Slide 1

Techniques To Discern Whether A Given Underground Mine Map Is Accurately Portrayed and Referenced to the Surface.

By: Robert D. Gibson
Illinois Department of Natural Resources
Office of Mines and Minerals
Abandoned Mine Lands Division

Slide 2

Accuracy and Precision of Mine Map and Map Geo-rectification

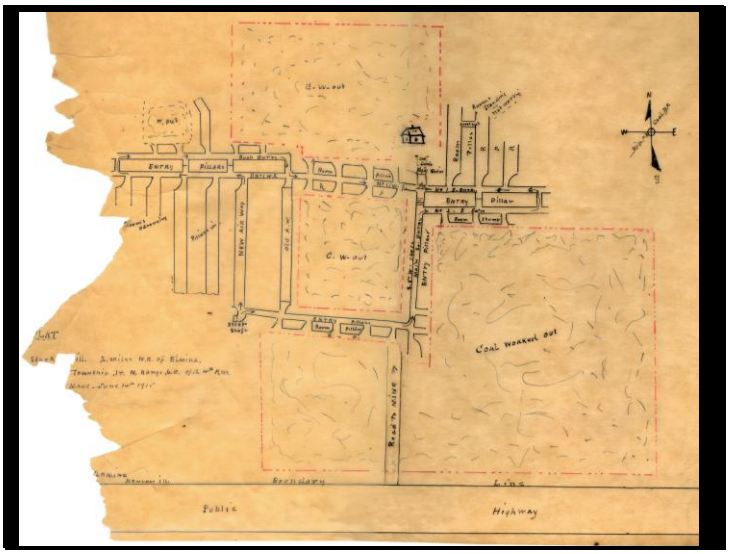
Not All Mine Maps Are Created Equal

Slide 3

Mine Map Considerations

- Is the map intended as a pictorial rendering or as a precise representation of mining conditions ?

Slide 4



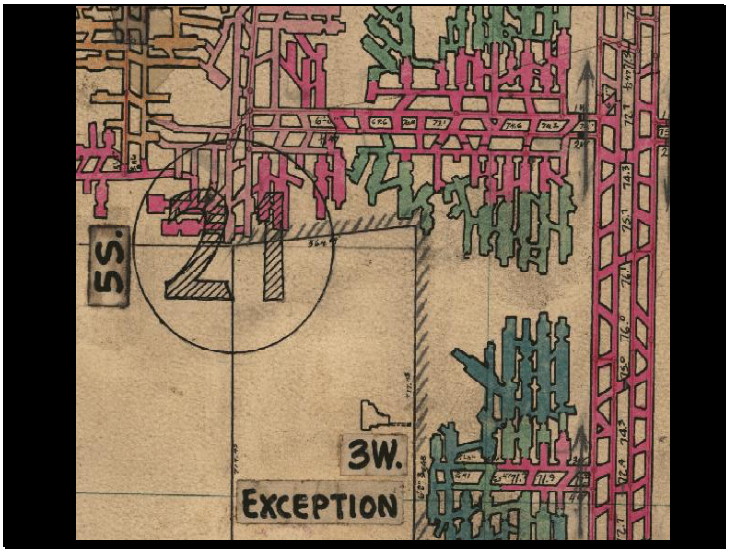
1911 Mine map. Scale is missing. Pillars are proportional. Note Dip is included. Example of a map that cannot be geo-rectified due to insufficient surface information. It may be possible to locate, with GPS, the shaft and road intersection shown on the map and place the mining in its approximate location. Fortunately such poor maps are relatively few.

Slide 5

Mine Map Considerations

- Is the map intended as a pictorial rendering or as a precise representation of mining conditions ?
- How close does the map intend to portray actual pillar geometry ?

Slide 6



Slide 7

Mine Map Considerations

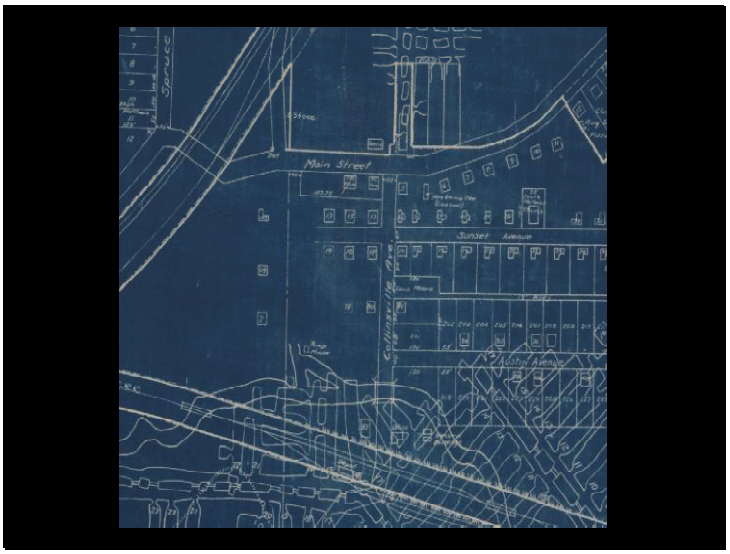
- Is the map intended as a pictorial rendering or as a precise representation of mining conditions ?
- How close does the map intend to portray pillar geometry ?
- Is the map scaled appropriately for intended use ?

Slide 8

Mine Map Considerations

- Is the map intended as a pictorial rendering or as a precise representation of mining conditions ?
- How close does the map intend to portray pillar geometry ?
- Is the map scaled appropriately for intended use ?
- Does the map include sufficient surface features for geo-rectification ?

Slide 9



1931 Map. Blue line mine map (segment) contained in the Illinois Mine Map Archives. This map is somewhat unusual in that it has an abundance of surface information plotted relative to the mine workings.

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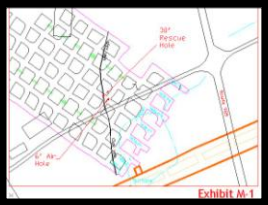
Mine Map Considerations

- Is the map intended as a pictorial rendering or as a precise representation of mining conditions ?
- How close does the map intend to portray pillar geometry ?
- Is the map scaled appropriately for intended use ?
- Does the map include sufficient surface features ?
- Is the map complete ?

Slide 11

QueCreek



From: US Department of Labor – QueCreek Mine Rescue

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Not All Mine Maps Are Created Equal However, the norm is that …

- Good faith effort was made by coal companies in mapping their workings as accurately as possible.

Slide 13

Not All Mine Maps Are Created Equal However, the norm is that …

- Good faith effort was made by coal companies in mapping their workings as accurately as possible.
- The same good faith effort is being made by various governmental programs in geo-rectifying the mine maps.

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How Can We Confirm The Accuracy And Precision Of The Mine Map And Geo-Rectification Process ?

- Map Inspection

Slide 15

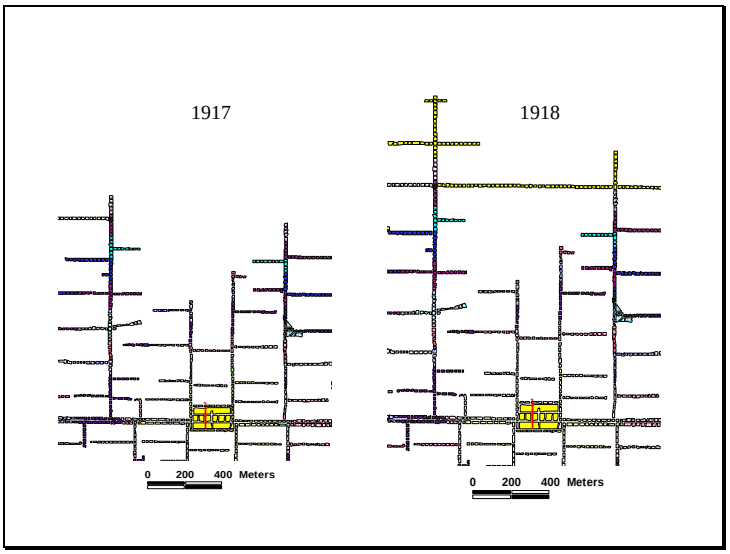

Figure 8. Example showing Entry development in the Madison County No. 6 Mine and the high level of accuracy possible in old mines.
1,800 ft (east and west of shaft) 4,800 ft north – over 18 years, no offset. (400 m x 1,100 m)

Slide 16

How Can We Confirm The Accuracy And Precision Of The Mine Map And Geo-Rectification Process ?

- Map Inspection
- GPS measurement of surface features shown on the mine map.

Slide 17

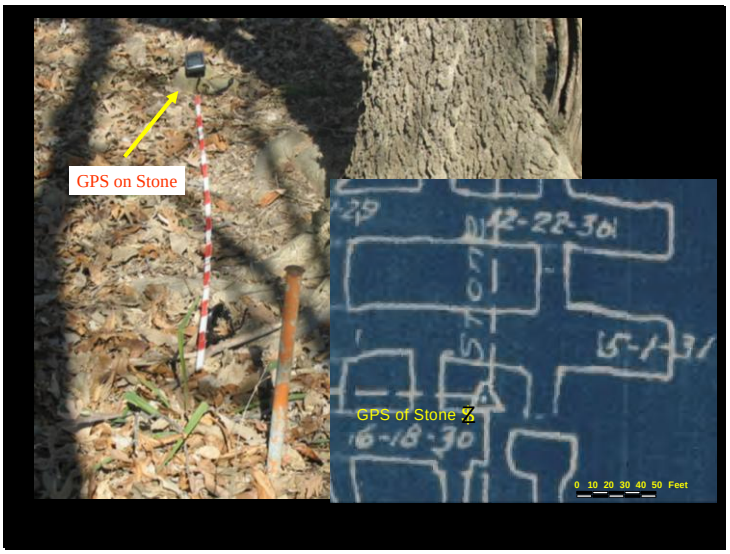

Figure 12. Photograph of stone used in mine survey shown on the mine map inset and its GPS measurement location.

Slide 18

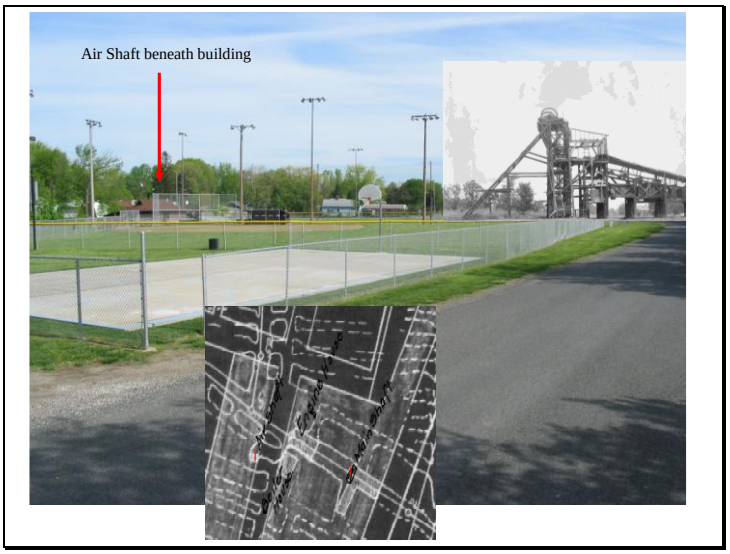

Figure 11. Surface land use development frequently obscures shaft locations making precise X-Y coordinate measurements difficult (From: Gibson, 2005).

Slide 19

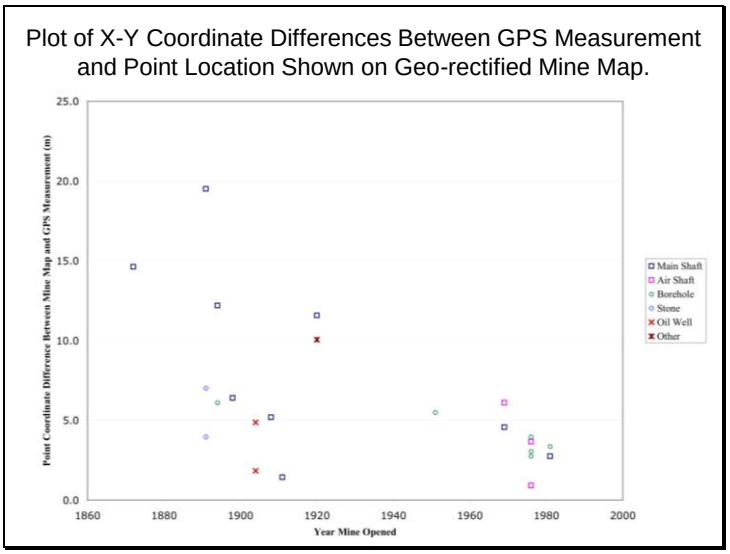

Figure 13. Plot of X-Y coordinate difference between GPS measurement and point location shown on geo-rectified mine map.

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How Can We Confirm The Accuracy And Precision Of The Mine Map And Geo-Rectification Process ?

- Map Inspection
- GPS measurement of surface features shown on the mine map.
- Subsidence as an indicator

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Subsidence Characteristics in Relation to Underground Mining

- Subsidence forms directly above the mine failure.

From: Young, 1916

Slide 22

Subsidence Characteristics in Relation to Underground Mining

- Subsidence forms directly above the mine failure.
- Subsidence related ground cracks form within a panel at ribside.

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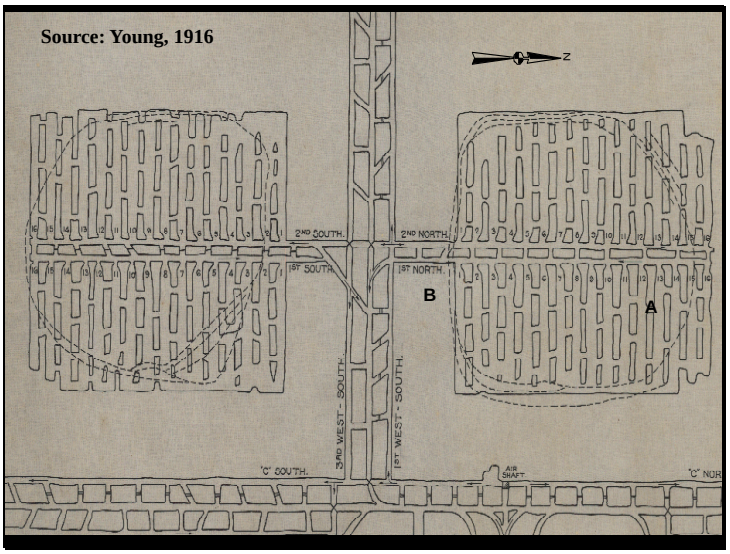
Slide 23



1916 Map. “Plan of two panels of a Franklin County mine, 550 feet deep. Subsidence caused surface cracks as indicated. Over the north panel at A the crack was 8 to 10 inches wide, and at B were two smaller cracks” (Young, 1916).

Slide 24

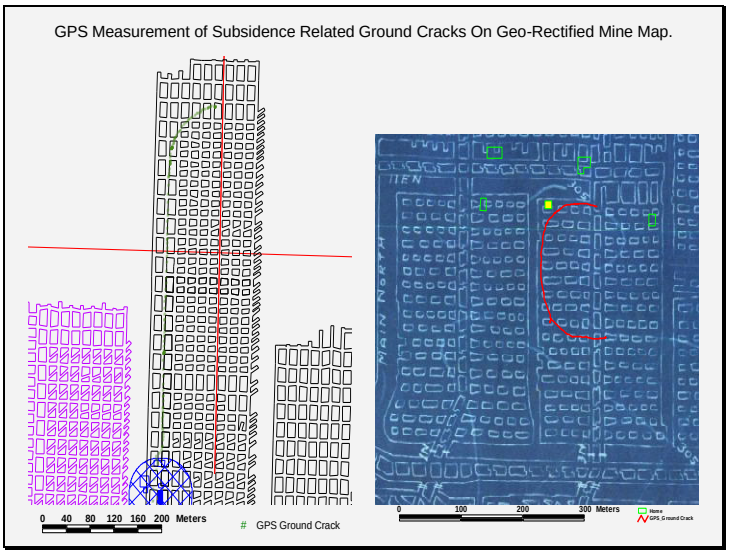


Figure 14. GPS measurement of subsidence related ground cracks plotted relative to geo-rectified mine maps for two case in central Illinois..

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Subsidence Characteristics in Relation to Underground Mining

Young, 1916:

- Subsidence forms directly above the mine failure .
- Subsidence related ground cracks form within a panel at ribside.

Herbert and Rutledge, 1927:

- Subsidence related ground movements can be measured quantitatively.

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- Ground settlement increases in magnitude through time until subsidence is complete.

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Subsidence Characteristics in Relation to Underground Mining

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- Subsidence related ground cracks form within a panel at ribside.

Herbert and Rutledge, 1927:

- Subsidence related ground movements can be measured quantitatively.
- Ground settlement increases in magnitude through time until subsidence is complete.
- Maximum settlement occurs over the panel and decreases in magnitude until there is zero settlement at or near ribside.

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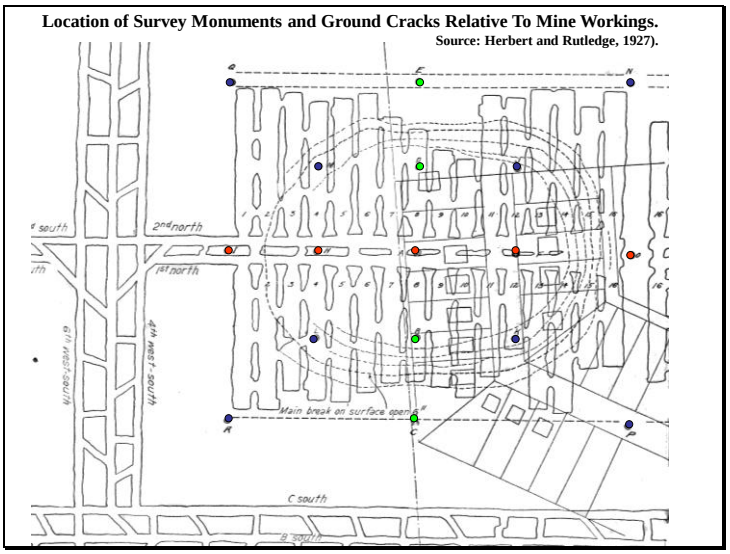

Note: location of ground cracks confirm Young's earlier observations.
"Study of subsidence over first and second north panel entries off fifth west south at D. Room interval, center to center of rooms, 40 ft.; barrier pillar, 150 ft.; number of rooms on panel, 16; fire pillar, 50 ft." (Herbert and Rutledge, 1927).

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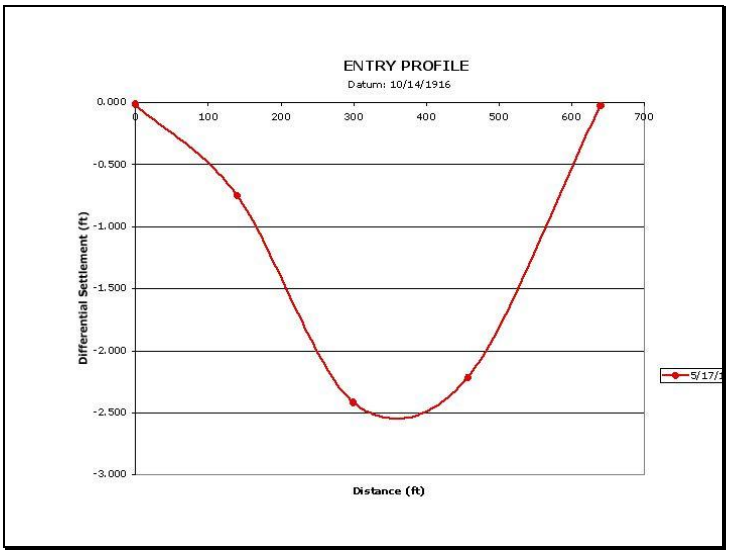
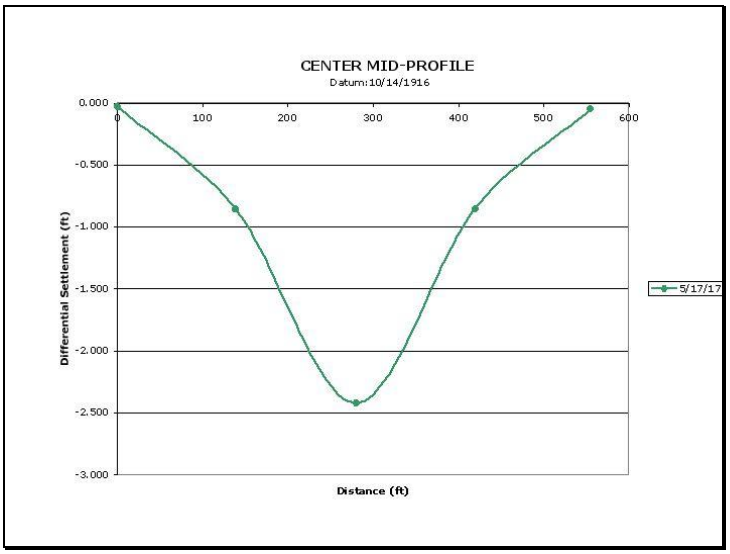

ENTRY PROFILE
Datum: 10/14/1916
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
0
100
200
300
400
500
600
700
Differential Settlement (ft)
Distance (ft)
5/17/2

Slide 30


CENTER MID-PROFILE
Datum:10/14/1916
0.000
-0.500
-1.000
-1.500
-2.000
-2.500
-3.000
0
100
200
300
400
500
600
Differential Settlement (ft)
Distance (ft)
5/17/17

Slide 31

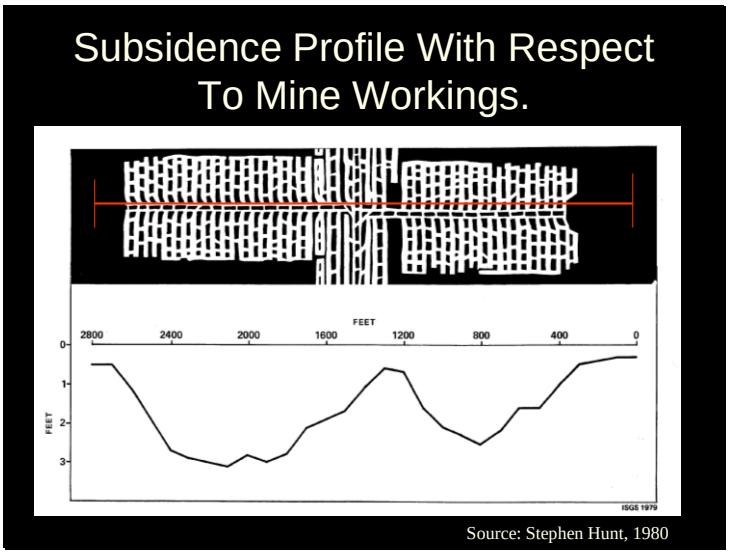


Figure 5. Subsidence profile plotted with respect to the mine workings. Note the decreased settlement associated with the barrier pillar adjacent to the entry. (After: Stephen Hunt, 1980).

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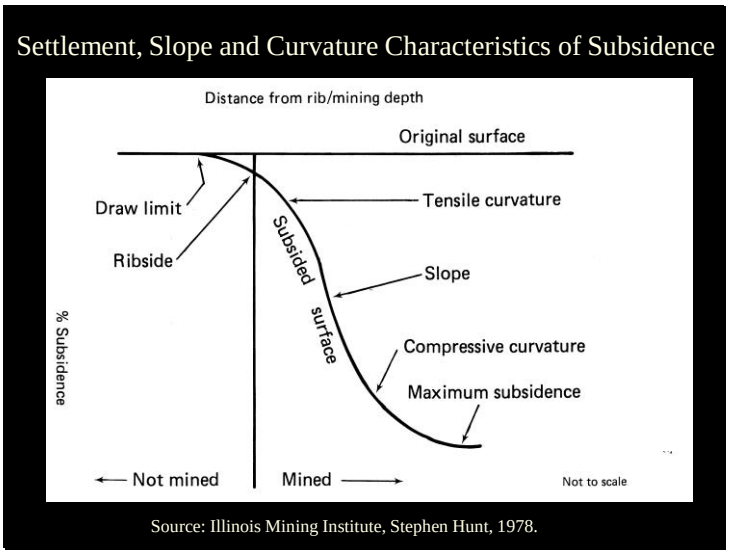

Figure 4. “Diagram showing the features common to most subsidence profiles.” (From: Stephen Hunt, 1978))

Slide 33

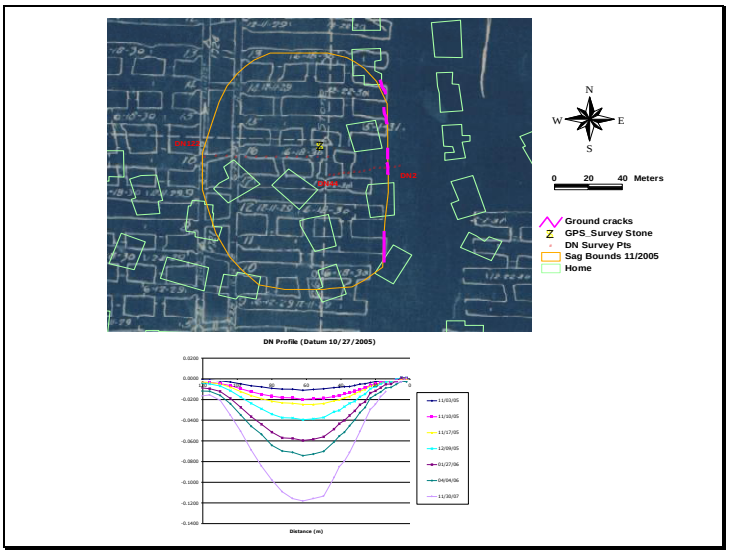

Figure 21. GPS measurement of ground cracks and DN Profile survey monuments plotted relative to a geo-rectified mine map. The differential vertical settlement measured along Profile DN is shown at the same horizontal scale as the mine map to facilitate direct comparison.

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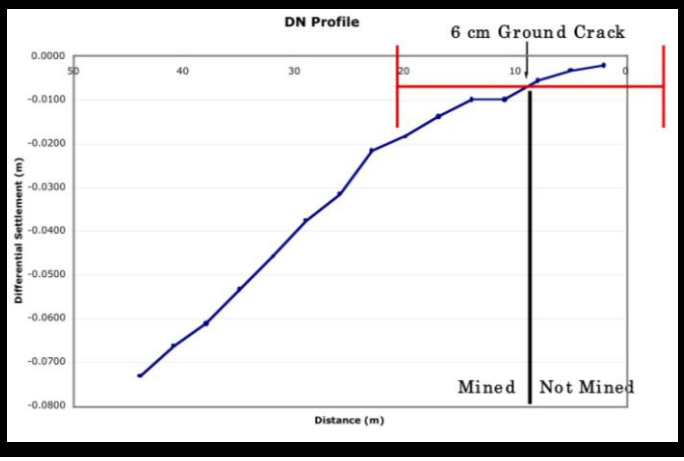
Subsidence Profiles Relative To Ribside



Slide 35

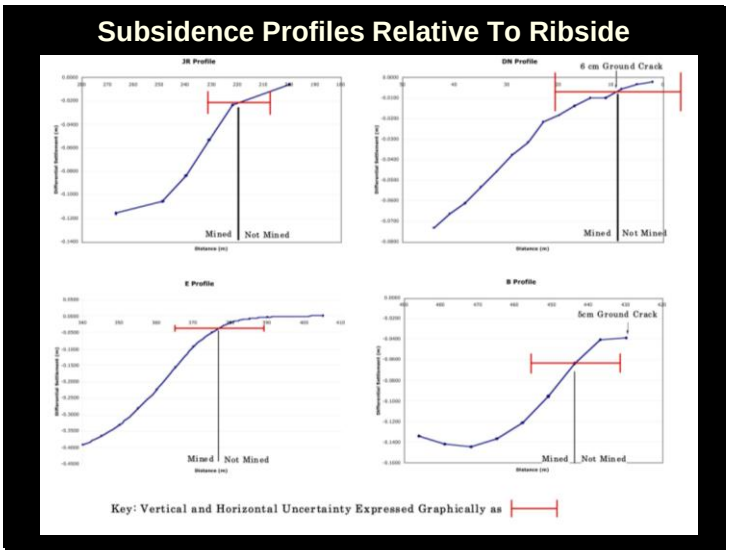


Figure 16. Subsidence profiles and ribside positioning. Vertical Certainty: Bauer and Van Roosendaal, 1992 suggested that (+/-) 0.9cm was a practical lower limit of precision. Horizontal Certainty: USGS – 90% of well defined points are to be plotted within 1/50th of an inch (40 ft).

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Subsidence Information Sources

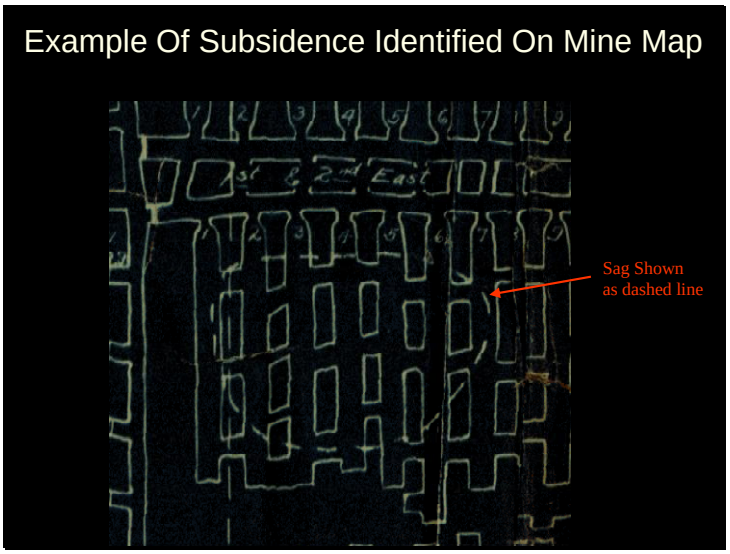
- Direct field measurement of active subsidence.
  - GPS ground cracks
  - Establish Survey Profiles

Slide 37

Subsidence Information Sources

- Direct field measurement of active subsidence.
  - GPS ground cracks
  - Establish Survey Profiles
- Historical Records and Subsidence Studies.

Slide 38


Example Of Subsidence Identified On Mine Map
East
Sag Shown
as dashed line

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Subsidence Information Sources

- Direct field measurement of active subsidence.
  - GPS ground cracks
  - Establish Survey Profiles
- Historical Records and Subsidence Studies.
- Aerial Photography.

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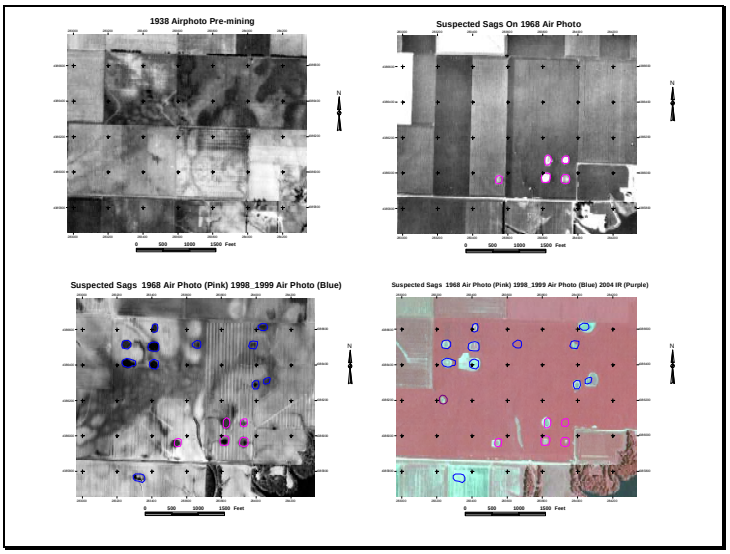

Figure 9. Suspected subsidence features identified using geo-rectified aerial photography from different time periods. Area mined post 1938. Bauer and Van Roosendaal,1983 recommend 1:4,000 to 1:10,000 scale AP when drainage shows high contrast – basically, fly your own. However, ‘off-the-shelf’ DOQ’s work pretty good.

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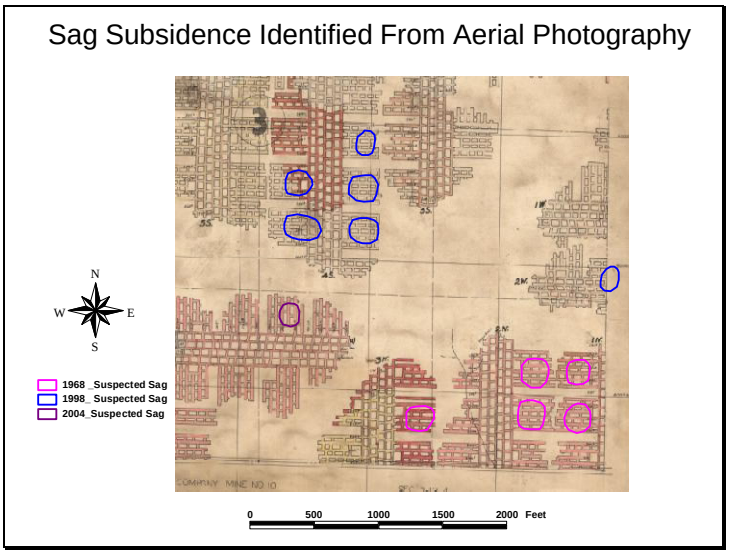

Figure 10. Sag development identified from aerial photography taken through time plotted relative to mine workings.

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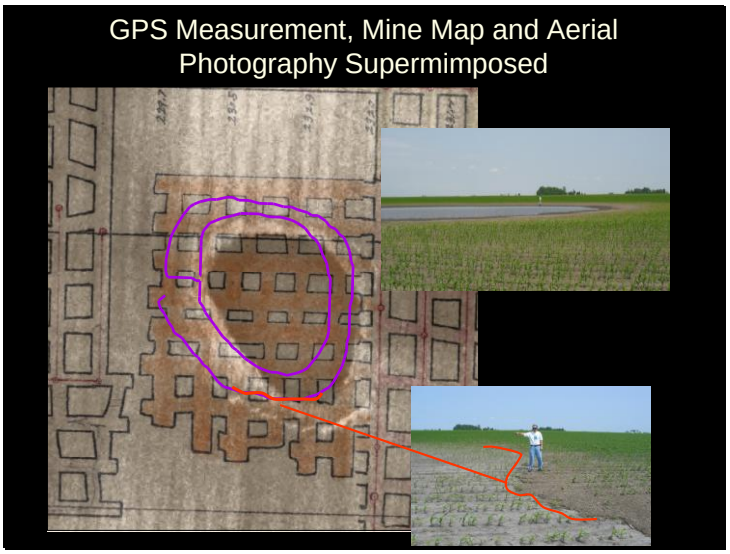

Figure 15. GPS measurement of subsidence induced ponded water and strandlines plotted relative to mine workings.

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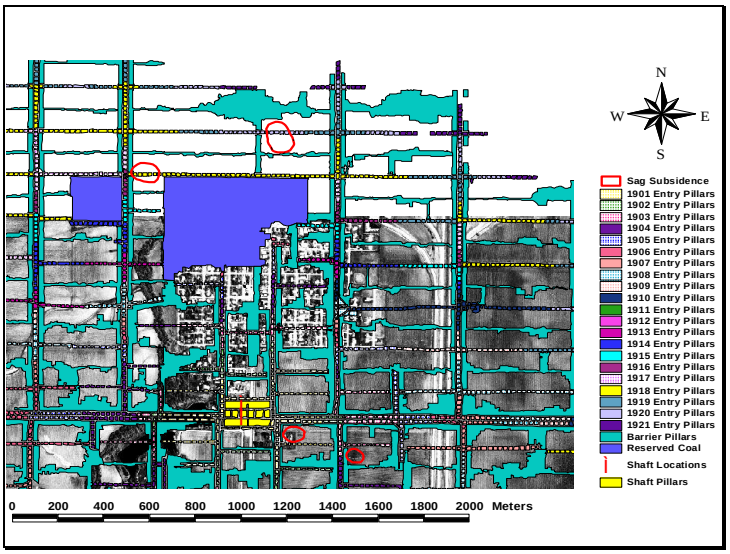

Figure 17. Subsidence events plotted relative to mine development on the north half of the mine. Northern most sag is highlighted in Figure 18.

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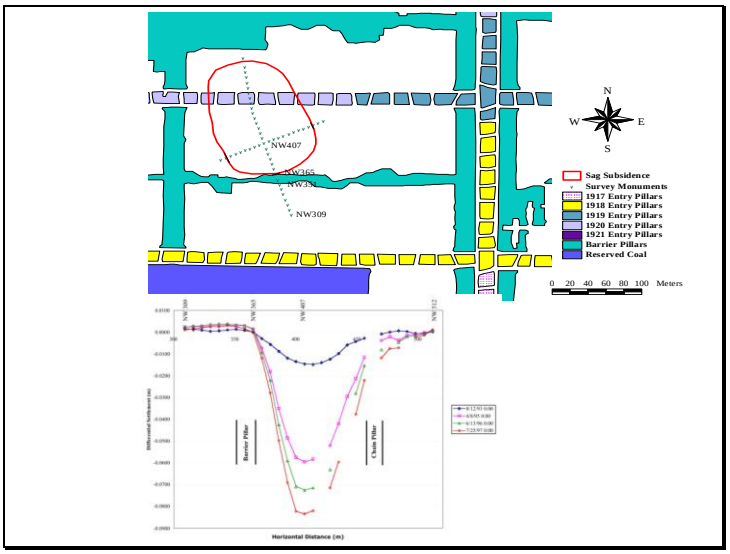

Figure 18. Approximate location of Profile NW with respect to mining. Note the influence of the barrier pillar on vertical settlement and that the 1918 entry pillars shown above are the same of those illustrated and discussed in Figure 8.

Slide 45

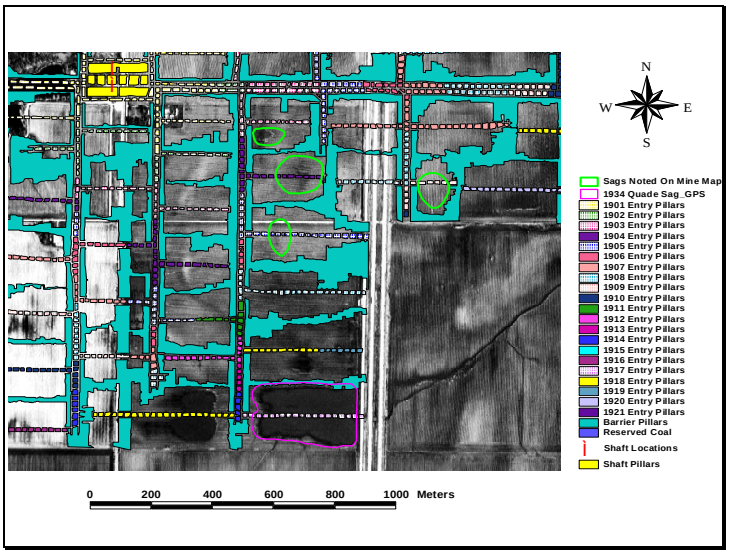

Figure 19. Shown are subsidence events, GPS measurement and mine workings plotted relative to a 1998 DOQ. Subsidences shown in green are those identified by the coal company while the mine was active (pre-1925). Subsidence shown in purple, was identified by J.C. Quade (Figure 20) in 1934 and re-mapped by the author in 2004 using GPS.

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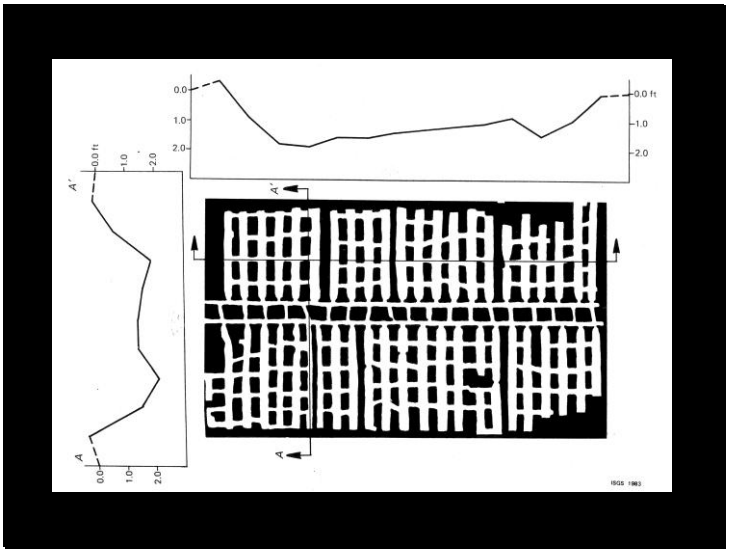

Figure 20. “Map and subsidence profiles of production panel in No. 6 Mine of the Madison Coal Corporation
based on survey by Quade, 1934.” (DeMaris and Bauer, 1983).

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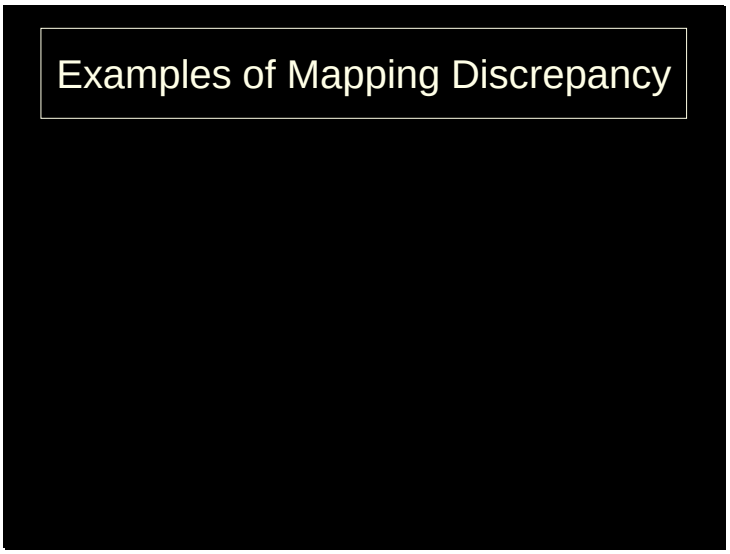

Slide 48

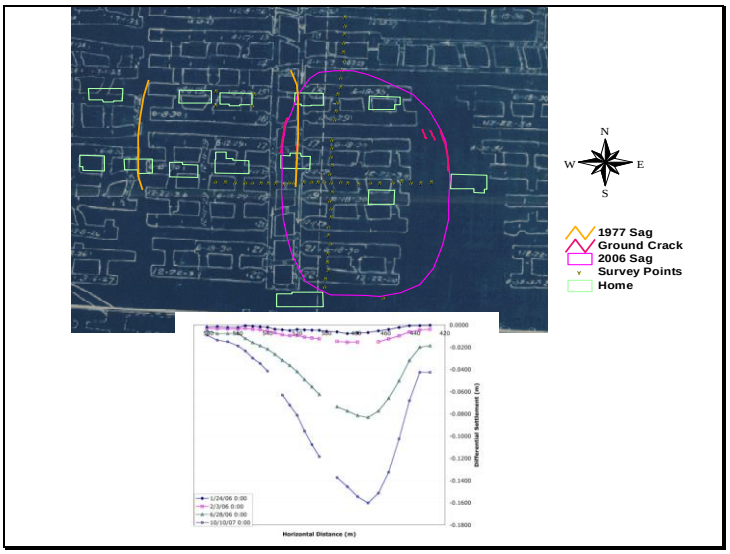

Figure 22. The boundary of two subsidence events, ground cracks, homes and survey monitoring points plotted relative to mine workings

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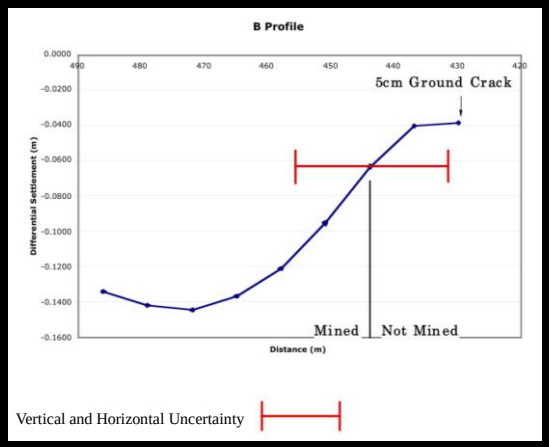
Subsidence Profiles Relative To Ribside



Slide 50

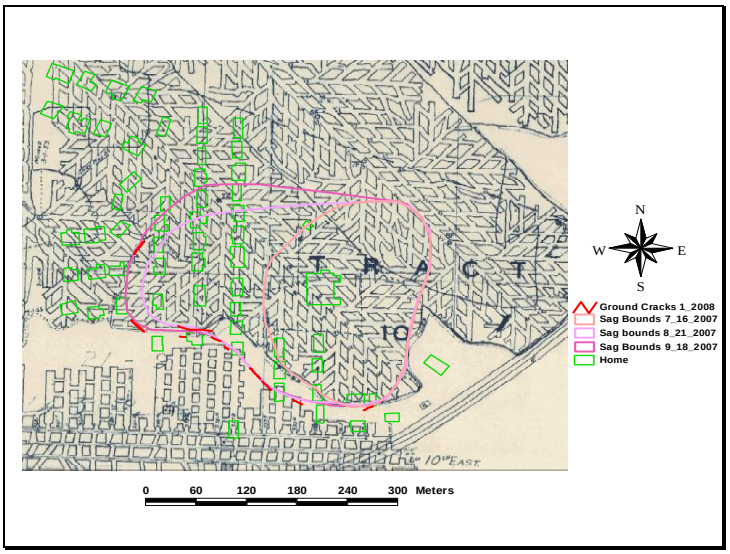


Figure 23. Example of progressive mine failure causing damage to numerous homes and potentially threatening many more.

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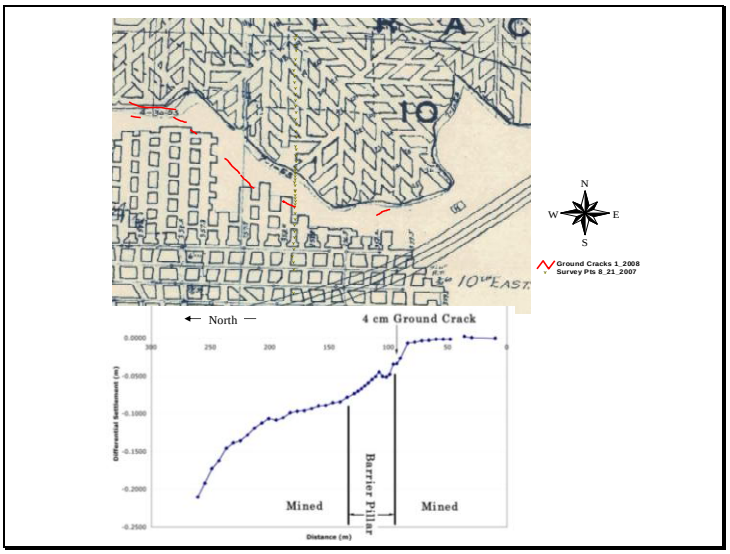

Figure 24. Large ground cracks, survey monuments and differential settlement Profile EG located relative to geo-rectified mine workings.
Crack location and settlement data indicate that the mine workings are improperly located with respect to ground surface.

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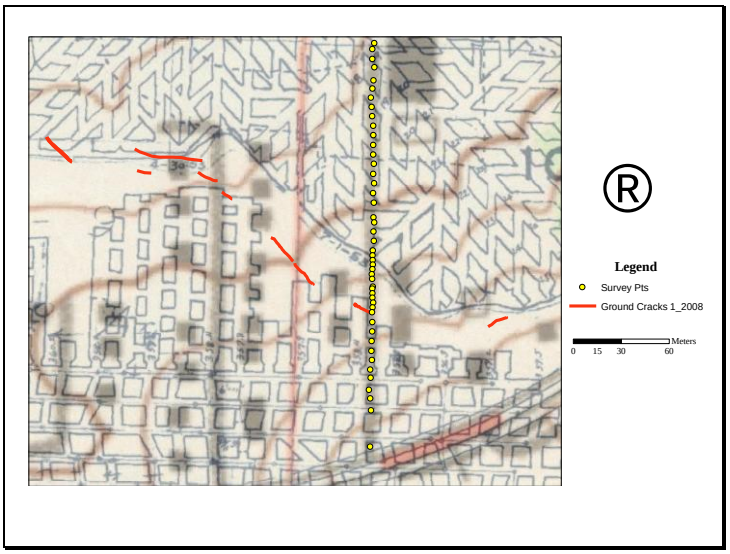

Figure 25. Ground cracks, Profile EG survey points, and geo-rectified mine map positioning with respect to the reference topographic map.