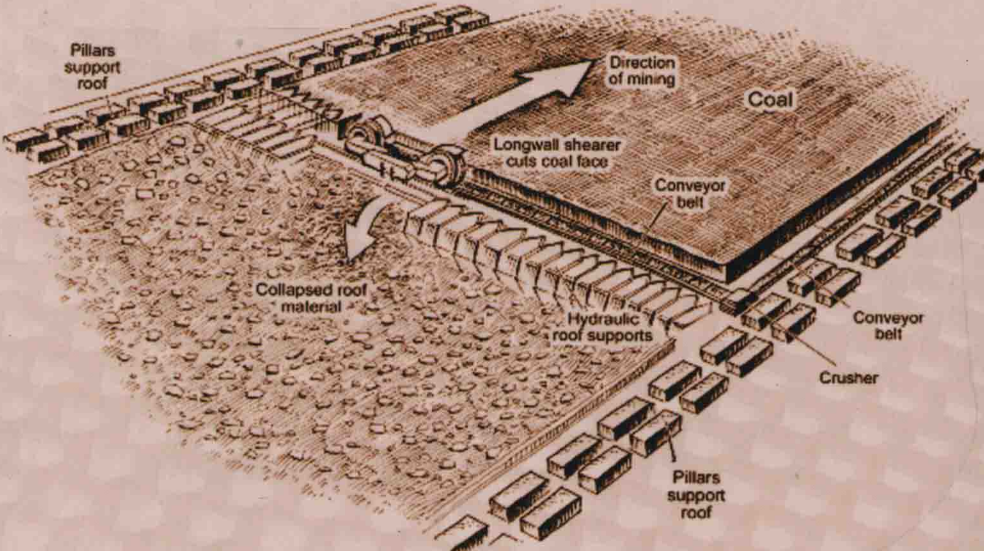

The Impacts of Longwall Mining on Groundwater Systems Over Thin Overburden in A Coal Mine of Appalachia Coalfield in United States

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ABSTRACT

The underground mining industry is dependant upon the implementation of an engineering design and strategy to adequately and safely control the surrounding rock mass. Therefore, an analysis of surface and subsurface affects has been conducted in to better understand the relationship between the subsidence mechanism and hydrological impact of subsidence in areas with low cover.

The purpose of this study is to determine the strata movement and the effects of longwall mining subsidence on surface- and ground-water system by using the measurement and the modeling simulation methods.

Slug tests were performed to determine the rock hydraulic conductivity of pre- and post-mining conditions. Three water wells were drilled down to the proposed deformation zone to monitor the different water level fluctuations throughout the mining period. These water elevation records were used to calibrate the groundwater flow models(GGU-SS-FLOW3D).

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Yang LI

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LIST OF SYMBOLS

H	Maximum height of the dewatered zone (m)
M	Mining height (m)
a	Coefficients depending on the overburden strata lithology
c	Mean square deviation
F-I-P	Spring flow increase post mining
ND	No apparent dewatering
PD-R	Partial dewatering with recovery
PD-NR	Partial dewatering with No recovery
CD-R	Complete dewatering with recovery
CD-NR	Complete dewatering with No recovery
V	Valley topographic position
K_x, K_y, K_z	Conductivities along the components
h	Piezometric head
S	Storage coefficient
b	Aquifer thickness
S_s	Specific storage
T	Transmissibility
t	Time
T_{mean}	Average daily air temperature(℃)
Δ	Slope of the vapor pressure curve(kPa/℃)
T_{avg}	Average air temperature(℃)
G	Soil heat flux, usually, $G = 0.1R_n$
R_n	Net radiation at the crop surface[MJ/(m^2 · d)]
R_a	Extraterrestrial radiation
G_{sc}	Solar constant[0.082MJ/(m^2 · mine)]
D_r	Inverse relative distance from the Earth to the Sun
φ	Latitude(rad)

δ	Solar declination(rad)
w_s	Sunset hour angle(rad)
e_s	Vapor pressure at saturation
e_a	Actual vapor pressure
u_2	Wind speed(m/s)
ϕ	Relative humidity
r_c	Radius of the well casing(m)(ft)
r_w	Radius of the well(including gravel envelope)(m)(ft)
R_e	Radial distance over which head is dissipated(m)(ft)
L_e	Length of the screen(m)(ft)
H_0	Drawdown at time $t=0$(m)(ft)
A	The cross sectional area(m^2)(ft^2)
h_1	The height of the inlet head(m) (ft)
h_2	The height of the outlet head(m)(ft)
l	The path length of the flow(m)(ft)
K	Hydraulic conductivity(m/day)(ft/day)
k	Permeability(cm/s)
ρ	Density of the fluid(kg/m^3)
g	Acceleration of gravity(m/s^2)
μ	Absolute viscosity of the fluid($N \cdot s/m^2$)
γ	The specific weight of water[$kg/(m^2 \cdot s^2)$]
α	The compressibility of the bulk aquifer material[$(m/kg) \cdot s^2$]
n	The porosity of the material
β	The compressibility of water[$(m/kg) \cdot s^2$]
R	Recharge/discharge rate

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Longwall Mining

Longwall mining method is a highly productive underground mining method in which a panel or a block of coal is completely extracted. The panel is typically range 1000 ft(1 ft = 0.3048 m) wide and 10000 ft long or more. The recovery ratio in a given coal seam reaches 80% of total virgin coal block. In the past decades, longwall production and productivity grew rapidly due to significant improvements in longwall equipment and mining technology. Longwall Mining method has been major underground coal mining method in the U. S. since 1990 s. When a longwall panel of sufficient width and lengthen is excavated, the overburden roof strata are disturbed in order of severity from the immediate roof to the surface(Peng,2008). Therefore, loss or interruption of streams and overburden aquifers are common concern in coal industry, and among the landowners and environment groups.

In general, strata movement response to full extraction mining depends strongly on the location and thickness of the strong strata and mining geometry(mining height and panel width). For the convenience of discussion, strata movement can be generalized as follows:

Figure 1-1 shows the four zones of disturbance in the overburden strata in response to the longwall mining. The coal seam has been extracted and the immediate roof is allowed to collapse into the void that is left as the face retreats. The intermediate roof strata break into irregular shapes until the piles of the fallen rock fragments are sufficiently high to support the overhanging strata. The effective porosity and storage capacity in this zone are much higher than those of the insitu condition. The water contained in the caved zone, which is typical 2 to 8 times the mining height, is completely drained into the coal seam level.

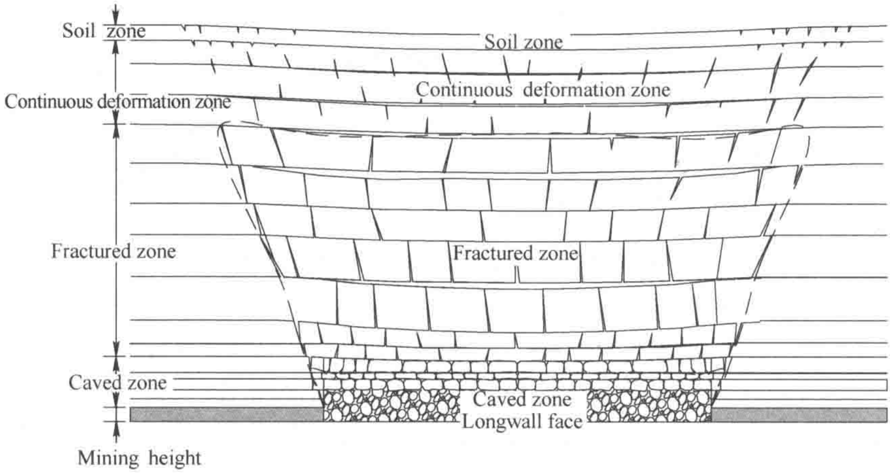

Figure 1-1　Overburden movement induced by longwall mining

The fractured zone is located above the caved zone, the strata break into regular blocks by vertical or sub-vertical fractures due to bending, and horizontal cracks due to bed separation that form along pre-existing plane of weakness, and by the separation of beds as strata bend during subsidence. Mining induced fracturing and bedding separation increase the vertical and horizontal hydraulic conductivity and storativity of the strata. The lower fractured strata usually have a larger vertical and horizontal conductivity than that of the upper strata. The water table in this zone flows downward to the caved zone due to the gravity and flows horizontally along the bed separations.

The surface soil/rock crack zone consists of two types of cracks. One is the original surface crack induced by the tectonic tension stress due to structural geological activities such as volumetric shrinkage, temperature change, and differential settlement. It extends around 50 ft below the surface in this study area. Another one is the secondary crack induced by surface subsidence. The depth and pattern of surface cracks induced by subsidence depend on rock mass properties and overburden depth.

Between the fractured zone and surface crack zone is the continuous deformation/aquiclude zone. The strata in this zone deform gently without causing any major cracks that extend long enough to cut through the thickness of the strata, as in the fractured zone (Peng, 2006). The groundwater flows horizontally along the bedding planes, causing very little vertical seepage to the lower strata because little change occurs in the rock permeability characteristic.

The degree of dewatering of groundwater depends on the severity and position in the zones of disturbance induced by longwall mining. Subsidence induced fractures and bed separations generally increase hydraulic conductivity and storativity over the affected overburden strata, enhance hydraulic connections between the aquifers and the mined excavation.

1.2 Purpose and Scope

1.2.1 Purpose

Large-scale longwall mining of shallow coal seams can disturb or even damage the overlying aquifers (Li and Zhou, 2006; Zhang and Shen, 2004), and thus can lead to considerable water loss and aggravation of the vulnerable ecological environment. The protection of water resources associated with the large-scale and high-efficiency mining of shallow coal seams has been a challenge in terms of coal exploitation in the northwest of China (Zhang et al., 2009a, b).

There is a vast shallow seam coal field under the southern edge of Maowusu Desert in northwest China, called the Shenfu Coalfield. It has the largest reserve and best quality of coal in China. Its proven reserve is 223600 Mt and the estimate reserve is 60001000 Gt. The coal is low in ash, sulfur, and phosphor contents, but has a high heating value. The geological condition is also simple, being flat and shallow in depth. Since the coal seams are shallow and the surface is covered with thick sandy soils, water is stored at the bottom of the sandy layer that is underlaid by the clay layer. Therefore, the clay layer acts as an aquiclude for the ground water, and its stability is important for pre-serving the ground water, which sustains the local population. As underground mining expands, a large amount of surface water seeps down in some mining areas, depleting surface water and speeding up desertification in sandy soil areas.

The following five items are discussed in this study:

(1) Analysis of geological and hydro-geological settings above the longwall mining panels.

(2) Survey of the surface movement including longitudinal and transverse horizontal displacements along the longwall face.

(3) Monitor the overburden strata movement by installing borehole extensometers.

(4) Field tests and computer modeling to determine the hydraulic conductivity.

(5) Develop a groundwater system model to determine the water table fluctuation pre- and post-longwall mining.

The purpose of this study is to test the hydraulic-property values at the pre-mining and post-mining conditions and demonstrate the water table contours over the longwall panel before and after longwall mining and to better understand the dewatering of shallow aquifers and surface waters related to ground subsidence from longwall mining in shallow coal seam.

1.2.2 The scope of study area

The project study area is located at 265 Quiet Valley Road in Greene County, Pennsylvania, on a farm owned by Mr. William Patton (Figure 1-2). It is located within the Garrard Fort Quadrangle in Whiteley Township. The physiography of the site can be described as topographically variable hillside settings. The prospected mining block is block B and the groundwater loss evaluation is located in Panel B5 and Panel B6. Water table monitoring program and rock strata deformation extensometers were installed above these two panels in order to monitor the water table fluctuation and overbur-

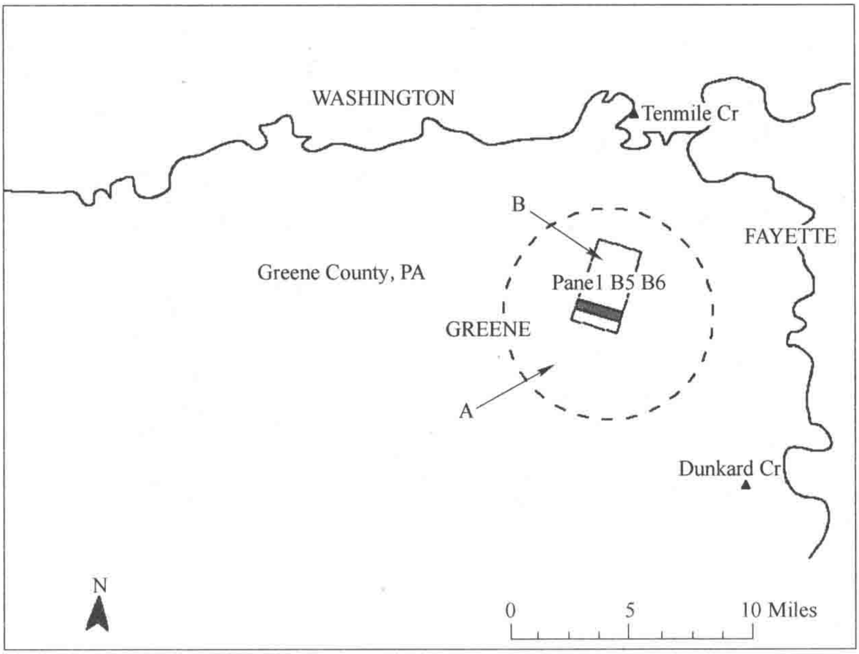

Figure 1-2 The location of study area

den rock strata movement during longwall mining period.

The study area is surrounded by three big rivers (Figure 1-3). The South Fork Tenmile located in the north is a 3rd order stream that has a drainage area of 338 square miles. Tenmile Creek flows from South Franklin Township, Washington County, PA and drains east for approximately 12 miles, serving as the northeastern border between Washington and Greene County, and eventually empties into the Monongahela River at Millsboro.

Whiteley Creek that is located in the south of the study area has a total drainage area of 54.4 square miles. It originates in Whiteley Township and flows east to the Monongahela River.

The 128-mile Monongahela River starts at Fairmont, WV, and ends at Pittsburgh, PA where the river meets the Allegheny River and form the Ohio River. Generally flowing northward, the Monongahela River is formed by the

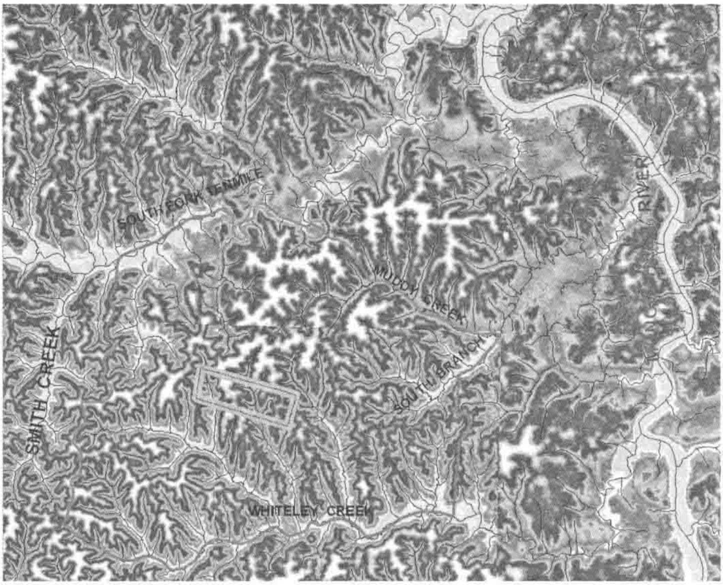

Figure 1-3 The surface watershed of study area

Tygart River and the West Fork River about 1.4 miles above Fairmont, WV. In the State of West Virginia, the Monongahela River traverses Marion and Monongalia Counties and flows for approximately 37 miles to the Pennsylvania - West Virginia border. At Pittsburgh, it meets the Allegheny River to form the Ohio River.

This study is a site-specific hydrogeologic analysis conducted before, during, and after mining at a site located over a selected longwall panels. Data from subsidence and groundwater monitoring over the study panels were collected, compiled, and analyzed to provide documentation of the mechanics of groundwater fluctuations. The study deals specifically with water level fluctuations in aquifers utilized for domestic water supplies.

1.3 Literature Review

A review of overburden movement and potential longwall mining impacts on groundwater system is necessary to better understanding the dewatering