Non-conventional Surface Ground Behavior Induced by Underground Mining in Pennsylvania

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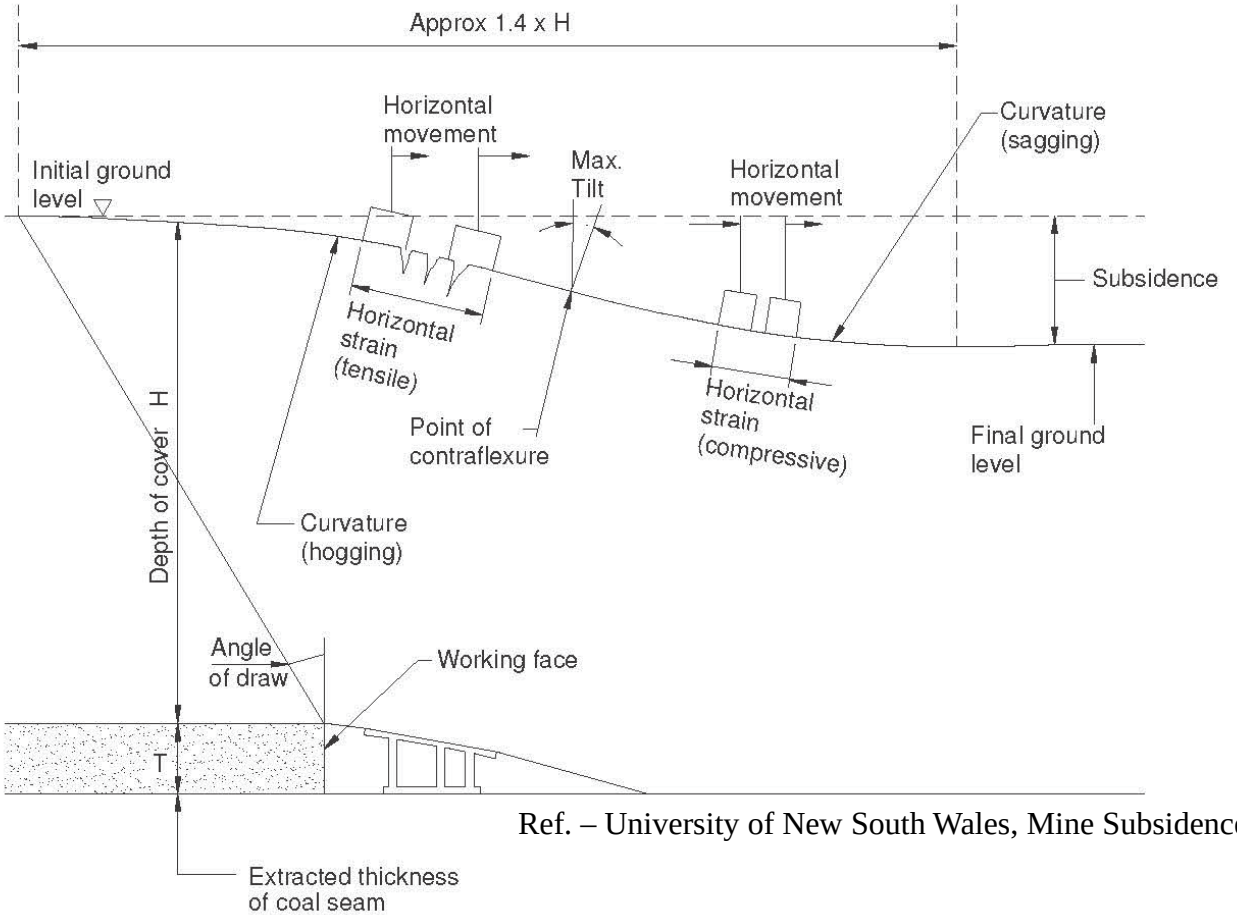
The conventional understanding of coal mine subsidence on which most current subsidence prediction techniques are based, includes the concept of angle of draw which effectively limits the lateral extent of subsidence effects and impacts

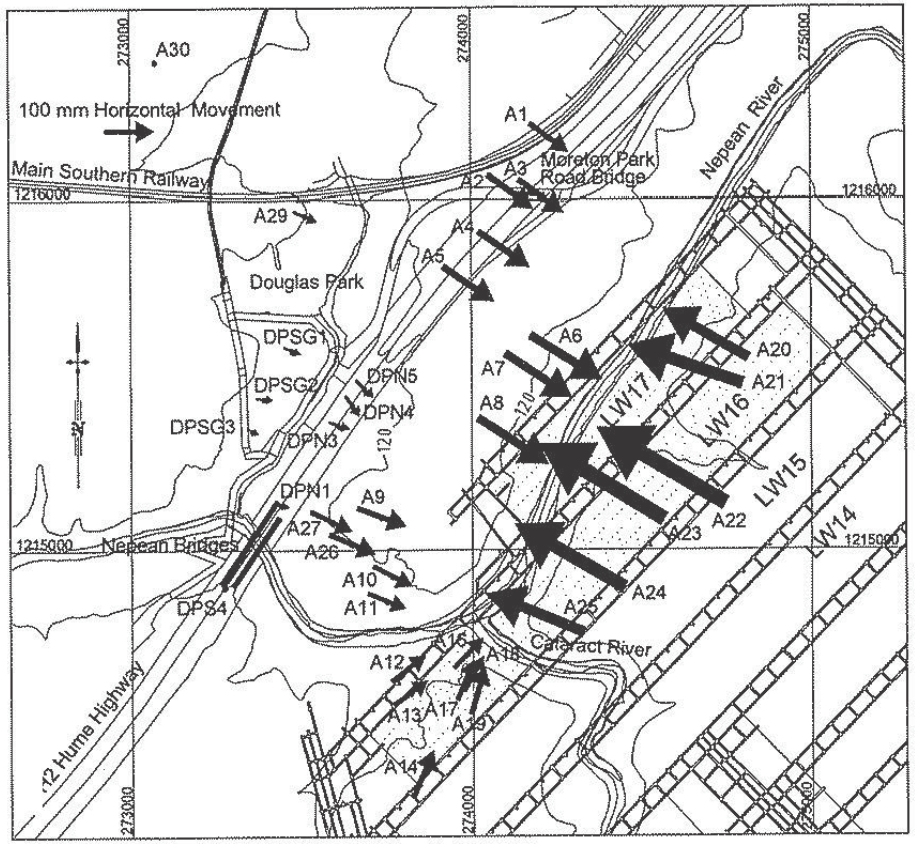


Ref. – University of New South Wales, Mine Subsidence Engineering - 2005

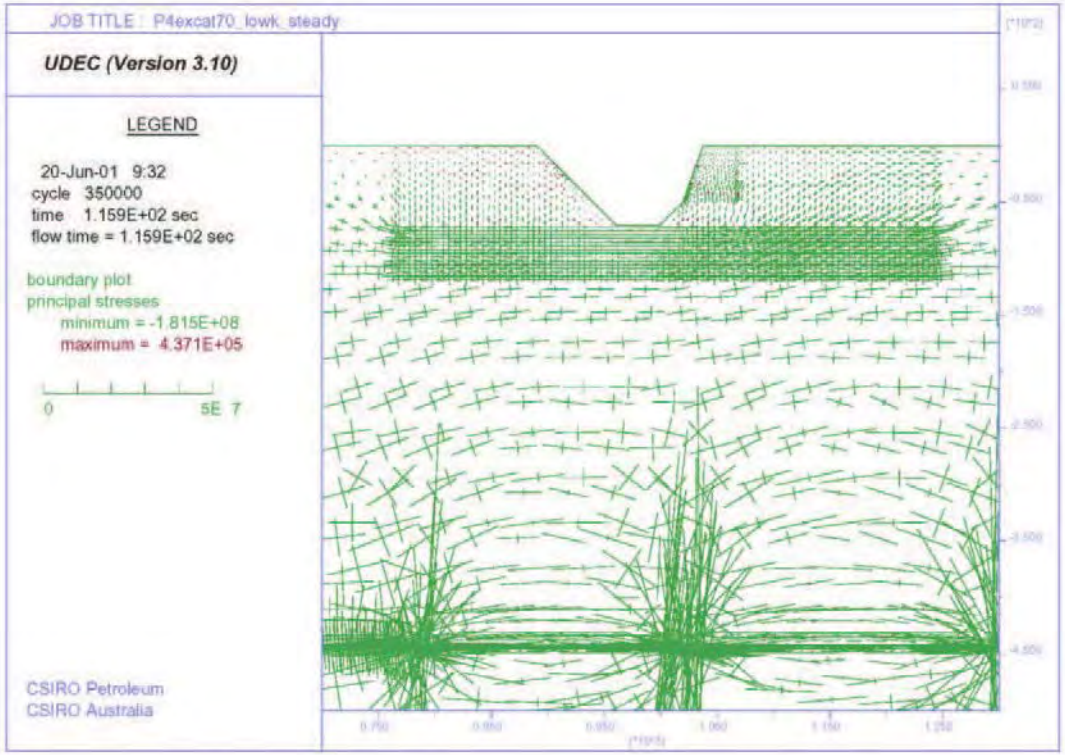
Experience from Australia over the last two or three decades has identified what is referred to as non-conventional surface subsidence behaviour. This is found to occur in areas of irregular surface topography or variable terrain, and is characterised by phenomena such as valley closure, valley floor uplift or upsidence, and far-field horizontal movements, all of which can occur beyond the conventional angle of draw limits.

These ground movements, although small, may occur over 1.2 miles from the longwall mine panel and well outside the angle of draw.

Geodetic survey results show that horizontal movements of up to 1 inch can occur even where underground longwall coal mining is about 1 mile from the survey monuments. Movements are generally directed toward the mined longwall panel. However, in some cases, the movements are in the direction of the nearby valley, or of the major principal stress.



Ref. B. Hebblewhite, (2006) ???????

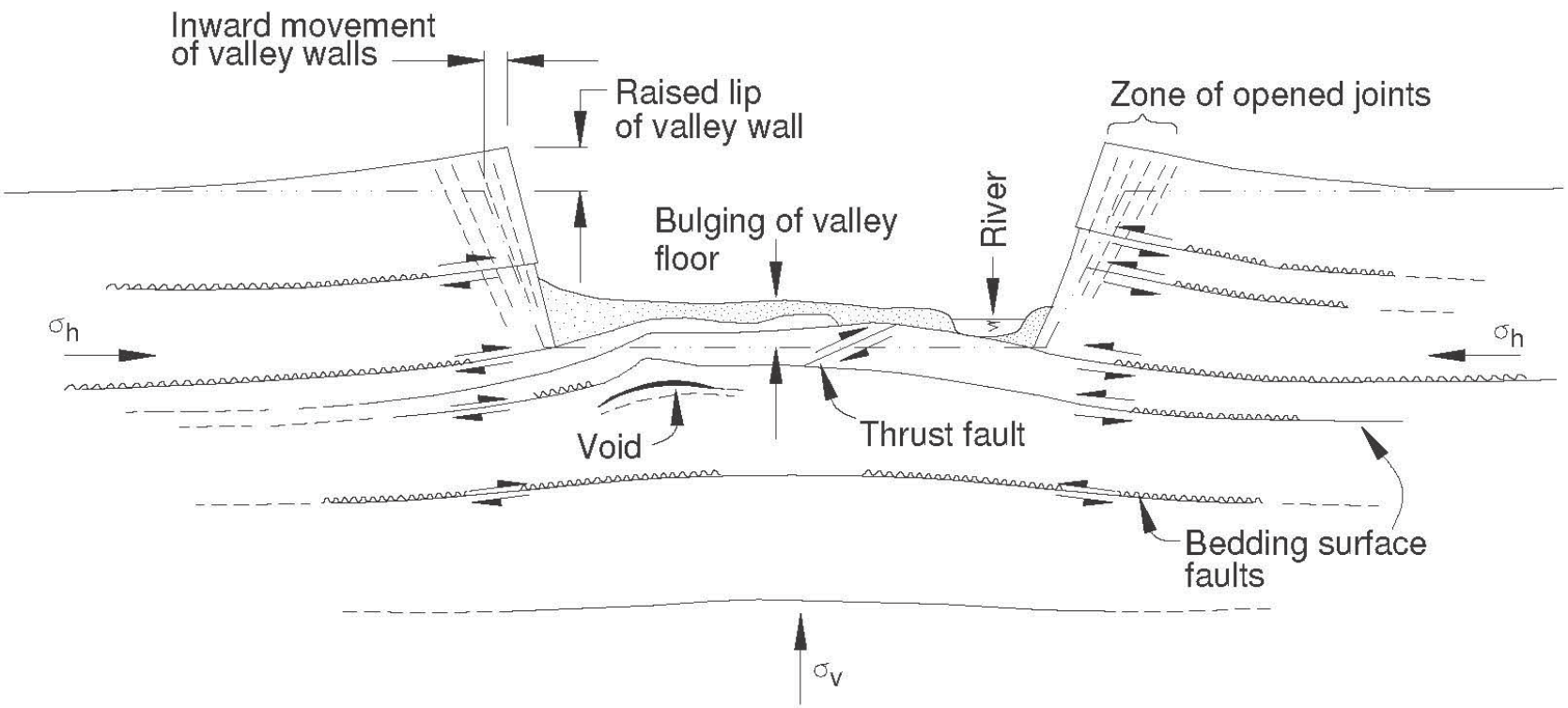


ACARP Report – Waddington & Associates Pty Limited, 2002

Factors which influence valley bulging and closure movements as a result of longwall mining include:

- Mine geometry and the nature of mining
- Valley location relative to the mined panel
- Valley depth
- Geology
- Horizontal in-situ stress

Valley Stress Relief has become widely recognized and accepted in the United States. Valley closures and deformations of the valley floor reported in conjunction with Australian longwall coal mining are similar to observations of valley stress relief.



(After Patton and Hendron 1972)

- Ryerson Station Dam in Greene County, Pennsylvania
- 515-foot-long concrete gravity dam
- Completed in 1960.
- No major problem until July 2005
- In July 2005, leakage from the east side of the dam reached 80 gallons per minute
- The dam exhibited significant structural deformations.

Leakage

June 15, 2005	20 gallons per minute
July 13, 2005	35 gallons per minute
July 18, 2005	45 gallons per minute
July 26, 2005	60 gallons per minute
July 28, 2005	80 gallons per minute

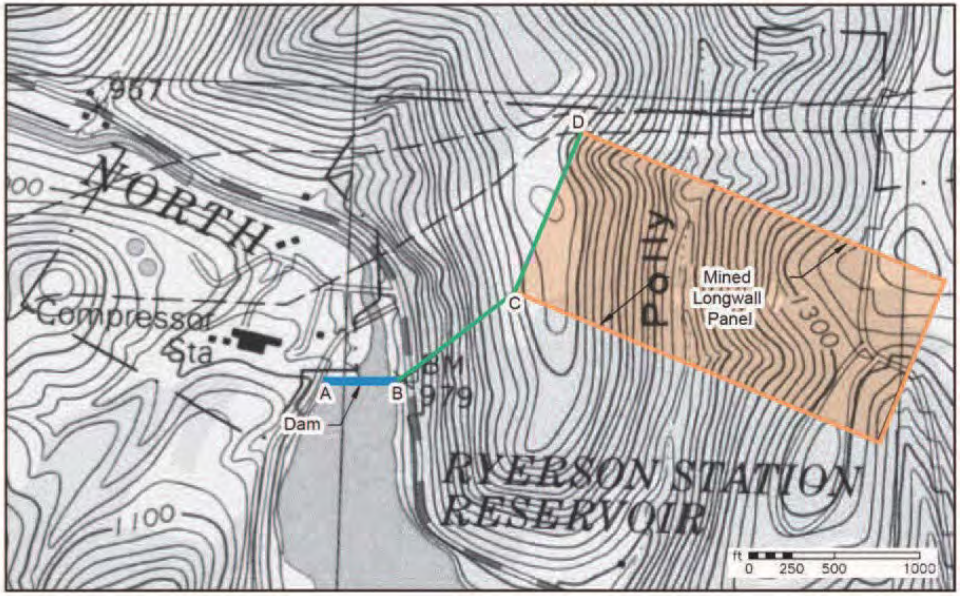
Ref. Pennsylvania Department of Environmental Protection, 2010

- Pennsylvania DEP ordered draining the reservoir
- Breaching the dam was subsequently ordered.

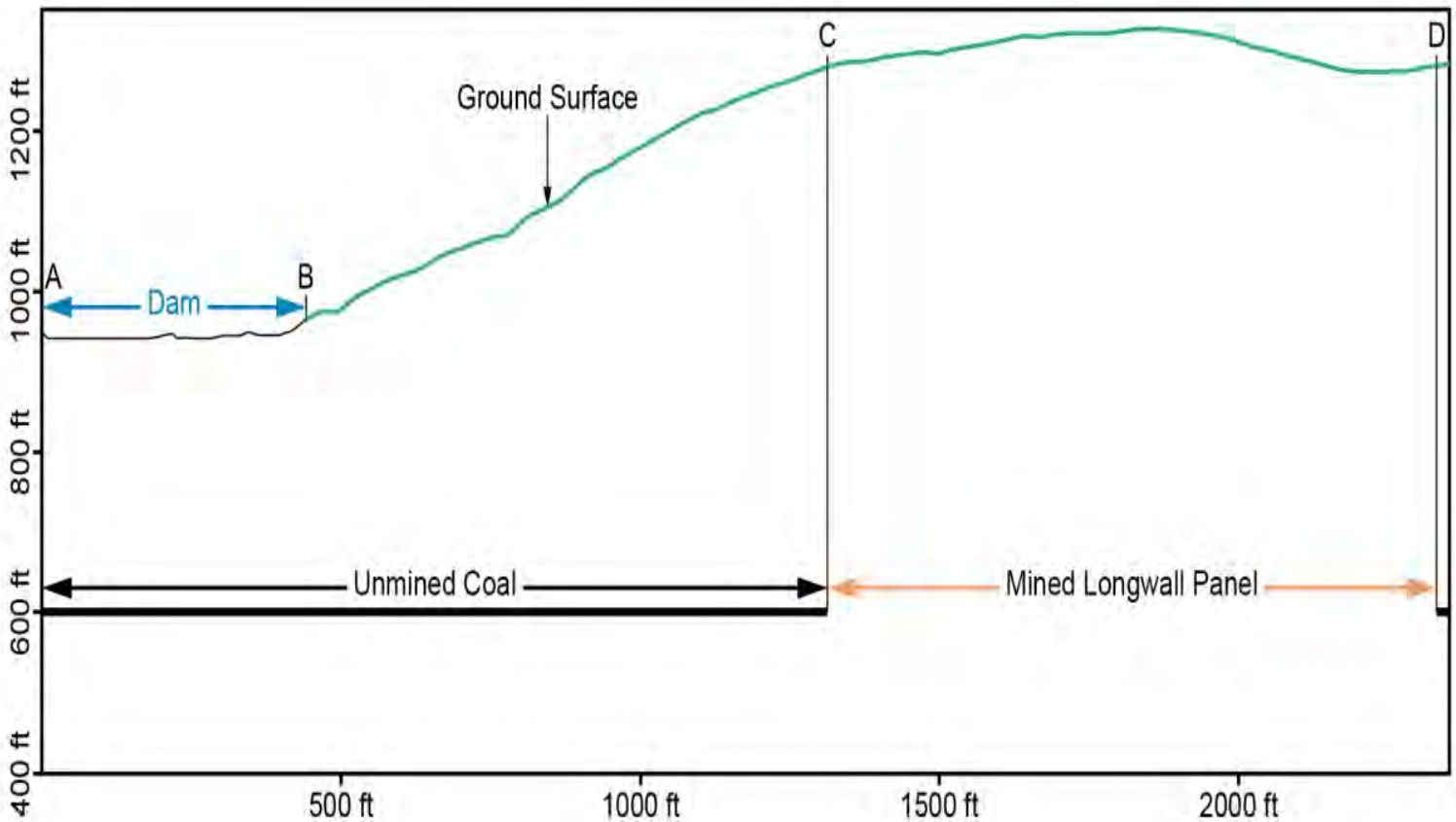
Leaking Drain
on East Abutment

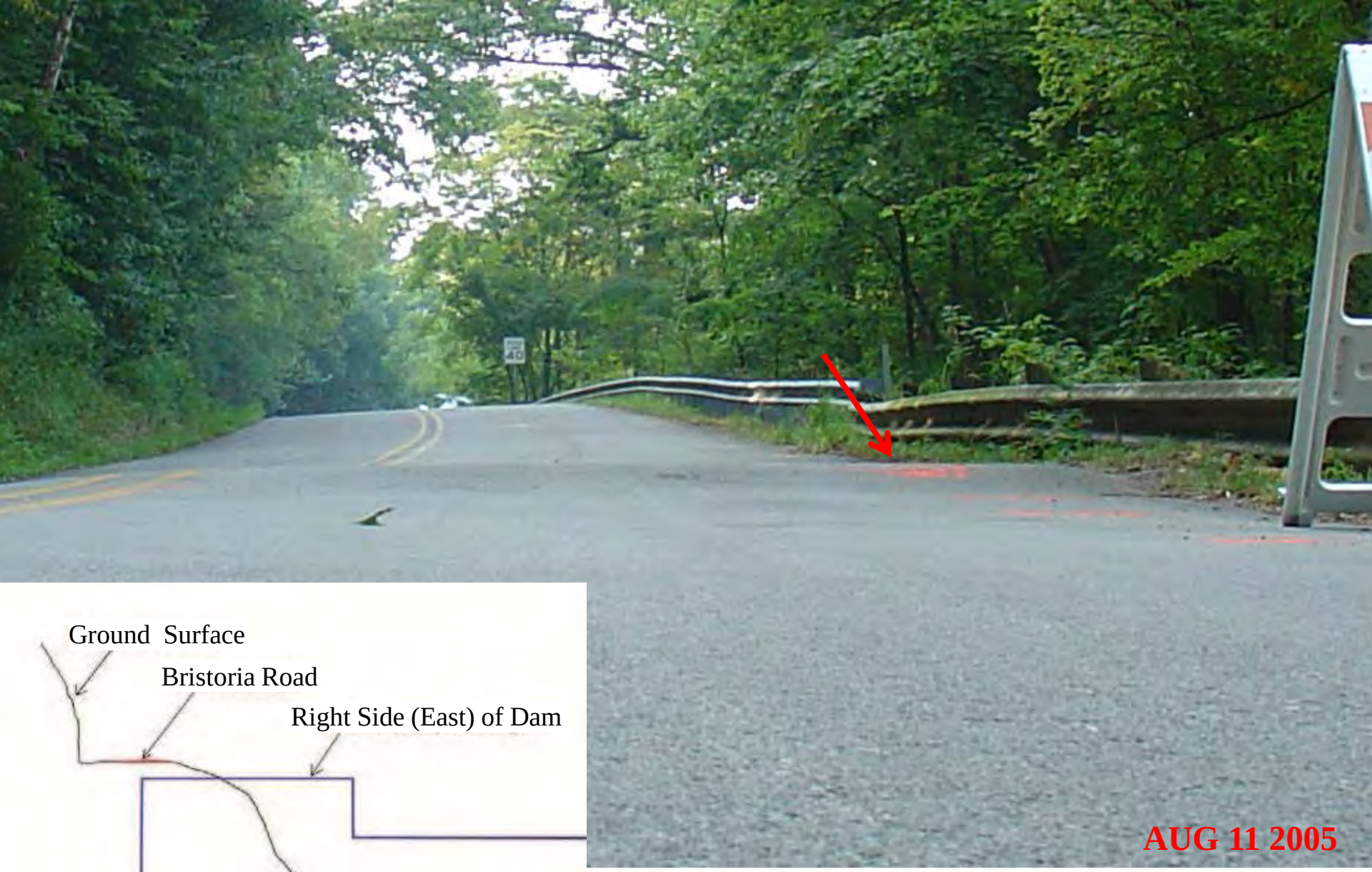
Ref. Pennsylvania Department of Environmental Protection, 2010

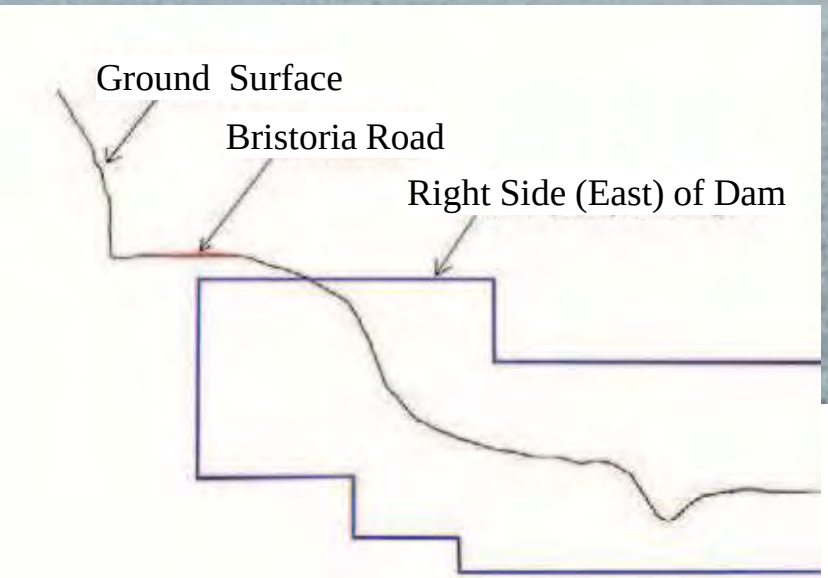
- Ryerson Station Dam blocked the North Fork of the Dunkard Fork of Wheeling Creek.
- Top of the Dam – elevation 979 feet
- At east end of dam the hillside rises steeply to above elevation 1,300 feet amsl
- Area underlain by interbedded shale and sandstone
- Pittsburgh Coal seam at elevation 600 feet amsl, about 350 feet below the dam elevation
- Longwall mine panel located northeast of dam under high hill



The closest edge of the mined panel to the east end of the dam was approximately 900 feet. The mined Pittsburgh Coal seam was at a level approximately 350 feet below the dam and over 700 feet below the high hill to the east.







Ref. Pennsylvania Department of Environmental Protection, 2010

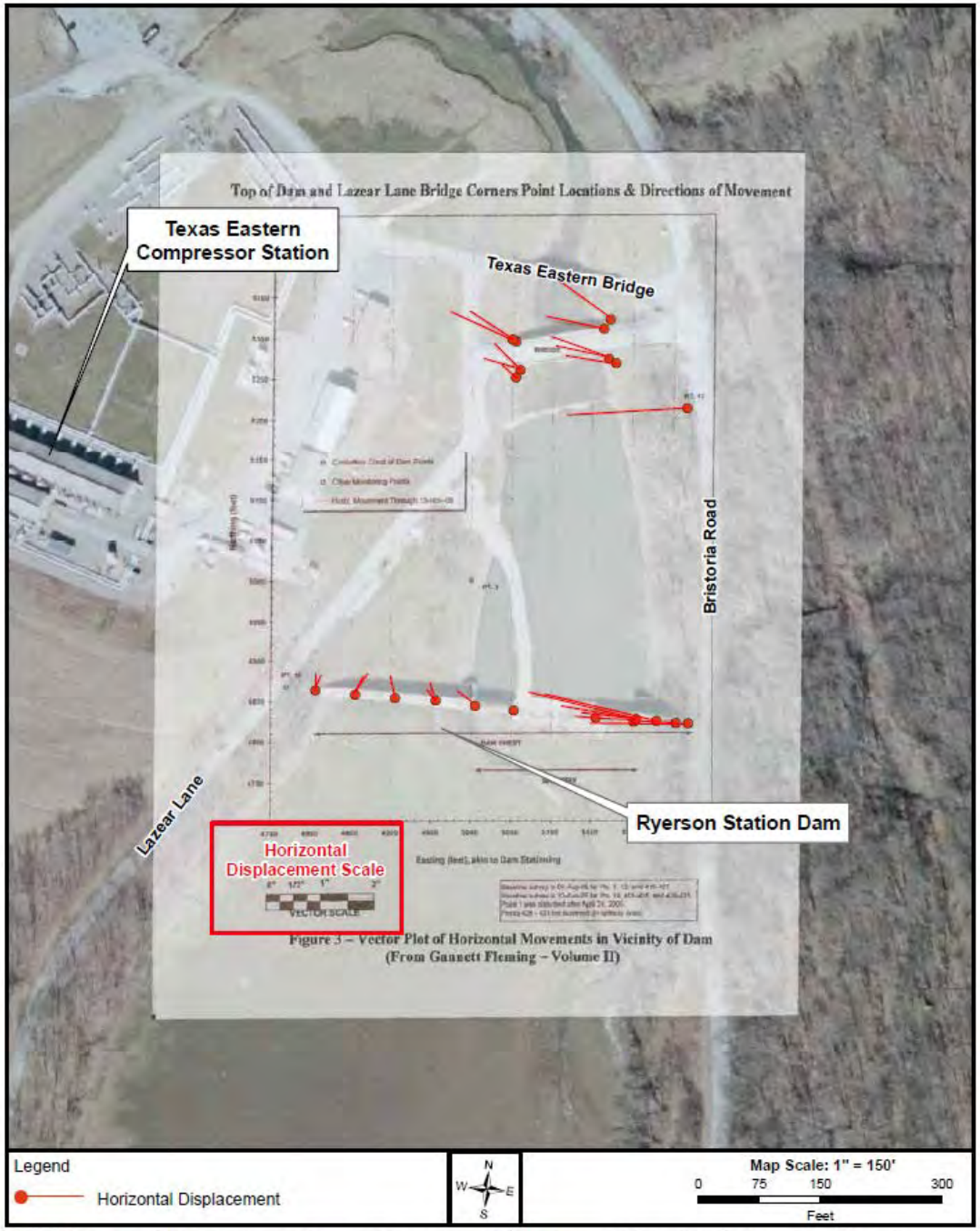
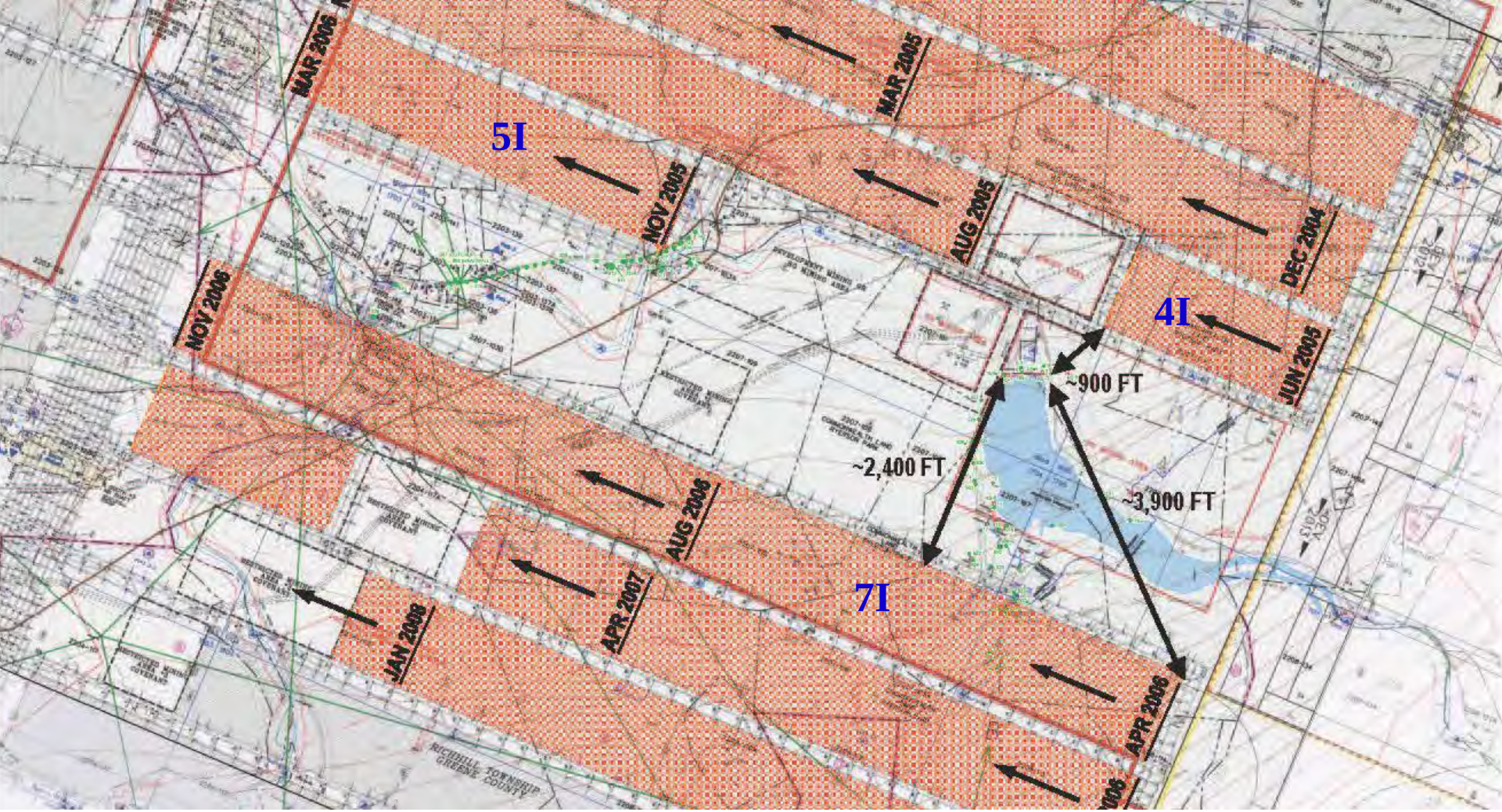
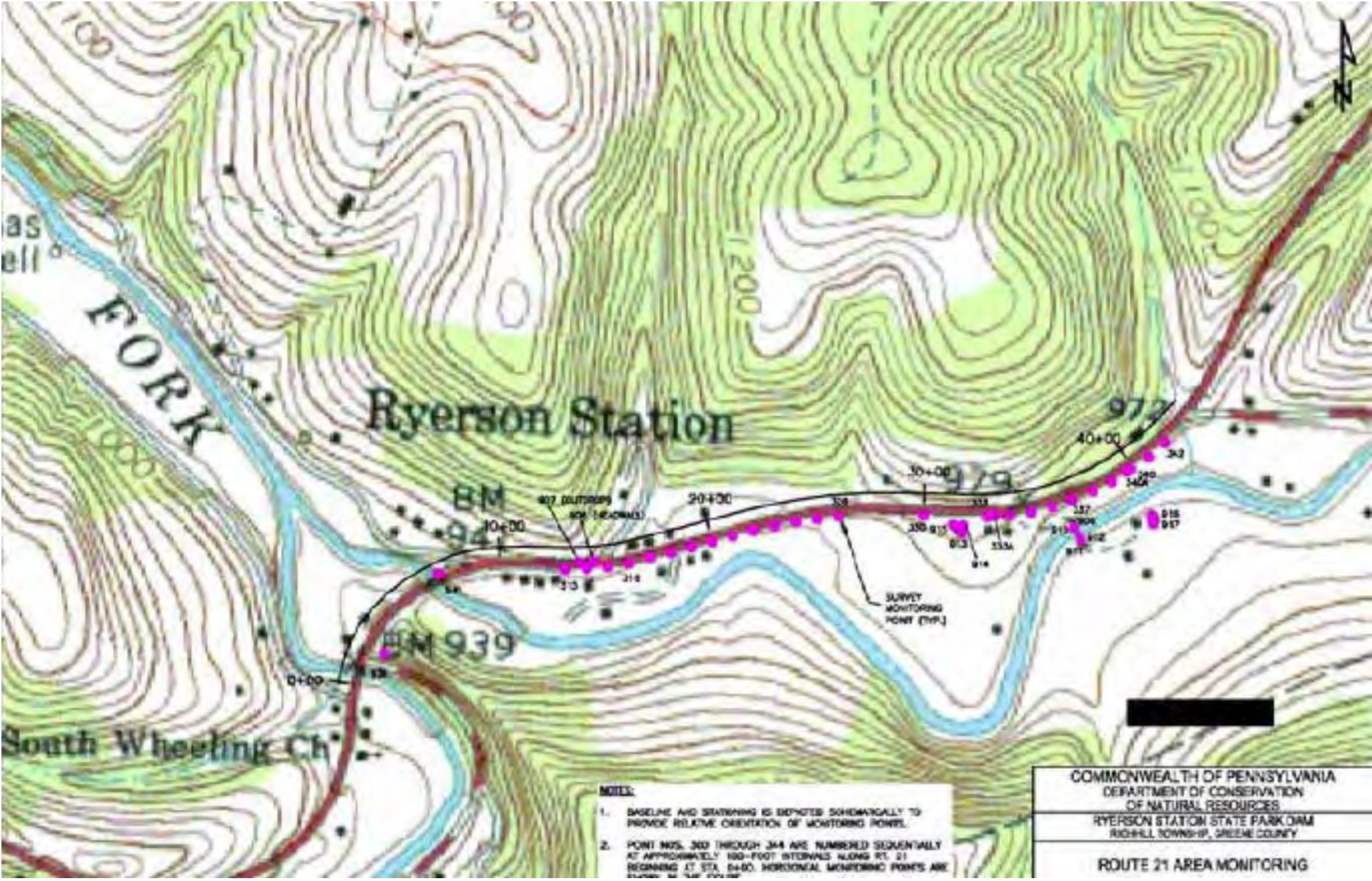


Figure IV-1: Top of Ryerson Station Dam and Lazear Lane Bridge Corners Vector Plot of Movements Through November 15, 2006 (Gannett Flemming - Volume II) Laid Over Aerial Imagery from the PAMAP Project.

Significant structural movement of the Ryerson Station Dam, evident just following observation of the July 2005 leakage, included 2 inches of westward movement of the east side of the dam, and uplift of the east side by several inches.



Mining of longwall panel 5I, located approximately 4,000 feet west of the Ryerson Station Dam under high hills north of the North Fork, was started on November 23, 2005, and was completed in late March 2006. Although this panel is well west of the dam, it was of interest due to its location under high hills adjacent to the North Fork of the Dunkard Fork of Wheeling Creek, a topographic and longwall mining relationship similar to Ryerson Station Dam.



Panel 5I was mined from east to west under high hills with State Route 21 located in the North Fork Valley at the toe of the high hills. Geodetic survey monitoring points were established along Route 21.

- Survey points at and near the southeast corner of the mine panel, as expected, moved toward the undermined area.
- A private bridge located approximately 200 feet south of the southeast corner of the panel also moved north toward the mine panel.
- A residence located approximately 300 feet southeast of the southeast corner of the panel moved about 1 inch south, away from the mine panel, between January 20 and February 13, 2006.
- Survey points further west along State Route 21 also moved away from the mine panel.

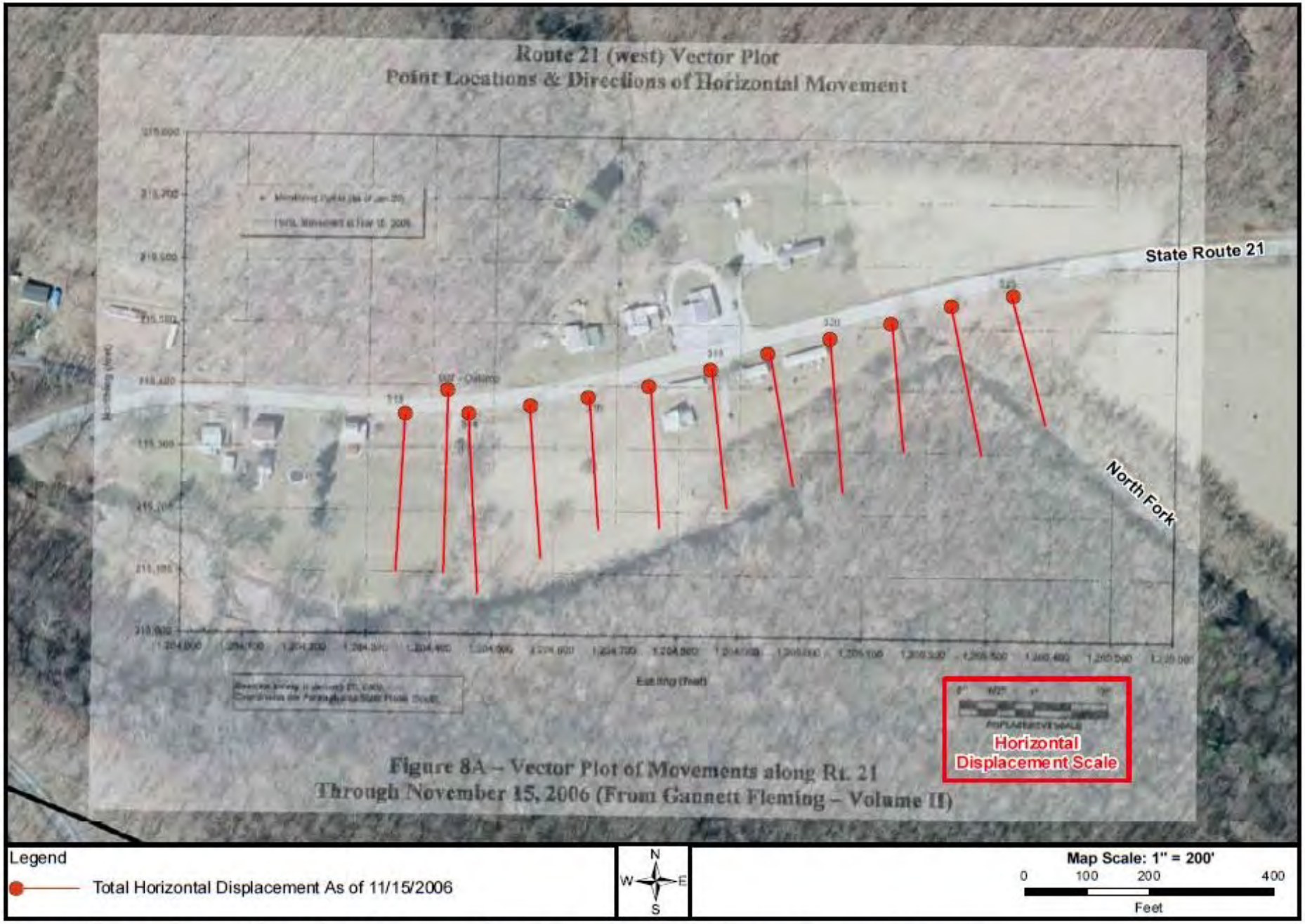


Figure IV-5: Route 21 (west) Vector Plot of Movements Through November 15, 2006 (Gannett Flemming - Volume II) Laid Over Aerial Imagery from the PAMAP Project.

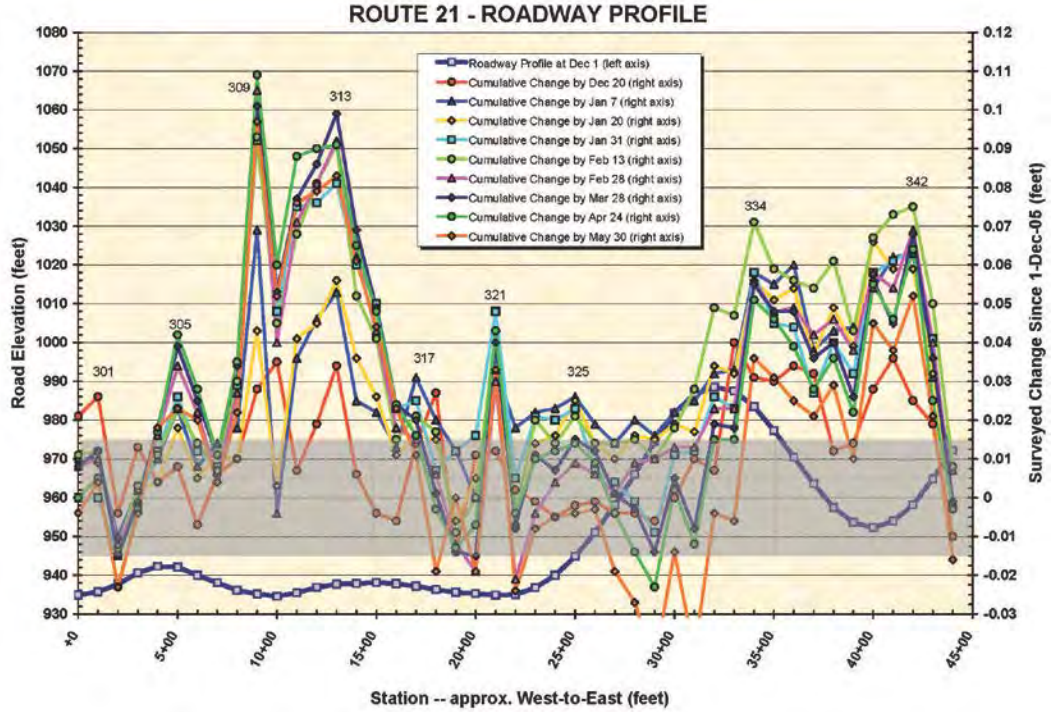
Survey points along Route 21 and well outside the angle of draw of Longwall Panel 5I moved south away from the Panel.

Horizontal Movements from January 20 to February 13, 2006

SURVEY POINT	Approximate Distance from Southside of Mine Panel 5I – feet	HORIZONTAL MOVEMENT
323	650	1.4 inches
322	700	2.1 inches
320	850	1.4 inches
316	1100	1.2 inches
313	1250	1.6 inches

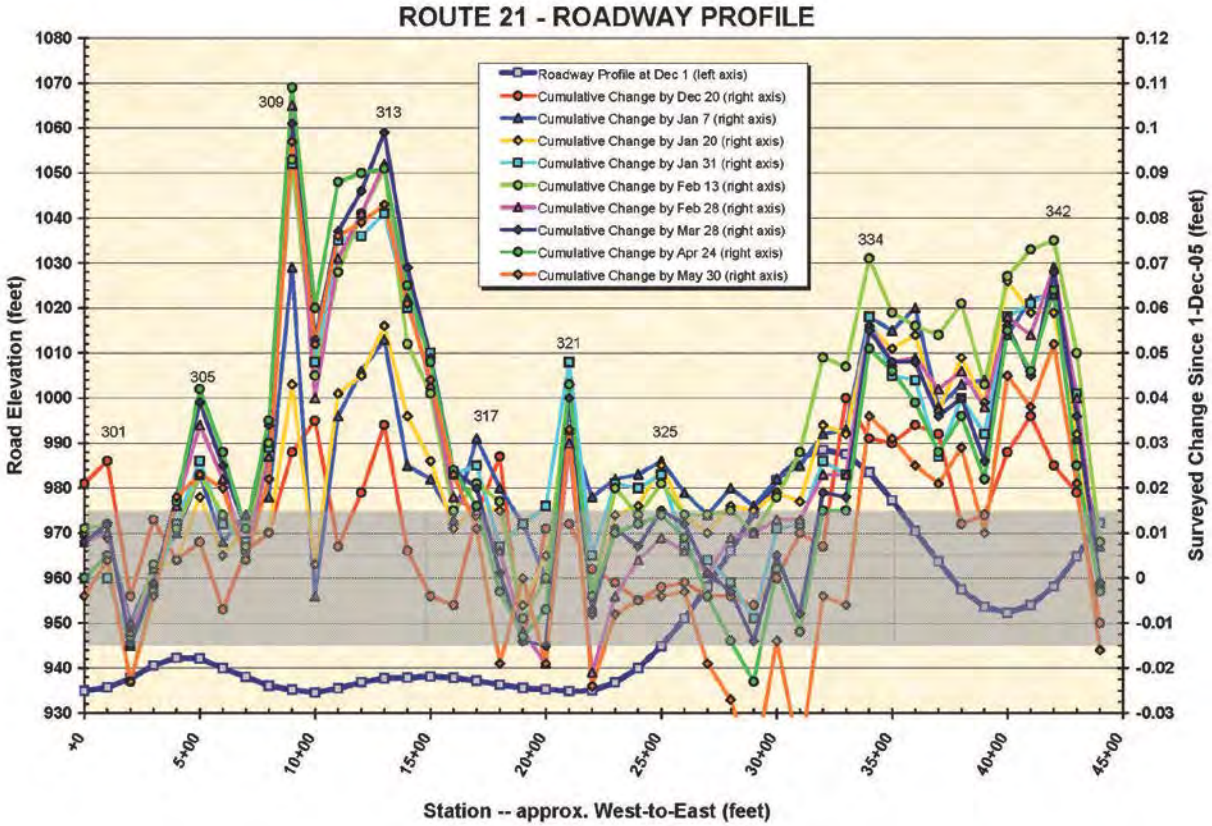
Mine Panel 5I had advanced westward prior to Gannett Fleming obtaining initial horizontal readings on January 20, 2006. Had monitoring been initiated prior to mining of the panel it is likely that the horizontal movements away from the mine panel shown above would be greater.

Monitoring the vertical movement of the survey points along Route 21 began on December 1, 2005, in advance of significant panel advance westward.



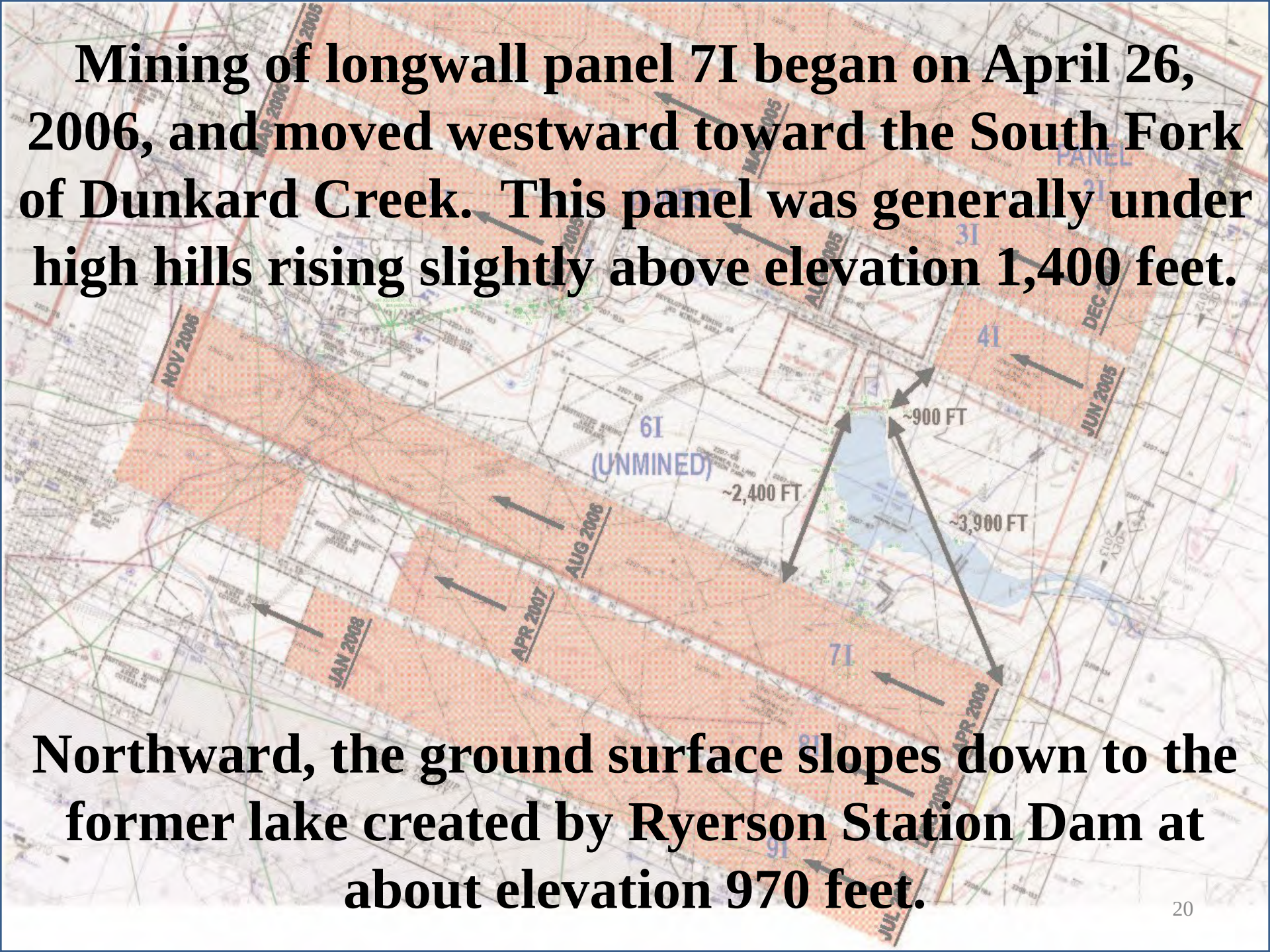
Vertical movements of the same points shown above between December 1, 2005, and February 13, 2006, are as follows:

SURVEY POINT	Approximate Distance from Southside of Mine Panel 5I – feet	VERTICAL MOVEMENT
323	650	0.24 inches
320	850	0.19 inches
316	1100	0.18 inches
313	1250	1.1 inches



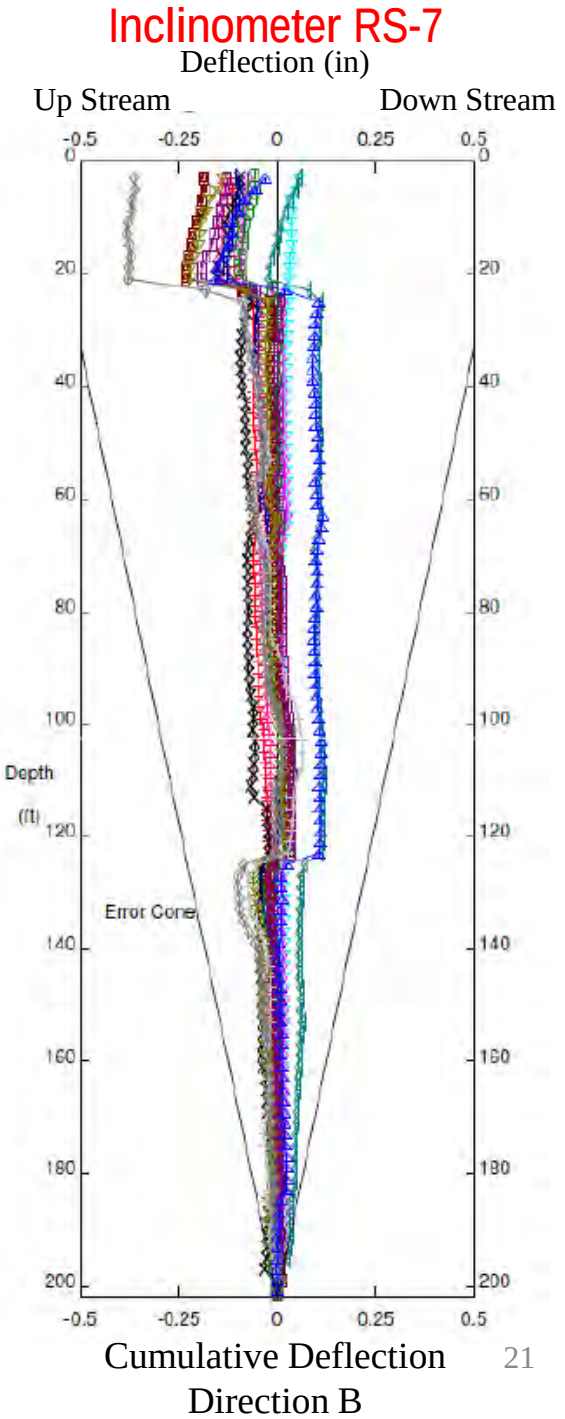
Examination of the results of the survey data indicated that the greatest heave occurred where State Route 21 was closest to the toe of the steep hillside. This heave or rotational uplift being greatest where the road is closest to the toe of the high hills is similar to the observations at the east end of Ryerson Station Dam.

Mining of longwall panel 7I began on April 26, 2006, and moved westward toward the South Fork of Dunkard Creek. This panel was generally under high hills rising slightly above elevation 1,400 feet.



Northward, the ground surface slopes down to the former lake created by Ryerson Station Dam at about elevation 970 feet.

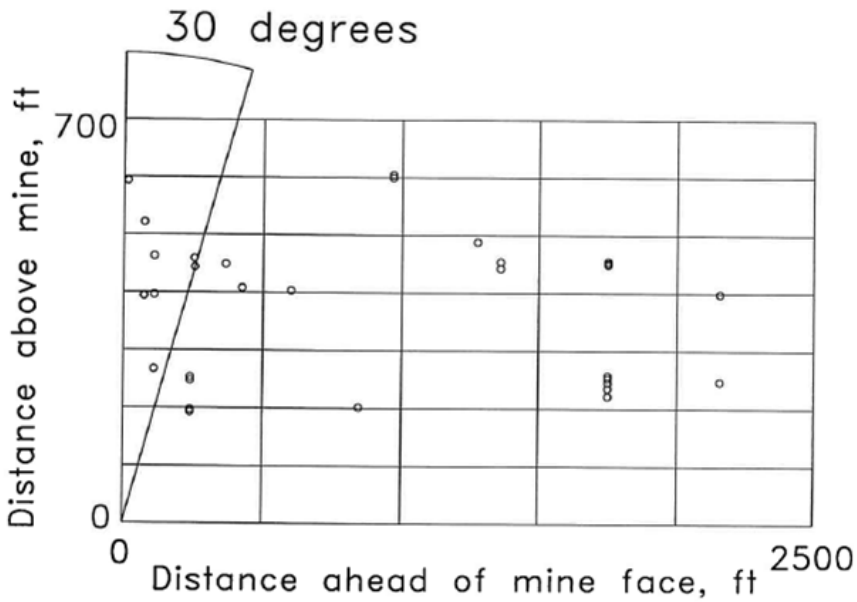
- In early 2006, five inclinometers were installed in the rock strata below the dam center line
- No significant movements were recorded by these inclinometers until mining of Longwall Panel 7I occurred 2500 feet south of the dam in the summer and fall of 2006
- Movements occurred at several levels below the dam that were interpreted as rock bedding plane slip.
- Some of the movements were sufficient to deform the inclinometers preventing their further use.
- Reactivation of surface movements of the dam were recorded by surveying between July through September, 2006.

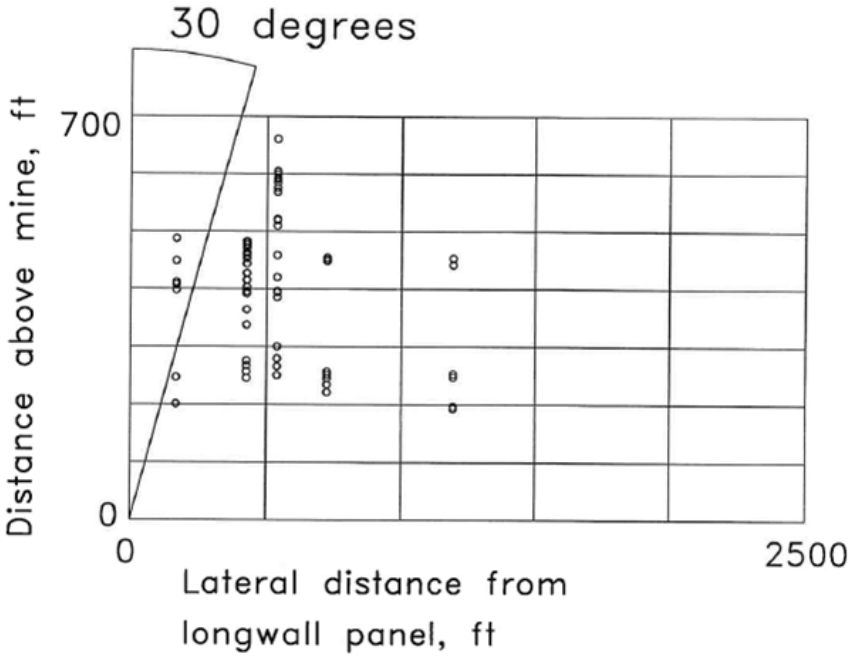


In September 2005, an out-of-service pipeline was observed to have heaved out of a stream bed approximately 1,500 feet downstream of the dam. Two pipelines located in a compressor station just downstream of the dam also moved. These pipes were located approximately 1,200 feet from longwall panel 4I.

Another example of far-field surface deformation associated with longwall mining in Pennsylvania involves Interstate 70 in Washington County. In 1999 and 2000, during longwall mining beneath the highway, ground deformations were monitored using Time Domain Reflectometry to interrogate coaxial cable installed in seven deep holes Deformations occurred within the overburden over 1,000 feet in front of the mine panel face, well beyond the limits of anticipated movement around the mine panel (GeoTDR, Inc. 2001).

Ref. Pennsylvania Department of Environmental Protection, 2004





GeoTDR, Inc.
720 Greencrest Drive
Westerville, OH 43081
614-895-1400

DSGN	
DR	KMO
CHK	JFS
APVD	KMO

PENNSYLVANIA DEPT. OF ENVIRONMENTAL PROTECTION
INTERSTATE 70 SUBSIDENCE MONITORING
SOUTH STRABANE TOWNSHIP, WASHINGTON COUNTY, PA

FIGURE 8
SHEARING ALONG ROCK
MASS DISCONTINUITIES

DATE	OCTOBER 2001
PROJ ID	01-T-09311
FILE	01-T-09311-20

Ref. Pennsylvania Department of Environmental Protection, 2004

Conclusion

Based on observations following the 2005 leakage of Ryerson Station Dam and other events described herein it is appropriate to say that the non conventional ground movements related to mining observed for many years in Australia occur in Pennsylvania. The movements are small and have only been recorded by careful topographic surveying, and surveys of structural damage or ground deformations. It appears the most likely features to be damaged are structures, such as concrete dams and pipelines, which extend across valleys in areas of significant relief.

References

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