Mitigation of Abandoned Mine Entries at Swanbank Enterprise Development, Ipswich, Australia

10th Interstate Technical Group on Abandoned Underground Mines Workshop Harrisonburg, VA

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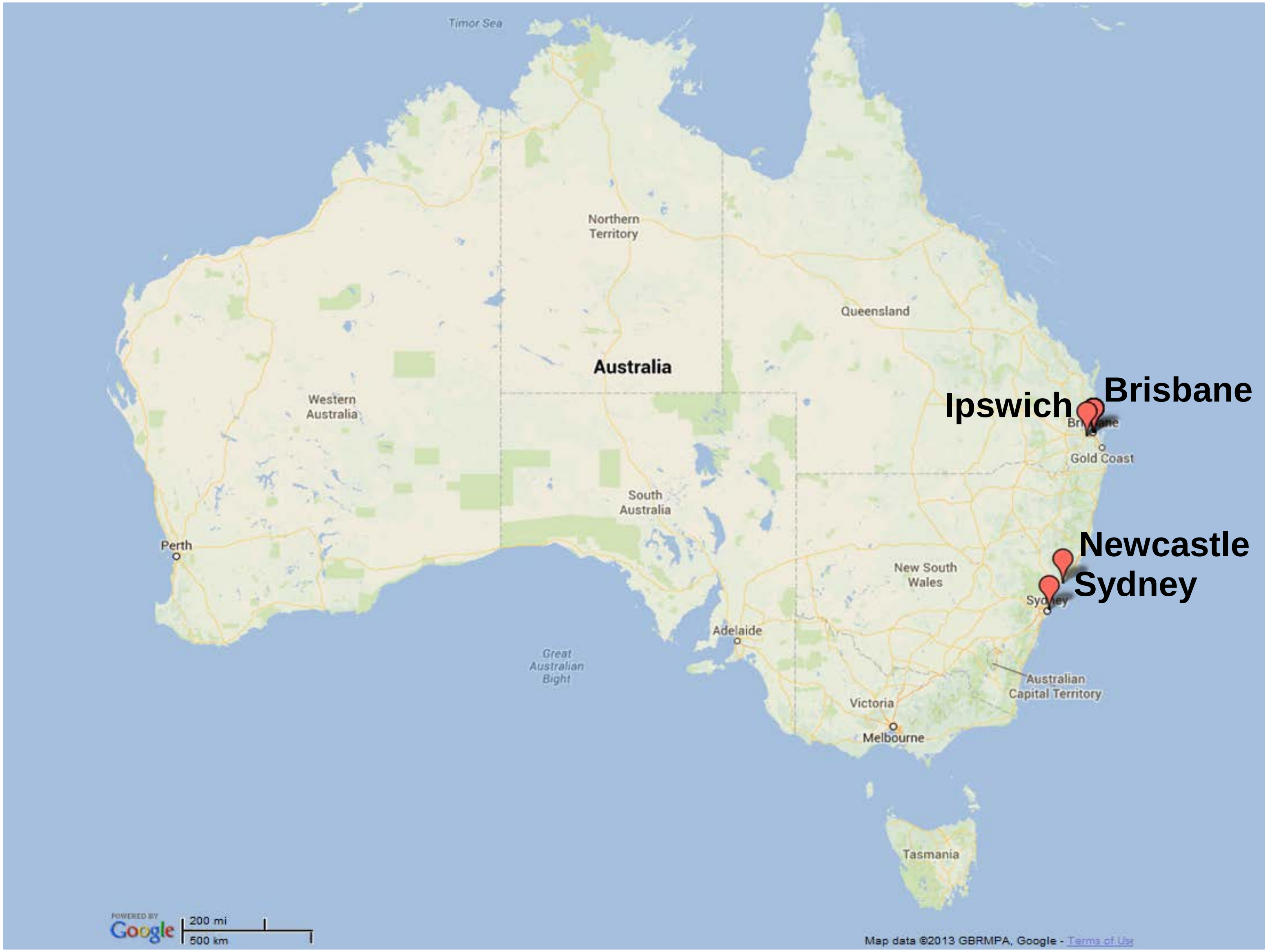
Site Location



Introduction

- The purpose of the project was to stabilize abandoned coal mine entries at three mines to allow redevelopment of the site.

- The entries consisted of cut and cover Armco Steel Arch sections connecting to tunnels in rock or coal, tunnels excavated in rock, and a shaft. The entries were constructed between about 1900 and the 1996.

- Storage areas for materials were planned over the entries.

- No investigation was performed.

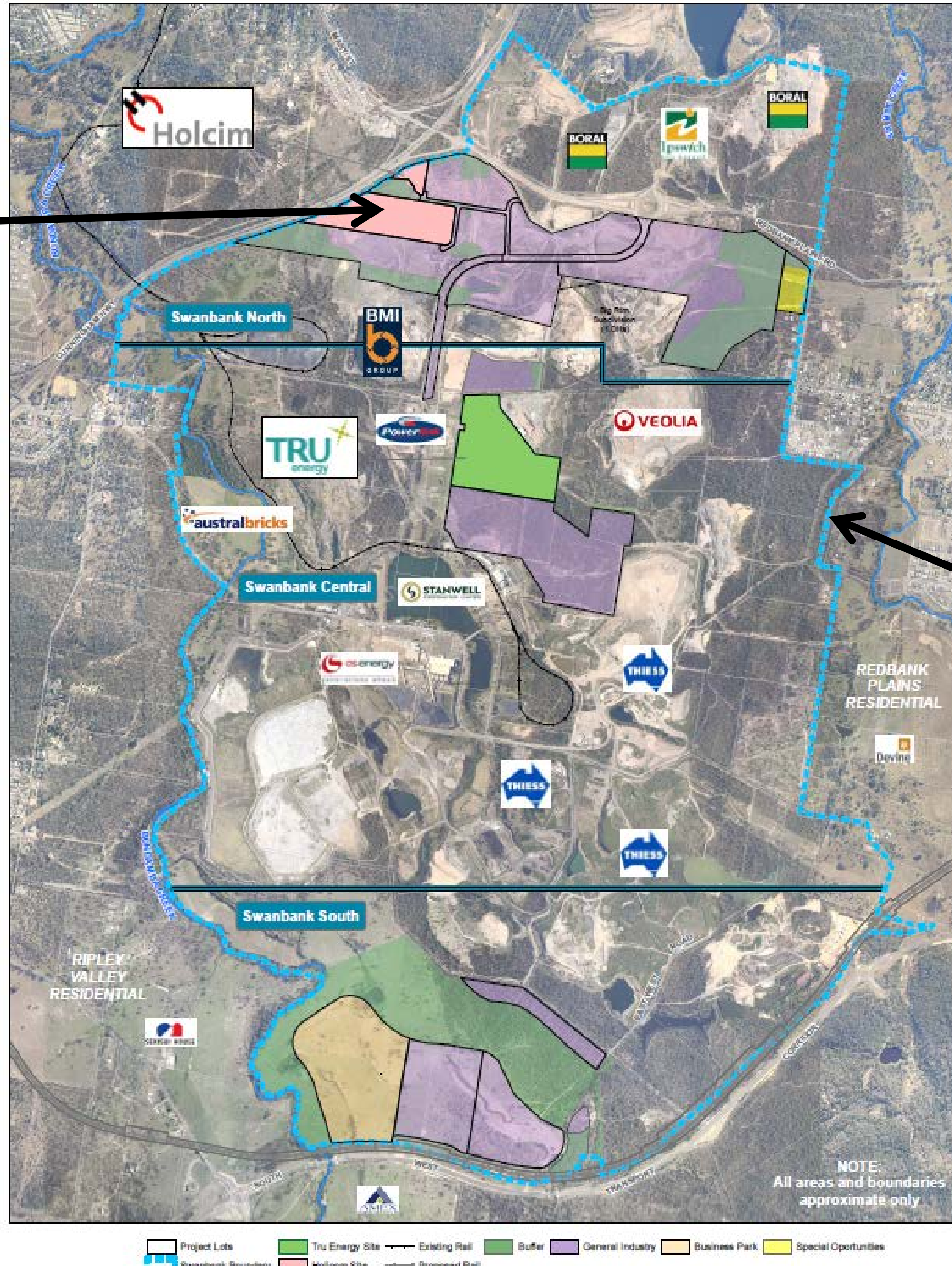
Swanbank Enterprise Park is strategically located adjacent to the Ripley Valley, the fastest growing metropolitan region in Australia, with an estimated future population of 120,000. The development is just 28kms from Brisbane and 10 minutes from Ipswich. Proximity to this burgeoning growth corridor provides an outstanding resource from which skilled workers can be drawn.

Swanbank Enterprise Park is a green 5436 ac (2,200ha) master planned estate with 741ac (300ha) of prime industrial land available for the development of major industry. Swanbank will be the largest industrial estate in South East Queensland, meticulously master planned, not just for efficiency, but also for environmental sustainability. 3459ac (1,400ha) have been set-aside as conservation and buffer areas.

Swanbank is perfectly positioned to integrate seamlessly with one of Australia's fastest growing regions. Outstanding cooperation with local government planning ensures efficient approval processes. Built around an existing power station, this master planned estate will deliver far more than economical energy: with the Cunningham Highway to the North and the Centenary Highway to the South, access couldn't be easier. Markets, ports, raw materials and skilled workers are all within easy reach.

Project Area

Edge of Development



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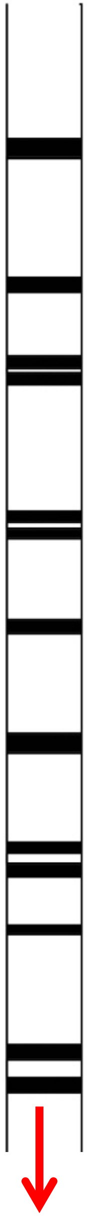
Triassic Age Ipswich Coal Measures Stratigraphy



Not to scale

Blackstone Formation

Seam Name	Seam Thickness		
Thomas/New Found Out	26.2-29.6 ft. (8-9m) Splits in places.		
Aberdare	22.11-26.2 ft. (7-8m)		
Bluff	Up to 29.6 ft. (9m) Splits in places.		
Four Foot	2 Splits	8.2 ft. (2.5m)	← Aberdare "Aspro" No. 4
Bergin	13.1-16.4 ft. (4-5m) Splits.		← Rhondda No. 5
Striped Bacon	8.2 ft. (2.5m)	Consistent.	
Rob Roy	6.6 ft.(2m) Tops 8.2 Ft. (2.5m) Bottoms		
Lindsay's Hard	6.6 ft. (2m)		
Cochrane	8.2 Ft. (2.5m)	3.3-49.2 ft. (1-15m)	← New Hill
Ritchie	9.11 ft. (3m)	Interburden	

Tivoli Form

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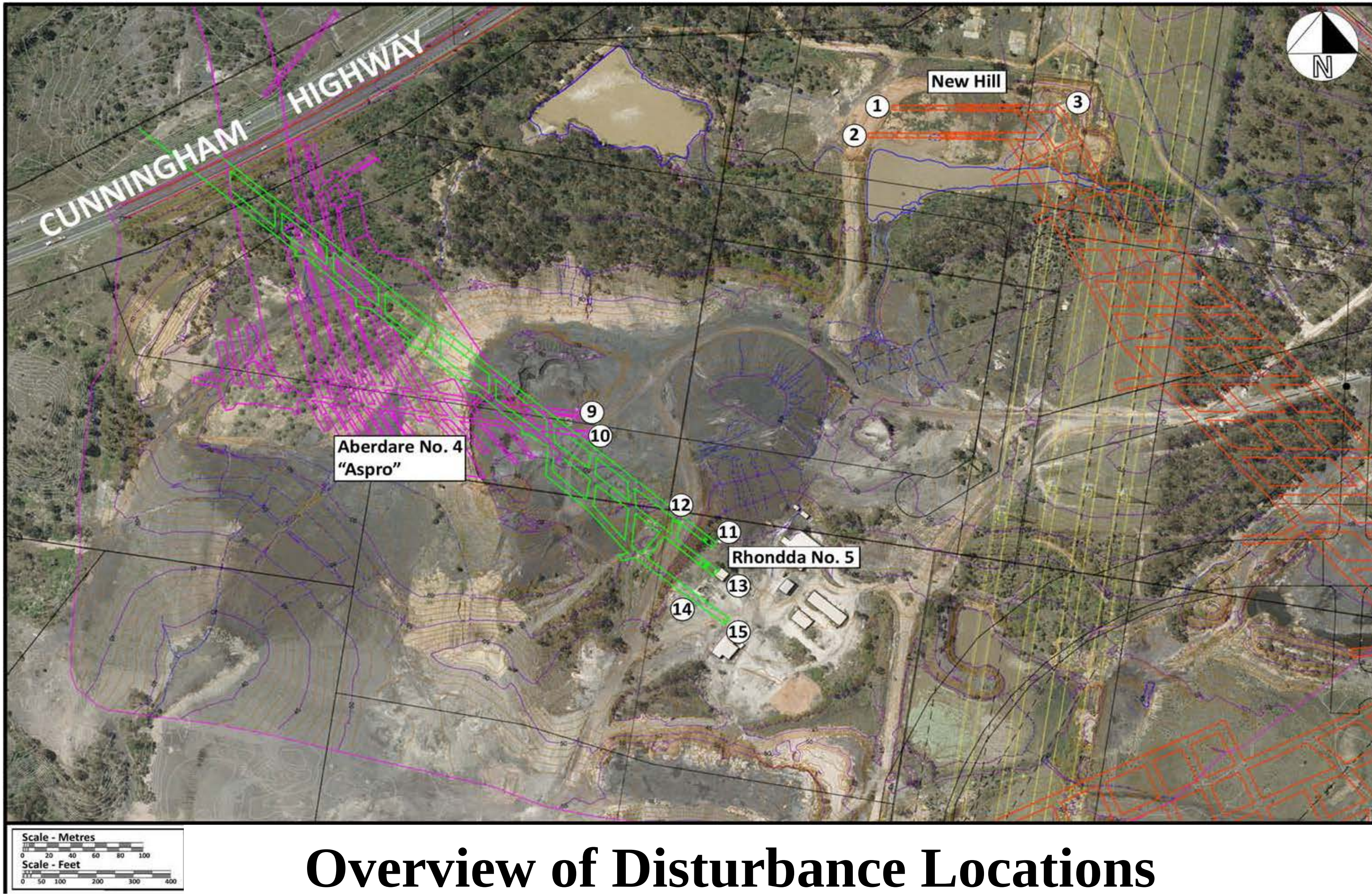

Overview of Disturbance Locations

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Rhondda No. 5 Colliery
Entry Tunnels
Disturbances 11, 13, and 15

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Rhondda No. 5 Colliery

Background

•Three Armco steel arch cut and cover tunnels to the Bergins Seam;

•Mined 1976 to 1998;

•Tunnels sealed at end of mining by puncturing the Armco Section and placing a clay plug in the tunnel;

•Two of the entries were covered with coal waste.

Existing Conditions

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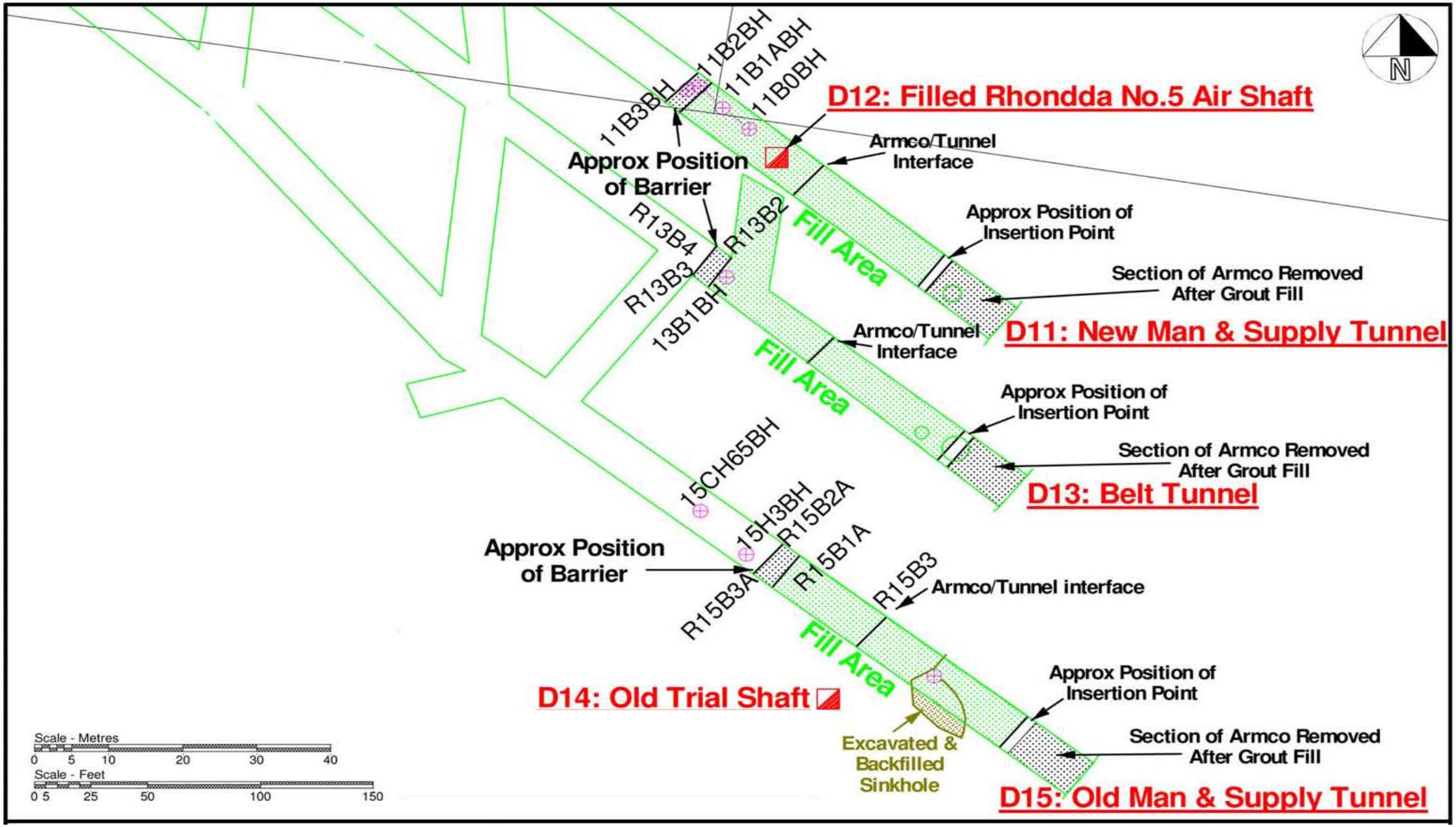
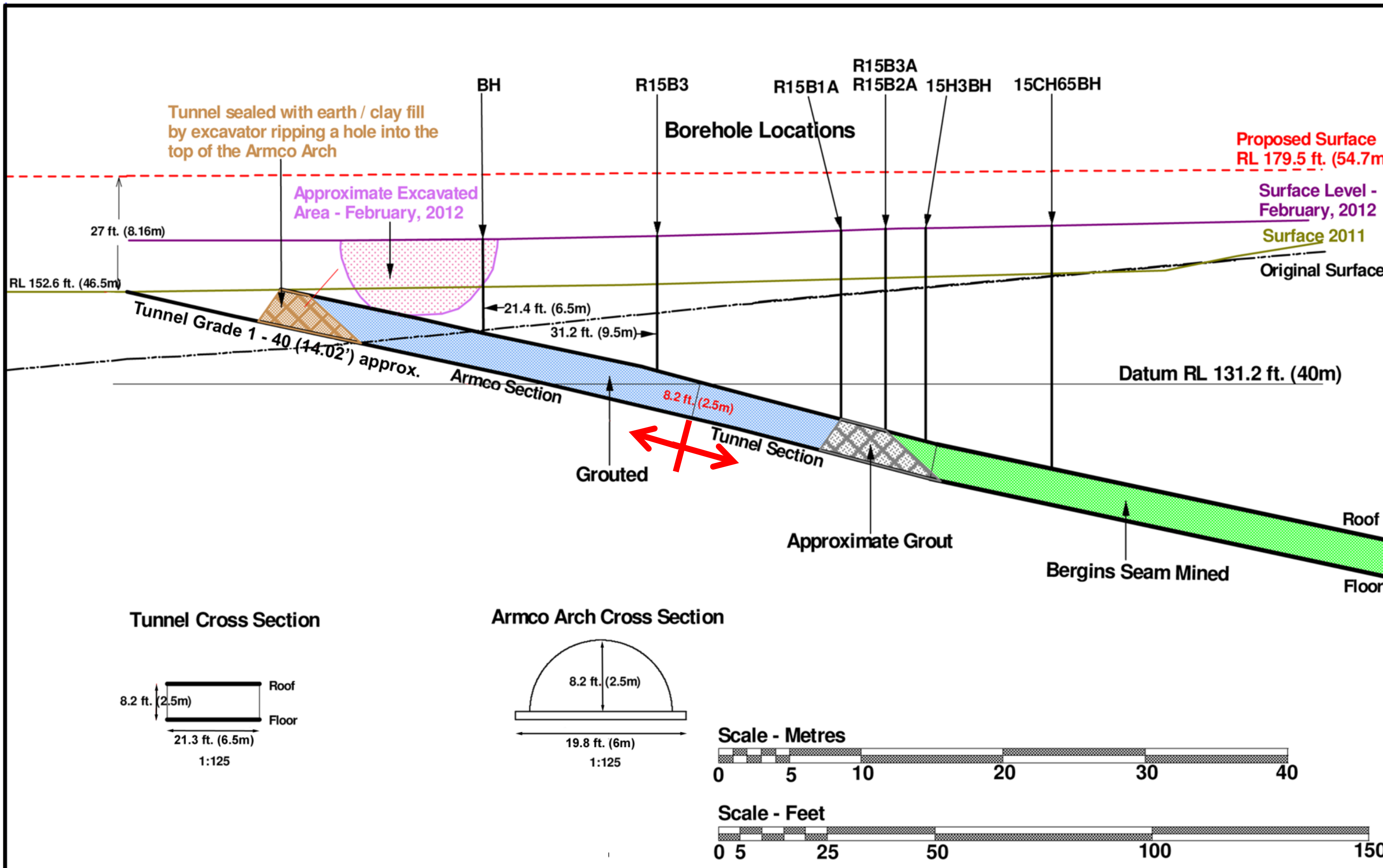
Rhondda No. 5 Colliery



Plan View of Disturbances

Rhondda No. 5 Colliery



Original Man & Supply Tunnel Profile

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Rhondda No. 5 Colliery

Disturbance D13 - Entrance to Belt Tunnel

Rhondda No. 5 Colliery

Mitigation

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Rhondda No. 5 Colliery

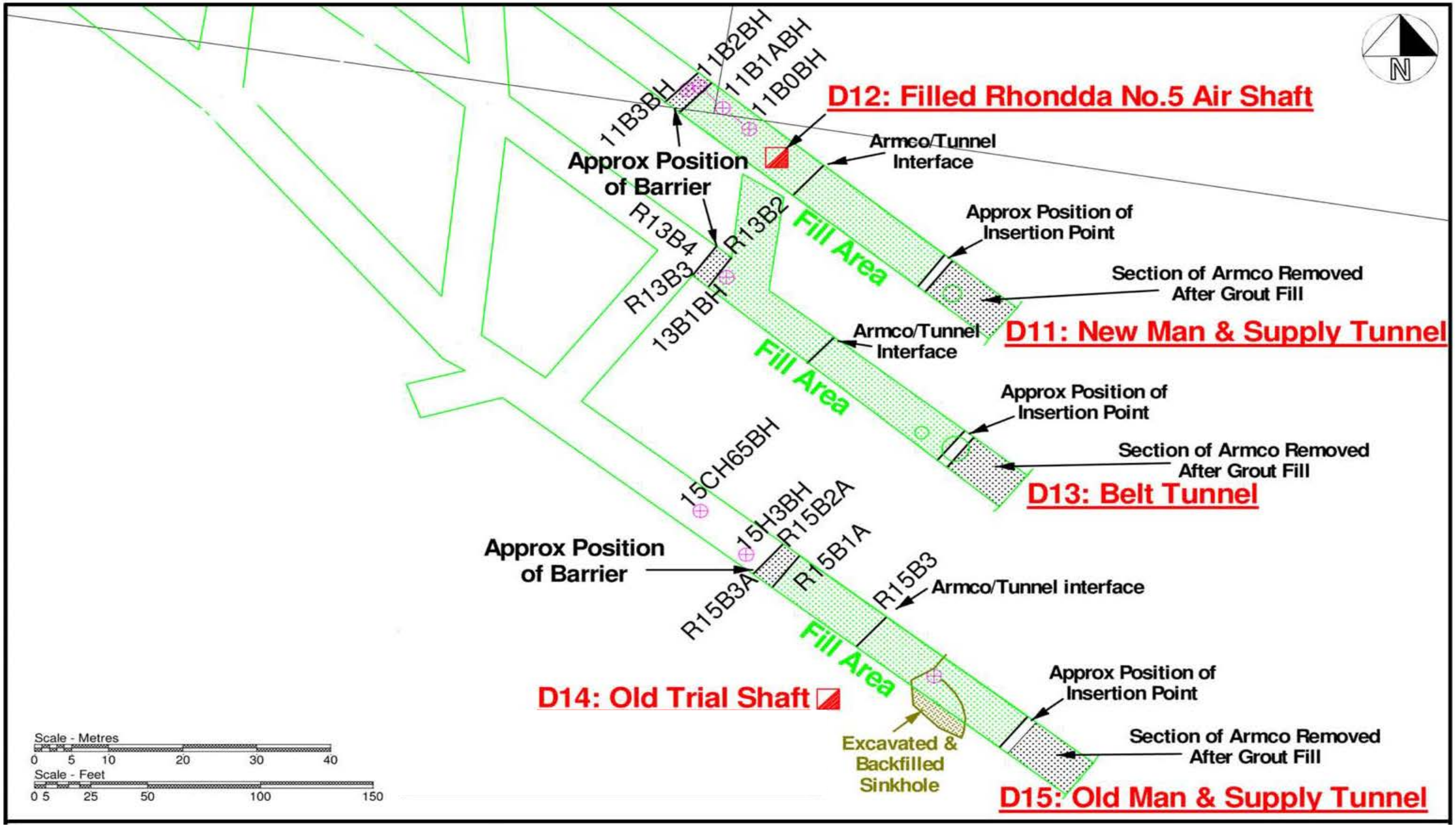
Disturbance Mitigation Procedure:

- **Drill grout holes into the tunnel and create a grout barrier to lessen the potential for the escape of mine gases and mine water;**

- **Grout upslope section of tunnel above barrier;**

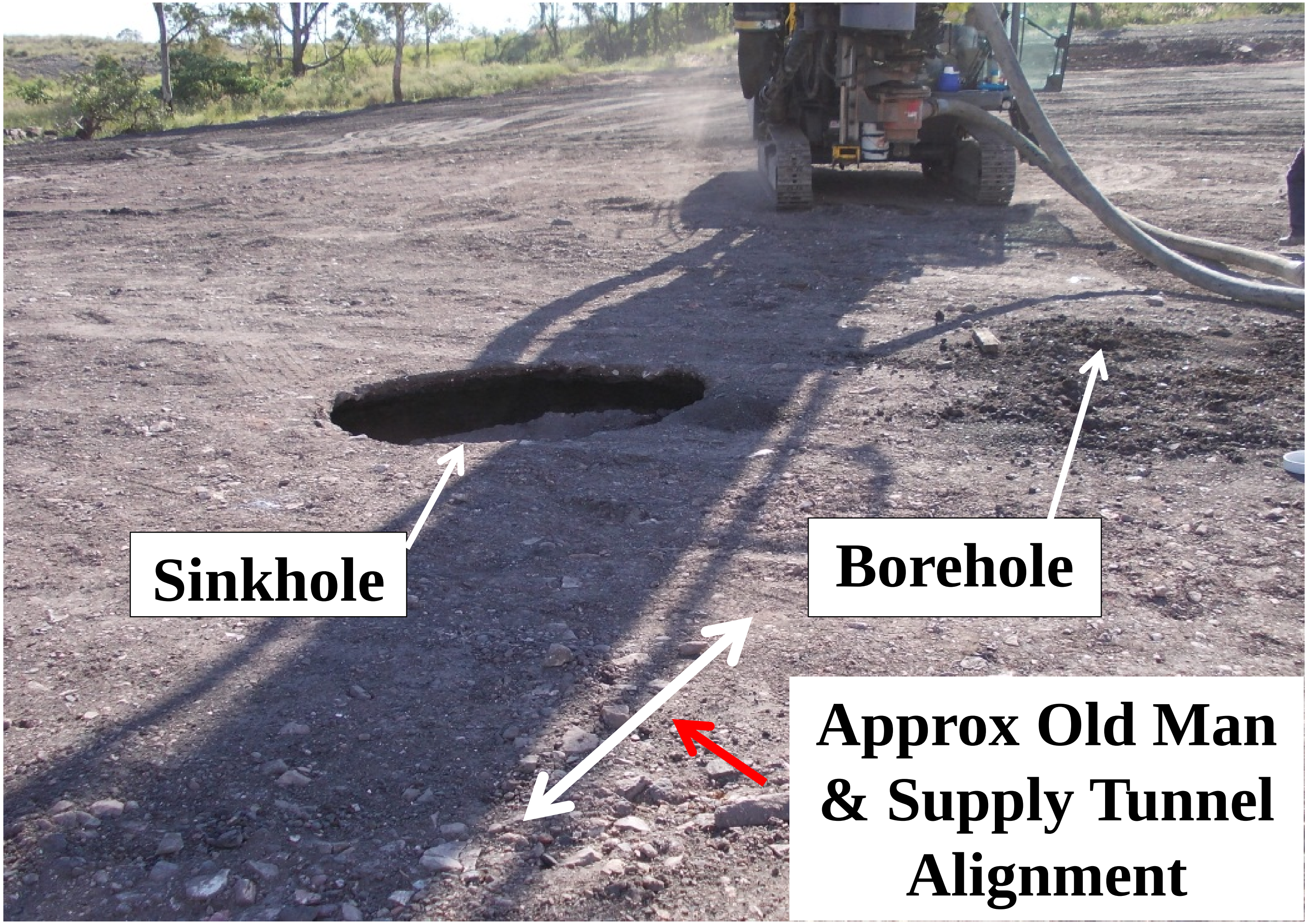
- **Over-excavate entry and backfill with compacted material.**

Rhondda No. 5 Colliery



Plan View of Disturbances

Rhondda No. 5 Colliery



Sinkhole Development During Drilling of 1st Grout Hole

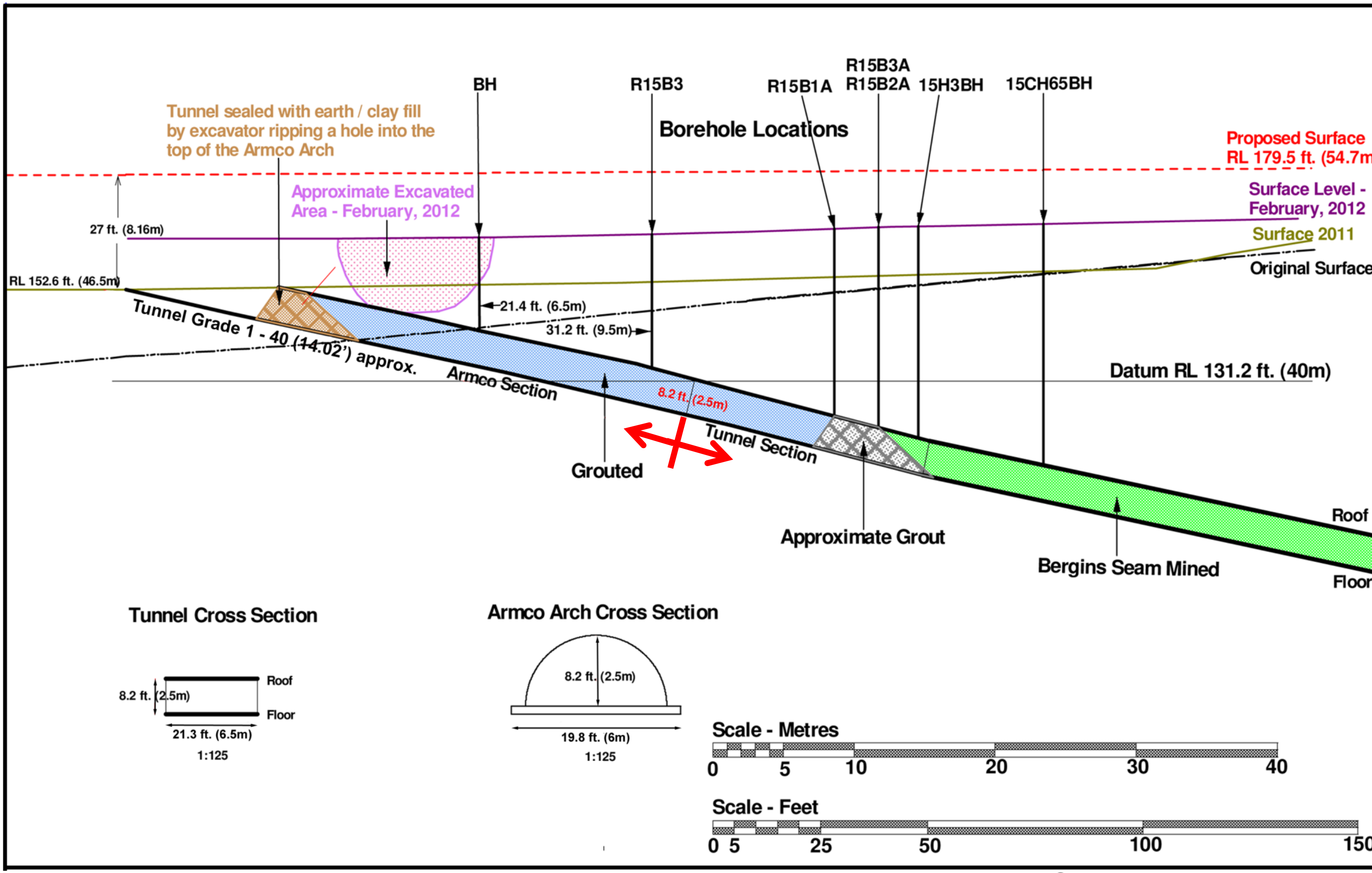
Rhondda No. 5 Colliery

Sinkhole views

Rhondda No. 5 Colliery

Sinkhole Test Pit

Rhondda No. 5 Colliery



Original Man & Supply Tunnel Profile

Rhondda No. 5 Colliery

Sinkhole Test Pit con't

- Dug down to about 20ft (6m), just above arch, and could not dig deeper;
- Sinkhole may have been caused by disturbing backfill along the outsides of the arch or piping may have been occurring on the outside of the arch and the piping area collapsed.

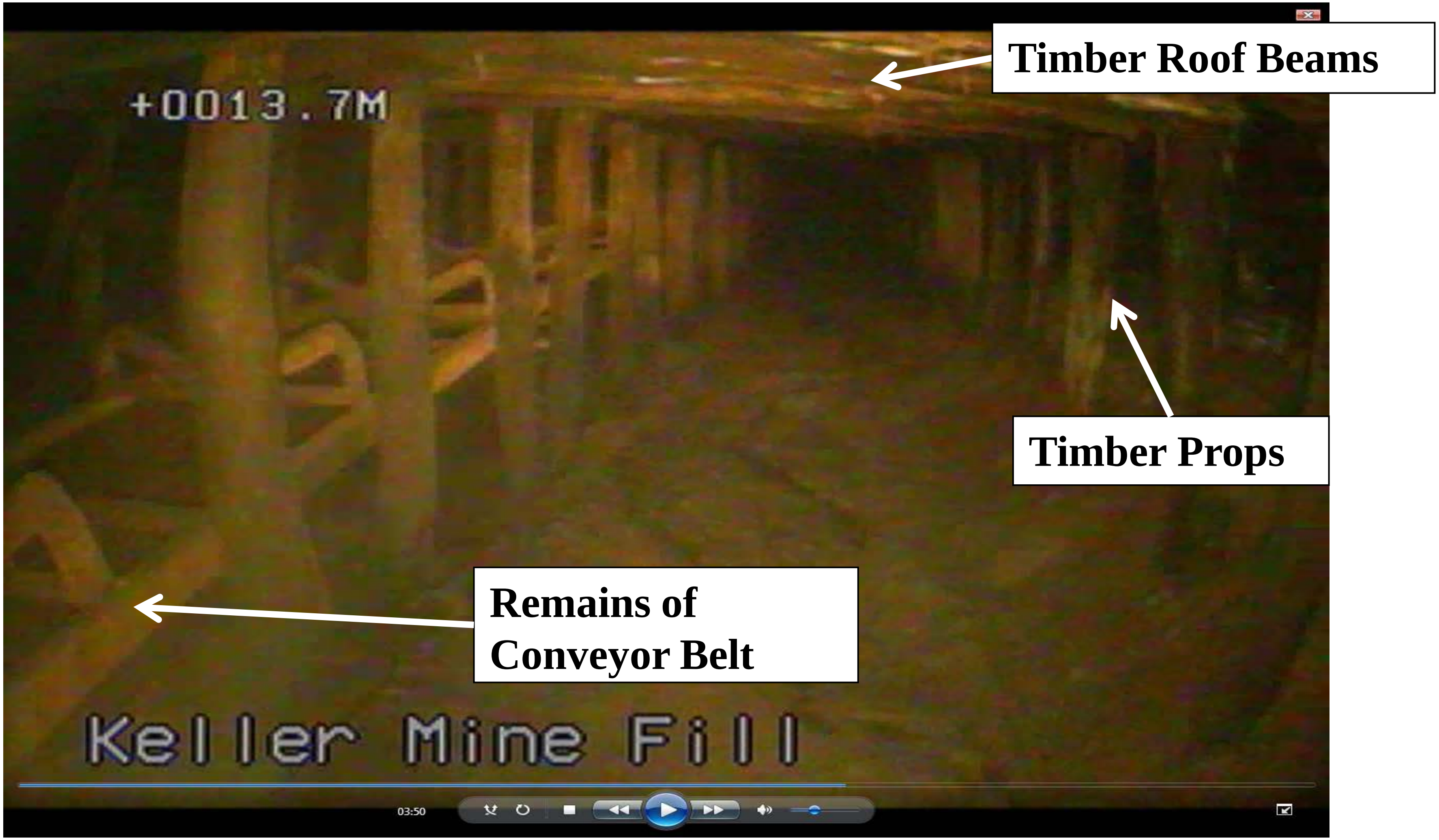
Rhondda No. 5 Colliery

Drilling resumed with Atlas Copco L8 Rig over the portion of tunnel in rock, but stopped drilling since holes wouldn't stay open in the refuse material and rig could not install casing.

Rhondda No. 5 Colliery

Hutte Rig drilled remainder of grout holes in Rhondda area since it could install casing

Rhondda No. 5 Colliery

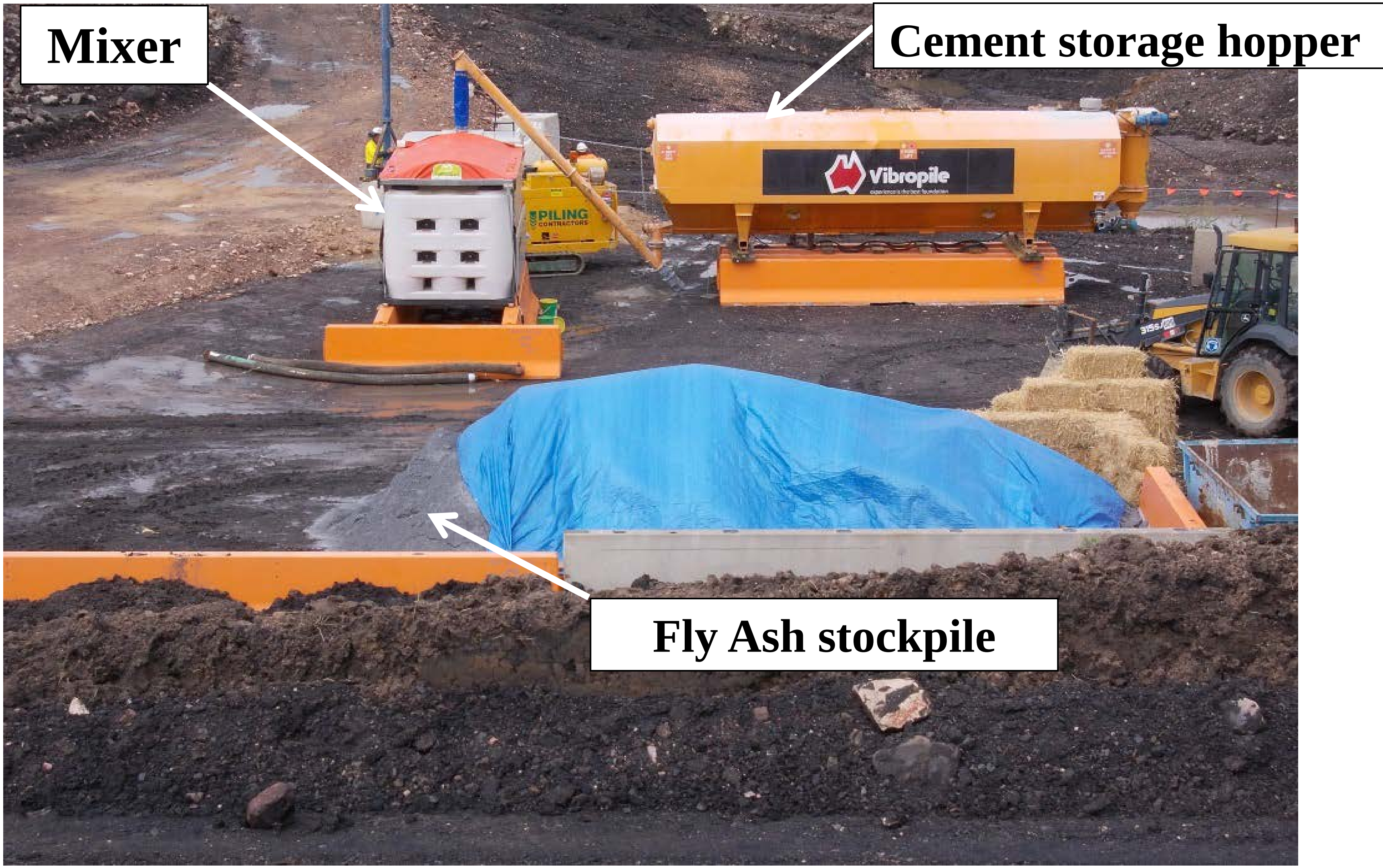


View looking upslope in Belt Tunnel (D13) before grouting

Rhondda No. 5 Colliery

Steel tremie pipe being lowered into hole prior to grout injection

Rhondda No. 5 Colliery



Batch Plant

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Rhondda No. 5 Colliery

Note Lumps

Close-up

Swanbank Pond Ash

Rhondda No. 5 Colliery

MIX	POND ASH (kg)	CRUSHER DUST (kg)	CEMENT (kg)	WATER (l)	FLOWABILITY	STRENGTH (MPa) [psi] 7 days	STRENGTH (MPa) [psi] 28 days
Barrier	382	1117	127	385	Slump 55-65mm (2 – 2.5in)	1.3 [189]	3.8 [551]
Infill 1	897	0	87	555	Flow Trough 230mm	0.95 [138]	2.2 [319]
Infill 2	322	941	175	453	Flow Trough 320mm	3.55 [515]	8.4 [1218]

Proposed Grout Mix Components and Properties

Rhondda No. 5 Colliery

Infill Grout in Hopper (25 – 35 Sec Flow Cone)

Slump Test on Barrier Grout (6 in slump)

Grout Consistency

Rhondda No. 5 Colliery

Grout being fed into agitator truck from batch plant

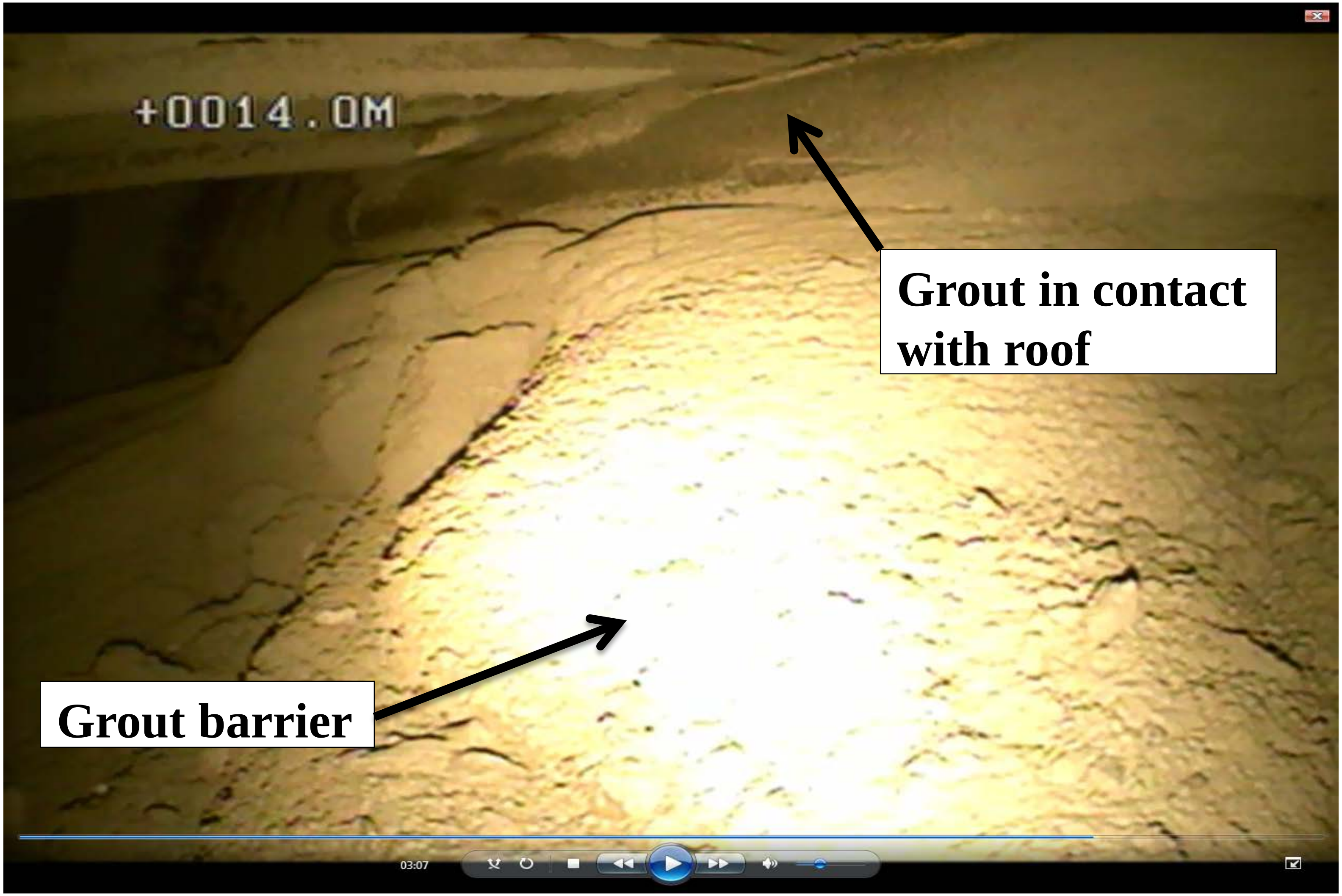
Rhondda No. 5 Colliery

Grout being fed from agitator truck to concrete pump for pumping to grout hole

Rhondda No. 5 Colliery

Formation of grout barrier in progress – Conveyor Support being enveloped in grout

Rhondda No. 5 Colliery



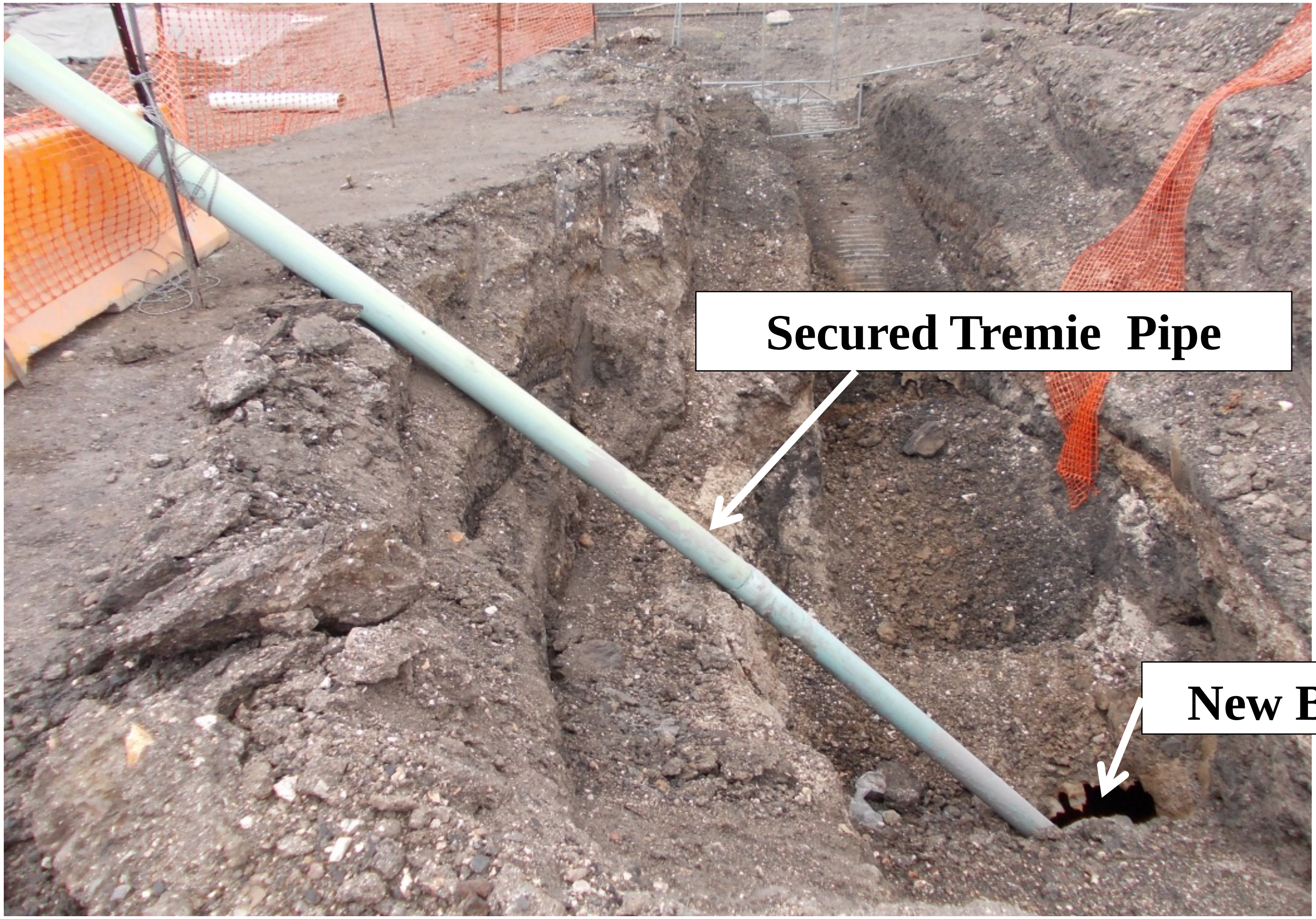
Barrier nearing completion

Rhondda No. 5 Colliery

Bag over other hole to check for pressure from grout

Gauge at injection hole to check pressure build-up

Rhondda No. 5 Colliery



UPVC tremie pipe for injection of grout in breach in Armco Section upslope of barrier in Belt Tunnel (D13)

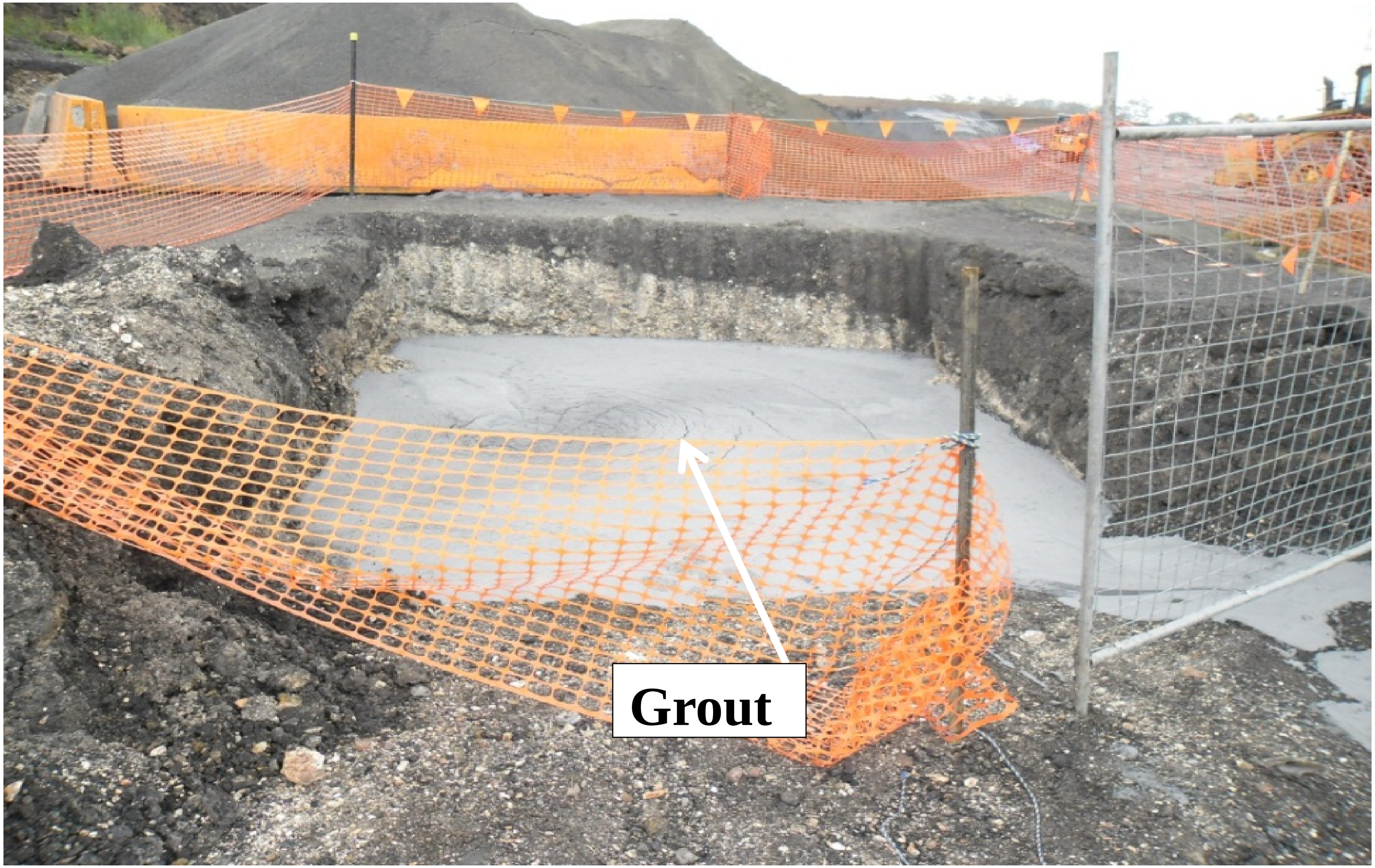
Rhondda No. 5 Colliery

Over - excavation of old Man & Supply Tunnel (D15) to remove Armco section, showing the original breach looking downslope

Rhondda No. 5 Colliery

New breach and previous collapse in Old Man & Supply Tunnel (D15) looking downslope

Rhondda No. 5 Colliery



Excavation filled with grout at New Man & Supply Tunnel (D11)

Rhondda No. 5 Colliery

Disturbance	Armco Section of Tunnel			Portion of Tunnel in Rock			Total Theoretical Volume of Tunnel to be Grouted (m^3)	Volume of Grout injected (m^3)	Percentage of Tunnel filled based on Grout Take vs. Theoretical Volume[3]	Barrier Grout Volume (m^3)
	Length[1] (m)	Cross-sectional area (m^2)	Theoretical Volume (m^3)	Length[2] (m)	Cross-sectional area (m^2)	Theoretical Volume (m^3)				
New Man & Supply (D11)	19	11.3	214	21	18.3	382	596	543	91%	522
Belt (D13)	22	11.3	248	18	16.3	293	541	963	178%	480
Old Man & Supply (D15)	24	11.3	271	14	16.3	227	498	395	79%	338

1 – Length downslope of breach and start of rock tunnel,
2 – Length from Armco Section to plug, cross cuts not included
3 – Contribution from barrier grout and debris in the tunnel ignored

Grouting Quantities for the Rhondda area

New Hill Colliery
Entry Tunnels and Air Shaft
Disturbances D1, D2, and D3

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New Hill Colliery

Background

- Two Armco steel arch cut and cover tunnels connecting to rock tunnels to access the Cochrane Seam;
- One air shaft;
- Mined 1996 to 1998;
- Armco arch tunnels sealed at end of mining by removing the upper portion of the Armco arch tunnel and installing a plate;
- Airshaft filled with coal waste and covered with clay cap;
- Area regraded;
- Area to be filled and used for material storage.

New Hill Colliery

Tunnels

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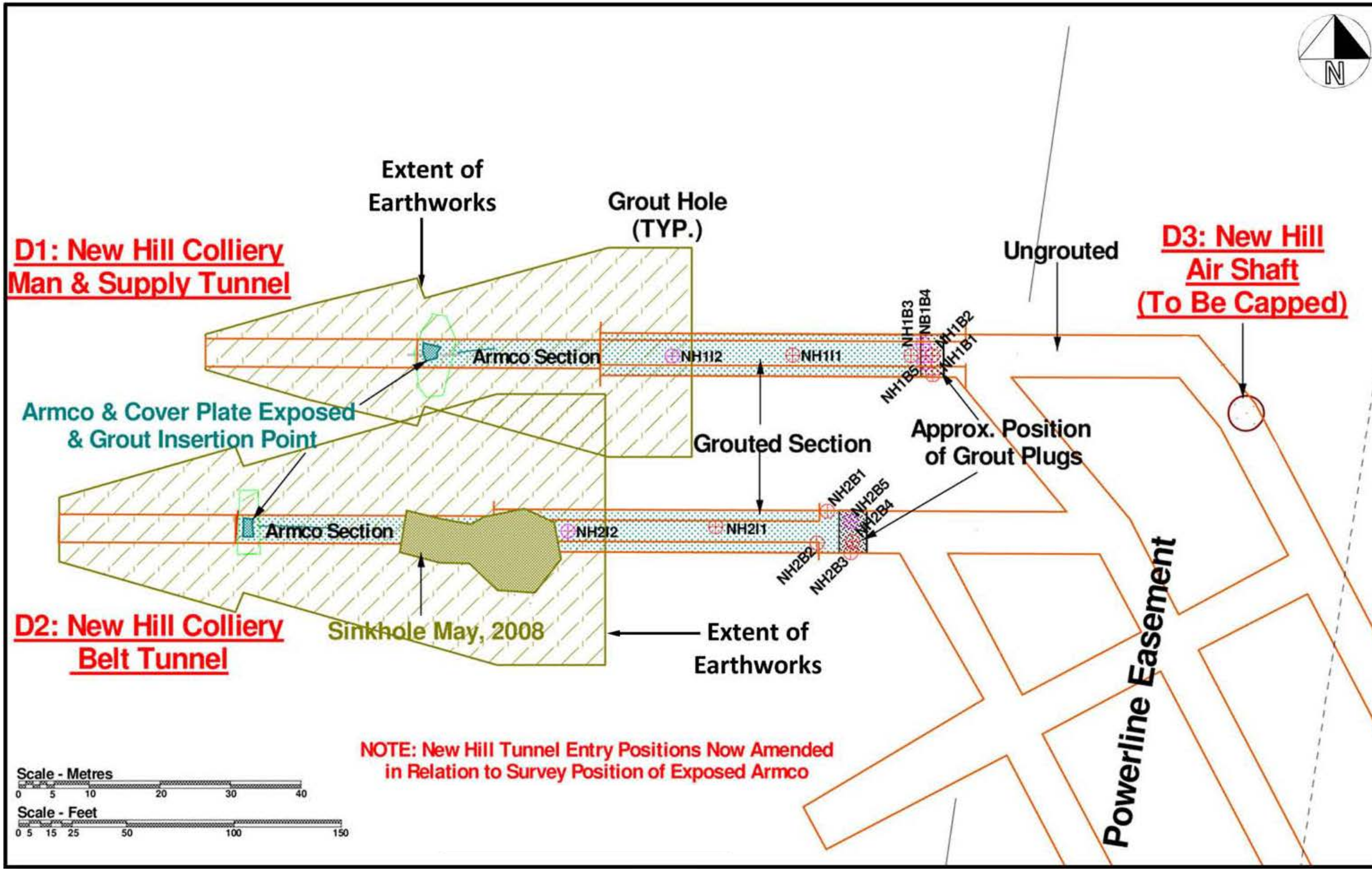
New Hill Colliery

Existing Conditions

New Hill Colliery



Excavation for Armco Tunnel Installation and Air Shaft location

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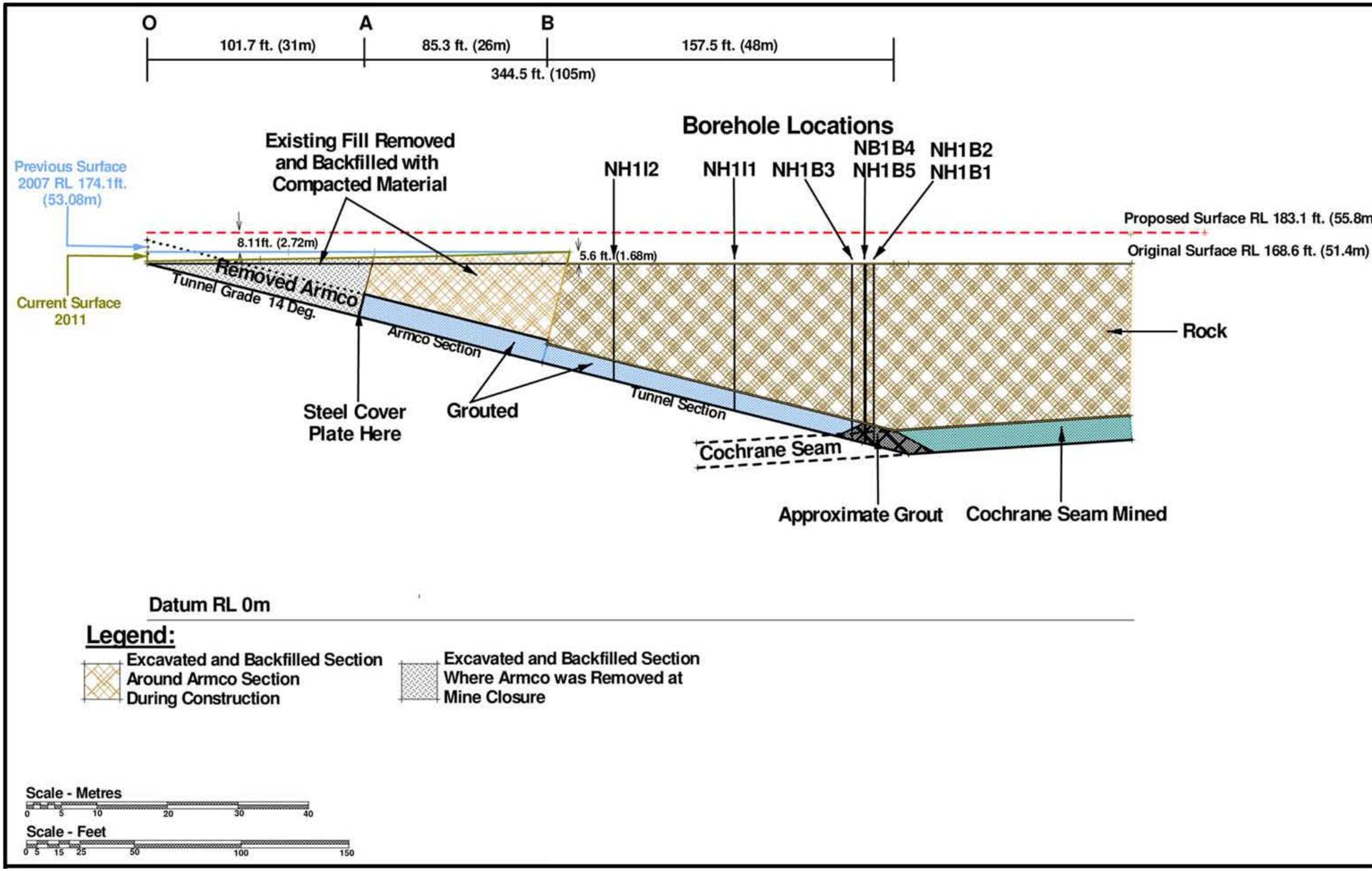
New Hill Colliery

Man & Supply Tunnel and Pit Head at closure – Aug 1997

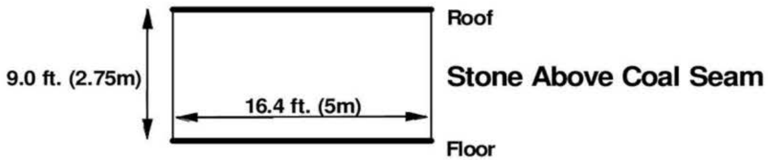
Courtesy Bob Bitmead/ Alan Brims

New Hill Colliery



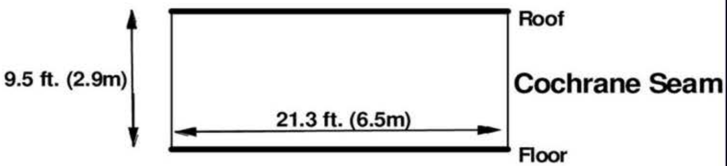
Man and Supply Tunnel Profile

New Hill Colliery



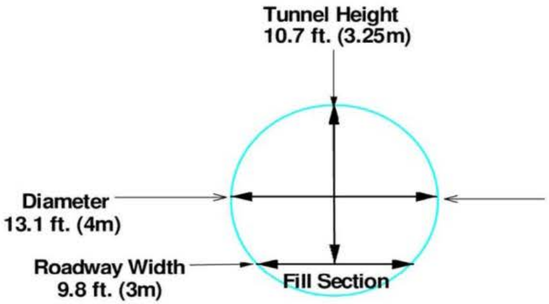
Man & Supply Tunnel

Cross Section through the Tunnel Section of the Mine Tunnel



Belt Tunnel

Cross Section through the Tunnel Roadway in the Coal Seam



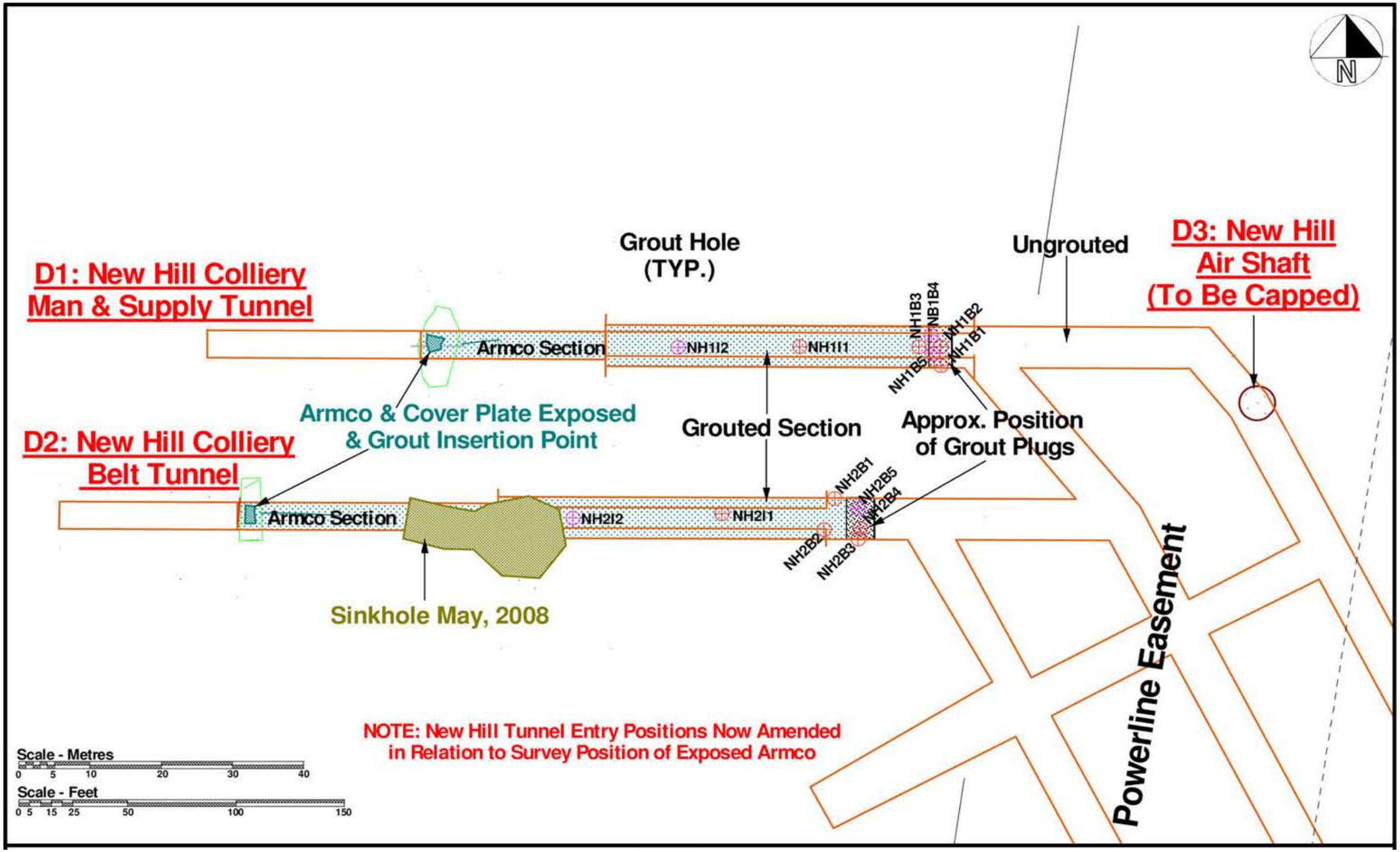
Man & Supply and Belt Tunnel Armco Section

Typical Tunnel Cross Section

New Hill Colliery

Tunnel Mitigation

New Hill Colliery



Tunnel Mitigation

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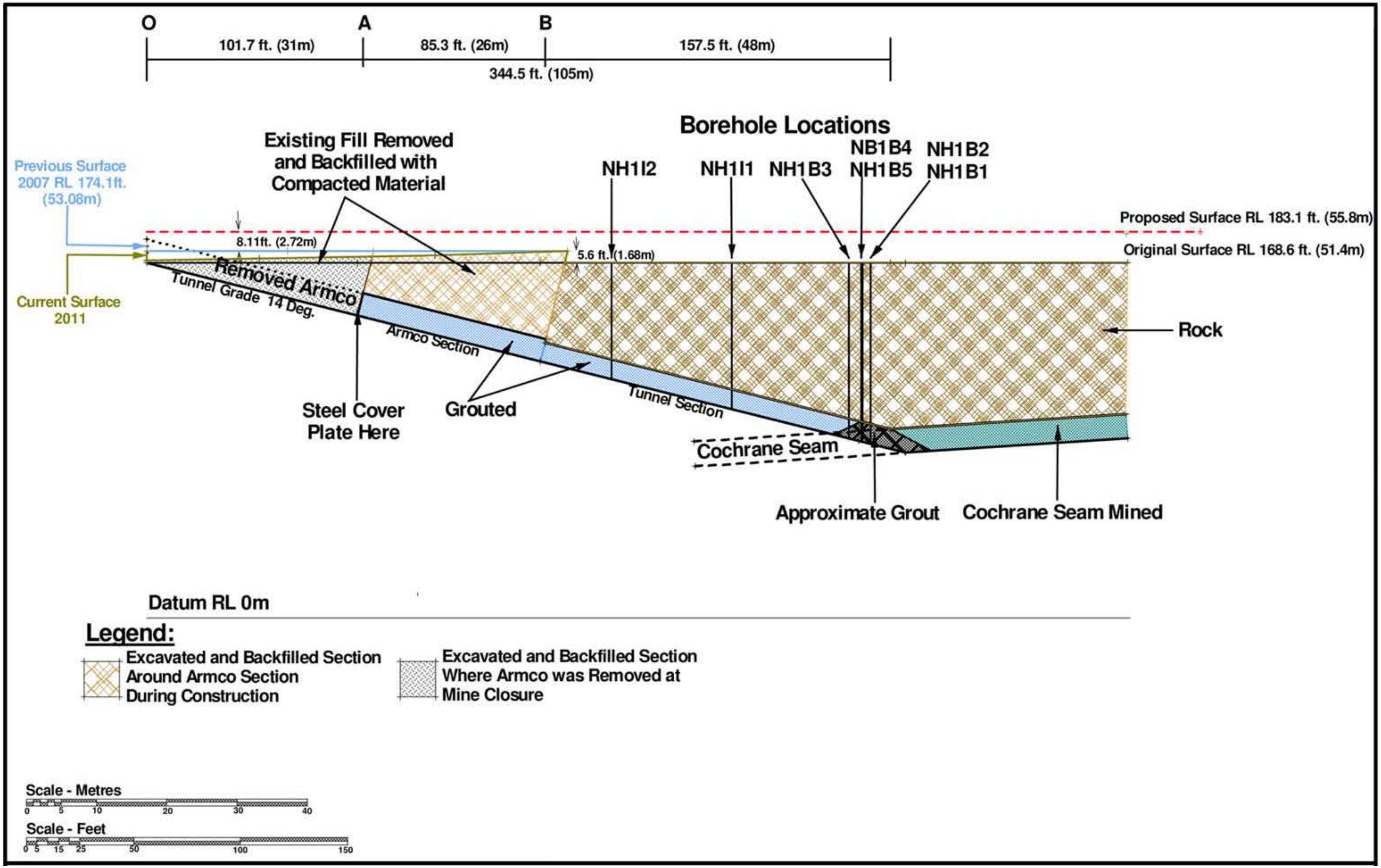
New Hill Colliery



Man and Supply Tunnel Profile

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New Hill Colliery

Sinkhole over Belt Tunnel – May 2008
Approx. Dia = 26ft (8m) and Depth = 20ft (6m)

New Hill Colliery

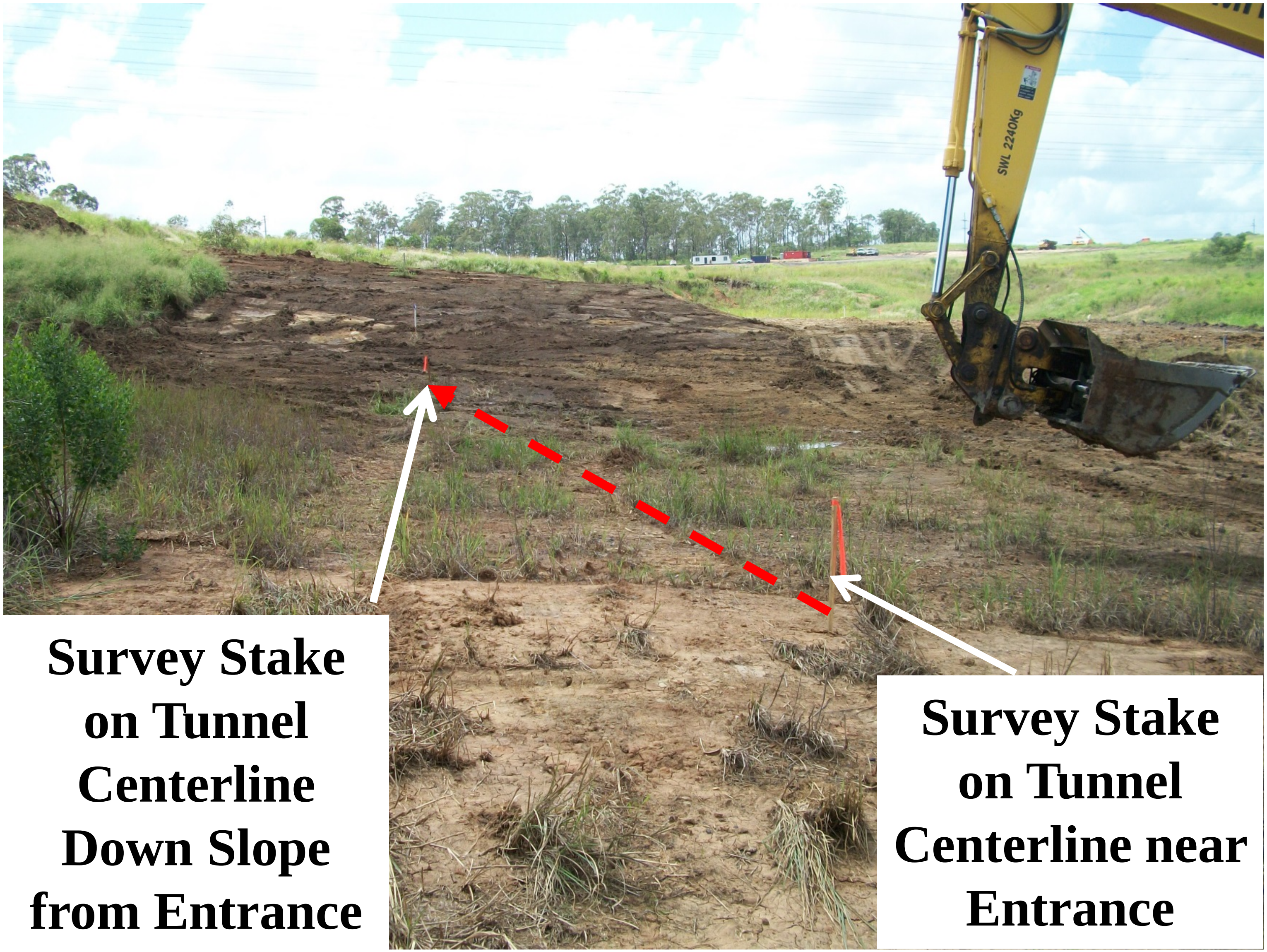
Backfilled sinkhole area at Belt Tunnel prior to drilling

New Hill Colliery

Tunnel Location Procedure

- Survey two points on alignment based on mine map;
- Locate tunnel by excavating test pits to top of arch on alignment down slope of entrance;
- Survey centerline of exposed arch;
- Adjust alignment;
- Drill grout holes.

New Hill Colliery



New Hill Colliery

Test Pit to Locate Tunnel Excavated Perpendicular to Tunnel Axis

Surveyed Tunnel Centerline Near Upper End of Tunnel

New Hill Colliery

Poor Backfill

New Hill Colliery

Exposing upslope Corrugation in top of Armco section

New Hill Colliery

Armco Arch Section Uncovered

New Hill Colliery

CL Stake

Arch CL within 1m of Survey Location

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New Hill Colliery

Grout Hole Drilling for Tunnels

New Hill Colliery

Overview of drilling area

New Hill Colliery

Fitting on cap

Filled bag

Gas sampling at grout hole

New Hill Colliery

Tent for borehole camera viewing

New Hill Colliery

Note: Mesh roof support

Side of Tunnel

Man & Supply Tunnel (D1) – View looking up slope in rock tunnel from NH1B1

New Hill Colliery

View from borehole camera looking upslope at material from sinkhole in rock tunnel portion of Belt Tunnel

New Hill Colliery

LOCATION	HOLE	DATE DRILLED	SOIL OVERBURDEN DEPTH (m)	DEPTH TO TOP OF VOID (m)	DEPTH TO BOTTOM OF VOID (m)	VOID HEIGHT (m)	HOLE DEPTH (m)	COMMENTS
New Hill 1	NH1-I2	26/04/2012	5	14	18	4	18	
New Hill 2	NH2-V1	26/04/2012	7	28	31	3	33	
New Hill 1	NH1-B4	23/04/2012	2.5	25			25	
New Hill 1	NH1-B5	23/04/2012	3	9			25	
New Hill 2	NH2-I2	20/04/2012	11	22.5	26	3.5	26	
New Hill 2	NH2-I1	19/04/2012	2.6	25	28.5	3.5	28.5	
New Hill 2	NH2-B4	4/04/2012	3.42	31.2	34.65	3.45	34.65	
New Hill 2	NH2-B5	2/04/2012	9	31	34.5	3.5	34.5	
New Hill 2	NH2-I1	29/03/2012	2.6	25.03	28.56	3.53	28.56	
New Hill 1	NH1-I1	28/03/2012	2.88	22.12	25.98	3.86	25.98	
New Hill 2	NH2-B4	26/03/2012	3.42	31.2	34.65	3.45	34.65	
New Hill 2	NH2-B3	19/03/2012	4.4	33.31	34.31	1	34.31	
New Hill 1	NH1-B2	29/02/2012	1.77	26.03	29.13	3.1	29.13	
New Hill 1	NH1-B3	29/02/2012	0.8	25.66	29.05	3.39	29.05	
New Hill 2	NH2-B1	29/02/2012	2.51			0	36	Hole aborted at 36m due to missing tunnel
New Hill 2	NH2-B2	29/02/2012	1.51	29.35	31.85	2.5	31.85	
New Hill 1	NH1-B1	28/02/2012	1	24.93	28.36	3.43	28.36	

Drilling Summary

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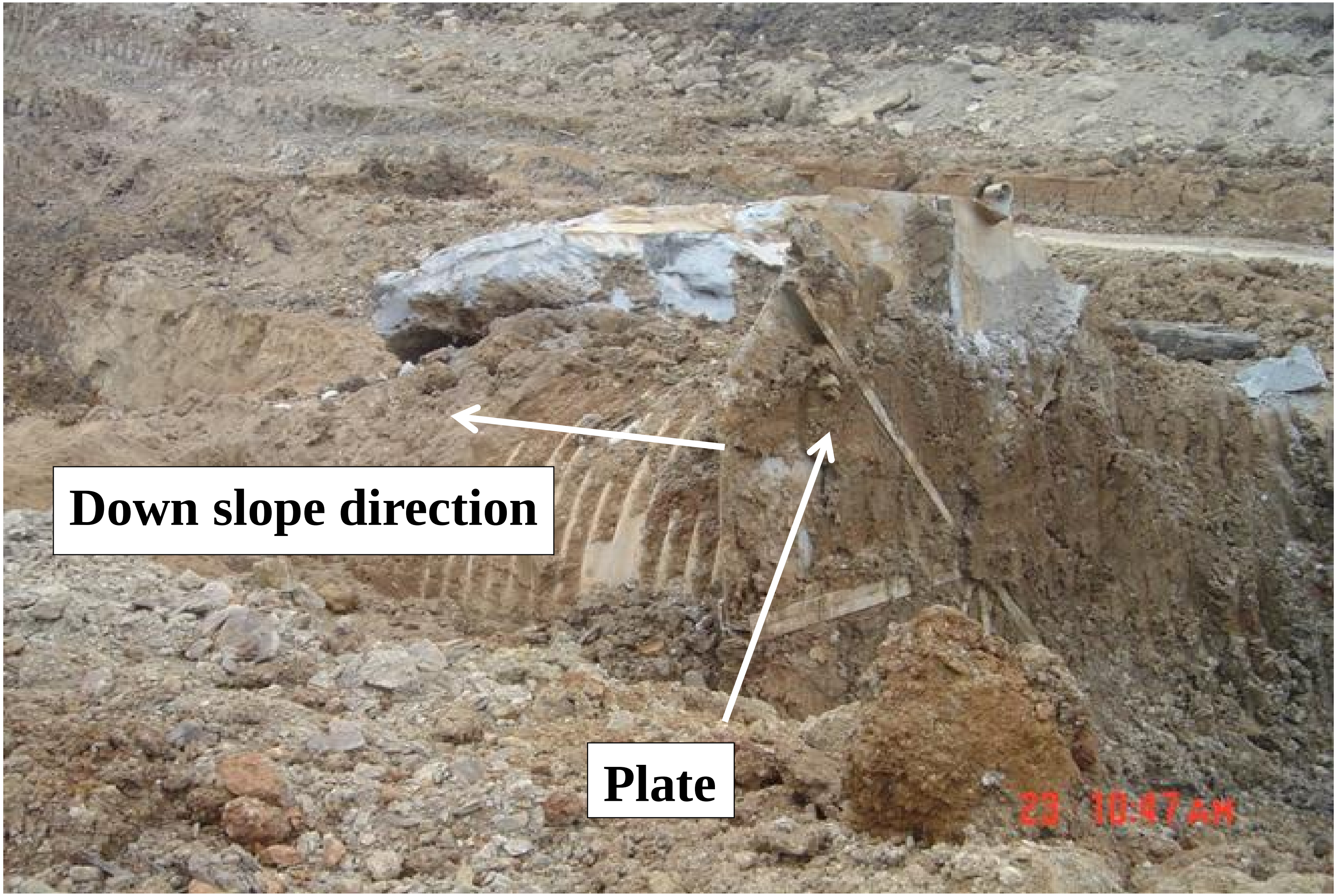
New Hill Colliery

Belt Tunnel and Sinkhole Over-excavation after grouting

New Hill Colliery



Exposed Armco section & steel cover plate installed at mine closure

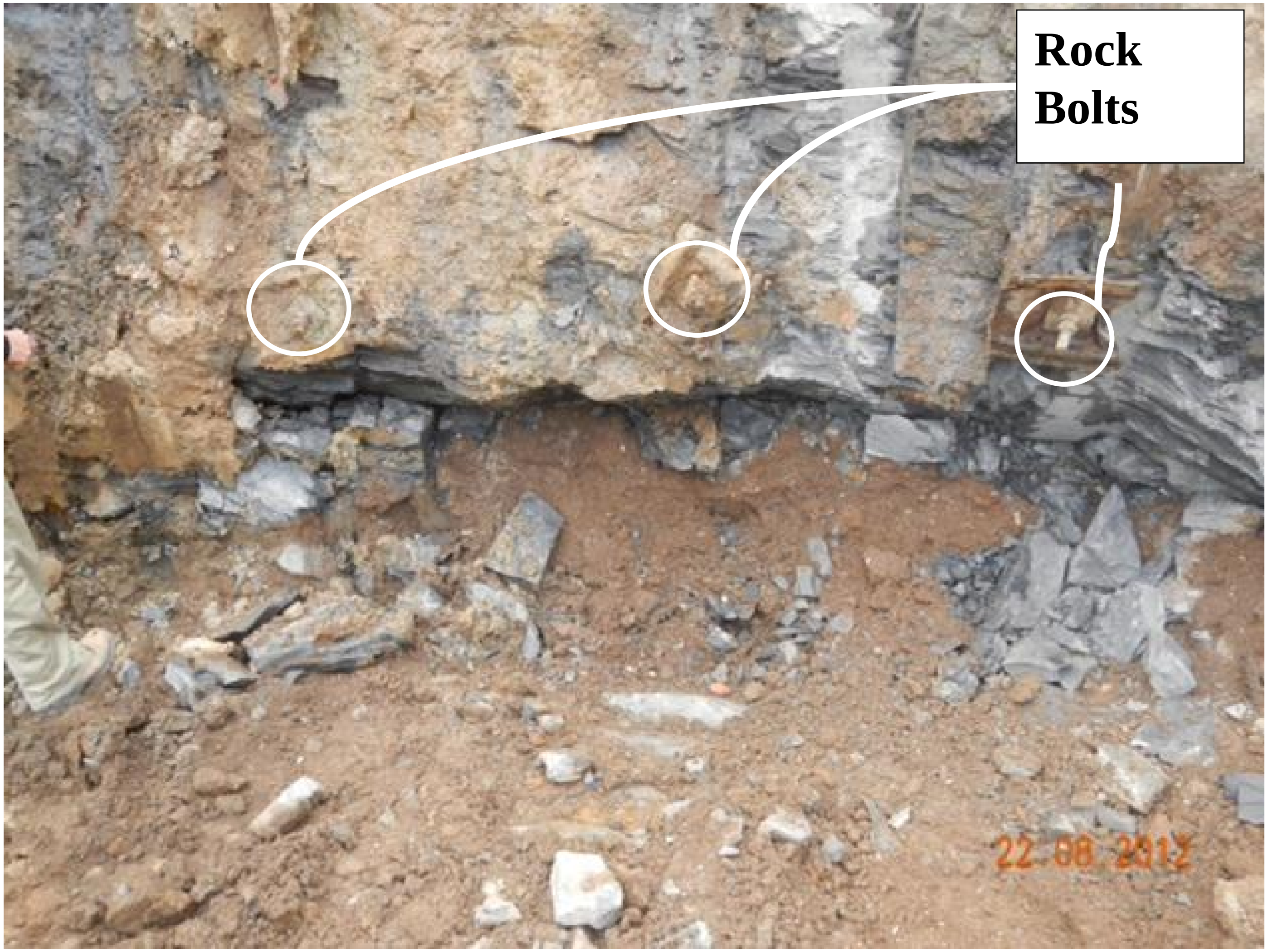
New Hill Colliery

Top of tunnel in rock

Area where Armco tunnel was located

Exposed Armco / rock tunnel interface in sinkhole over-excavation

New Hill Colliery

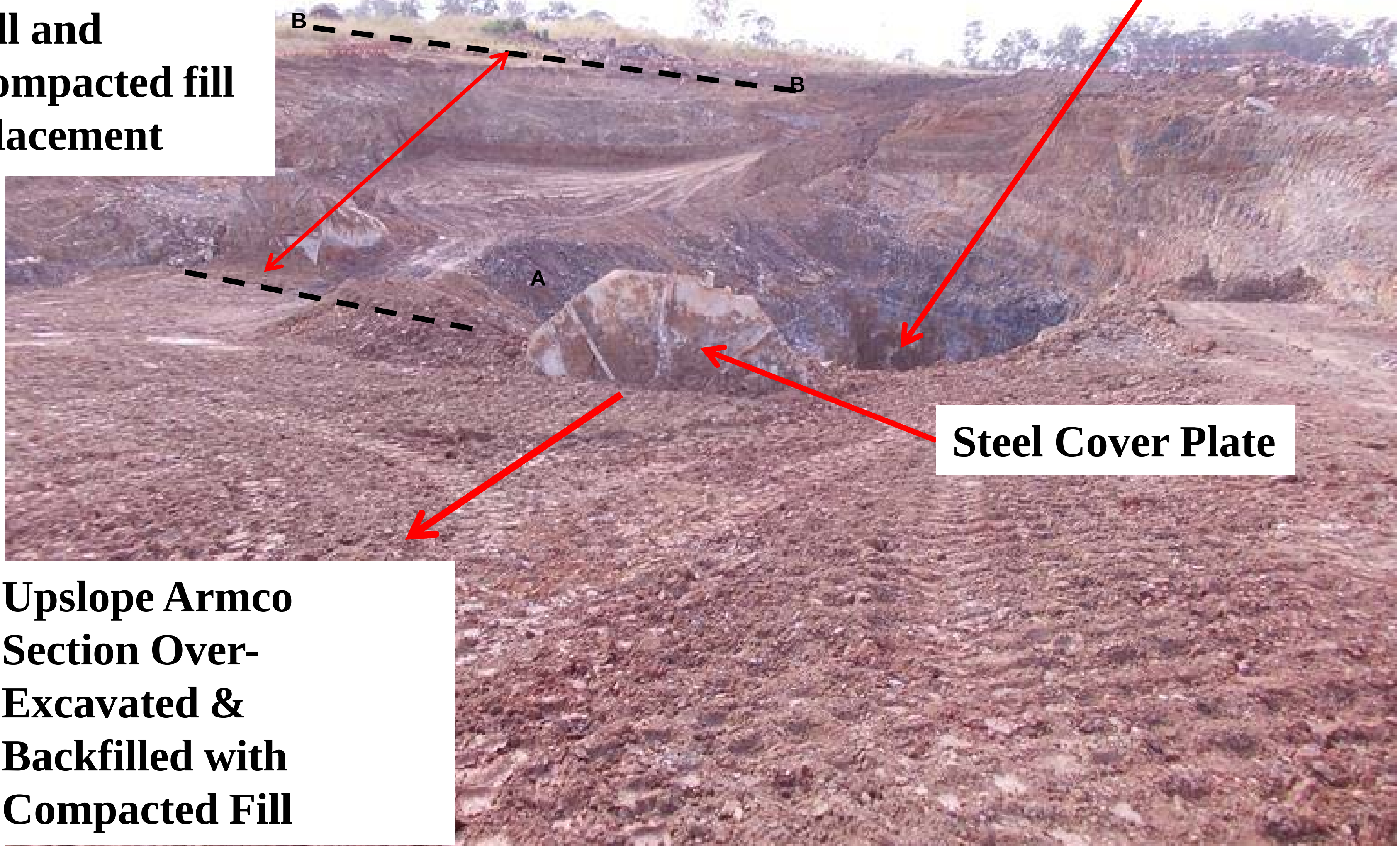


Close-up of rock tunnel roof at interface

New Hill Colliery

Area with over – excavation of uncontrolled fill and compacted fill placement

Rock Portion of tunnel



Steel Cover Plate

Upslope Armco Section Over-Excavated & Backfilled with Compacted Fill

Removal of uncontrolled fill in sinkhole over Belt Tunnel area

New Hill Colliery

Compacted backfilled sinkhole area

New Hill Air Shaft

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New Hill Colliery

Air Shaft Background and Mitigation

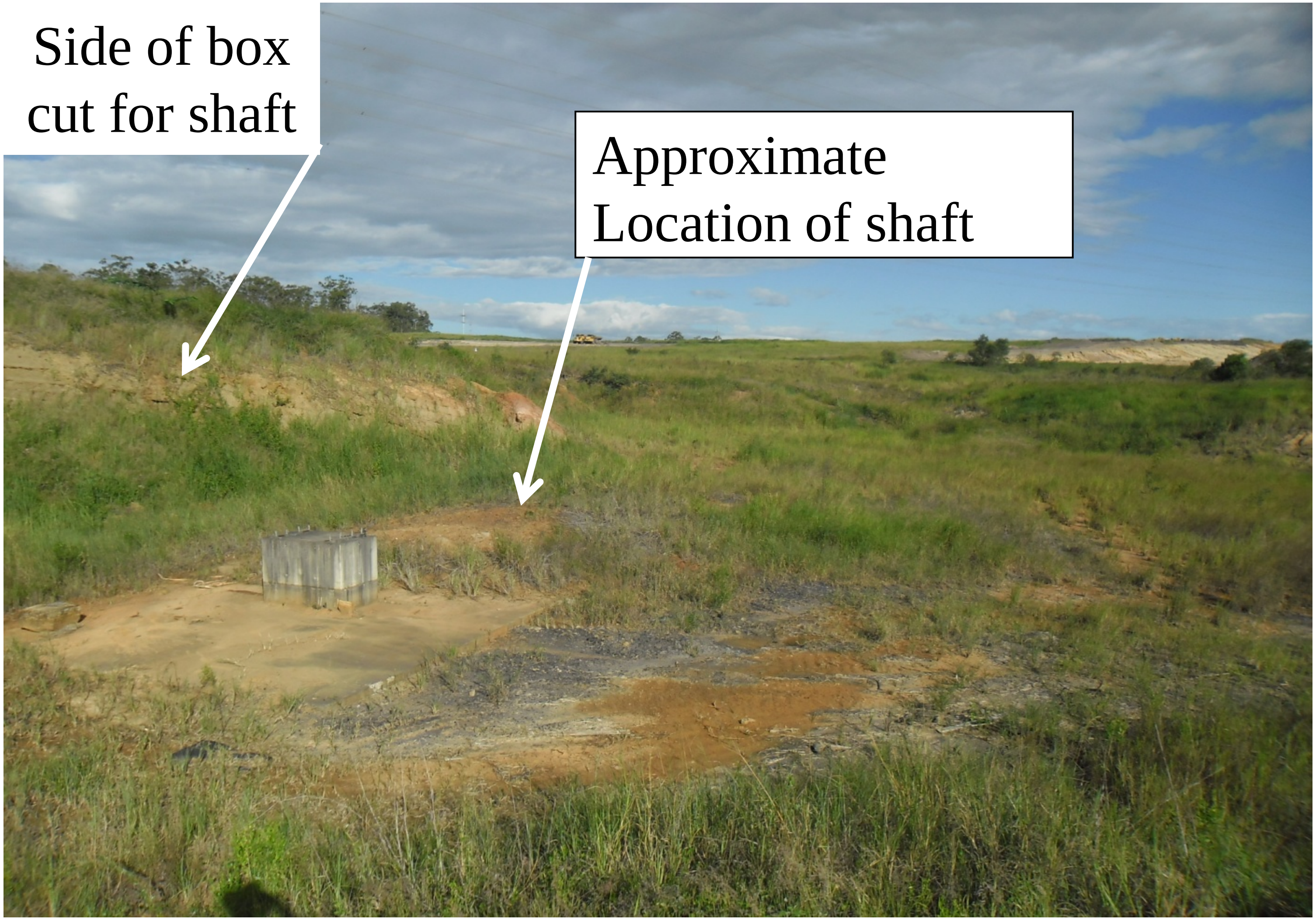
Shaft was backfilled with coal waste at the end of mining;

There was a concern that the coal waste could migrate into the mine workings and result in a sinkhole;

Mitigation consisted of exposing shaft and capping with geotextile sandwich;

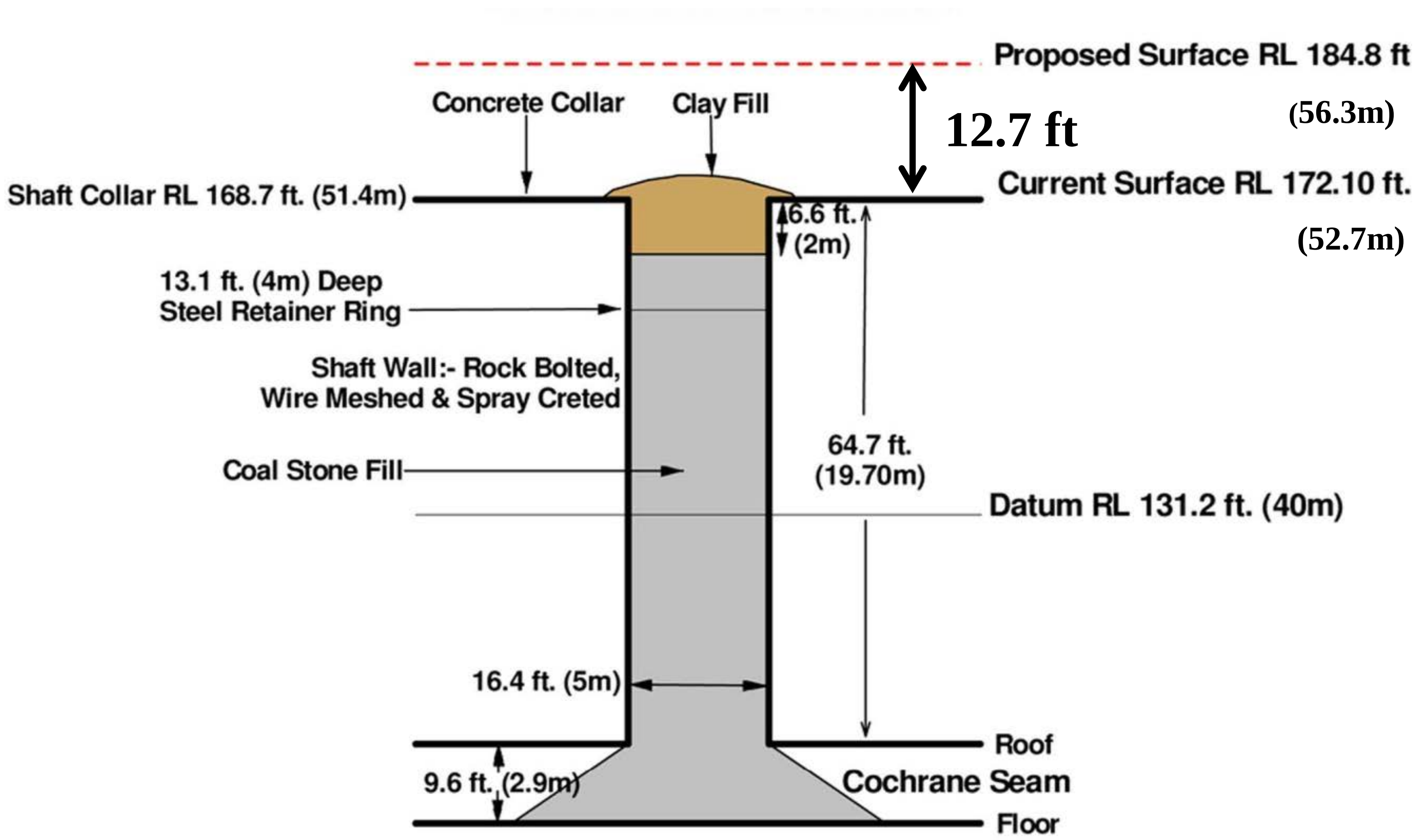
Area to be filled and used for material storage.

New Hill Colliery



Location of airshaft

New Hill Colliery



Section of shaft after mine closure

New Hill Colliery

Exposed air shaft looking South

New Hill Shaft Capping Procedure

1. The ground around the shaft was raised to the top of the shaft collar level using compacted fill;
2. A trench was excavated around the outside perimeter of the shaft where it is in contact with the adjacent rock, to allow for the placement of a geosynthetic filter layer;
3. A concrete layer was placed on top of the metal lip, located on the top of the shaft, to lessen damage to the geosynthetic filter layer that would have occurred if it had been in contact with the sharp mental lip;
4. The pad at the level of the geosynthetic layer was prepared by compacting the existing soil material inside the shaft with a compactor attached to the end of an excavator arm;
5. An about 300mm thick layer of clayey sand with weathered sandstone gravel sized rock fragments fill was placed over the shaft and the surrounding area and compacted with a compactor attached to the end of an excavator arm;
6. The first layer of geotextile layer (Mirafi PET 800 woven polyester) with two overlapping sections, each 16m long and 5m wide, was laid over the shaft. The overlapping width of two geotextile layers is about 1m;
7. A layer of 100mm thick clayey sand fill was placed above the first geotextile layer and compacted using a sheet foot rollers attached the end of the excavator arm;
8. The second layer of a single geotextile strip (Mirafi PET 800, woven polyester), 16m in length and 5m in width) was placed centrally over the shaft, in the same direction as the first layer;
9. A layer of 100mm thick clayey sand fill was placed above the second geotextile layer and compacted using a sheet foot rollers attached the end of the excavator arm;
10. The third layer of Mirafi PET 800 woven polyester geotextile layer with two overlapping sections in 16m long each was placed over the shaft. The direction of the geotextile sections are perpendicular (90^{o}) to that of the first layer
11. A layer of 100mm thick clayey sand with some weathered sandstone rock fragments was placed and compacted over the geosynthetic material, using hand held compactor;
12. The fourth layer consisting of a single geotextile strip (Mirafi PET 800, woven polyester strip, 16m in length) was placed centrally over the shaft in the same direction as the third layer;
13. Additional fill was placed over the geotextile to bring the area to the final design grade.

New Hill Colliery

Metal lip on top of shaft covered by concrete layer to reduce potential for ripping of geotextile

New Hill Colliery

First geotextile layer spread over shaft

New Hill Colliery

Compacted fill after the third geosynthetic layer

New Hill Shaft Capping - Residual Risks

The following risks have been identified as part of the design process:

1. Deflections leading to potentially large surface displacements:
    a. A geotextile will deflect when loaded;
    b. Additional layers of geotextile have been added so that the serviceability load is developed at smaller strains;
2. The land use of the shaft will be assumed as hardstand and no structures are to be constructed;
3. Future excavation, drilling or piling:
    a. The geotextile acts as a tension membrane. As such, any damage to the material has the capacity to induce a failure;
    b. Power lines currently exist above the shaft. No structure will be constructed under the power lines, which should preclude the potential for excavations and structures to be built in the area;
    c. This disturbance will be documented as a long term risk in the mining remediation report and should also be documented in any land agreements;
4. Ground level developments:
    a. The geotextile requires the weight of the overlying soil to generate adequate bonding between the soil and the fabric. Should the amount of soil be reduced, the bonding capacity between the soil and the geotextile is reduced and it could be pulled out;
    b. Additional bond length has been added to the textile to improve future flexibility for ground levels;
    c. A conservative design has been implemented whereby bond on only one side of the geotextile has been assumed.
5. Other constraints
    a. Gas from the mine may emanate from the shaft;
    b. Drainage should be diverted from the area;
    c. Potential for combustion in the coalstone.

Regular visual observations of the surface should be undertaken to assess if settlement and cracking are occurring. If settlement is occurring, the area should be re-levelled to improve drainage.

Aberdare No. 4 “Aspro Colliery”
Mine Entries
Disturbances 9 and 10

Taylor Mining Services Pty Ltd

MORETON GEOTECHNICAL SERVICES

Swanbank Enterprise Park

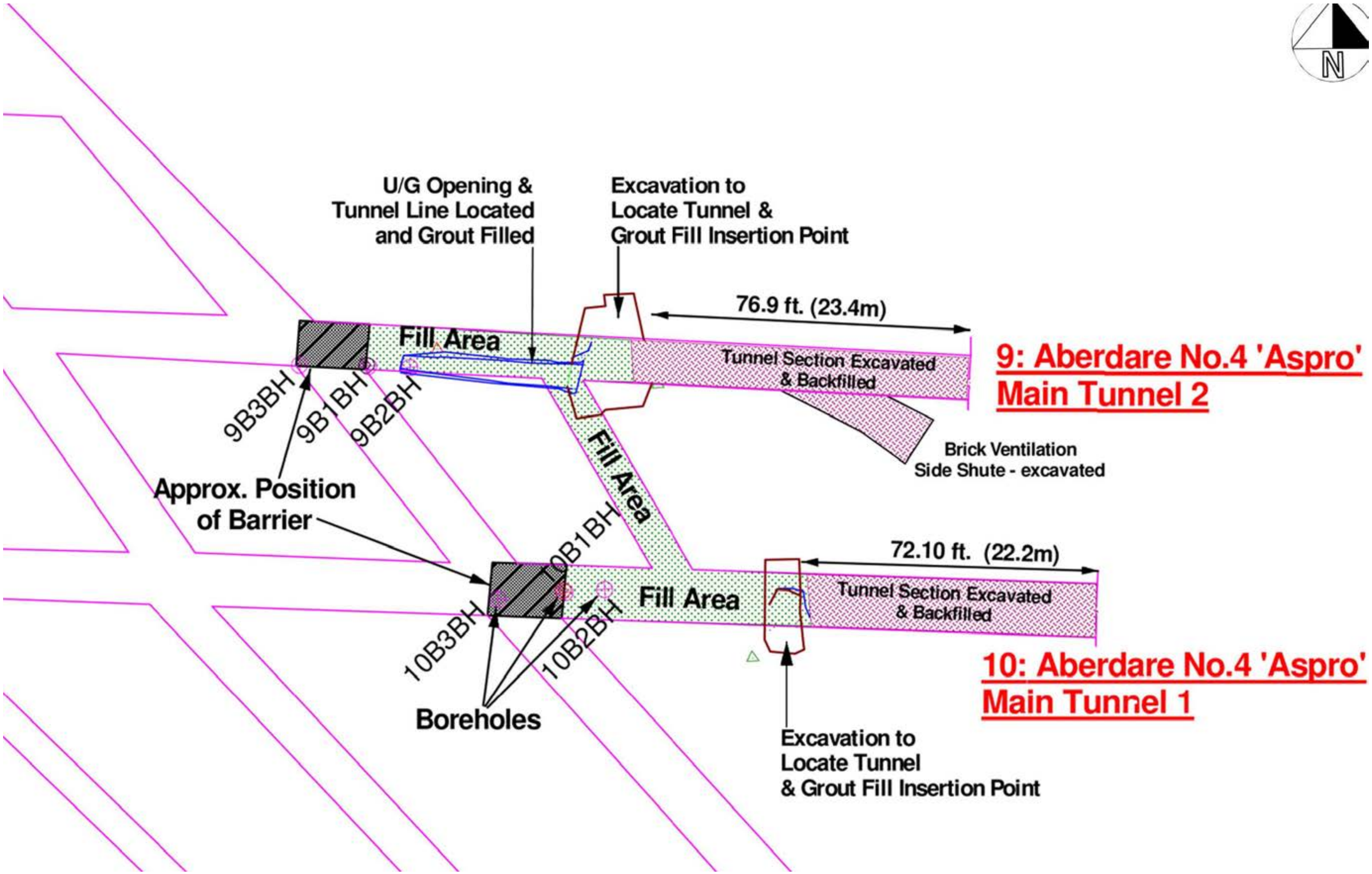
coffey geotechnics SPECIALISTS MANAGING THE EARTH

Aberdare No. 4 "Aspro" Colliery

Background

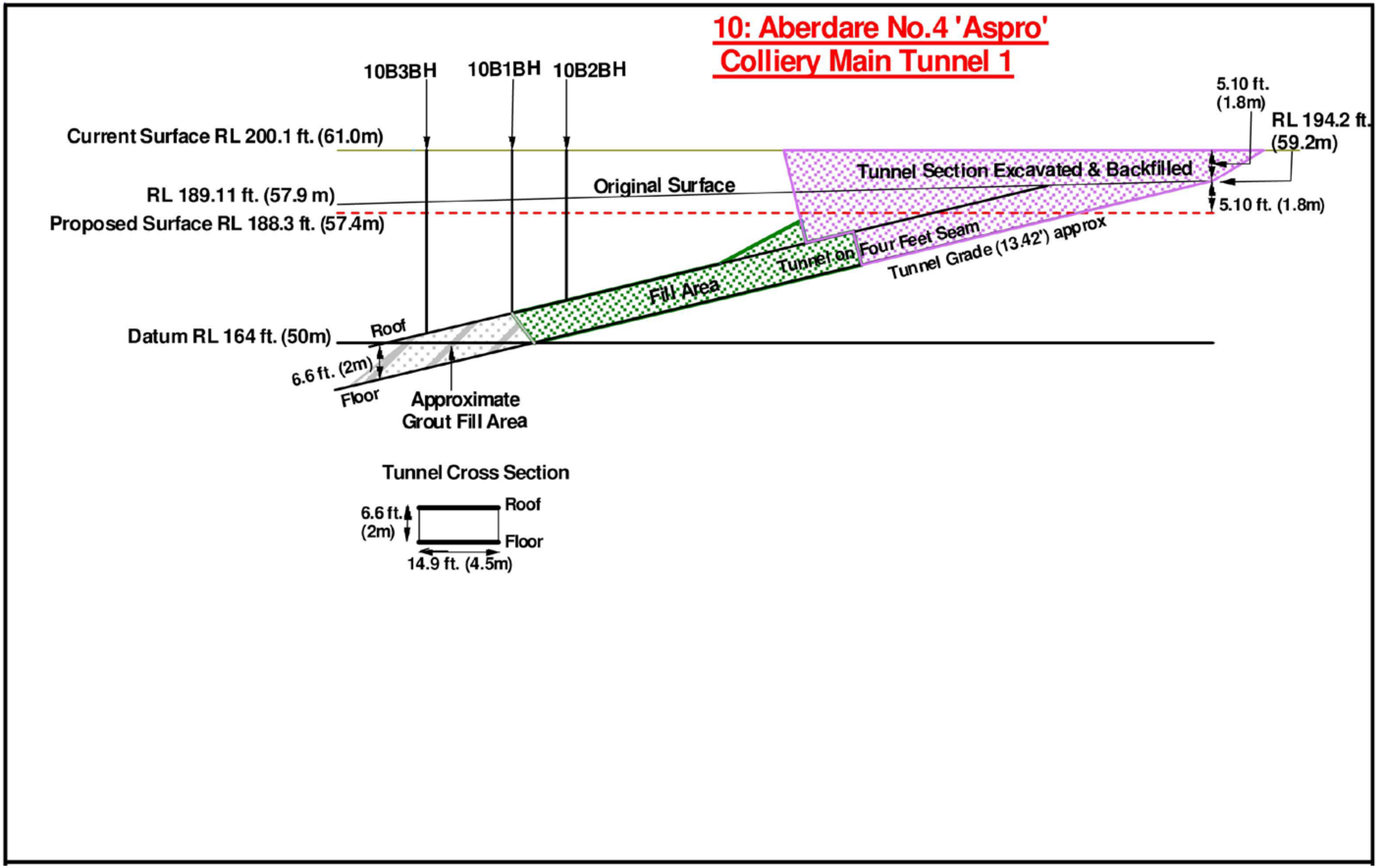
- Two rock tunnels used to access the Four Feet Seam;
- The mine operated between 1902 and 1913;
- Entries covered with coal waste at some time in the past;
- Area to be used for materials storage;
- Mitigation similar to other tunnels.

Aberdare No.4 "Aspro" Colliery



Main Tunnels Plan View

Aberdare No. 4 “Aspro” Colliery

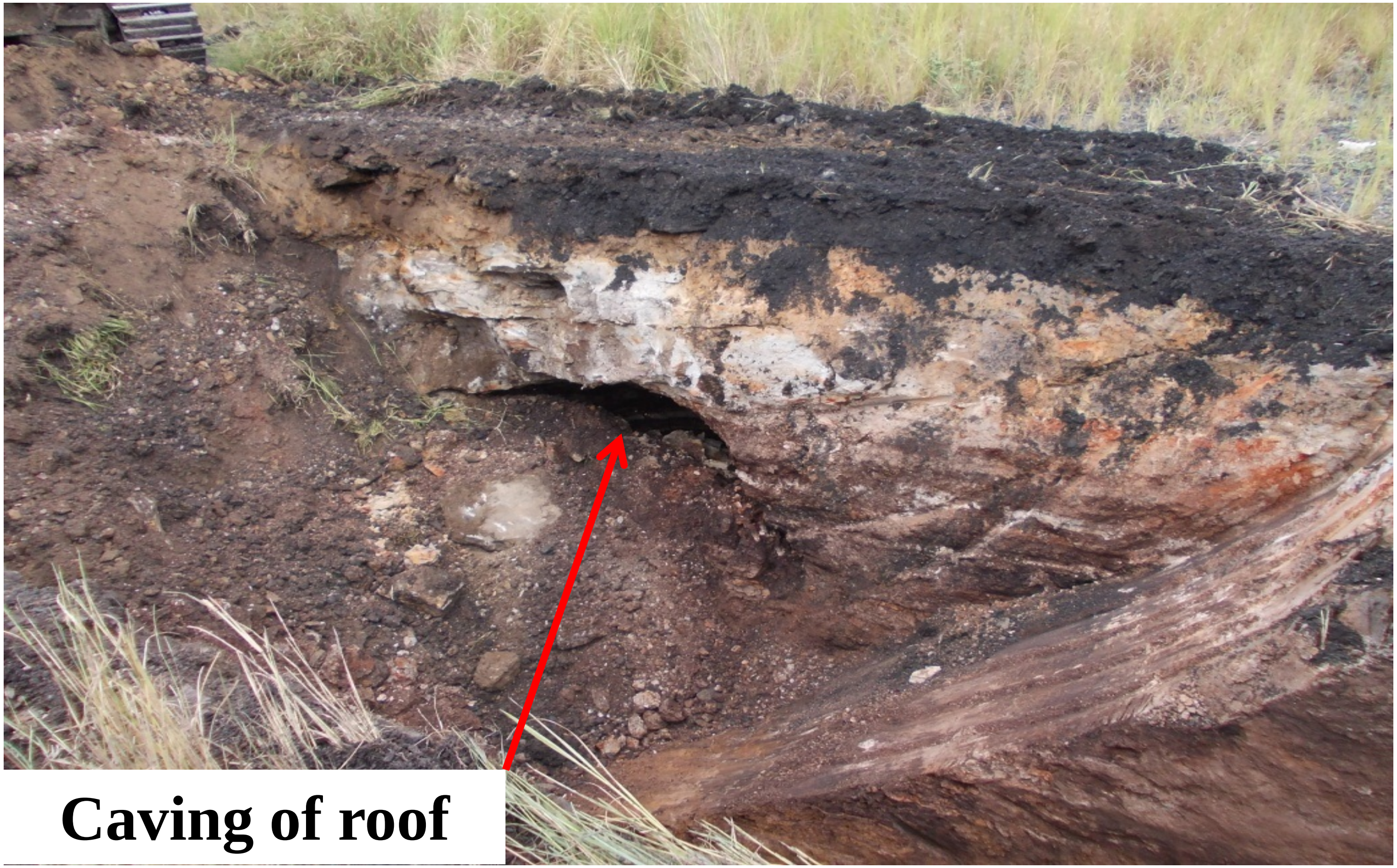


Main Tunnel 1 Profile

Aberdare No.4 “Aspro” Colliery

Tunnel Location by Test Pit Excavation

Aberdare No.4 "Aspro" Colliery



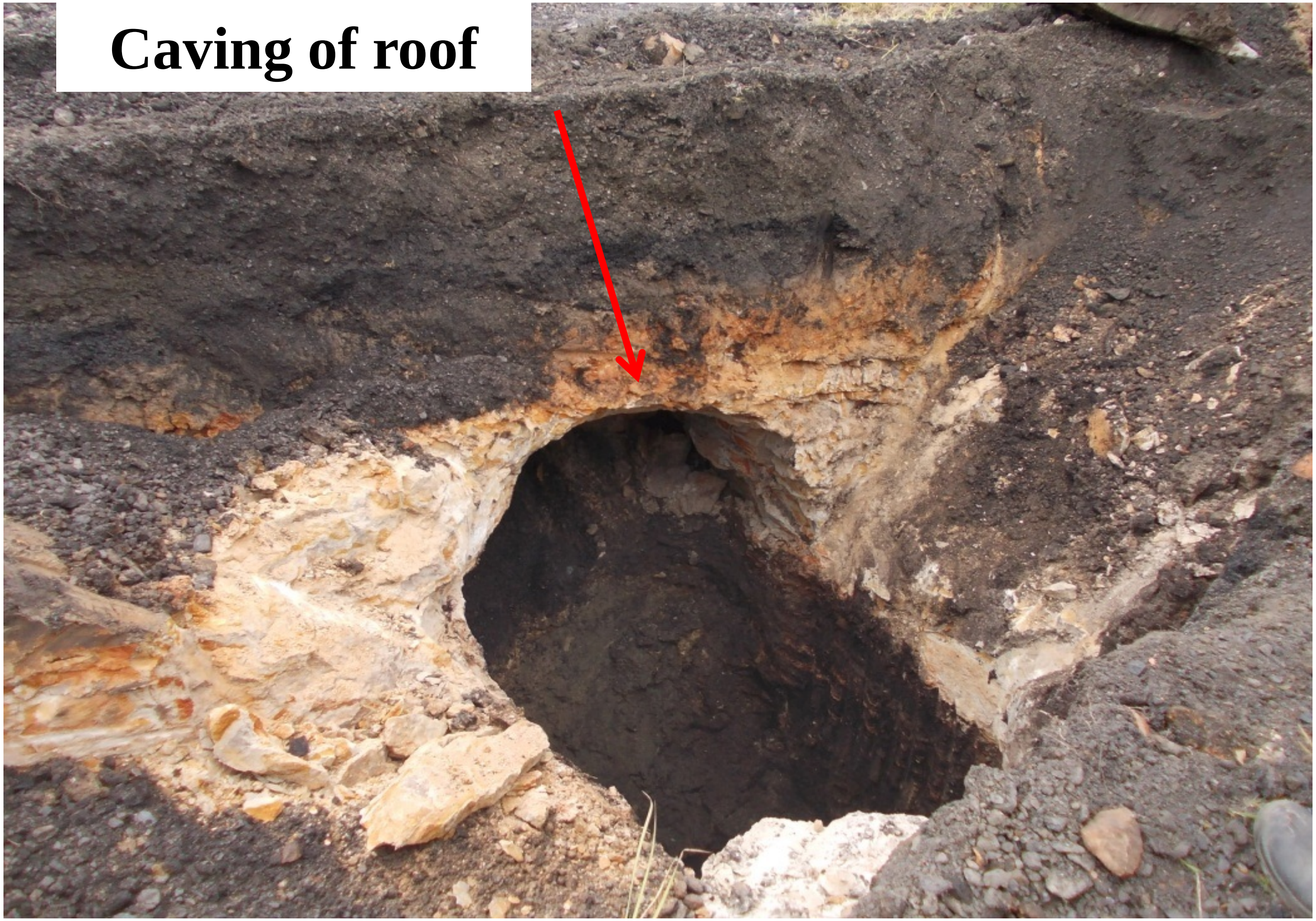
Caving of roof

Excavation at Tunnel 2

Aberdare No.4 "Aspro" Colliery

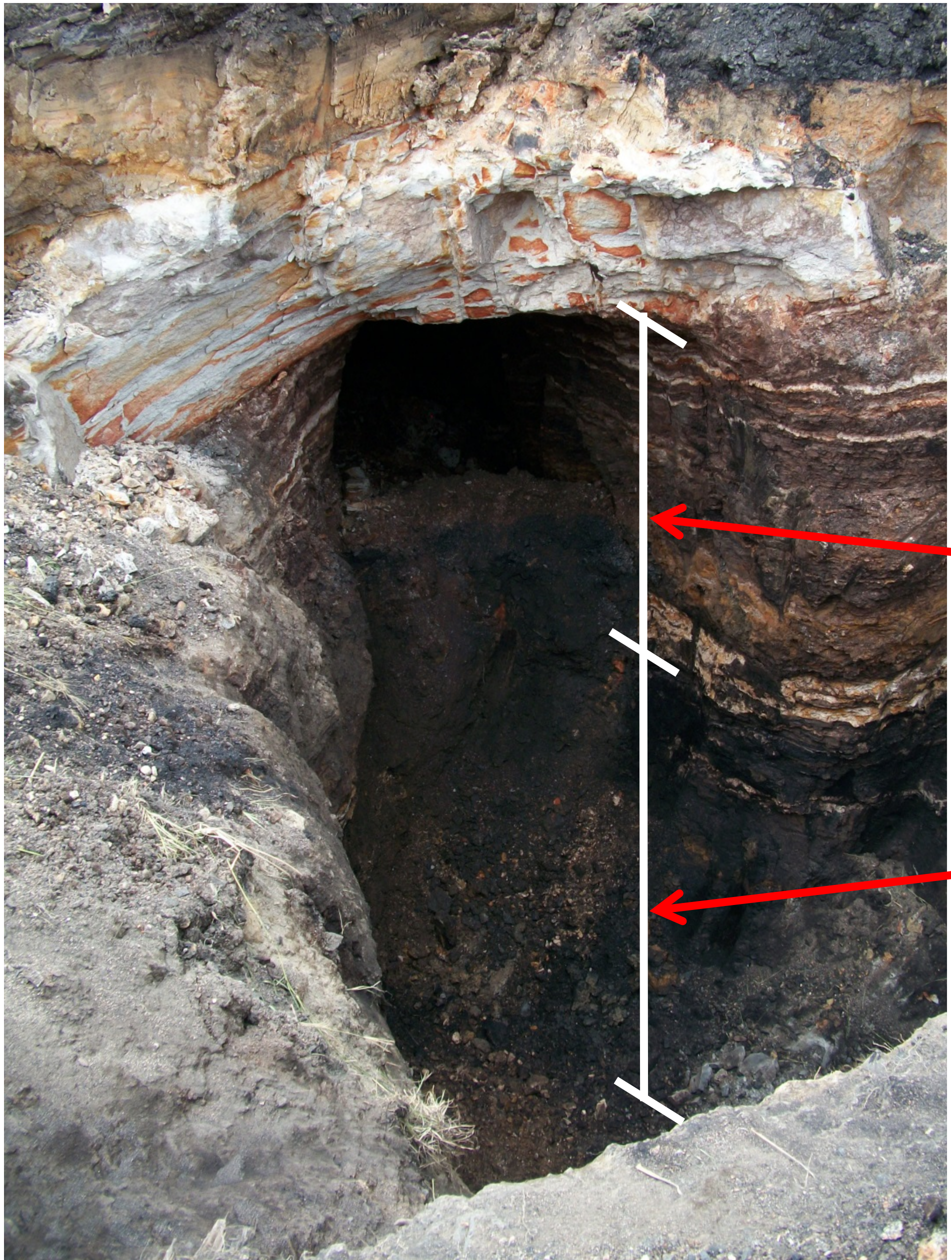
Caving encountered during excavation at Tunnel 1

Aberdare No.4 "Aspro" Colliery



Excavation at Tunnel 1

Aberdare No.4 "Aspro" Colliery



Section of 4 ft Seam and upper split

Upper Split - Unmined poor coal and clay bands

Mined portion of seam

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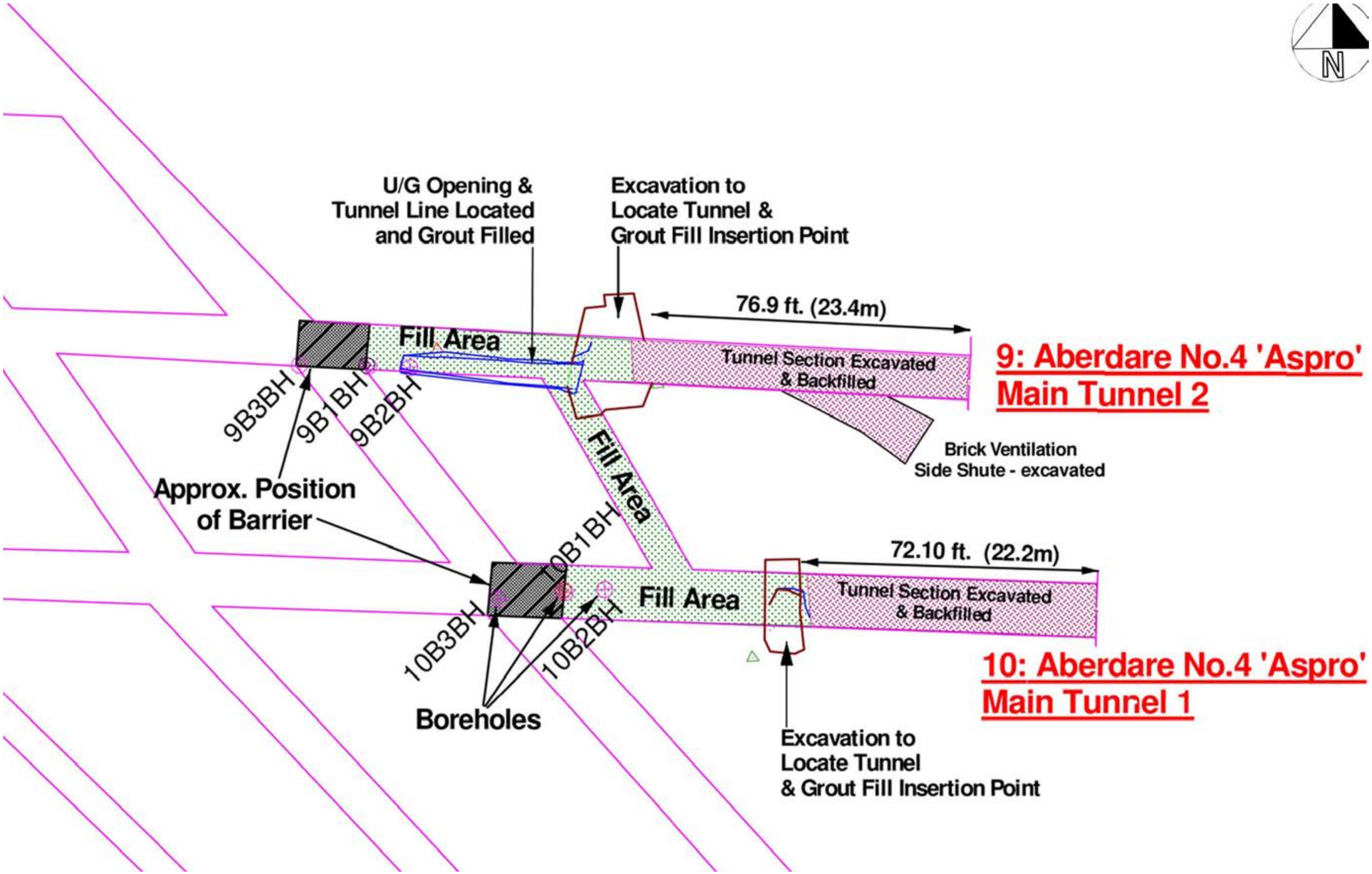
Aberdare No.4 "Aspro" Colliery

View of caved material that appears to have fallen in one block

Aberdare No.4 "Aspro" Colliery

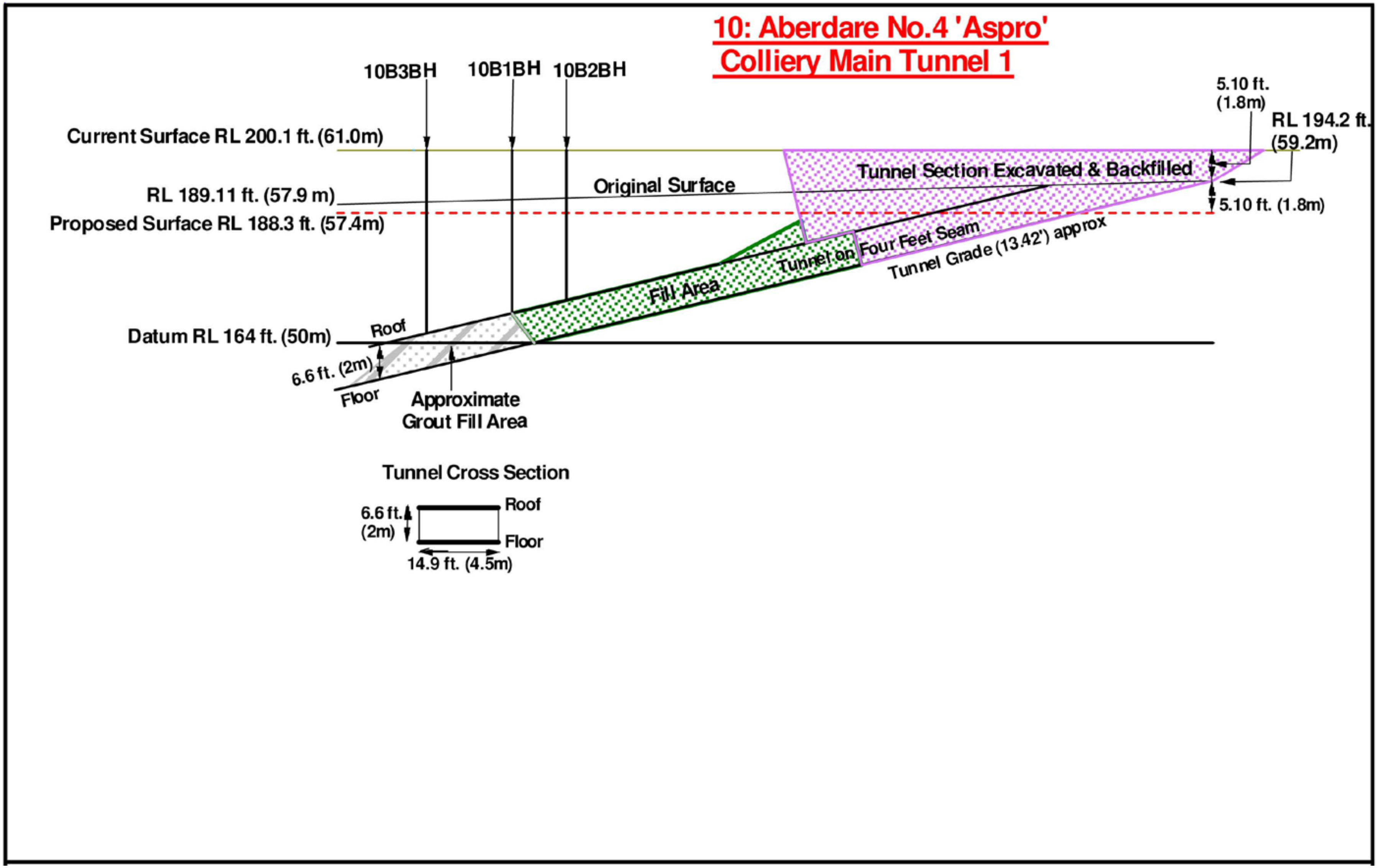
Mitigation

Aberdare No.4 “Aspro” Colliery



Main Tunnels Plan View

Aberdare No. 4 “Aspro” Colliery

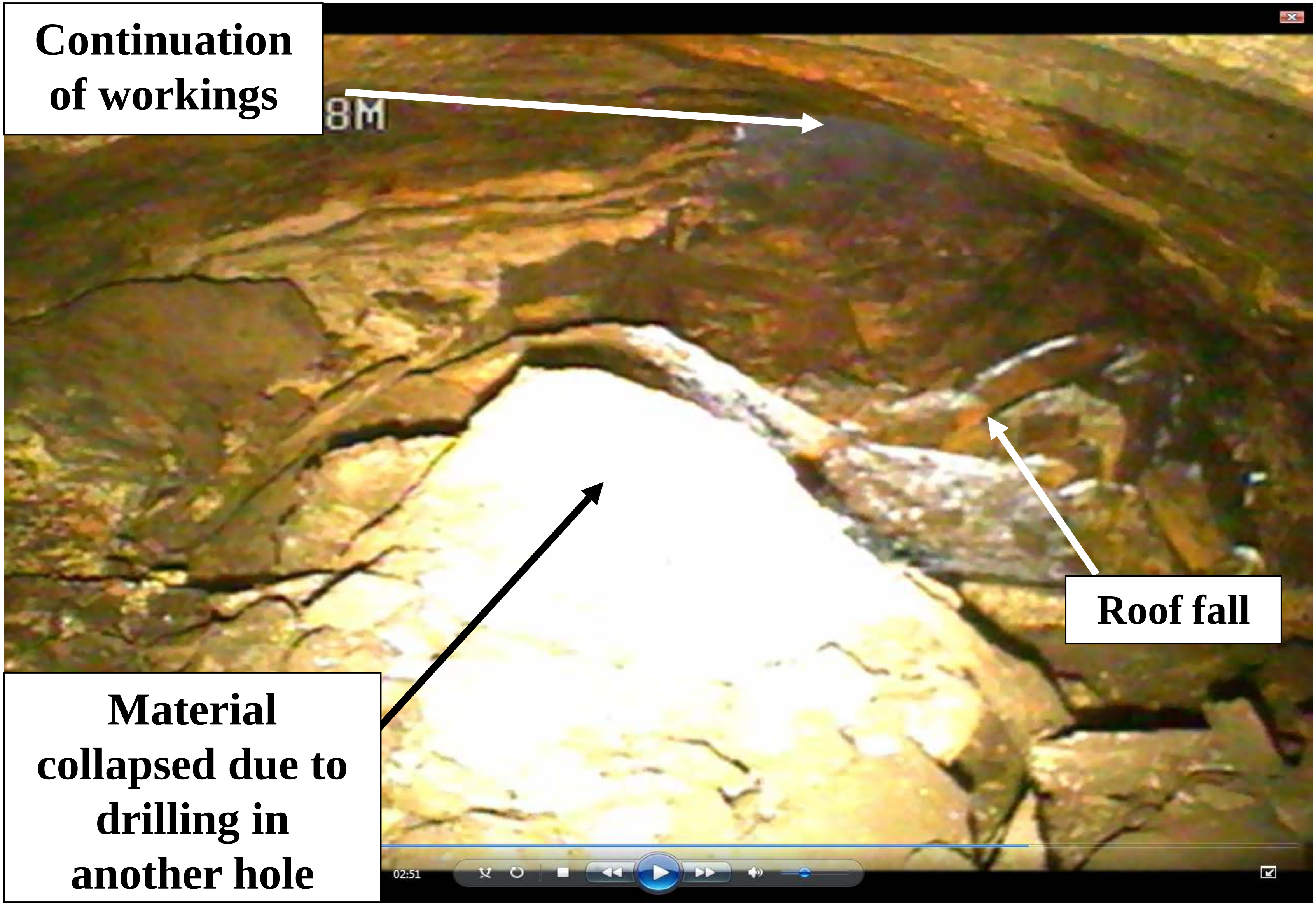


Main Tunnel 1 Profile

Aberdare No.4 “Aspro” Colliery

Grout hole drilling

Aberdare No.4 "Aspro" Colliery



Side view from barrier hole looking up slope in Tunnel 2

Aberdare No.4 "Aspro" Colliery

Down looking view showing roof fall in Tunnel 2

Aberdare No.4 "Aspro" Colliery

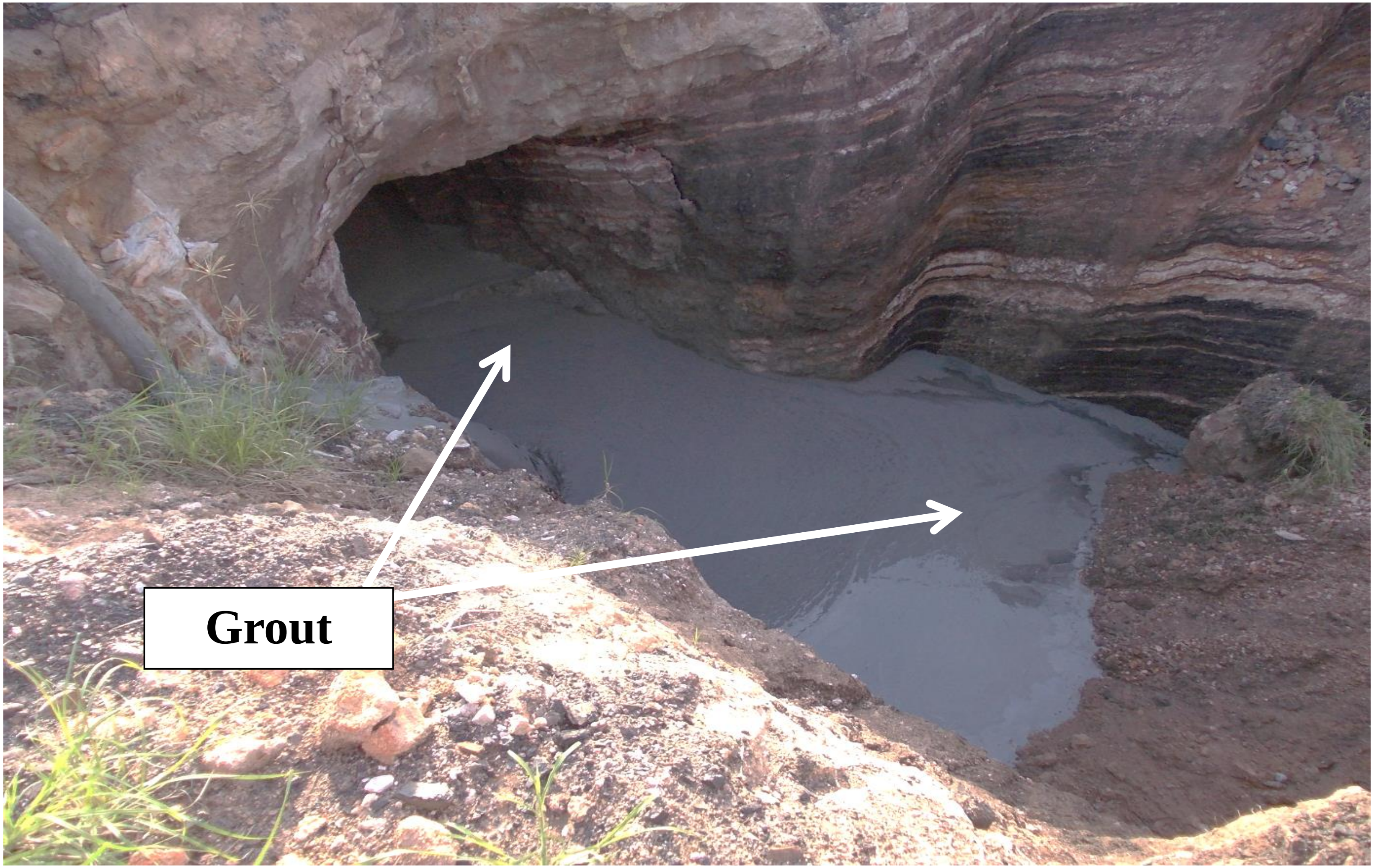
Hole	Date Drilled	Overburden Depth (m)	Depth to Top of Void (m)	Depth to Bottom of Void (m)	Void Height (m)	Comments
AB10-V1	11/05/2012	0.9			0	
AB10-V2	11/05/2012	1.44	8.27	10.79	2.52	Drilled into D10
AB10-V3	11/05/2012	0.67			0	
AB10-V4	11/05/2012	1.34			0	
AB10-V5	11/05/2012	1.22	8.61	9.44	0.83	
AB10-B3	6/03/2012	2.3	10.31	15.4	5.09	
AB9-B3	6/03/2012	3	8.49	15.81	7.32	
AB10-B2	24/02/2012	1.9	9.12	12.75	3.63	
AB10-B1	24/02/2012	1.77	9.92	13.71	3.79	
AB9-B2	24/02/2012	2.23	9.03	12.62	3.59	
AB9-B1	24/02/2012	2.84	9.79	13.84	4.05	

Drilling Summary

Aberdare No.4 “Aspro” Colliery

Grout being pumped from agitator truck into grout hole through tremie pipe

Aberdare No. 4 “Aspro” Colliery



Grouting from the excavation in Tunnel 1

Aberdare No. 4 "Aspro" Colliery

Tunnel 2 after filling with grout

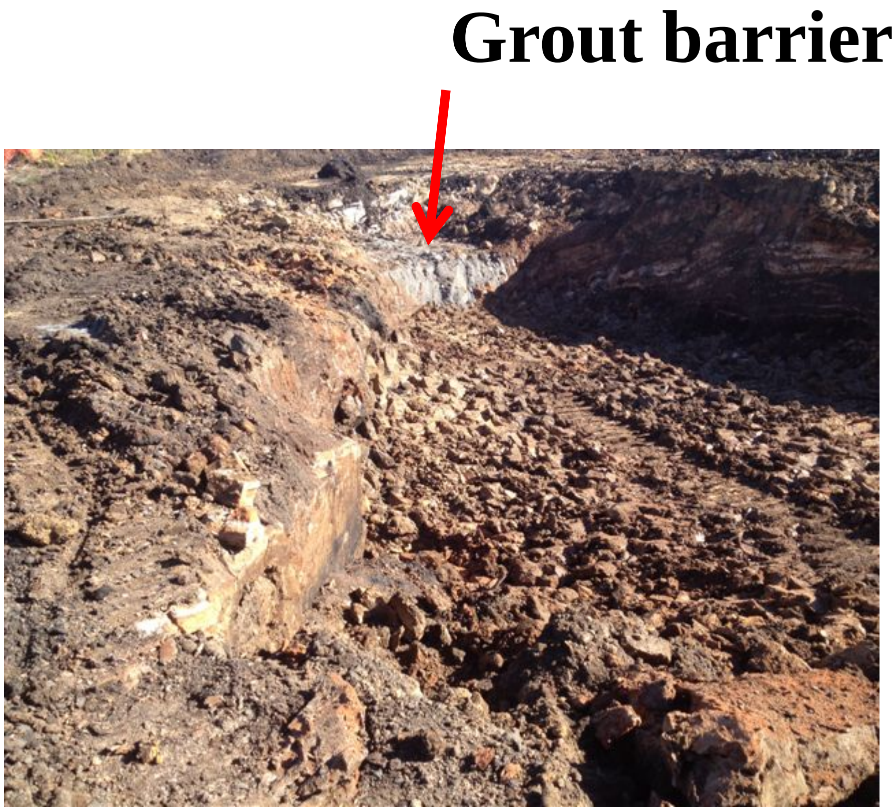
Aberdare No. 4 “Aspro” Colliery

Disturbance	Tunnel dimensions			Volume of Grout injected [3] (m³)	Percentage of Tunnel filled based on Grout Take vs. Theoretical volume[4]	Barrier Grout Volume (m³)
	Length [1] (m)	Cross-sectional area (m^2)	Theoretical Volume [2] (m^3)			
Tunnel 1 D10	18	5.4	134.7	101	75%	42
Tunnel 2 D9	22	5.4	157.5	186	118%	24

1 – Cross cut not included
2 – Void height estimated as 1.2m
3 – Contribution from barrier grout and debris in the tunnel ignored
4 - Includes grout used to fill excavation

Grouting Quantities

Aberdare No. 4 "Aspro" Colliery



Over – excavation and backfill of tunnel section upslope from grout barrier

Conclusions

- **A variety of methods may be needed to mitigate abandoned mine entries;**

- **The original construction of the entry and closure must also be considered as part of the mitigation design;**

- **The original closure may have been suitable for its purpose, but may not be adequate for redevelopment purposes;**

- **Impacts from mine gases and water must be considered;**

Conclusions Continued

- **Changes may need to be made during construction when the feature is exposed;**

- **Good coordination between the Owner, Contractor, and Engineer are needed to deal with changes;**

- **Sites with abandoned underground workings can be mitigated to allow redevelopment, thereby putting waste land to good use.**

Box Flat Disaster

17 miners killed in gas explosion while fighting mine fire - July 31st, 1972

Questions

What happened?