REPORT

993415

REMOTE SENSING OF FORESTLAND ABOVE LONGWALL MINING AREAS WASHINGTON AND GREENE COUNTIES, PENNSYLVANIA

1.0 BACKGROUND AND STUDY APPROACH

1.1 INTRODUCTION

D'Appolonia Engineering Division of Ground Technology, Inc., (D'Appolonia) was contracted (BMR-99-01) by the Pennsylvania Department of Environmental Protection (DEP) Bureau of Mining and Reclamation to conduct remote sensing of forestland above longwall mining areas in Washington and Greene Counties, Pennsylvania. SenSyTech, Inc. Imaging Group (SenSyTech) provided primary technical support for the remote sensing tasks and Dr. Donald D. Davis, Forest Pathologist with The Pennsylvania State University, provided consulting services on forest evaluation and health conditions for the project. In accordance with the November 1999 proposal, the work was planned with the following major tasks comprising:

- Sites Selection
- Remote Sensing
- Imaging Analysis
- Report Preparation

The imaging analysis task included analysis of subsidence at selected study areas and evaluation of sites identified from the imagery in the field (ground truthing).

The work initiated in March 2000 and a Sites Selection Report was issued in May 2000. Candidate sites identified in the Sites Selection Report were authorized by DEP for study on June 2, 2000. Remote sensing consisting of airborne multispectral scanning, satellite color infrared imagery, and airborne color infrared photography was conducted between June 30 and September 22, 2000. Ground studies to observe and characterize the forestland were conducted in May as part of the Sites Selection Report and between August 29 and September 28, 2000 for field validation of areas of stressed tree canopy identified from the remote sensing imagery.

This section presents a discussion of previous studies of subsidence impacts on vegetation, a statement of the problem, and the project objectives and approach. The balance of the report presents the site selection, remote sensing, subsidence analyses, field reconnaissance (ground truthing), findings and conclusions, and recommendations. Also enclosed are appendices which present the remote scanning imagery (Appendices A and B); Airborne Multispectral Scanning (AMS) equipment specifications and associated flight logs (Appendix C); and field notes, tree survey data, and photographs from the field reconnaissance (Appendices D, E and F).

1.2 PREVIOUS STUDIES

1.2.1 Illinois Studies

A number of studies were performed in Illinois as part of the Illinois Mine Subsidence Research Program (IMSRP). Longwall mining has been employed for many years in southern Illinois, which is an area where the terrain is generally flat and the land usage is agricultural. These studies were generally led by Dr. Robert G. Darmody of the Department of Agronomy of the University of Illinois at Urbana-Champaign(1,2,3,4). Studies that were reviewed for this project addressed topics such as:

- Effects on Soils and Hydrology
- Effects on Crop Production
- Modeling Agricultural Impacts
- Effectiveness of Cropland Mitigation

In general, it was found that the effects of subsidence on agricultural crops were inversely proportional to overall ground slope. Areas with slopes greater than 12 percent showed little effect, while generally flat areas (slope less than 1.5 percent) showed moderate to severe subsidence effects. It was concluded that nearly level areas were more sensitive to subsidence because of the greater probability that closed depressions will form and because of the proximity of the groundwater table to the surface for the low permeability surficial soils in the region of the study. However, the overall crop yield reduction in subsided areas for three consecutive years that included one dry year, one wet year and one normal year was less than 10 percent.

1.2.2 Ohio-Pennsylvania-West Virginia Studies

Some studies have been performed for sites in eastern Ohio, northern West Virginia and southwestern Pennsylvania, where the terrain is similar to the project study areas in Washington and Greene Counties, Pennsylvania. Most notable of these were studies conducted by Dr. James R. Runkle of Wright State University. In a study performed under the direction of Dr. Runkle, surface soil moisture and tree growth were compared at sites over newly mined longwall panels and unmined control areas(5).

With respect to soil moisture, the study found no significant differences between groups of soil probes in the undermined and control areas. All groups showed the same annual patterns, both in the wet year (1990) and the subsequent dry year (1991). With respect to tree growth, Runkle concluded that no consistent, significant response to longwall mining could be detected. He discusses two localized phenomena that could result from subsidence. These are local ponding due to the filling of newly created depressions and land slippage. Runkle concluded that on the basis of his study no consistent general impact on soil moisture or tree growth is apparent from longwall mining and that the effects of longwall mining “seem highly specific and localized.”

1.2.3 Summary of Previous Research Efforts

The Illinois studies demonstrate that in flat terrain, the effect of longwall mining on crop yields can be significant. The primary mechanism for this effect is the creation of shallow areas of depression with reduced drainage. The Illinois studies found that this effect diminishes as the ground slope increases, becoming negligible at a ground slope of 12 percent.

Runkle, in his work conducted in terrain similar to the proposed study (Washington Greene counties, Pennsylvania) concluded that no effects on soil moisture or tree growth due to the mining could be identified. He does cite the creation of pools in depressions and some slippage (surficial slope failures) due to the mining. He also indicates that white ash may have been affected by subsidence at his study site in Pennsylvania.

1.3 STATEMENT OF THE PROBLEM

Longwall mining systems result in complete extraction of coal within the production panel, typically of the order of 900 feet in width and extending to 10,000 feet in length.

Barrier and setup pillars at the perimeter of the panel provide support for installation of the equipment and recovery of the coal, and these pillars remain in place, leading to differential subsidence of the rock overburden across the mine.

Extraction of coal with advance of the longwall system leads to loss of support of the mine roof, creating compressive and tensile stresses in the overburden. Because it may take a year or more to advance through the production panel, transient compressive/ tensile stresses occur above and in advance of the longwall face. The impact of the transient stress field on the overburden is related to the type of overburden and thickness, extraction thickness and panel width, speed of mine face advance, and surface topography. At the panel perimeter, the compressive/tensile zones are quickly established following advance of the longwall. These effects include opening of joints or overburden fracturing and surface terrain impacts. Consequential impacts such as depletion of ground or surface water, alterations to surface drainage, and damage to surface structures may also be observed. Some of these impacts may be temporary in nature, either due to the transitory stress field or processes that restore groundwater and surface water conditions.

Since much of the terrain over longwall mines in Washington and Greene counties is covered by forests, the consequential impacts cited above could affect forest growth and cause stress damage to trees. If vegetative stress damage to the tree canopy occurs, it is unknown whether the effect is temporary or permanent. Possible mechanisms for forestland impacts include:

- Soil moisture loss due to groundwater or surface water depletion;
- Soil moisture gain due to terrain impacts, such as depressions which hold moisture and may lead to wetlands creation; and
- Root damage due to subsidence fracturing or slope movements.

1.4 PROJECT OBJECTIVES AND APPROACH

The purpose of this study is to explore the occurrence of tree canopy stress due to longwall mining activities using remote sensing, establish whether or not it can routinely be detected, and determine the spatial relationship to longwall mine workings and the increase or decrease with time related to mining activities. This project has utilized remote sensing technology to collect multispectral image data, which was analyzed to detect vegetation stress.

The project approach consists of the following principal elements:

- Selection of study sites
- Identification on the imagery of areas of stressed tree canopy at study sites
- Reconnaissance in the field to identify causes of stress observed on the imagery

The above elements relate to identification of field sites with stressed tree canopy and evaluation of these sites in the field. From study sites in the approximate range of 400 to 900 acres, areas of forest canopy distress were identified (typically 1 to 10 acres) on the imagery, and ground based reconnaissance and tree health evaluation of plots within the distressed areas (typically about one-half acre) were performed. The ground based reconnaissance focused primarily on areas of canopy distress for identification of the tree species and causal factors of the distress, and was not intended to characterize the remainder of the large forestland areas.

Additionally, areas of potential or actual impacts from longwall mine subsidence were identified through engineering analyses and/or direct observation. The associated imagery was reviewed for vegetation distress, and selected locations were observed in the field for evaluation of canopy stress.

1.4.1 Selection of Study Sites

The study sites were selected from among the longwall mines in Washington and Greene Counties, Pennsylvania in the following three categories:

- Sites undermined during or prior to 1990 (for longer-term impact assessment);
- Sites undermined between 1995 and 1999 (for shorter-term impact assessment); and

- Non-undermined control sites located near the undermined sites (for comparison with the undermined sites).

Candidate sites were evaluated based upon a review of aerial photography and field reconnaissance. Various factors such as extent of forest cover; forest type, density and condition; site access and other criteria were considered in the selection process. The following three mines with each of the three above categories of mine conditions were selected:

- Bailey Mine (Study sites A-1, A-2, and A-3)
- Blacksville Nos. 1 and 2 Mine (Study sites B-1, B-2, and B-3)
- Humphrey No. 7 Mine (Study sites D-1, D-2, and D-3)

This process is described in Section 2.0 of this report.

1.4.2 Remote Sensing

The primary means of stressed tree canopy identification was Airborne Multispectral Scanning (AMS). The following types of images were collected using the SenSyTech AMS equipment:

- Natural color
- Color infrared
- Normalized Difference Vegetation Index (NDVI)
- Day and night thermal

The AMS data were collected on June 30 and July 2, 2000. Additional color infrared imagery was collected on four different dates between July 20 and September 22, 2000. The data collection effort is described in Section 3.0 of this report.

The multispectral scanning imagery utilized in this study is presented in Appendix A. The figures in the appendix show natural color, color infrared, normalized difference vegetation index (NDVI), and day and night thermal images for each of nine study sites that were evaluated. In addition to the multispectral imagery, satellite color infrared imagery and airborne color infrared photographic images were obtained at four times between June 30 and September 22, 2000. A figure for each study site showing the color infrared imagery obtained is presented in Appendix B. Specifications for Airborne Multispectral Scanning (AMS) performed for the project and associated flight logs are presented in Appendix C.

1.4.3 Subsidence Analysis

Subsidence analyses using the Surface Deformation Prediction System (SDPS) Software were conducted for the study sites for the purpose of identifying locations of highest subsidence and strain magnitudes. These areas on the imagery were examined for tree canopy stress. Section 4.0 presents the subsidence analysis.

1.4.4 Imaging Analysis

Areas of stressed tree canopy were identified from the imagery using the IMAGINE 8.4[(6)] software from ERDAS. The analysis of the imagery is described in Section 5.0 of this report. Areas of stressed tree canopy were marked on images of the study sites. The images included reference grids to facilitate field reconnaissance.

1.4.5 Field Reconnaissance

The field reconnaissance (ground truthing) effort was performed during the period from August 29 to September 28, 2000. The reconnaissance team visited many of the stressed tree canopy sites identified from the imagery, as well as selected areas of predicted or observed subsidence effects. Some field sites could not be accessed because of difficult locations or problems gaining access permission.

Tree stands reflecting conditions observed on the imagery were evaluated with respect to factors such as trunk quality, crown quality, overall vigor, branch dieback, foliage transparency, and defoliation. Observed subsidence features such as ground cracks were also noted. A description of the ground truthing effort related to areas of potentially stressed tree canopy identified from the imagery is provided in Section 6.0 of this report.

Based on the subsidence predictions for the sites undermined by longwall mines, locations of higher tensile strain were evaluated by the reconnaissance team. Additionally, subsidence pools had previously been documented along Enlow Fork on and near project study site A-1 at the Bailey Mine. The pools and the segments along the stream between pools were evaluated by the field reconnaissance team. Also, in the course of property owner notification, a property (Lee property) adjacent to study site D-1 at the Humphrey No. 7 Mine, where the owner reported tree damage from subsidence, was identified. This property was subsequently evaluated by the field reconnaissance team. The field reconnaissance effort related to the areas of predicted or known subsidence is described in Section 7.0.

1.4.6 Data Evaluation

The utility of remote sensing imagery for identifying tree canopy stress related to mine subsidence was evaluated. Also data from tree surveys at field sites from the three types of study sites were compared to determine if differences were apparent between undermined and control sites and between recently undermined study sites and study sites undermined prior to 1990. Tree survey data from the subsidence pools along Enlow Fork were compared to similar data at between-pool stream segments. The findings and conclusions developed in the course of this study are presented in Section 8.0. Recommendations related to possible refinements of this study or additional investigations are presented in Section 9.0.