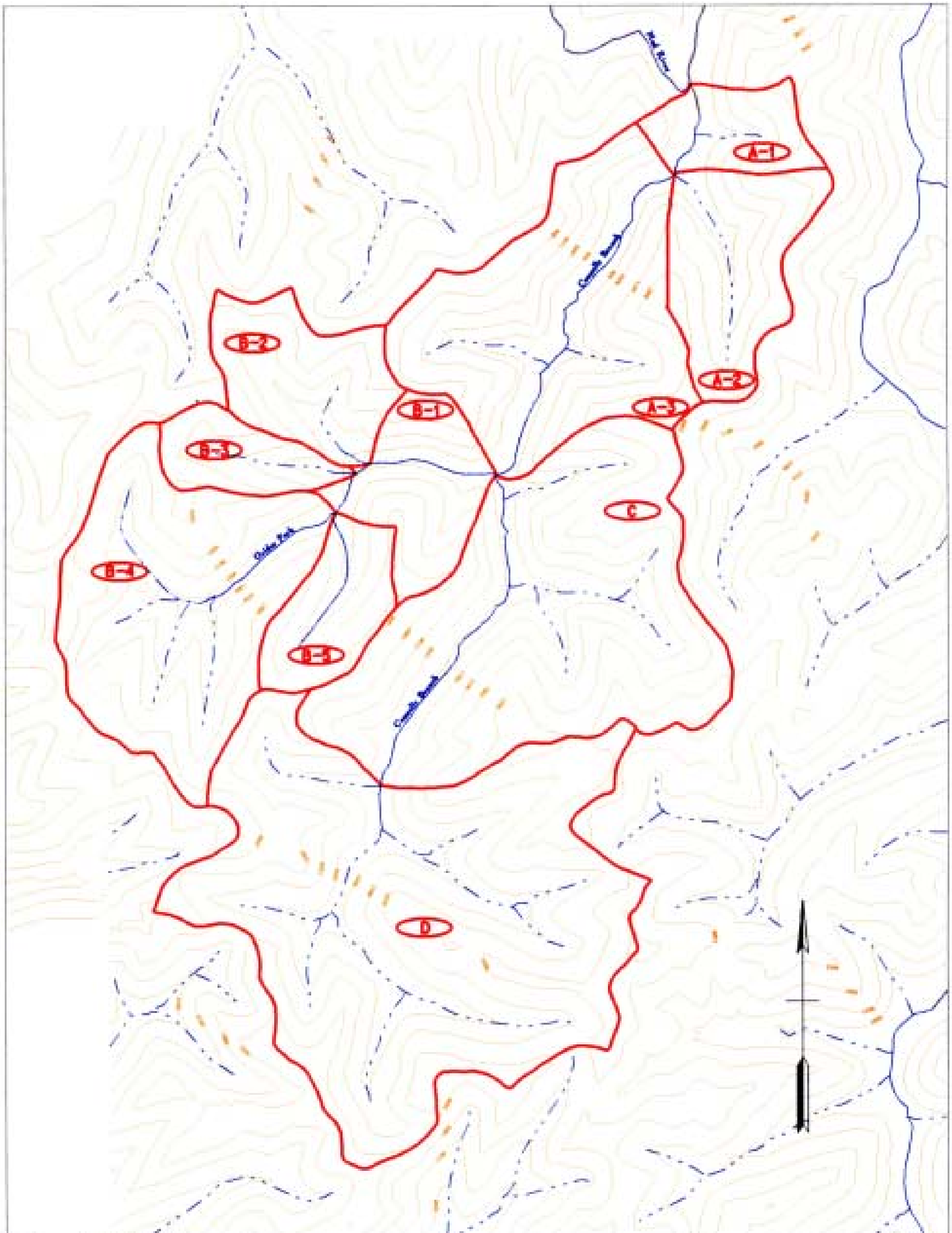
Plate 1 shows the runoff subareas.

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

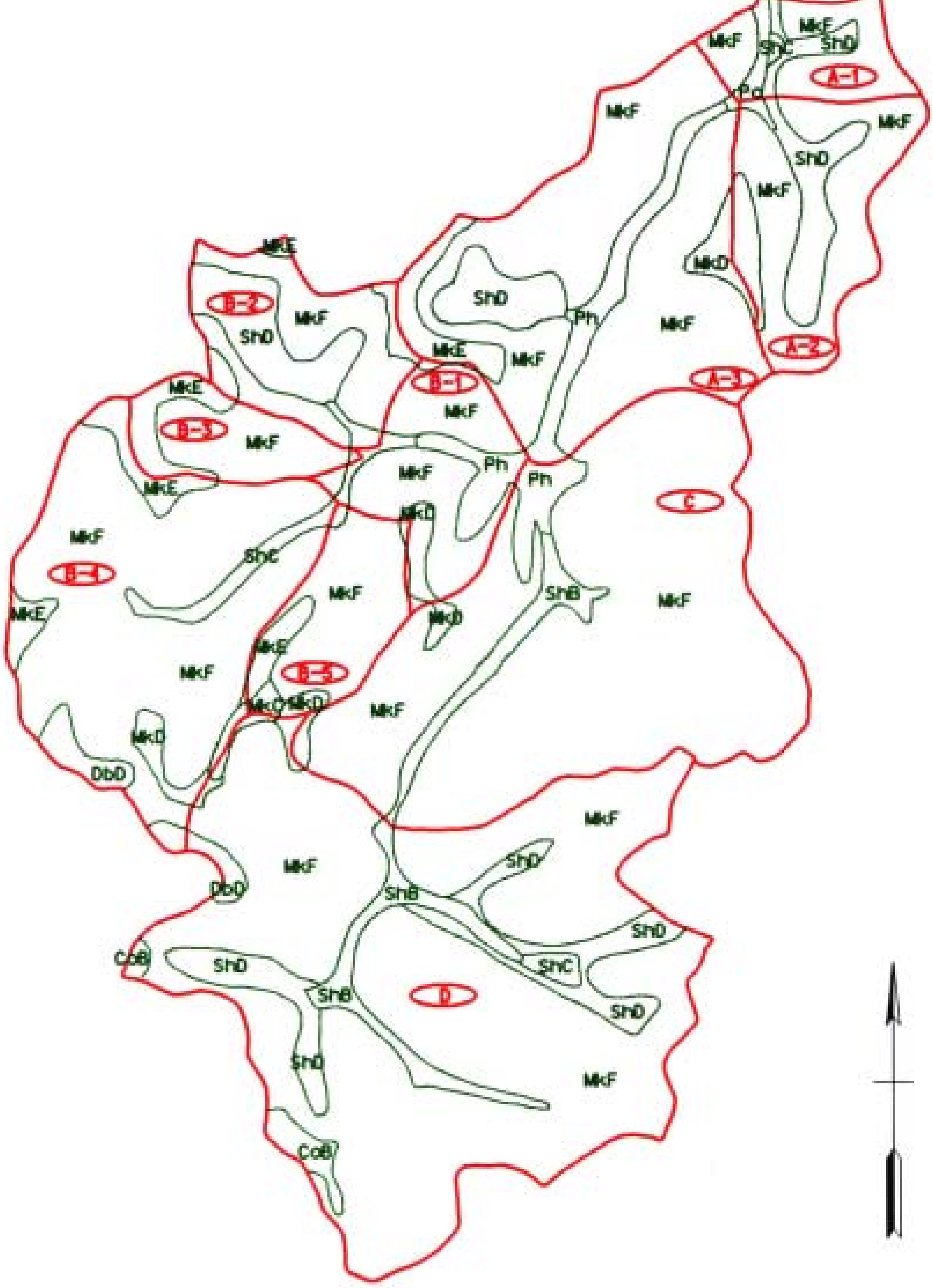
Plate 2 shows the soil type subareas.



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.

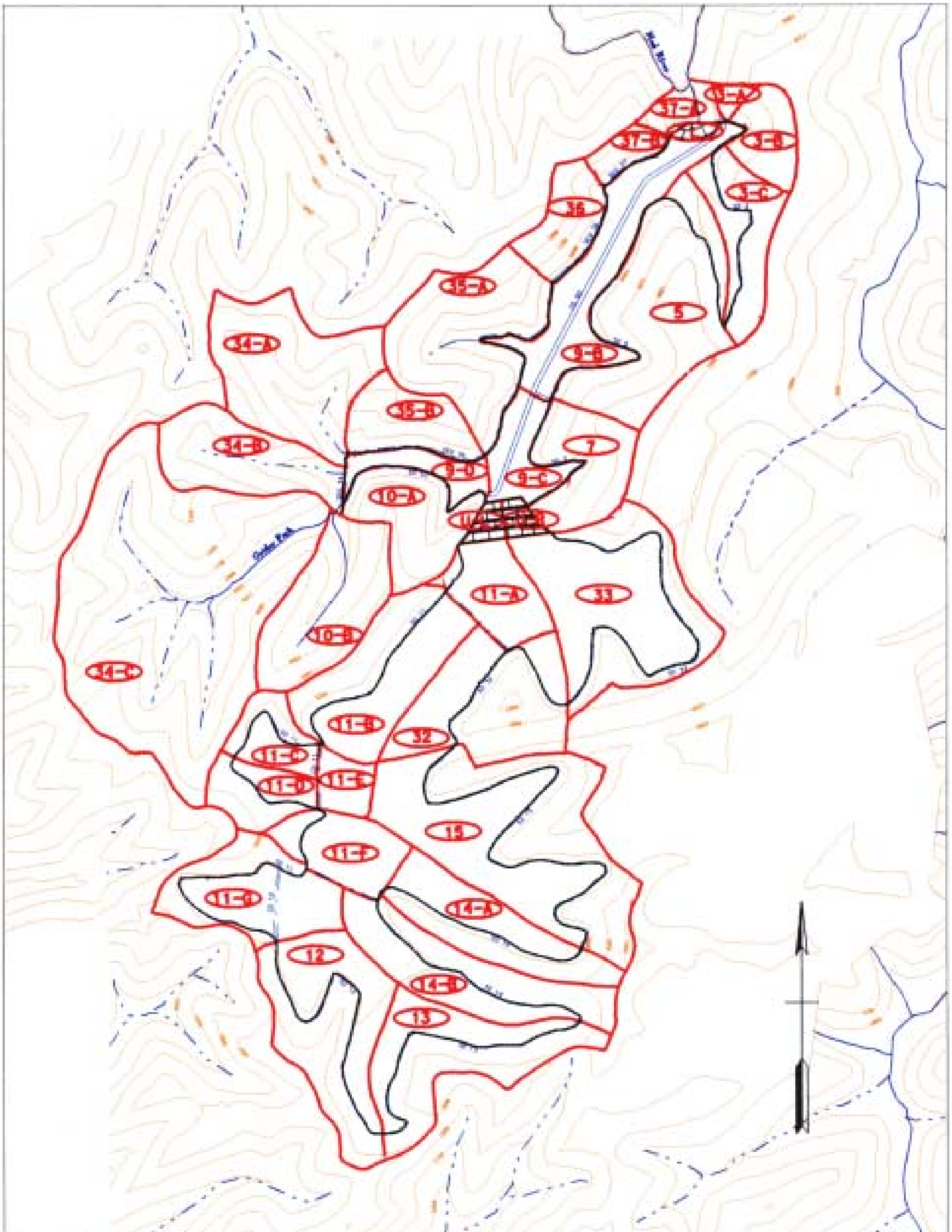
Soil Types and SCS Runoff Curve Numbers

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.



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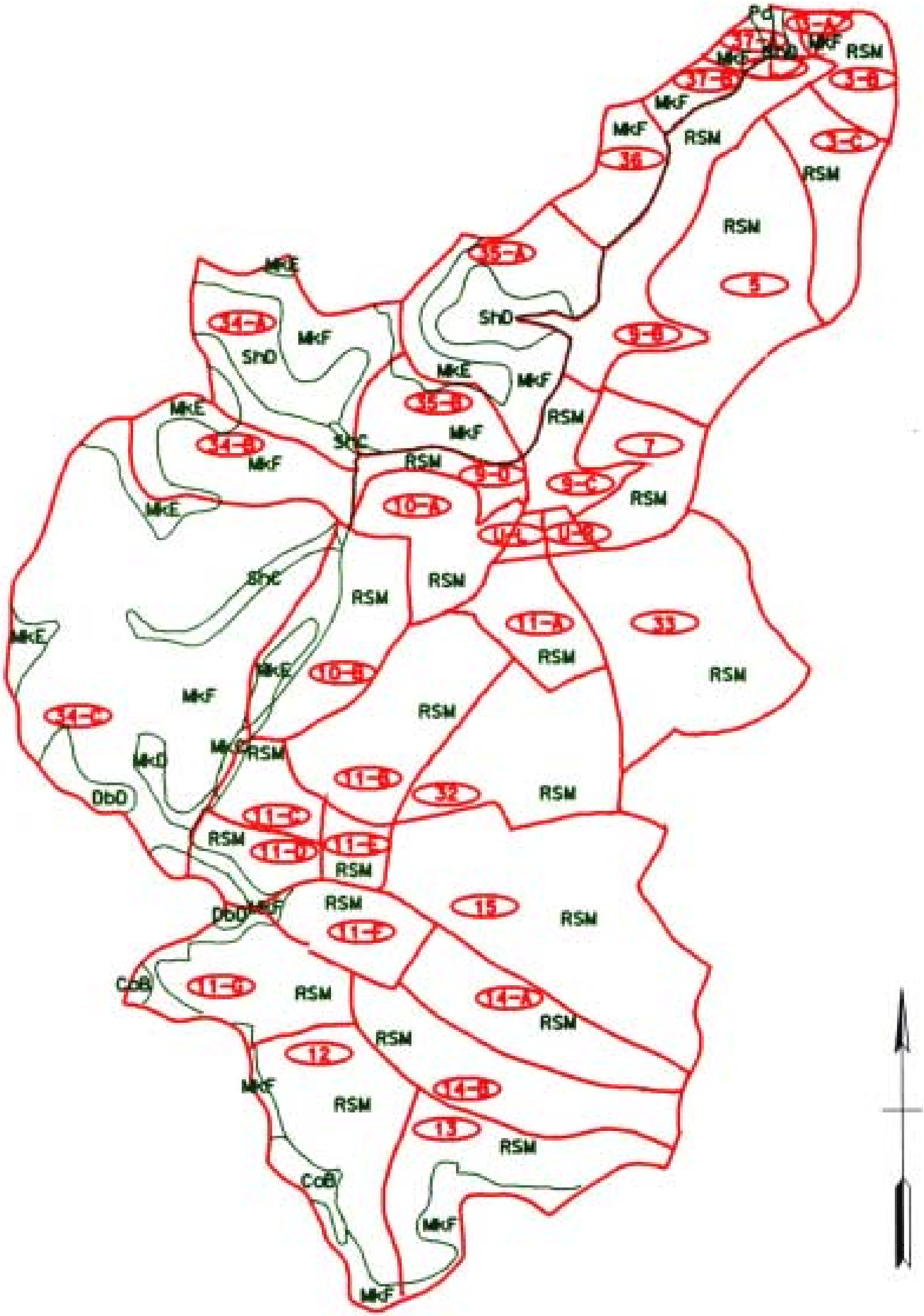
Post Mining Condition
Runoff Subareas

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.

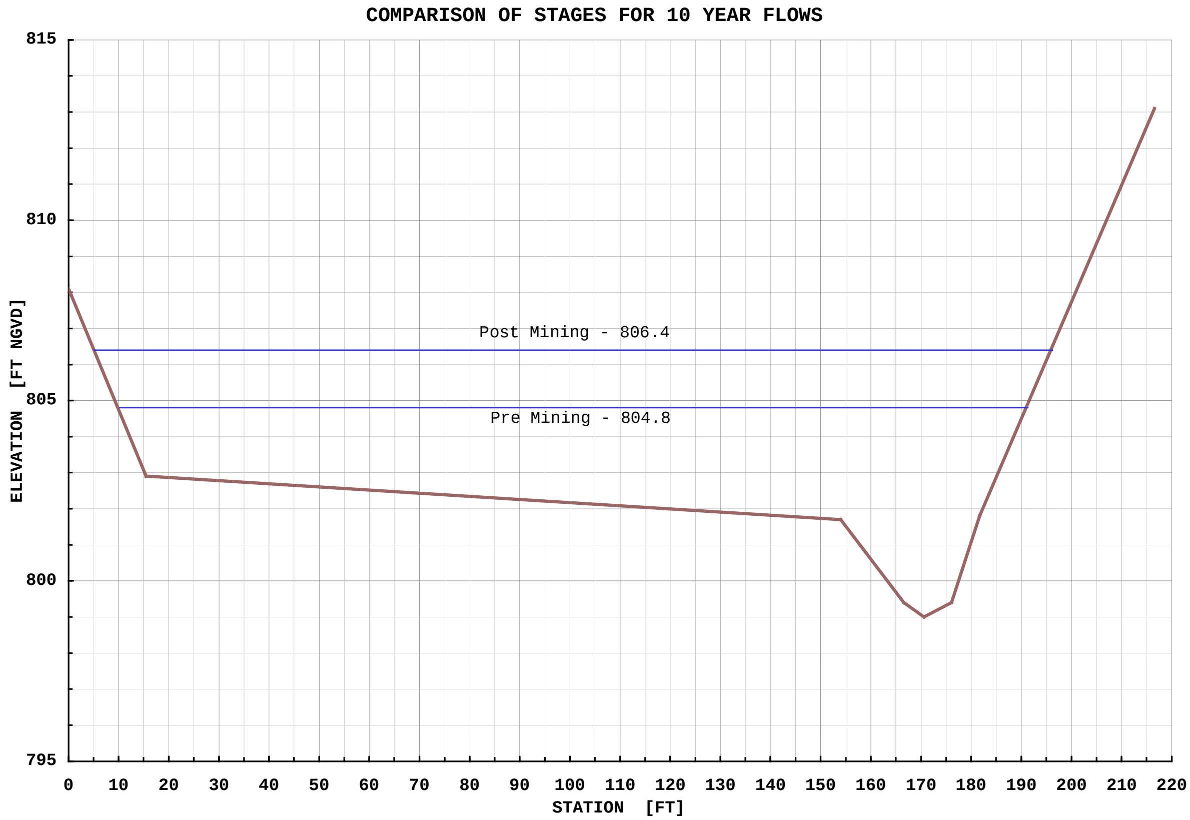
The following table shows the 10 and 100 year flows and water surface elevations:

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

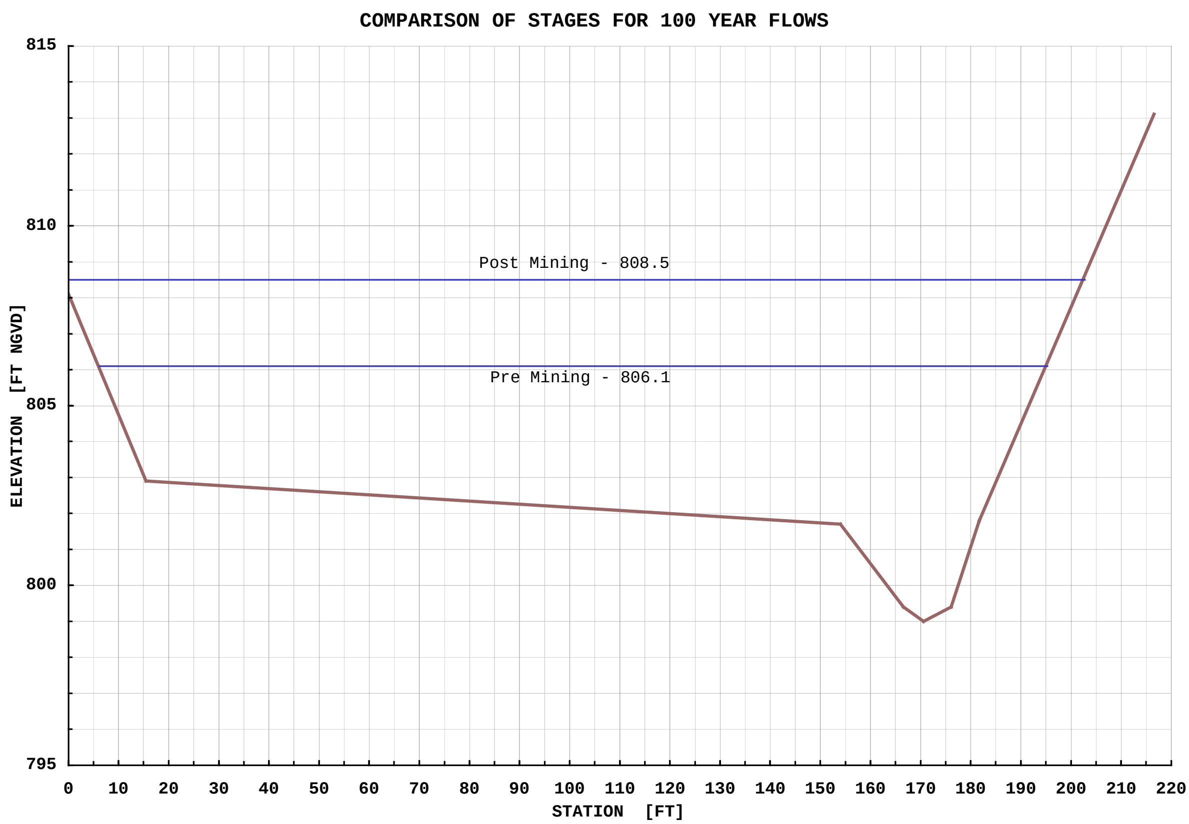
YR = Years
CFS = Cubic Feet per Second
FT NGVD = Feet above National Geodetic Vertical Datum

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



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

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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