Surface Mining Activity in Eight Southern West Virginia Watersheds

Technical Applications & Geographical Information Systems Unit
West Virginia Division of Environmental Protection

Introduction

This document relates the results of a study to determine the location and extent of surface mining operations for eight contiguous watersheds in Southern West Vriginia. The study involved manual interpretation of a variety of satellite images acquired in 1990, 1994, and 1998. Image data was supplemented by ancillary digital data that included mining permit boundaries, an abandoned mine lands database, and digital USGS topographic quadrangles. Criteria were developed to conclusively identify ground disturbances caused by surface mining operations. After creating a digital representation of mined areas, it was possible to estimate total area and miles of stream impacted for each watershed included in the study area.

Study Area

Eight watersheds of the Coal and Guyandotte Rivers in southern West Virginia were selected for study. The watersheds were selected following an analysis of mining permits submitted to WVDEP's Office of Mining & Reclamation. The analysis showed that three of the top five most heavily permitted watersheds formed a contiguous group. Five adjacent watersheds were later added to this core area.

The predominant landcover pattern in this area is Oak-Hickory forest over rugged terrain. Highway and railroad networks follow watercourses in narrow steep valleys, linking small dispersed communities elongated along the valley floors. Agriculture in this area is marginal, largely confined to small plots on the richer soil of river bottoms in the valleys. Surface mining typically occurs on the ridges above valley settlements, though there are exceptions to this rule. In studying this area there was little evidence of any significant ridgetop landuse other than mining, such as timber cutting.

Data Sources

SPOT panchromatic satellite images with 10 meter resolution were available for 1990 and 1994. The 1990 image completely covered three of the target watersheds. Landsat TM multispectral images, resampled to 25 meter resolution, were available for 1994 and 1998. Additionally, a fused Landsat and IRS product was available for 1998-99 for part of the study area. The temporal distribution of images permitted an analysis of mining expansion between 1990-94 and 1994-98 for three of the watersheds, and the latter period for the whole study area.

Ancillary data, in the form of mine boundaries, were available for some of the permits issued in the study area. An abandoned mine lands database, depicting features related to past mining that had not been adequately reclaimed, was also available. Finally, 7.5' digital topographic maps from the USGS, known as Digital Raster Graphics (DRGs), were occasionally used to improve spatial accuracy and verify contour mining.

After the mining polygons had been created, an analysis was conducted using watershed boundary and stream data. The analysis used the standard 11-digit watersheds created by the National Resource Conservation Service (NRCS). The stream data, used to estimate the total miles of streams directly affected by mining, was digitized from USGS 7.5' topographic maps. The coverage was created using Digital Line Graph (DLG) data created by the state GIS technical center at West Virginia University, supplemented with areas digitized from USGS DRG's by TAGIS. The original DLG data was modified by deleting one bank of streams that were depicted on the source map as having a distinct left and right bank. In addition, all lakes and impoundments were deleted, in order to estimate total stream miles in a watershed.

It is recognized that much disagreement exists over what constitutes a stream, particularly involving watercourses that are intermittent or ephemeral in character. This study does not claim to have used a definitive representation of streams, as none exists. However, the source (USGS maps) represents a common and well understood source of information about geographical features, and therefore provides the best context for interpreting the results of this analysis. Detailed mapping of stream extents, even within the area of this study, may represent an investment in time and resources that few agencies can approach, and still would not solve the academic debate.

Methods

The general landcover transition in surface mining is from full forest, to exposed rock and soil, to grass fields sometimes containing planted trees or bushes. Hypothetically, a site eventually may become overgrown with dense shrubs in an ongoing process of vegetative succession, though this process could not be verified from the imagery alone.

In addition to general landcover changes, surface mining often has characteristic patterns and features that distinguish it from other land uses. These patterns include narrow swaths that follow the contours of mountains (contour mining), and valley fills, in which overburden is placed in headwater stream valleys. Valley fills typically appear as a distinctive 'V' shaped feature, bisected by a rock ditch running down the center, with perpendicular terraces, or steps, at intervals from top to bottom. Mining activity also can be inferred from irregular clearings that are directly connected via haul roads to valley fills and other known mining sites.

In general it is possible to differentiate the basic landcover types using the panchromatic SPOT images using characteristics of texture and brightness. The SPOT scenes also could resolve features such as valley fills that could not be identified on Landsat images. The multispectral nature of Landsat scenes were valuable in instances where color could be used to determine landcover transitions that were indistinct on panchromatic scenes due to a lack of contrast, particularly in areas of deep shadow. The fused TM/IRS images were in some cases far superior in appearance, due to the five meter resolution of the IRS (gray scale) source. However, the product lacked the spectral resolution needed to resolve features on north facing ridges, which are common in this area. Some of the blame may be due to low sun angle because the image was captured during the winter. There also was apparently some snow cover in the TM scene, which complicated interpretation.

Two techniques for landcover classification were considered for the study. Several classifications using maximum likelihood and neural network methods were produced using the Landsat images. However, the results were not considered accurate enough to estimate quantitatively the changes in landcover type between the two available dates (1990 & 1994). The iterative nature of supervised classifications made this approach too time consuming, given available tools, for the desired time line of the study. We concluded that more effective software for selecting training sites, visualizing their separability, and performing classifications in an iterative sequence would have been very valuable for making the classifications more useful.

Methods for conducting change analysis also were pursued. The most effective technique involved the creation of a two band image containing a Normalized Difference Vegetation Index (NDVI) for each date. Because NDVI is a surrogate for vegetation vigor, the extreme disruptions associated with surface mining is readily apparent when such an image is displayed. It also was possible to produce classifications based on the two-band image that separated various types of change between the two dates.

All images contained varying amounts of registration error, relative to 1:24000 DRG or DLG sources. Thus while the ability to capture the proper shape and size of the disturbed area was dependent upon the spectral characteristics of the best available image, it was sometimes necessary to use the scanned USGS maps to improve the locational accuracy of the polygon. In these cases completed polygons were sometimes shifted to match elevation contours and streams. Disturbed areas drawn on 7.5' quadrangles were not used to adjust polygon positions, but were sometimes useful in confirming the general shape and scope of disturbance. The digitized mine permit coverage was not used as a reference source to determine the positioning of polygons, but was used to locate or confirm disturbances in areas where interpretation of the images was difficult.

Some areas of intense contour mining were not attempted. Instead, the Abandoned Mine Lands database was used to estimate the extent of mining in these areas. The AML database contained digitized lines representing potentially dangerous highwalls left over after mining. A buffer operation was performed on these features using a conservative 5 meter distance, producing 10 meter contour mining polygons. Note that in many areas, contour mining appeared to be wider than the 10 meter standard, and that the AML database only showed areas where there was known to be a highwall, which does not include all the disturbed area (e.g.the AML office is typically not concerned with areas that have been backfilled) Therefore, disturbed areas estimated using the AML database most likely underestimated the total disturbed area.

Criteria were developed to verify a disturbance as related to surface mining. Only verified sites were used in subsequent analysis. Mining areas are identified as:

1. areas that contain a clearly identifiable valley fill.

2. areas that match a permit boundary. That is, the digitized permit boundary matches a significant feature of the disturbed area polygon, such that there is no reasonable doubt that the two are related, and that the disturbed area and the permitted area occupy the same space, *i.e.,* the similarity is not due to a shared boundary between two adjacent features. The boundary need not describe or encompass the entire disturbed area, since the permit database is not complete and may not reflect recent expansions of existing permits. Additionally, the disturbed area may represent a work in progress that has not yet expanded to the limits of the permitted area.

3. areas that are obvious expansions of otherwise verified sites, and areas that are clearly connected to verified sites by short connecting roads.

4. areas that clearly match features of the abandoned mine lands database. The majority of these cases involve linear highwalls left after contour mining.

5. linear areas that appear to be the result of contour mining when they occur in a localized region where other established contour mining has taken place (as verified by one of the other methods, usually the AML database) Mining activity is extrapolated based on the unique shape of the feature, the fact that it follows the topographical contour, and that other similar activity has taken place in the area.

Results

After identifying all mining-related areas, the analysis used simple GIS operations to estimate cumulative watershed area and stream miles impacted by surface mining. Table 1 relates the total disturbed area in each target watershed that can be attributed to surface mining activity for each of the dates represented by the source imagery. Over 62 square miles of disturbed area, representing over 7.5% of the aggregate watershed area, has been disturbed by surface mining operations through 1998. Two of the watersheds, Buffalo Creek and Direct Drains of the Guandotte, have had over 10% of their surface area disturbed by surface mining. These figures represent combined reclaimed and active operations. The figures relating to expansion appear to confirm that surface mining was accelerating in the latter half of the decade for those watersheds where data is available. From 1990-94 the three watersheds saw less than 1 square mile of additional disturbance related to mining, while all three gained over 1 square mile between 1994-98. Acceleration was especially dramatic in the Guandotte River Direct Drains above Logan, where the total area more than doubled.

The mining polygons also were used to estimate the number of stream miles impacted by surface mining operations. Table 2 shows total miles of streams directly impacted by mining activity, i.e.

those streams digitized from USGS 7.5' maps that fall inside the mining polygons. Over 127 miles of streams were estimated to fall within the boundaries of areas where mining activity has taken place. For several of the watersheds with complete coverage, it also was possible to estimate the percentage of total streams affected. While it is recognized that USGS maps do not represent a definitive source for identifying all the streams in the watershed, they are common and well understood source, and therefore provide a good context for understanding and evaluating the results.

Watershed	Disturbed area, square miles			Expansion, square miles		Percent of total watershed area		
	1990	1994	1998	1990-94	1994-98	1990	1994	1998
Upper Mud River	na	3.00	5.26	na	2.26	na	3.12%	5.47%
Lower Little Coal River	na	5.87	8.32	na	2.45	na	3.81%	5.40%
Coal River	na	7.42	11.10	na	3.68	na	6.16%	9.20%
Spruce Creek	8.92	9.77	11.16	0.85	1.39	7.07%	7.75%	8.85%
Upper Pond Fork	na	4.52	5.52	na	1.00	na	4.39%	5.36%
Guyandotte River Direct Drains	2.69	3.13	8.02	0.44	4.89	3.56%	4.14%	10.61%
Island Creek	6.14	6.98	8.20	0.84	1.22	5.84%	6.64%	7.80%
Buffalo Creek	na	3.29	4.78	na	1.49	na	7.26%	10.53%

Table 1. Cumulative area affected by surface mining operations for selected West Virginia Watersheds. Fields with 'na' indicate areas where the 1990 source image did not cover the entire watershed.

Watershed	Stream miles affected	Percent of total streams
Buffalo Creek	6.30	6.67%
Coal River	17.81	na
Guyandotte River Direct Drains	16.96	9.81%
Island Creek	14.84	6.30%
Lower Little Coal River	21.23	na
Spruce Creek	23.13	8.06%
Upper Mud River	17.50	na
Upper Pond Fork	9.92	na

Table 2. Miles of streams within surface mined areas, 1998. Fields with 'na' indicate watersheds where 1:24000 scale stream coverage was not available.