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Effect of Various Valley Fill Restrictions on the Quantity of Coal Potentially Available for Mining

Introduction

Phase One of the Environmental Mountain Top Removal/Valley Fill (MTR/VF) Impact Technical Study was designed to estimate the effect of various valley fill restrictions on the quantity of coal potentially available to conduct mountain top removal operations and other types of mining throughout the state of West Virginia. The study also correlated the results in West Virginia to surface mining areas in Kentucky and Virginia. The estimations are based on a Geographic Information System (GIS) model developed by Resource Technologies Corporation (RTC) using MapInfo Professional and Vertical Mapper by Marconi that relies upon the following GIS data sets:

- Regional coal information maintained in the GIS including:
  - Coal Seam Elevation
  - Coal Seam Thickness

- Topographic information from the United States Geological Survey's National Elevation Data set (NED).

- Drainage basin polygons developed by RTC and the West Virginia University, Department of Resource Management (250, 150,75, and 35-acre basin coverage).

For this phase of the study, mountain top removal operations are defined as:

- Surface mining operations designed to mine multiple seams of coal by mining cross ridge: removing all seams of coal overlying a base seam. The base seam is exposed (outcrops) above drainage along the sides of the mountain. Stratigraphically higher seams of coal overlay the base seam. These seams may also outcrop along the sides of the mountain.

- By mining an entire area, across a ridge line, from coal outcrop to coal outcrop, the mountain top technique results in the:
  - Complete removal of a mountain top or portion of a mountain top.
  - Exploitation of all or nearly all seams of coal overlying and including the base seam within the mining area.
  - Generation of significant quantities of unconsolidated spoil that must be either returned to the mined area as backfill or placed in adjoining valleys as valley fill.

To assist in defining the technique, various advantages and disadvantages of the technique are summarized as follows:

- Mountain top mining is typically used to allow economic recovery of thin coal that is marginally mineable using other methods.

- By mining multiple seams simultaneously, the operations are designed to minimize stripping ratios and thus reduce extraction costs. Seams that are individually uneconomic to recover (too thin or underlying too much overburden) may be economically captured by mountain top removal operations.

- Multiple seam mining enables the operator to blend various coals to create marketable fuel products. This permits the economic recovery of some coal that may be individually uneconomic to exploit.

- Mountain top mining is also used to permit more efficient handling of overburden. Initial overburden is cast into hollows or valleys, creating room for effective mining at the seam level. Subsequent overburden can then be more efficiently handled and back-stacked on mined out portions of the mountain.

- The technique creates large valley fills and destroys the original contours and integrity of the original mountain structure above the base seam.

Phase One of the Economic Impact Technical Study was originally designed to estimate the effect of various valley-fill restrictions on the amount of coal potentially available to conduct mountaintop removal operations throughout the state of West Virginia. The estimations were based on a Geographic Information System (GIS) model developed by Resource Technologies Corporation (RTC) . The production of the Phase output, The steering committee determined that a further effort should undertaken to provide more specific output and to use more defined input data. As detailed in the paragraphs below the steering committee identified six issues to be addressed in the expanded effort. In addition, the steering committee desired to use the GIS output for examination of geospacial environmental concerns. This report and the associated data files are result of the expanded effort.

Specific Issues and Procedures Requirements identified by the Steering Committee:

The application of the model and a review of its output permitted the technical staff and steering committee to reconsider and refocus model requirements and expectations:

1. There are additional new data sets available which not available when the modeling effort was planned and executed. The use of these data may affect the conclusions. These data sets include:

    a. Digital elevation data sets with increased accuracy
    b. Polygons showing areas of deep mine depletion
    c. Polygons showing areas of surface mine depletion
    d. Polygons showing area of surface disturbance
    e. Polygons showing existing permitted valley fills
    f. Polygons showing existing Mountaintop Removal sites
    g. Polygons showing proposed Mountaintop Removal sites
    h. Geologic data from Kentucky and Virginia
    i. Revised coal outcrop, elevation and thickness from RTC efforts

2. There is a need to apply the procedure consistently to all "potential" mining types and coal sources including:

   a. Contour strip, highwall auger, conventional auger, and deep mining coals within the study area but not selected as potential mountain top sites

   b. Contour strip, highwall auger, conventional auger, and deep mining coals within the mountaintop areas that may become available for mining as mountain top sites are reduced or eliminated by increasing valley fill restrictions

   c. Contour strip coal that could augment mountain top recovery from seams below the base seam of the MTR site but still are above drainage. Coal to be exploited only to the extent that there is "excess fill space" available in each restrictive scenario.

3. There is a need to apply the procduere or account for the procedure on coals which may become available from Kentucky and Virginia.

Based on recent discussions with the EIS steering committee (Office of Surface Mining and West Virginia DEP) a number of issues are to be addressed by rerunning the GIS model using revised procedures and accessing new data. The new runs will permit estimating on a smaller region basis, more accurate allocation of past depletion, a more equal treatment of Kentucky and Virginia coal, and more consistent input concerning alternative coal sources: auger, contour strip, highwall, and deep mining. The following paragraphs address each issue independently:

Issue #1: **Receipt of recently available new data indicates that the earlier procedure used by RTC may overestimate the quantity of remaining coal resources that could potentially be exploited via mountain top removal procedures. This issue has yet to be proven.** The committee requires RTC to develop a procedure to consider the now available site-specific estimates of coal depletion. This effort is intended to better assess the impact of identifiable previous mining on Mining Resource and Related Valley Fill Area (MRRVF) coal resource estimations. Specifically, the procedure is to use site-specific historic mining information (coal depletion) for mines occurring since 1980 (deep mines) and since 1982 (surface mines) rather than the regional allocation of depletion by seam currently used. OSMRE, EPA, WVGES, and WVU have provided polygon data concerning the post 1980 mining information. Regional allocation of pre-1980/1982 mining will still be applied to the tonnage estimates.

Originally, regional allocation of coal depletion was chosen because of the absence of accurate statewide historic mining location information. "Mining Resource Areas" were selected assuming a virgin coal situation. Possible future coal production was reduced by subtracting a prorated portion of the regional historic production from the future coal production estimates. (This was completed by seam by county using Division of Labor and Industry annual reports. Seam names were normalized to standard US Bureau of Mines Bituminous numerical seam codes.)

By postulating virgin coal, it was assumed that the errors of commission would equal the errors of omission; that is, there would be just as many over-estimates as under estimates and on a statewide or regional basis the overall estimate would be acceptable. It was decided that this procedure would 1) remove any bias in the selection of potential "Mining Sites" and 2) allow the model to select potential "Mining Sites" based on unbiased stripping ratios. This bias was perceived to stem from the imperfect nature of the known historic mine maps. Using "virgin" coal allowed for the selection of all possible sites. Regional depletion allowed for the reduction in coal to be produced. Given the data available at the time, the committee agreed to this procedure. It must also be noted that the original intention of the effort was to model the likely proportionate loss of coal related to fill restrictions and not the prediction of actual sites and tonnages of coal to be produced.

Since the project was initiated, OSMRE has reviewed and accepted polygonal GIS data (WVGES) depicting depletion of sections of certain seams of coal (Coalburg, Stockton, Five Block) from deep mining activities in the MTR region. OSMRE has also accepted maps of surface mine permits dated from 1980 to date and polygons depicting surface disturbance related to mining from current USGS topographic maps. The committee requires that RTC use these data to further improve estimates of the available coal tonnages delineated by the RTC GIS model. This revised procedure will require rerunning the model following the depletion of specific seams of coal as identified by the new information:

a. Polygons of active surface mining permits and prior disturbed areas will be used to remove specific sites from consideration prior to model site selection by stripping ratio. It will assumed that currently active, permitted mine sites will be handled by some form of exception or "grand fathering" as related to some form of fill restrictions. Tonnage related to these specific sites can be reintroduced to the economic model based on legal and economic assumptions not related to the GIS.

b. Polygons of deep mining depletion will be used to remove specific **seam segments** from the data-set prior to model site selection by stripping ratio.

c. Pre 1980 deep-mined coal will be subtracted from the tonnage results following site selection – the same procedure used to date. Pre 1982 surface mined coal will be subtracted from the tonnage results following site selection – the same procedure used to date.

d. All previous selection procedures concerning Mountaintop Mining Sites (stripping ratios, above drainage, crop to crop coal, minimum tonnage, etc.) will still be implemented.

Note that the polygons of surface mines and disturbed areas do not identify specific seams mined. It will be assumed that the disturbance removed the top seams and as a result the site is removed as a potential MTR location – the site will fail by the stripping ratio test. There is no accurate way to ascertain the specific seam exploited at these sites nor is there a method to quantify the amount of coal removed at these locations.

Issue #2: **Given the recent availability of new data the original procedure used by RTC may overestimate the quantity of remaining fill sites.** Like issue #1, this issue has yet to be proven. Similar to the coal portion of the model, the model assumed universal availability of valley sites for fills. As was discussed in the preliminary report, there was no measure available other than site-specific analysis to ascertain which among valleys "technically" available would be practically available. The existing model makes no such differentiation. OSM now has available polygon coverage of existing fill sites (post 1982 polygons and pre 1982 point of base of toe). The committee requires that RTC use these data to remove valleys from the universe of fill sites available.

For the previous effort, RTC used the most recent DEM (30 meters) topographic data available to estimate overburden quantity and fill capacity. Presumably the DEM data captures topographic modifications caused by all but the most recent fills and overburden removal operations. Therefore, the RTC fill and overburden calculations may only be out of date at these recent locations. However, an examination of the polygon data provided by OSMRE shows that many of the existing fills are less than 50 acres. These small fills may not be accounted for in the DEM data. Additionally, OSMRE requires that RTC use the newer WNED data for the topographic base. This is the topographic base now being used by other researchers concerned with the project.

To satisfy the committee's request, RTC proposes that the elevation base used for the model be compared to the fill inventory. If there are significant changes warranted, RTC will use the polygon map to modify the DEM model used to calculate overburden generated and fill space available.

Issue #3: **The model should provide tonnage estimates of coal and the effect on likely production of surface mineable coal not included in the identified mountaintop resource areas.** It is necessary to identify additional tons, acres, and fill for coal that has not heretofore been included in the analysis. This would permit the research team to develop a "consistent" picture of the effect of fill restrictions across mining types and regions. The effort is needed since there appears to be no way to correlate the results of the MTR resource areas to non-MTR (contour only) areas. The areas that do not contain MTR sites are topographically and structurally different than those that do contain MTR sites. For example, the topography may be less steep, the hollows may be less deep, the drainage patterns may be different, and the coal may have greater or lessor dip. Analysis of these areas and comparison of the results to the MTR resource areas would prove useful to the economic and ecologic impact estimations.

To complete this effort, RTC will use outcrop maps and WNEDs to estimate virgin coal amenable to 12:1 contour (surface coal) and mining. The coal will be depleted by 1) polygons of mining activity and 2) regional depletion algorithms(same as currently used on MTR resource areas). Fill polygons will be constructed for surface contour operations. The model will be used to analyze the loss of resources related to increasing fill restrictions related to constrained drainage basin sizes. The model will identify potential non-mountaintop "mineable" coal resources as follows:

- Contour Mining: minimum 12 inch thickness, 80% recovery, maximum 12:1 overburden/coal ratio (bcy/recoverable tons), maximum above seam slope of 33 degrees (no stable backfill possible), and a minimum recoverable clean tons for operation of 500,000.

- Highwall Mining: on selected stable contour benches wider than 120 feet, minimum of 42 inch thickness, 33% recovery, and a minimum recoverable clean tons for operation of 250,000.

- Conventional Auger: on selected stable contour benches averaging 120 feet, minimum 24 inch thickness, 33% recovery, and a minimum recoverable clean tons for operation of 100,000.

- Underground Mining: an in-place reserve block exceeding 3,000,000 tons (main seam), minimum 36 inch thickness, 40-60% mining recovery, 35% prep loss, and a minimum recoverable clean tons for operation of 750,000, multiple seams at least 100 vertical feet separation. The deep tonnage estimates are seen as “residual” to the MTM Contour, and Highwall, and Auger coal estimates.

Issue #4: **Capture surface mineable coal <u>below</u> the “base seam” of the MTR resource areas.** As discussed by the committee, it would be useful to identify additional tons, acres, and fill for coal which was not captured by the MTR exploitation. This effort would assume “maximization” of fill space utilization at each MTR site. Coal would be added to potential production to the extent the fill could handle overburden (spoil) generated by exploiting additional coal. Coal would be added to the remaining production as coal is sterilized through the scenarios as by using outcrop maps and DEMS to estimate virgin coal amenable to 12:1 mining. The coal tonnage would be depleted as follows by: 1) assessing polygons of mining activity and 2) by the regional depletion algorithms(same as currently used on MTR resource areas). The model will be used to “integrate” the below-base seam coal into each scenario.

Issue #5: **Capture surface mineable coal which could be alternatively mined at the MTR resource areas if MTR is no longer amenable as an extraction technique.** The preliminary modeling and data production for this has been completed under the existing contract. The model will inventory alternative potential production from coal removed from the inventory of potential mountain sites by the regulatory scenarios as follows:

- Contour Mining: minimum 12 inch thickness, 80% recovery, maximum 12:1 overburden/coal ratio (bcy/recoverable tons), maximum above seam slope of 33 degrees (no stable backfill possible), and a minimum recoverable clean tons for operation of 500,000.

- Highwall Mining: on selected stable contour benches wider than 120 feet, minimum of 42 inch thickness, 33% recovery, and a minimum recoverable clean tons for operation of 250,000.

- Conventional Auger: on selected stable contour benches averaging 120 feet, minimum 24 inch thickness, 33% recovery, and a minimum recoverable clean tons for operation of 100,000.

- Underground Mining: an in-place reserve block exceeding 3,000,000 tons (main seam), minimum 36 inch thickness, 40-60% mining recovery, 35% prep loss, and a minimum recoverable clean tons for operation of 750,000, multiple seams at least 100 vertical feet separation.

Issue #6: **Apply West Virginia results to Eastern Kentucky and northwestern Virginia coal fields.** Two options are available:

- Apply some statistical or geostatistical measure to estimate Kentucky and Virginia from West Virginia research.

- Map Kentucky and Virginia Coal fields and apply the same modeling procedure used in West Virginia to the Kentucky and Virginia situation.

Concerning the first option: A statistical measure based on tons per acre, fills per basin, fills per ton, topographic province, drainage basin characteristics, (average slopes, streams per square mile, etc.) or other characteristic(s) may be useful and efficient to compare/correlate West Virginia results to the other states.

The WVU, Hill and Assoc. and RTC team strongly believes that mapping the KY and VA resources could prove expensive and time consuming. The technical team is therefore proposing instead, that topographic, hydrologic, structural, geomorphologic, and/or coal geology correlations (between regions of West Virginia and similar regions in the adjoining states) be used to estimate the effects of drainage basis restrictions on coal production in these states. This will allow the modeling to take advantage of the extensive research completed in West Virginia and maintain some control of budget and schedule. The project team will use all available information to analyze and compare regions and subregions in West Virginia to find correlations between regional topography, regulatory changes and changes in predicted coal production. These correlations will be used to predict similar changes in similar provinces in Kentucky and Virginia.

Concerning the second option, OSMRE now has available incomplete KYGS Geologic data concerning specific eastern seams. The data is for five primary eastern Kentucky coal seams. In a two phase process:

1) RTC can examine this data to determine compatibility with the model. The data will also be examined to determine the depth of coverage and the ultimate utility to the model process. To estimate the total tonnage of coal available and to select sites by cumulative stripping ratio criteria, RTC will be required to estimate the depth and thickness of the "less important" seams as they relate to the mapped primary seams. Stratigraphic interval and thickness will have to be estimated from available information. (Much of the effort required to construct the West Virginia coal GIS data base was expended on the interval and thickness estimation from divergent sources of data. In the case of the West Virginia data, the EIS project has benefitted from this effort without contributing to its cost.)

2) If the data are compatible and useful, RTC can then estimate the time and cost necessary to process the model in a similar fashion to the procedures used in West Virginia.

An initial task would be a trial effort which may or may not result in a complete mapping/modeling effort.

OSM may be able to produce VA Geologic data concerning specific Virginia seams. Like the Kentucky situation, if this data is available, RTC will examine it to determine compatibility with the model. Like the Kentucky data, the Va data could also be examined to determine the depth of coverage and the ultimate utility to the model process. If the data is compatible and useful RTC can then estimate the time and cost necessary to process the model.

This second option is really a two phase effort in itself. The first phase of which could take 3 to 4 weeks. Following the initial study RTC would report to the Project manager concerning the usefulness of proceeding with the Kentucky and Virginia mapping effort and would propose a budget and time frame. This effort could prove expensive and long.

Recommendation concerning Issue# 6: Based on conversations and planning efforts involving the research team, option 1 (Issue #6 (a) is the option being proposed for this effort. The effort will involve team members from RTC, OSMRE, WVDEP, WVU, EPA, and Hill and Associates. RTC will act as host and moderator of the effort. RTC will produce a brief report covering the results of the investigation and the recommendations. Following acceptance of the report by the committee and project manager, RTC will implement the estimating procedures and provide the output by county and HUC region to Hill and Associates and WVU.

Based on recent discussions with OSM and WV DEP personnel, the following process[1] will be tested, presented to the panel and used as appropriate:

1) Empirical data will be collected as follows:

a) The volume of excess spoil generated per unit weight of coal surface mined can be calculated for West Virginia, Kentucky, and Virginia using existing fill inventories and related historic coal production by mine. This approach uses empirical data to compare the amount of excess spoil generated per ton of coal surface mined in sections or topographic/mining provinces of West Virginia to that mined in Kentucky and in Virginia. Surface mine production statistics are maintained by mine by the each state's Property and Severance Tax Departments and the Office of Surface Mining and Reclamation and Enforcement. OSM has developed an GIS inventory of "as-built" fill polygons. The GIS information includes the permit number for each fil polygon. The procedure will develop an empirical base to relate fill to coal by region and by state. The development of the "base" must also address the varying state requirements which were applied to the fill construction and mining process as well as the changing fill structure requirements over time. This data may also be used to estimate differences in economic stripping ratio.

b) General topographic information such as average slope, number of mountain peaks per unit area, number of streams per unit area, tons of surface mineable coal per unit area, etc. will be examined.

c) The GIS will be exercised to use this information to demarcate the "boundaries" of topographic/mining/fill regions.

[1] Paraphrased from efforts written by M. Robinson, OSM. and reviewed during December 5, 2001, 8:30 am phone conversation including: J. Kern, D.Van DeLinde, Paul Rothman, G.Blaylock, Dave Hartos, and Thomas Mastrorocco.

2) The quantity of spoil produced per unit area is related to the tonnage of coal produced per unit area. Unit are si related to the topography of overlying overburden. The quantity of coal relates to the aggregate volume of multiple coal seams likely to be recovered by surface mining methods. The amount of spoil returned to the mined area is affected by operational techniques and topography. Assuming similar operational techniques, the amount of spoil material returned to the mined area is greater in less steep areas than in steep areas. The excess spoil per unit area produced in West Virginia or sections of West Virginia will be compared to excess spoil per unit area ratio in Virginia and Kentucky (or multiple regions in Kentucky). The empirical fill data developed above will used to test and adjust these correlations.

Adjustments to the detailed analysis of production-reduction in West Virginia can then be made by applying a ratio of Kentucky/Virginia excess spoil per unit area numbers to West Virginia excess spoil per unit area numbers.

For example: If the excess spoil per unit number in West Virginia is 10,000 cubic yards per acre and 8,000 yards per acre in Kentucky, the production-reduction percentage in West Virginia is reduced by 80 percent in Kentucky. And so, if under the 150-acre limit scenario, the production-reduction is 26 percent in West Virginia, Kentucky's production-reduction number for the 150-acre scenario is 26 percent times 80 percent, which equals to 20.8 percent. These percentages will be adjusted based on the empirical information, particularly the fill inventory. The process may follow the following procedure:

1. For the MTM/VF polygons identified by RTC, calculate the affective average aggregate coal thickness (or volume or tonnage) per unit area under the unconstrained scenario.

2. For the MTM/VF study area in West Virginia, calculate the average slope. If warranted, in lieu of the entire West Virginia study area calculate the average slope for the MTM polygons and adjacent area.

3. The average slope calculated in step 2 represents the base slope. It will be assumed that the ratio of bulked spoil returned versus bulked spoil not returned used by RTC in West Virginia (i.e. the 65 / 35 ratio) depends on base slope. Adjustments to this ratio based on lesser or greater slopes, if warranted will be applied to Kentucky (or regions in Kentucky) using a similar method. Mining experts should be consulted to determine what constitutes a reasonable adjustment.

4. Based on OSM's review of AOC and excess spoil placement in Virginia, a combination of topography and on-bench storage allows 85 percent of the bulked spoil material to returned on the mine site or existing benches. And so, in lieu of doing a detailed slope analysis, an 85/15 ratio should be used.

5. Using KYGS and VPI, information, the average aggregate thickness of coal (coal volume or tonnage) per unit area will be calculated for cumulative MTM polygons in Kentucky and Virginia. In the case of Kentucky, the average aggregate thickness can be done regionally if slope regions are identified.

Summary of Data Sources

Coal Data (Issue #1)

Seamless, statewide GIS coverages for each named seam in the state have been developed by RTC under contract with the State of West Virginia, Department of Tax and Revenue. Seamless digital GIS coverage means the coal is mapped in a single projection as a continuous layer, regardless of political boundaries.

Sixty-one named seams are maintained, the thirty-one seams in southern West Virginia available for mountain top removal mining are used in this study. Statewide seam name correlations were developed using the West Virginia Geologic Survey (Blake) revised stratigraphic nomenclature. Each seam is portrayed by four statewide seamless 30-meter grid coverages: elevation, thickness, sulfur and BTU. Relating the coal elevation coverages with statewide NED coverages creates overburden and outcrop grids. More than 300,000 data points are used to develop the coal grid coverages. These coverages are updated annually. Updates include new data collected by the Department of Tax and revue from tax returns and tax appeals and geologic map revisions produced by the West Virginia Geologic and Economic Survey. Permission for the use of these data for the purpose of conducting this study was obtained from the West Virginia Department of Tax and Revenue.

Sources for the data points include:

- United States Geological Survey
- West Virginia Geologic and Economic Survey Coal Elevation and Outcrop Quadrangle Maps
- West Virginia Mine Map Index
- County geologic reports
- Coal mine permit documents (West Virginia Department of Environmental Protection)
- Coal property owner and coal mine operator annual tax returns including drill core logs, geologic maps, and mine plans
- U.S. Department of Energy, Energy Information Agency reports identifying coal sources
- Other public and private data sources

Average resolution of the coal occurrence data points is five miles. Data can be significantly denser for some seams in some regions and less dense for other seams in other areas of the state. Specific elevation attributes are included in approximately 24,000 of the points. Elevation is inferred from another 40,000 ± points (i.e., surface mine locations, drift mine entries, 1/9 quad sampling from WVGES structure/contour geological maps).

The elevation points were used to interpolate the statewide elevation grid for each individual coal seam. Limits or bounds of the interpolation were developed for each seam by known mapped features such as the Eastern Front of coal occurrence. The elevations of seams represented with only sparse data were developed from known intervals with underlying and overlying seams with dense data points: reference datum seams. Nearest neighbor and inverse distance weighting were used to develop the grid coverages within the interpolation bounds.

Subtracting the coal elevation from the surface NED grid created coal occurrence and overburden grids. Negative cells (cells where the interpolated coal is above the surface elevation) are converted to null value. The result is a series of grids showing the outcrop pattern of the coal along the basic topographic patterns of the state. The coal occurrence is used to remove interpolated data cells from the thickness and coal characteristic grids. In 1998, an initial series of seam occurrence, thickness, and quality maps were produced. Various geologists and coal operators familiar with coal operations throughout the state reviewed the maps. Interpolation bounds were modified and new data points were added based on these reviews. This data was used to revise the map output. The revised set of maps was subjected to public scrutiny by way of their use for tax assessment purposes. As a result, where appropriate, interpolation bounds have been modified and new data points have been added to again revise and correct the map output. This is an annual correction process and has been completed twice.

Surface Elevation Data

Elevation data for the entire Mountain Top/Valley Fill study area was purchased from the EROS Data Center. The National Elevation Data set is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection.

Drainage Basin Polygons (Issue #2)

RTC and the West Virginia University, Department of Agriculture and Resource Economics, using ArcInfo and the NED of the study area, developed various size drainage polygons. The drainage basin polygons represent the disturbed area due to mining within a watershed. Starting with the NED grid, a succession of ArcGrid functions were used to create grids that lead to the watershed polygons:

> *Flowdirection:* Creates a flow direction grid that represents which direction water would flow out of each NED cell.
>
> *Flowaccumulation:* Creates a grid that counts how many cells are 'upstream' of each cell using the Flowdirection grid. Each cell is assigned the value of the number of cells upstream.
>
> Convert to point coverage: Create a point coverage of cells from the Flowaccumulation grid that has the value within the size range of the watershed of interest. For example, to create the 150 acre drainage basins, if the cells of the NED were one square acre, then all the cells that have a Flowaccumulation value of 150 would be converted to a point. These points represent the outlet of a 150-acre watershed. For the MTR process a range of values had to be used because not every watershed had exactly the correct number of cells. A range of 100-200 acres was used for the 150-acre scenario.
>
> *Watershed:* Creates a watershed boundary polygon starting at the point coverage and draws the boundary based on the flow direction grid.

For example, the 150-acre drainage coverage created for the West Virginia Study Area contained 22,174 polygons varying in size from 99.96 acres to 199.96 acres with a mean of 141.17 acres. A portion of this coverage is shown in Figure 1. In Figure 1, the individual drainage basins are shown as they overlay the natural topography with red being a ridge top and blue being a streambed. As shown in the figure, the basins vary somewhat in size and define watersheds**.**

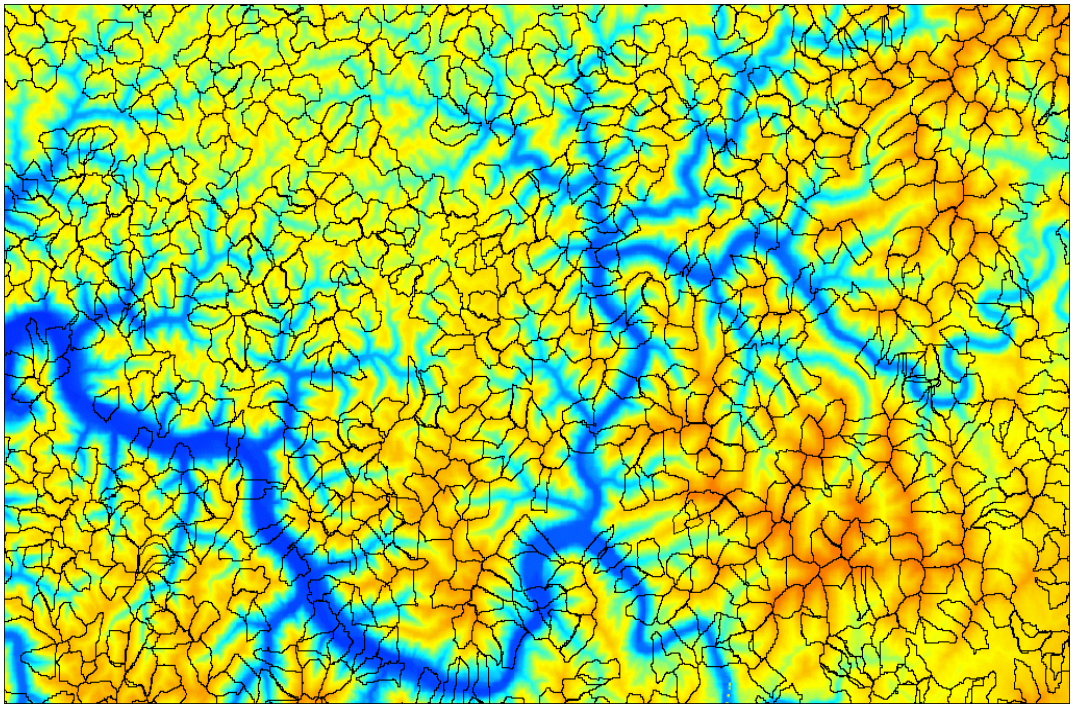

Figure 1: 150 acre disturbed area coverage over NED.

Summary of Procedures

<u>Mine Site Identification</u> (Issue #1)

To more efficiently allocate computer processing time, subsets of the statewide coal coverages were created. These subset grids (thickness and elevation for each seam at each potential mountain top mining site) included only coal that occurred above drainage.

Converting the grid extent of the coal into polygons created a set of outcrop polygons. A polygon represents the extent of each individual block of coal, as shown in Figure 2. The process resulted in the creation of more than 2232 irregular shaped polygons involving 31 seams in the MTR/VF section of the state. Polygons ranged in size from less than one acre to more than 30,000 acres. Polygons less than 5 acres were eliminated as too small to be included in the study.

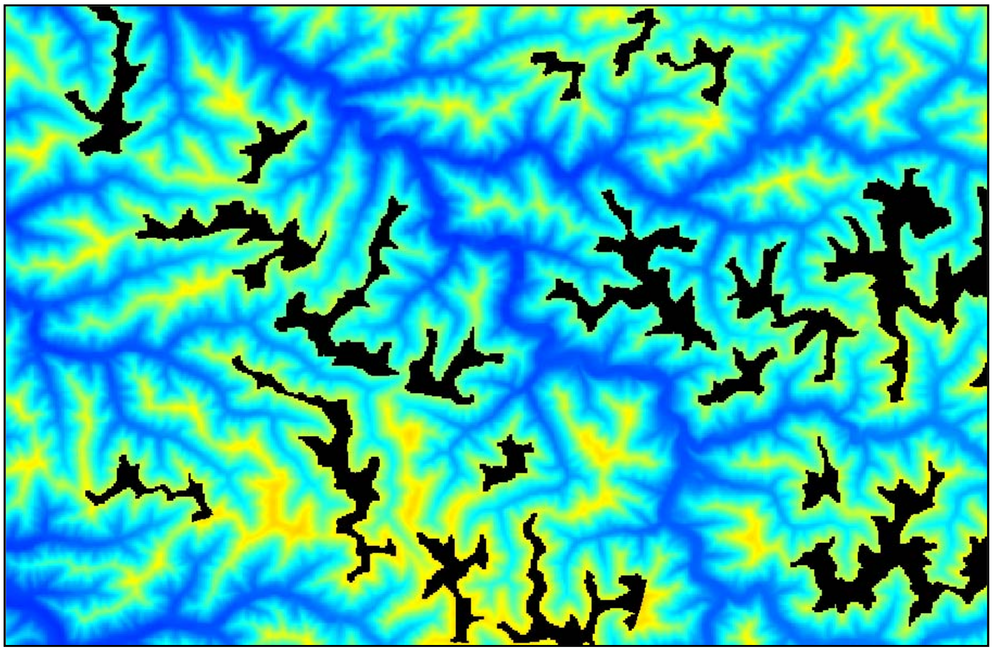

Figure 2: Coal Seam Polygons (Black)

Using the GIS, thickness grids and overburden grids for each seam were sampled by the polygons. Coal volume and overburden volume for each coal polygon were calculated. Coal volume was calculated from the thickness grids as cubic meter inches and converted to tons. Overburden volume was calculated as the total cubic meter feet of material overlying the top of the coal, excluding overlying coal volume, to the surface and converted to cubic yards. Because the overburden grids were developed from the NED and the elevation maps, the shape of the mine site was taken into account.

Concentric polygons were identified, as shown in Figure 3. Each polygon represents an individual seam at a higher elevation at a multi seam location. Before any environmental or further economic considerations were applied, a total of 647 polygon sets were created. The number of seams in each set varied from one to 7. The polygons and related data for each concentric set were stacked in order of elevation with lowest being the bottom of the stack. Two checks were completed at this point: 1) were the seams in stratigraphic sequence, and 2) did the size of the polygon decrease with elevation (as the higher seams were identified up the mountain). The lowest seam polygon was designated as the site identifier. Concentric seams were identified by the base seam and a sequence number suffix.

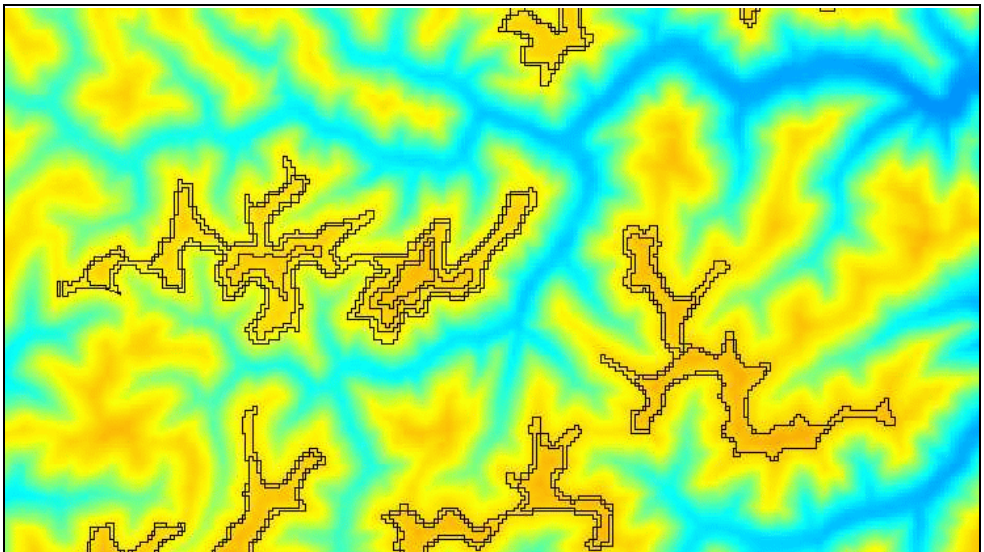

Figure 3: Concentric Coal Outcrop Polygons

Cumulative overburden was calculated for each coal polygon in each set. The calculations were developed from the highest seam to the lowest seam in each set. Cumulative and individual stripping ratios were calculated from the same data sets. A stripping ratio is calculated by dividing cubic yards of overburden by tons of recoverable coal. Recoverable coal is calculated at 70% of in-place coal. Thus, a data set was created for each mountain top area. An example of the calculations is shown in Table 1.

Table 1: Example of Calculations of Coal Tons and Stripping Ratios

Seam	Area (ac)	Elev. (ft)	Thick. (in)	Tons	Cumulative Tons	Cumulative Overburden	Stripping Ratio
Surface		1,675					
Seam 6	250	1,560	36	945,000	945,000	45,173,000	48 :1
Seam 5	400	1525	24	1,008,000	1,953,000	66,469,000	34 :1
Seam 4	1200	1500	20	2,520,000	4,473,000	111,642,000	25 :1
Seam 3	1500	1450	52	8,190,000	12,663,000	222,155,000	18 :1
Seam 2	1700	1400	68	12,138,000	24,801,000	343,747,000	14 :1
Seam 1	2000	1300	30	6,300,000	31,101,000	658,347,000	21 :1

*All data used on this table is for illustrative purposes only

This table demonstrates the concept of 'Best in Stack.' Notice how the stripping ratio, it is a cumulative stripping ratio, changes as more seams are added to the mountain top mine. The Seam 1 has a stripping ration of 21:1 while the next seam up has a stripping ration of 14:1. Using Seam 1 as the base seam would fail this site because the stripping ratio is too high. For this reason the Seam 2 is used as the base seam; it has enough tons of coal and it has an acceptable stripping ratio.

The GIS model was used to identify sets that could technically support mountain top removal coal mining operations. The selection of sites was based on the following assumptions:

- A site must encompass a minimum of 600,000 short tons of recoverable clean coal from a recovery rate of 70%. No maximum limit was set.
- The delineated site must have a stripping ratio (cubic yards of overburden/interburden spoil to tons of recoverable coal) below:
  - Statewide: 15:1
  - McDowell, Raleigh, and Wyoming Counties: 20:1

- All identified coal blocks are above the mean regional base drainage level.
- All identified base seam coal exceeds 12 inches in thickness.
- All sites must contain at least two seams.
- Coal located within incorporated towns is not considered as mineable.
- Polygons representing mining since 1981 removed from mineable coal.
- After identification of potential sites, the calculated tonnage of mineable coal is depleted via a 100-year historic production by seam. This reduction for previous "un-locatable" mining is allocated by county, prorated by the proportion of acres of the seam contained in the site to the acres of the same seam in the county. The mined tonnage is doubled to account for sterilization and under-reporting.
- Counties are used as units to accumulate coal and basin statistics.

Mountain top areas satisfying the above criteria were selected. A total of 510 mountain top area polygon stacks were identified (Figure 4). The polygons representing the model mountain top areas were compared to the location of existing or pending mountain top mines. Model polygons captured or surrounded more than 90% of the identified existing permitted mountain top mines.

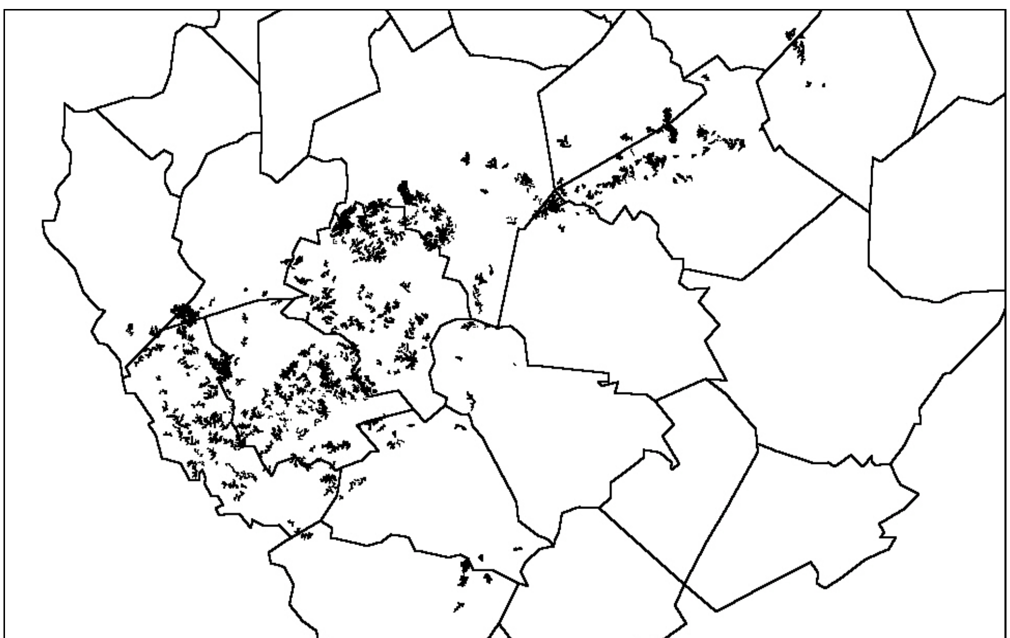

Figure 4: Mine sites in the Mountain Top Area

Valley Fills (Issue #2)

The valley fills are an integral part of the MTR process. The above steps were used to identify possible MTR sites based on technical mine selection criteria (an unconstrained environmental scenario). The valley fill analysis introduces environmental constraints on the site selection process. Four scenarios were analyzed: 250 acre disturbed areas, 150 acre disturbed areas, 75 acre disturbed areas, and 35 acre disturbed areas. The disturbed area encompasses both the mine and the fill area. A MTR site passes when there is enough volume available in the potential fill sites surrounding a mine site to accommodate the excess spoil generated from the mining operation per scenario. Excess spoil is the spoil that is not back filled on the mine site. To calculate excess fill the original overburden is expanded by 25% to represent swell. Sixty-five percent of the swollen spoil is back filled and 35% needs to be deposited in valley-fills. The process used to find the available volume in the fills surrounding a mine site is described below.

A buffer of 3,000 feet was constructed around the base polygon. This buffer represents a limitation on fill haulage distance. Adjacent 250, 150, 75, and 35 acre disturbed area polygons (produced by the process described above) were selected for each mountain top buffer area. To be selected the polygons had to touch the mountain top area.

The GIS was used to split-off those portions of the drainage polygons outside of the 3,000 foot buffers, portions overlapping the mountain top mine polygon, and portions across major highways. Polygons containing incorporated towns, federal and state parks, schools and cemeteries were eliminated from the data set as well.

Each fill was assigned an elevation of the associated base seam plus 50 feet. This elevation was used to replicate the back stacking of fill over the mined out area. The GIS was used to calculate the volume of fill space available between the land surface and the elevation of the polygon. In addition, the length, height, lowest elevation, and the slope of the ground surface were obtained for each fill polygon. The volume of each polygon was modified to account for the 27-degree slope of the fill toe (Figure 5).

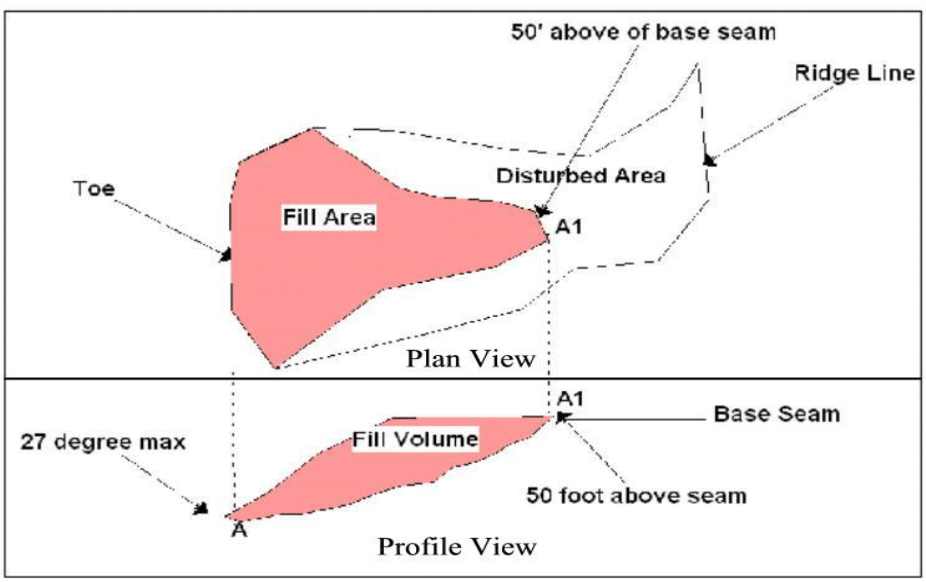

Figure 5: Fill Geometry

The volume in the fills surrounding a mine site was summed to produce the total spoil accommodation space for the mine. This value was compared to the estimate of valley fill to be generated by exploiting the coal. If the available fill space (volume in cubic yards available in valleys to receive fill) exceeded the valley fill to be generated by the potential mine, the site was identified as capable of supporting mountain top removal operation. If the site failed, the database for the mountain top area was reprocessed using the next higher seam as a base, enlarging the available fill spaces, raising the fill elevation (and thus the available volume), and decreasing the quantity of coal and fill to be stored. In most cases, retreating to the next higher seam was not an option, since the only way to obtain a suitable overall stripping ratio was usually to include the basal coal seam. This process was completed for each mine site at each scenario.

Figure 6 shows a MTR/VF mining site. The dark grey area within the red lines represents the entire area of potential mining activity. The dotted purple polygons represent potential fill areas selected to meet the 250-acreage limitation. (Note that not ALL potential or available fill space is required to satisfy the excess spoil demands.)

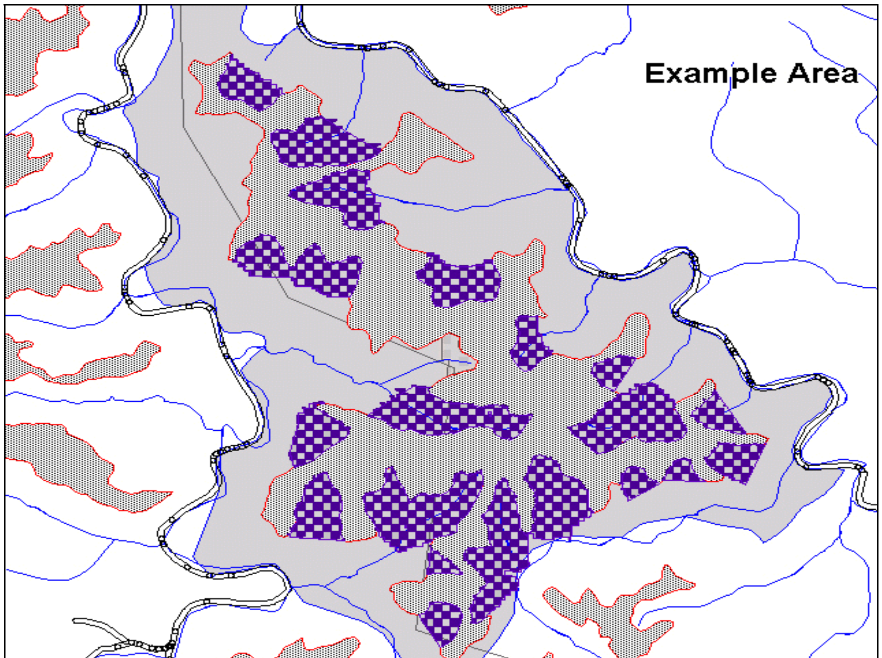

Figure 6: A mining area with fills

Table 2 summarizes the change in relative fill space availability as the drainage basin limitations become more restrictive. Figure 7 displays the mine site and the 21 fill sites.

Table 2: Summary of changes in fills space availability as shown in the Example Site**.**

Fill Site # (clockwise from top in Figure 6)	Maximum Fill area in acres per scenario			
	250	150	75	35
1	62	62	26	13
2	118	118	59	28
3	102	102	41	19
4	97	97	38	17
5	44	44	13	8
6	30	30	6	6
7	150	150	75	35
8	38	38	10	8
9	51	51	17	11

Fill Site # (clockwise from top in Figure 6)	Maximum Fill area in acres per scenario			
	250	150	75	35
10	18	18	2	2
11	24	24	4	4
12	123	123	52	24
13	132	132	56	26
14	41	41	11	8
15	17	17	2	2
16	122	122	46	21
17	84	84	38	18
18	71	71	33	16
19	121	121	46	21
20	71	71	33	16
21	133	133	58	27
Total	1,899	1,799	741	365
Average	86	82	34	17

Figure 7: Change in fills between scenarios

Table 2 and Figure 7 show that as the drainage basin limitation becomes more severe, the available fill space is constrained. In the 250-acre scenario, there are 21 potential fill sites available. These sites offer nearly 1,900 acres of potential fill area. In this scenario, the largest site can provide approximately 150 acres of fill space; the smallest potential fill site has 18 acres of space. The 35-acre scenario, in contrast, still shows 21 potential fill sites, however, they provide only 365 acres of potential fill space, with the largest at 35 acres and the smallest at two acres.

The following images (Figures 8 - 11) show another mountain top removal possibility. In this case, where the fills are drawn to scale the number of fill sites changes as the environmental scenario changes. In the more severe cases there are more fill sites available, but less total volume. At the 250 acre scenario, one large fill my encompass two or three hallows, while at the 35 acre scenario each hollow will have a separate fill.

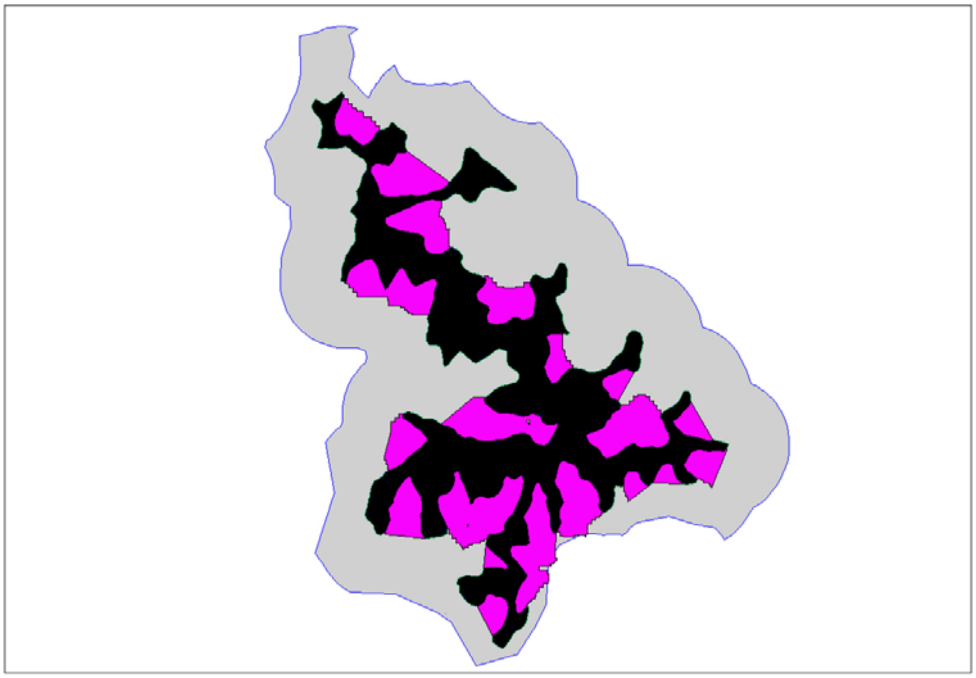

Figure 8: 250 acre scenario with 21 possible fill sites.

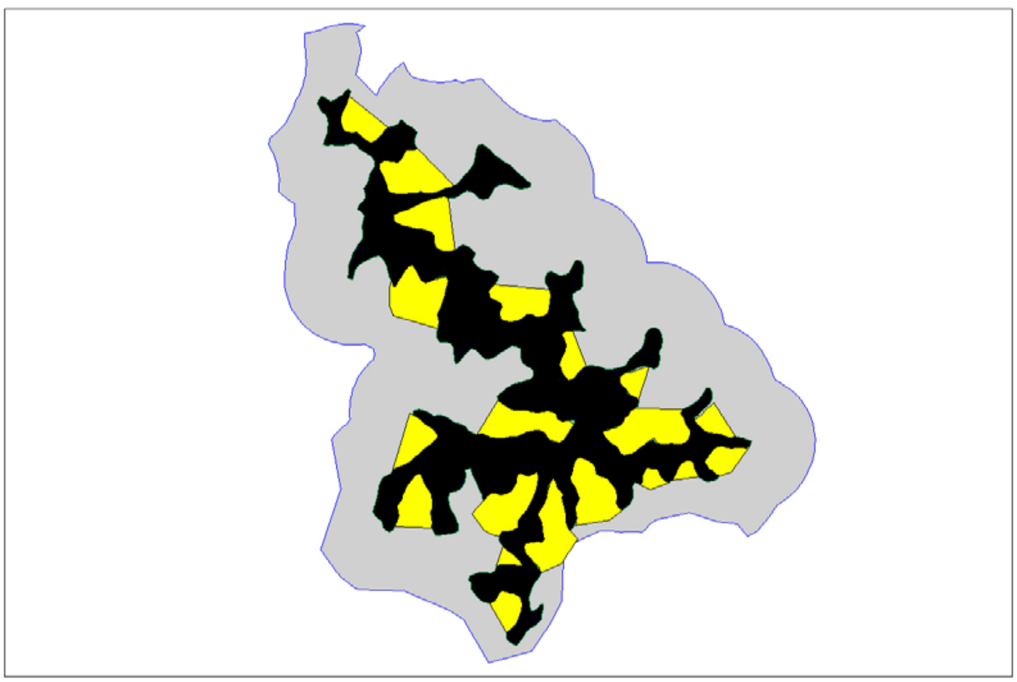

Figure 9: 150 acre scenario with 21 possible fill sites.

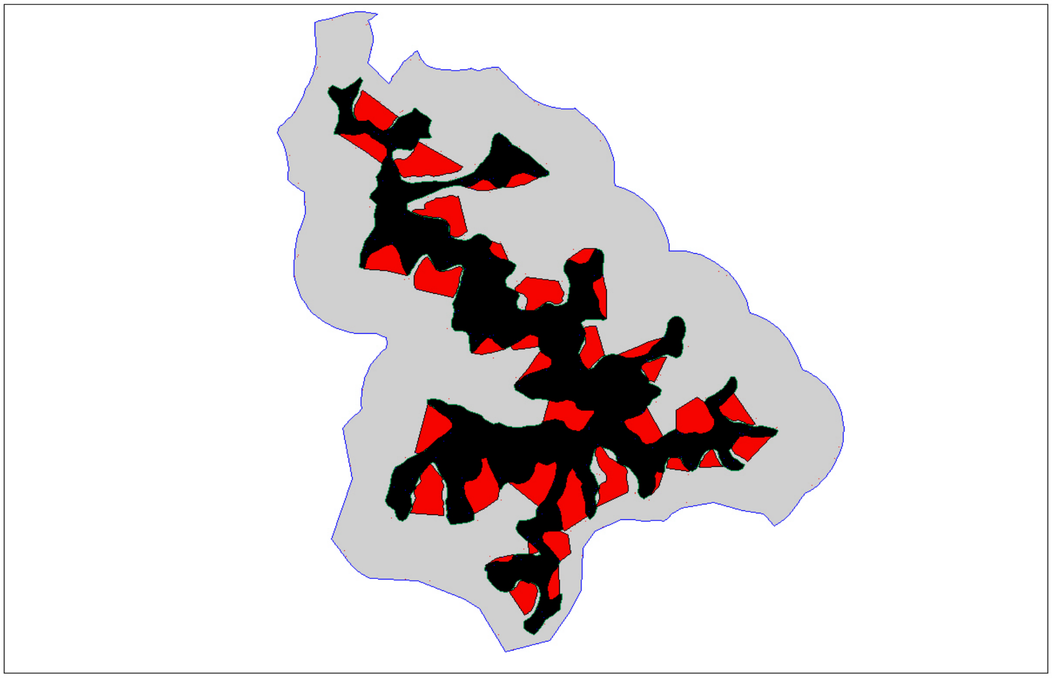

Figure 10: 75 acre scenario with 37 possible fill sites.

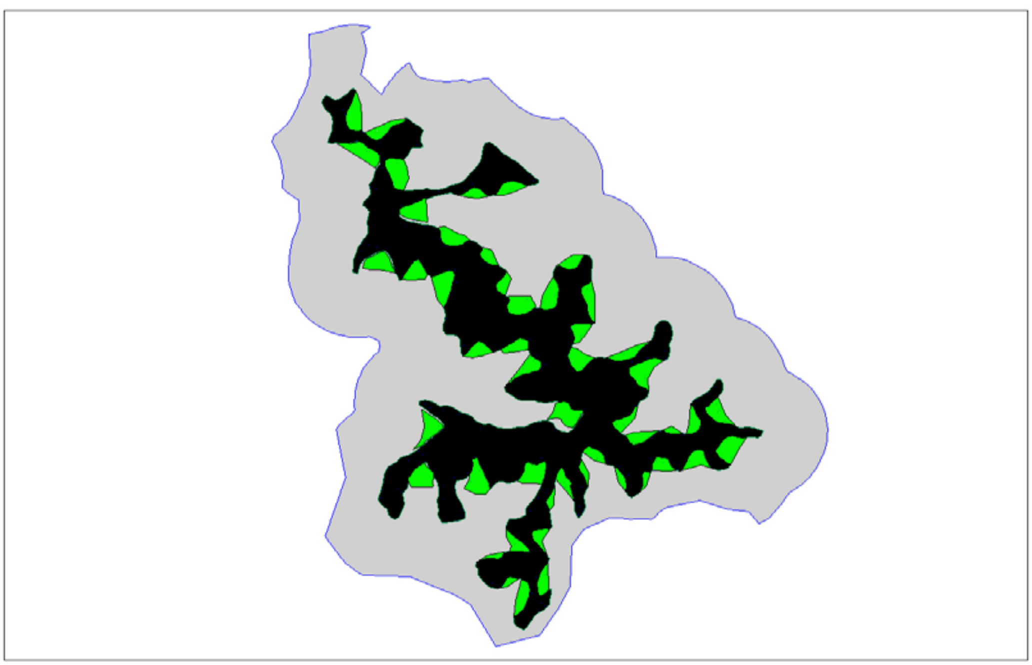

Figure 11: 35 acre scenario with 49 possible fill sites.

Summary of Results

The quantity of available fill volume is calculated for all potential mountain top mining areas identified in West Virginia. Available fill volume is used to determine the viability of each selected mining operation, i.e., if there is sufficient space to receive the valley fill generated by the model mine then the tonnage of coal available at the site is counted in the regional totals. This calculation is made for each selected mountain top mining area for each scenario. The procedure provides an estimate of coal obtainable at each mountain top mining site and thus the entire state. Previous production and current permitted production was subtracted from the coal available from each seam after the calculation of stripping ratios. There are no existing digital maps to accurately deplete all historic coal resources at specific sites before 1981. Therefore, the stripping ratios were calculated based on estimated tonnages of virgin coal. Tonnages for each seam were reduced for final reporting by depleting a prorated share of all known historic production within the municipal district and all existing permitted production by specific site through 1999.

As shown below in Figure 12 and Table 3, the addition of drainage basin size limitations for land disturbance significantly affects the total quantity of coal which may potentially be produced by mountain top removal operations.

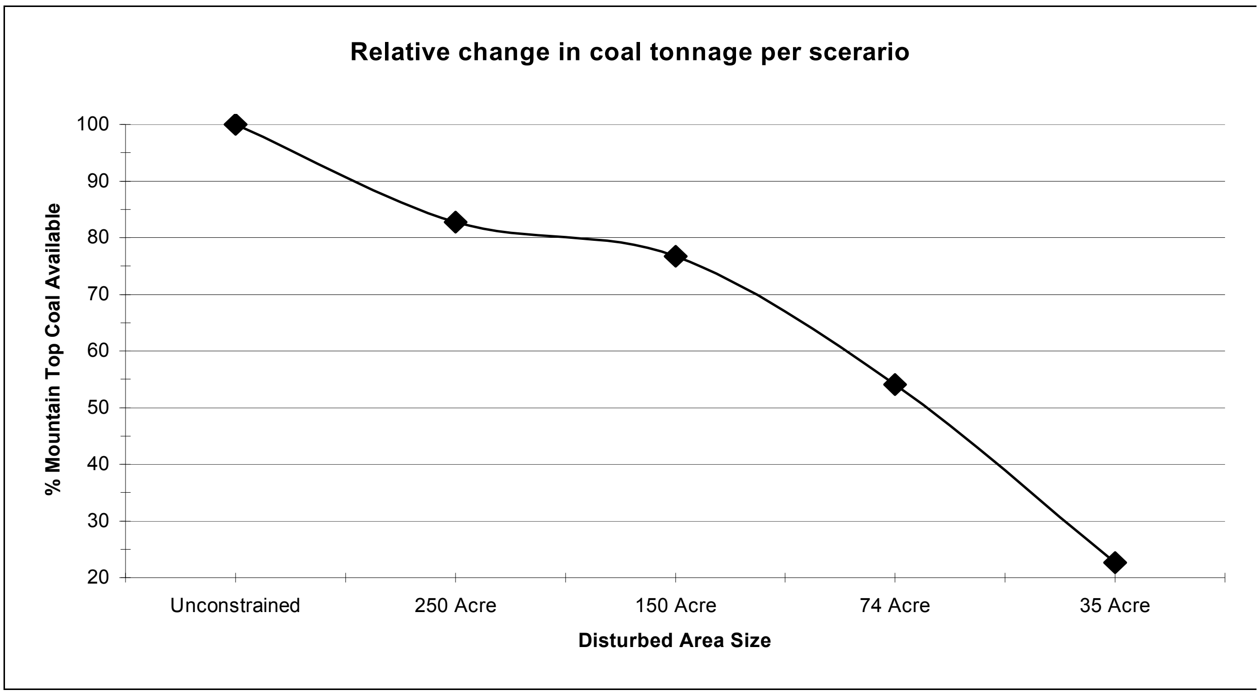

Figure 12: Potential Coal Available

Table 3: Overview of Effect of Basin Constraint					
	Unconstrained	**250 Acre**	**150 Acre**	**75 Acre**	**35 Acre**
Total Tons	1,111,223,494	919,512,131	852,829,517	600,324,203	252,053,489
% Change from Unconstrained		-17.25%	-23.25%	-45.98%	-77.32%

As shown above, imposing size limitations even at 250-acre drainage basin size reduces available coal by nearly 20%. Potential tonnage is further reduced at the 75-acre drainage basin limitation.

This is because a significant portion of a 75-acre drainage basin is included in the mine itself and thus is not available for fill. In addition, as the fill space size is reduced (the potential fill site is moved up the valley toward the mine site), the height of the toe is reduced. The space available is shallower and no longer capable of storing large quantities of fill. However, at the 75-acre level some new small hollows with some capacity for fill are now available. These hollows were the lateral sides of the larger fill area developed for the 150 and 250-acre scenarios.

As shown in Table 3, available tonnage is severely limited at the 35-acre level. More significantly than in the 75-acre scenario. A large portion of a 35-acre drainage basin is included within the mine itself and thus is not available for fill. In addition, the remaining space available tends to be very shallow and not capable of storing significant quantities of fill.

It must be emphasized that the GIS model includes all available fill sites, regardless of ownership or other environmental and cultural conflicts. Many of the sites would not necessarily be chosen in the real world mine planning process. This factor tends to create an overestimation of the sites and thus the tonnage available. It is thought that this factor becomes more significant as the drainage basin constraint is made more severe. In the 35-acre case, nearly all available space is being used to sustain the residual production. In the 250 and 150-acre scenarios, less than 10% of the available space is actually used for valley fill.

The Office of Surface Mining Reclamation and Enforcement (OSMRE) commissioned a study with selected mine operators to assess the impact of drainage basin limitations on potential coal production at specific mine sites. This effort resulted in similar predictions of coal loss at the all restriction levels. Although the results were similar there are some distinct differences between the methods:

- The GIS model selects all possible sites to deposit fill. Some of these sites may be inappropriate for numerous reasons unidentified in the GIS database. These fill sites may not have been selected during the empirical study. In the large drainage basin scenarios, there is generally enough excess fill capacity available in numerous sites that differences in selection criteria are not a factor. At the smaller drainage basin level, additional fill sites identified through the GIS (and discounted in the empirical study) may offer enough space to satisfy the fill requirements.

- The GIS uses all potential fill sites, regardless of size. Numerous small fill sites may divide enough available space to keep marginal mine sites in the study.

- The GIS treats all potential fill sites equally, regardless of distance from the actual spoil production. The GIS criterion is that the fill sites are within 3,000 feet of the mine site. The GIS mine site may be thousands of acres; fill generation may actually occur significantly further than 3,000 feet from the GIS fill site. In the empirical study, the mine sites are most likely smaller subsets of the GIS mountain top mine areas. As a result, the empirical study mine sites may not be contiguous or have large enough fill sites to be feasible. This factor can only be exacerbated at the 35-acre basin level.

- The empirical study can be seen as starting from the same topographic and coal base as the GIS study. Because the study is based on real world conditions such as land ownership, mine planning requirements, coal transport requirements, etc., the empirical study can only add constraints to the selection and percent use constraints. The empirical study by definition cannot add potential fill sites to the selection process. Because the GIS study is based on decreasing the size of fills to fit into drainage basin constructs, the addition of criteria can only exacerbate the coal loss.

These factors do not invalidate the GIS study. The portion of the study was designed to examine the statewide effect of fill space limitations on the quantity of coal available for mining. The GIS study was not designed to provide site specific mine planning. Site-specific mine planning will always reduce the results of a GIS study of this scope. The GIS study does provide solid evidence concerning the trend of coal reduction resulting from the environmental limitation.

A data file, by potential mountain top site, listing: tons, sulfur, volatility and Btu by seam and county name was provided to Hill and Associates for econometric modeling purposes and is included in the Appendix I. Each polygon is a separate record in the data file. The sites are located in 14 counties and involve 31 different named coal seams. Gannet Flemming, another contractor to the EPA on the MTR/VF project received map layers of each scenario for their analysis. Their analysis relies on the amount of area that is disturbed by the MTR process. Mine site, fill site and alternative mining (discussed below) polygons were included.

Fill Site Optimization (Issue #2)

After an examination of the results, it was observed that for most passing MTR sites there was an overabundance of fill volume: more fill space than spoil. Another section of the Environmetnal Impact Statement for MTR/VF relies on the map footprints of the mine sites and fills. An overabundance of fill sites would lead to a larger disturbed area than necessary. For this reason RTC used two separate methods to optimize the fill space (Table 4). The first method used the biggest fills first. The second method placed fill in the head of each fill and moved out until the excess spoil was accommodated. Polygons for these two scenarios were delivered to Gannet Flemming for use in their analysis.

<u>Biggest to Smallest</u>

The biggest to smallest method utilizes the fills with the largest volume capacity first until all spoil is accommodated. This scenario simulated dumping spoil into the biggest fills around a mine site until all of the spoil is deposited. This means some of the smaller fills around the mine site were not used if they were not needed.

<u>Use a Little of each Fill</u>

The many little fills method places spoil in each available fill, moving concentrically outward until all spoil is accommodated. In this scenario spoil was deposited equally in each fill around the mine site. This simulates placing a spoil in the headwaters of each fill.

Table 4: Fill Optimization Results

	Original Fill Acres	Biggest to Smallest Acres	Many Little Acres

35 Acre Scenario	43,270	15,076	27,013
75 Acre Scenario	105,862	38,693	60,173
150 Acre Scenario	187,882	64,291	86,434
250 Acre Scenario	247,764	74,111	103,749

Notice that both methods lead to a much smaller disturbed area than using all possible fills. Surprisingly, the biggest to smallest method is considerably smaller than the many little acres. This is because the many little acre method used fill space near the mine site where there is little volume. The biggest to smallest method used the entire original fill, so it went further out into the valley for more volume.

Alternative Mining Sources (Issue #3, Issue #4, Issue #5)

The entire mountain top region was analyzed with respect to strip mining, auger mining and deep mining. These types of mining augment the total amount of coal that can be mined in each mountain top scenario. When a mountain top mine fails, alternative mining sources are implemented. The tonnage for each type of alternative mining changes with each scenario because the alternative mining methods are implemented in areas where a mountain top site cannot be used. For example, there is more coal mined with alternative methods in the 35-acre scenario than in the 250-acre scenario. This is because alterative mining methods were used at MTR sites that were included in the 250 acres scenario but failed in the 35-acre scenario.

<u>Strip Mining</u>

The GIS was used to identify possible strip (contour) mining locations throughout the entire state for the 31 coal seams investigated. Criteria included 12 inch coal thickness, a 12:1 stripping ratio, maximum surface slope of 33 degrees, 80% recovery and 500,000 in-place tons. After discussions with the steering committee's coal industry representative, Barry Doss, strip mine sites within 200 feet horizontally and 100 feet vertically were combined. This leads to more sites reaching the 500,000 ton criteria. The result is 'snakes' around mountain sides (Figure 13).

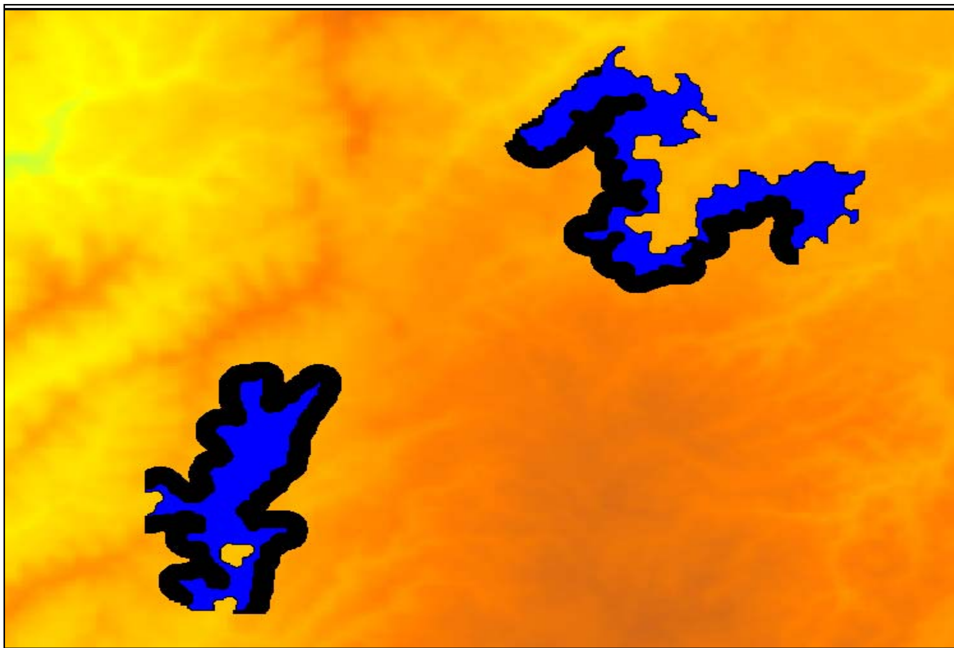

Figure 13: Strip (Blue) and Auger (Black) Mining

Auger Mining

Auger mining was analyzed everywhere where a viable strip operation was identified (the strip mine is used as the bench for the auger mining). Highwall mining and conventional auger mining was combined into one step as per discussions with Barry Doss. To mimic auger mining the GIS was used to calculate the tonnage of coal 600 feet into the mountain at a 35% recovery rate. The site had to have at least 250 ,000 clean recoverable tons and be 24 inches thick (Figure 13).

Deep Mining

The GIS also was used to simulate deep mining the entire state (Figure 14). A deep mine site had be below 200 feet of overburden, above the regional groundwater table, have coal at least 36 inches thick, and 750,000 clean tons at a recovery rate of 40% and prep loss at 35%. Previous deep mining polygons from the OSMRE were removed for the possible identified deep mines. Seams had to have 100 ft of interburden between them to be mined. For example, if seam 1 was 75 feet above seam 2 and seam 2 was 75 feet above seam 3, seams 1 and were mined, but seam 2 was not mined.

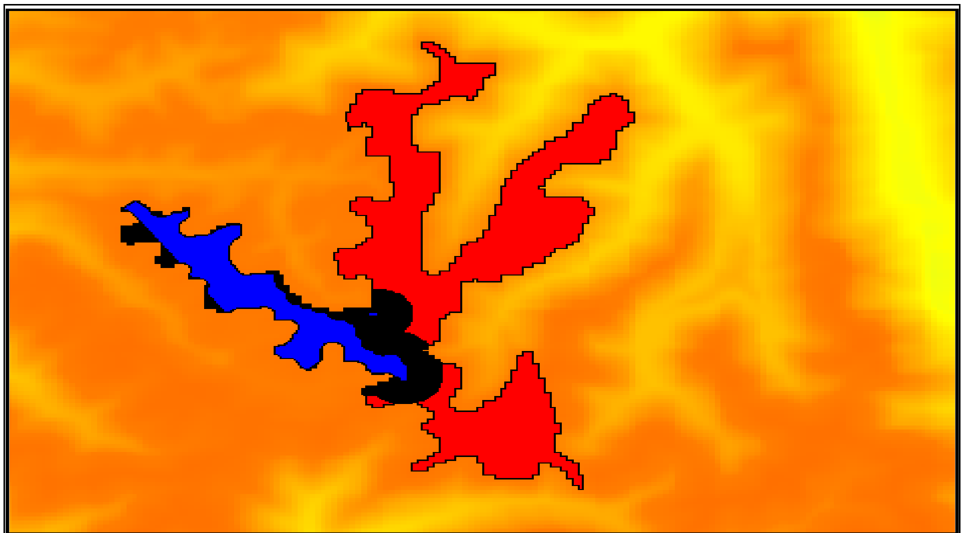

Figure 14: Deep mine (Red) with strip and auger mining

Figure 15 and Table 5 show the total tons available when using all mining types.

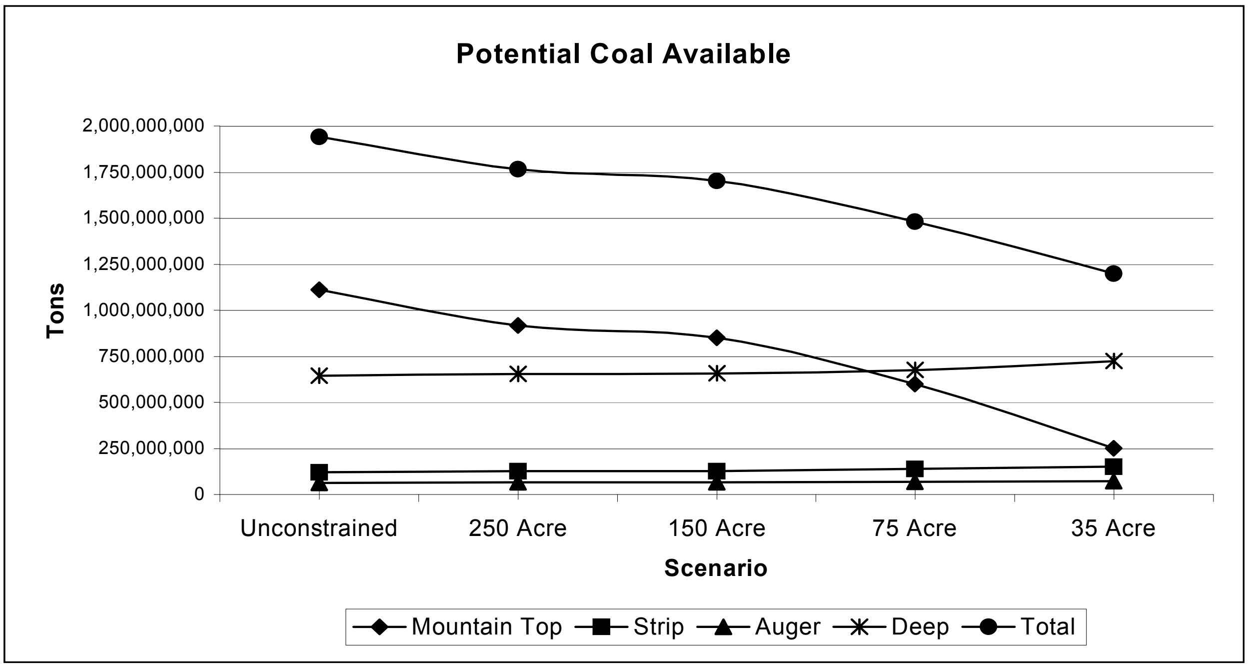

Figure 15: Tons per Mining Type

Table 5: Coal available (Tons)					
	Mountain Top	**Strip**	**Auger**	**Deep**	**Total**
Unconstrained	1,111,223,494	121,992,908	64,368,028	644,800,391	1,942,384,821
250 Acre	919,512,131	126,112,714	66,179,035	654,725,113	1,766,528,993
150 Acre	852,829,517	126,112,714	66,179,035	656,815,960	1,701,937,226
75 Acre	600,324,203	138,018,552	68,994,421	674,484,688	1,481,821,865
35 Acre	252,053,489	150,609,016	74,098,458	724,357,250	1,201,118,213

Correlation between West Virginia, Kentucky and Virginia (Issue #6)

The relative effects of the environmental restrictions on coal mining in West Virginia were applied to Kentucky and Virginia on a countywide basis. Because an extensive coal database was not available in Kentucky or Virginia the GIS analysis was not appropriate. Similar attributes had to be found between the counties of all three states to apply the results from West Virginia to the other two states. Attributes investigated included number of mountain tops, average slope of the topography, variance of slope, number of streams, and stream segment length. The reasoning behind this analysis is that counties with comparable features would have similar results with respect to MTR/VF environmental restrictions. For example, a county in Kentucky with the same number of mountain tops as a county in West Virginia may be expected to lose the same percentage of mineable coal between environmental scenarios.

To find the appropriate attribute to use as the link between the states, a correlation between the physical landscape of West Virginia and the MTR/VF results had to found. After many attempts to find an empirical relationship, the best relationship found that explains coal reduction between environmental scenarios is Landscape Slope Variance Coefficient. Landscape Slope Variance Coefficient represents the amount of change in the slope of the mountains per county. This factor had the highest positive correlation with respect to the MTR/VF scenario results. This implies that counties in Kentucky and Virginia with similar slope variance coefficients as counties in West Virginia would have the same relative changes in MTR/VF results as West Virginia.

Conclusions

As environmental constraints become more restrictive the amount of mountain top mining coal is severely limited. Strip, auger and deep mining can augment mountain top losses due to regulations, but only on a limited basis; the mountain top mining methods dominates the potential coal tonnage available in West Virginia. The results of the relative changes in mountain top mining in West Virginia due to regulations may be applied to Kentucky and Virginia on a countywide basis.

Appendix I: Results reported to Hill and Associates