CASE STUDY: MINE VOID INVESTIGATION AND REMEDIATION FOR THE WEST CHARLESTOWN BYPASS, NEWCASTLE

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SUMMARY

The completed West Charlestown Bypass project comprises a 6.5 km length of dual carriageway urban freeway southwest of the Newcastle CBD, in New South Wales, Australia. This section of State Highway 23 extends from the Pacific Highway at Windale in the south, to Charlestown Road at Kotara in the north. A 1 km length of the Bypass, at the northern extent of the works, traverses old underground mine workings with overburden depths as shallow as 5 m ranging up to 30 m. The mine workings are within the Australasian Coal Seam and they were undertaken by two collieries, initially in the 1800’s by the Australasian Coal Company and later in the early 1900’s by the Newcastle Myall Colliery. The presence of these old mine workings and associated subsidence effects posed a difficult problem for the design and construction of the Bypass.

The Bypass design was required to be safe and serviceable, considering the potential impact of ongoing mine subsidence associated with these workings. A number of treatment options were considered, with the adopted design including a combination of excavate, collapse and backfill of shallow mine workings, and grouting of voids where the workings were located at greater depths. This paper presents a case study of the pre-construction investigations, including discussion of the methodologies adopted and their success, the design requirements and options considered, and the completed mine void treatment works.

1 INTRODUCTION

The West Charlestown Bypass provides a link in the inner city bypass of Newcastle. This section comprises a 6.5 km length of dual carriageway motorway in an urban environment extending from the Pacific Highway at Windale in the south to Charlestown Road, South Kotara, in the north.

This paper presents a case study of the impact of shallow underground coal mine workings on the bypass investigation, design and construction. In doing so it presents the challenging issues that were identified and encountered during the project and the methods used to manage these issues.

2 SITE SETTING

The topography of the area of interest has an overall slope to the west and south-west across the Bypass alignment. A steeper incline rising to a topographic spur (Cut 7) occurs at the northern extent of the mined area.

The site is scattered with evidence of old mine workings including sink holes, subsidence features, tunnel entrances, earthworks/haulage routes and spoil piles.

2.1 GEOLOGICAL MODEL

The bypass route is located within the Newcastle Coal Measures. The area of interest is located within the Adamstown Sub-Group Tickhole Formation, which includes in descending stratigraphic order, the Australasian, Montrose and Wave Hill Coal Seams. The intermediate rock units associated with these seams consist of siltstone, sandstone and claystone, many of which are of tuffaceous origin.

The highest stratigraphic coal seam at this location, the Australasian Coal Seam, is somewhat of a geological outlier, in that it is confined to a topographic high, making it accessible from all sides. The 9 m to 12 m thick seam is located at shallow depths (up to 30 m) beneath the Bypass alignment and has been previously mined. The coal from this seam is of varying quality and contains numerous claystone interbeds.

The subsurface profile within the route corridor typically consists of a thin topsoil/fill layer (<0.5 m) overlying residual soils grading to highly to extremely weathered bedrock over a depth varying up to 5 m. These residual soils typically consist of medium to high plasticity clays and vary from stiff to very stiff consistency.

Siltstone and sandstone are underlying the residual soils, and overlying the coal workings in the Australasian Coal Seam. The siltstone and sandstone strata occur both as interbedded and as distinct units, with occasional carbonaceous...
bands and claystones. The siltstone and sandstone units vary from highly weathered to fresh, and increase in strength with depth from weak to strong. The regional dip direction of the strata was assessed to be south-westerly varying from 2° to 8°, but was typically 3°. A sandstone marker bed was identified during the investigations at the base of the Australasian Coal Seam. This was utilised to confirm the base of the coal seam during both the investigation and construction phases.

A number of sub-vertical joints were identified throughout the major cutting above the coal workings, with the two most prominent sets striking at 050° to 080° and approximately 150°. Observations of the western batter during construction showed these joints to be open and probably related to subsidence of the underlying mine workings.

3 COAL MINING HISTORY

Two abandoned coal mines were identified within the project corridor, namely

- The Australasian Colliery (circa 1876-1879)
- The Newcastle Myall Colliery (circa 1920-1935)

Both collieries employed “bord and pillar” mining techniques via tunnels driven from outcrop located to the west of the site. Shafts were also excavated from the surface to provide ventilation of the workings.

In addition to the two mines located at the site, an abandoned railway tunnel associated with coal transport for the earlier Australasian Colliery was also known, from information in the Australian Railway Historical Society Bulletin to pass under the northern extent of the site.

3.1 SOURCES OF INFORMATION

The primary source of information regarding the mining was the abandonment plan of the Newcastle Myall Colliery, which was available from the Department of Mineralogical Resources (DMR). This plan was sourced in two forms, the original abandonment plan (drafted 25 June 1935) and a later plan trace (drafted 9 January 1967). Both plans included a trace of workings at the adjacent Australasian Colliery. The mine abandonment plan trace is presented as Figure 1.

![Figure 1: Trace of Newcastle Myall Colliery mine abandonment plan (9 January 1967).](image)

Other sources of information researched as part of the investigations included the Newcastle Morning Herald and the Miners Advocate.

3.2 AUSTRALASIAN COLLIERY 1876-1879

This was the southernmost of the two collieries, and was originally intended to target the Borehole Seam at greater depth. However, when exploration shafts unveiled the 9 m plus Australasian Seam at shallow depth, the colliery proceeded with this seam as its target. The depth of mining below surface within the Australasian Colliery varies from 8 m up to 20 m.

Mining commenced with railway tunnel excavations to the north of the mine within the Montrose Seam. The railway tunnel was to provide a route from the mine to Newcastle Harbour (Australian Railway Historical Society Bulletin). However, records indicate that the coal extracted from the tunnel excavations was poor quality and could not be sold.
Notwithstanding, mining proceeded within the Australasian Coal Seam with total production from the mine recorded as 9,052 tons prior to the Australasian Coal Company’s liquidation in 1879.

3.3 NEWCASTLE MYALL COLLIERY 1920 – 1935
This colliery was situated to the north of the Australasian Colliery. The Newcastle Myall Colliery was a much larger mining operation. The majority of the known workings were located to the west of the road corridor. This mine employed a “Welsh Bord” pattern of mining with dimensions 5 m to 6 m wide and 2 m in height, with the pillars approximately 7 m in width. The depth of the workings within the project corridor varied from 5 m to approximately 30 m cover. The mine utilised natural ventilation from the nearby outcrop, in conjunction with the use of furnace shafts. Coal haulage was by horse drawn skips. The coal production from the Newcastle Myall Colliery was up to 30,000 tons per annum in 1926, with staff numbers varying between 4 up to 23 during the life of the mine.

There was a low degree of confidence in the details of the mine abandonment. This is reflected in several features on the plans including the lack of surveyed dates coinciding with the end of mining, evidence of illegal mining (ratholing) in the 1930’s and several drafted features that could not be interpreted with certainty. These latter features include open ended drives, a fire area, various tunnel entrances and overlapping line work on plans.

The drafting of the Australasian Colliery workings, which appear on the Newcastle Myall abandonment plans, is equally uncertain as it contains a large amount of unidentified line work and does not correlate well with local topography and coal seam outcrop.

On this basis, the investigations of the mine workings proceeded with the assumption that the workings on the plans represent the minimum amount of workings as opposed to necessarily being a true reflection of the mined extent.

4 PRE-CONSTRUCTION INVESTIGATIONS
The Roads and Traffic Authority (RTA) commenced general route investigations for the bypass in 1985. Those initial investigations included site mapping, test pits, seismic traversing, boreholes and limited mine void assessment and were predominately associated with the location of the surface features of both collieries. One RTA borehole at the northern extent of the route during these investigations encountered a 4 m void within the Australasian Coal Seam.

A later assessment of mine voids undertaken by the RTA attempted to orientate the mine abandonment plan. This assessment included excavations and survey at inferred tunnel entrances and detail ground survey of subsidence features, inferred shafts and the coal outcrop. From these investigations a “Best Fit” mine plan orientation was developed.

GHD became involved with the project in 1996 as engineering designers of the Bypass. In addition to general investigations for road design, a detailed mine void investigation was commenced, acknowledging the uncertainty of the mine abandonment plan orientation. These investigations were aimed at proving the extent and condition of the mine workings.

4.1 INVESTIGATION METHODS
The investigations utilised a variety of methods including:
- Percussion Drilling – primary investigation method (see Figure 2a),
- Cored Boreholes – provided calibration of percussion drilling logs,
- Down Hole Camera - enabled subsurface inspection to confirm inferred void conditions (see Figure 2b),
- Detail Site Survey – survey of surface features not previously identified, eg subsidence, tunnel features, etc.,
- Georadar – predominately to confirm the location of the railway tunnel, but not effective in mine void area due to extent of ground disturbance and
- Pump Out (Draw Down) Test – to assess the groundwater and mine water interaction for design purposes.

The primary method of investigation, percussion drilling, was undertaken with a track mounted air percussion drill rig. This drilling sought to confirm the depth to coal and the mine workings, if present. The drill holes generated were also utilised for piezometer installation within the coal workings to enable monitoring of water levels in the mine voids. The advantages of this method of subsurface investigation are high productivity (up to 10 holes or 150 metres of drilling per day), lower risk of drill rig damage in disturbed ground, ease of track mounted rig access to difficult areas and easy orientation of the hydraulic drill mast irrespective of the undulating ground surface.

The major disadvantage of using percussion drilling was the limited quality of borehole log that could be generated, given the reliance on limited cutting return, particularly within mine voids. This was managed by calibrating the
percussion drilling using a number of cored boreholes drilled in parallel with the percussion boreholes to verify the logging interpretations.

4.2 FIELDWORK INTERPRETATION
Sections were developed from the investigations, to assist with the interpretation of the mine void extent. An example section is provided as Figure 3.

In order to develop these mine void sections, the mine void condition was assessed on the basis of the investigative data. This was refined as the investigations progressed and was calibrated by the down hole camera inspection which visually confirmed mine void condition. Figure 4 presents an illustration of the variety of mine void conditions inferred from the drilling investigation.

The interpreted voided and non-voided areas identified from the sections were then plotted in plan in order to assess the mine abandonment plan orientation. The conclusions as to the mine abandonment plan orientation were as follows:

- Broad agreement with workings plan
- No correlation between plans of two collieries
- Australasian Colliery high uncertainty
- Numerous mine plan orientations possible
• “Best Fit” assumed for design consideration
• Workings are at base of coal seam, that is on “Sandstone Marker Band”
• Workings not expected at Myall Road Bridge

![Diagram showing inferred mine void conditions](image)

**Figure 4:** Inferred mine void conditions encountered by percussion drill holes.

Based on these conclusions it was decided that additional investigations would be undertaken during construction to improve the understanding of the orientation and accuracy of the mine abandonment plan. This presented a high level of contractual risk to the client. The design and documentation were developed to cater for this uncertainty in the methods and controls of the construction.

In addition to the assessment of the extent of mine workings, investigation was also undertaken to determine the groundwater conditions within the mine workings. This was carried out using a large scale draw down pump test with full-time piezometer monitoring to measure varying ground and mine water levels including the rate of recharge. Samples were also collected for groundwater chemistry testing. Conclusions drawn from the pump test were as follows:

- Southern (down dip) Australasian Colliery relatively dry
- Newcastle Myall Colliery water filled, drains down dip
- Poor hydraulic connection between collieries
- Physical nature of hydraulic barrier between collieries not known
- Minewater can be successfully drawn down
- Mine water seepage occurs at coal outcrop and mine entrances
- Minewater discharge during construction will likely require treatment for the presence of dissolved heavy metals and to adjust low pH (2.6 to 5.1) values.
- Recharge less than 0.1 ML/day in dry conditions

## 5 DESIGN PHASE

### 5.1 MINE VOIDS STRATEGY

The requirements of the Bypass design were investigated during the design phase of the project, in recognition of the potential influence of subsidence due to past mining. Relatively shallow but variable mining for coal had occurred beneath areas of the Bypass, affecting Cut 6, Fill 6, Cut 7 and Fill 7, north of Hillsborough Rd. Significant subsidence effects were evident at surface in the shallow-mined areas of Cut 6/Fill 6.

A Mine Voids Strategy was prepared and included in the earthworks specification. Options for grouting of the old mine workings and associated voids, or for over-excavation and backfilling in shallow-mined areas were considered and designed.

The strategy involved further investigations to be undertaken during the construction stage in the Cut 7/Fill 7 area, in order to assess the limit of workings and void grouting, to be carried out as part of the construction contract. Where deemed appropriate, a portion of the construction over the mined or suspected mined area could possibly proceed without remedial work to the mine workings and voids.

The statutory requirements of the Joint Coal Board (JCB) and Department of Mineral Resources (DMR) were determined by approaches to each authority, in relation to excavation of commercial quality coal from within the Bypass route corridor. The DMR required that an application was to be made. Fortunately, there was no requirement for the earthworks operation to embrace mining regulations when excavating coal.
However, significant constraints were anticipated for bulk excavation within the old workings, either as a construction method, or for winning of commercial quantities of coal. This was due to the safe working requirements of the DMR governing such operations, and the uncertainty of the extent and conditions of the workings revealed from the investigations carried out to that time.

5.2 DESIGN STRATEGY
Notwithstanding the results of the investigation discussed above, in relation to the mine workings plan overlay on the Bypass alignment, the geotechnical design issues for the Bypass were constrained by considerable uncertainty as to the conditions and actual extent of the workings beneath the Bypass corridor.

The workings appeared to be within the bottom 2.5 m to 3.0 m of the Australasian Coal Seam. The assumed base of the workings was marked by a persistent sandstone layer near the base of the seam. Further coal underlies the sandstone marker layer but was only a thin layer and was not likely to have been mined.

It was necessary to assume that the conditions within the workings (resulting from likely pillar robbing and subsequent collapse during mining, extensive subsidence of the weak roof conditions after mining ceased and the possibility of significant water-filled cavities), as inferred from the investigation results and from limited observations using the down-hole video camera, were consistently poor throughout.

In view of these conclusions, the methods to be adopted or likely to be suitable for treatment of the mine voids during construction included recognition of the following:

- uncertainty as to the number, arrangement, alignment, widths and extent of the old workings
- significant risks associated with the presence of water in the mine workings or in voids above the workings
- safe working practices and restrictions on working in any open excavations within or above the mined areas; in this regard, the requirements of the NSW Department of Mineral Resources need to be determined and fully complied with and
- the ability to provide a stable platform for support of the Bypass carriageway and associated structures.

In recognition of the significant engineering design uncertainty, and potential contractual risk, the RTA nominated the mine voids area as a Quarantine Area within the contract. In addition, the recognised constraints of the route and the requirements of the earthworks programme for the Bypass construction meant that staging of the mine voids treatment was critical to the project.

Haulage of excavated materials for placement in fill embankments at the early stages of the contract was limited by the bridge construction at Hillsborough Road and the availability of a haulage route through the mine voids area. Hence, the options for treatment of the mine voids needed to be considered in terms of their overall impact on the construction programme, as well as for practicality and cost.

Investigation of the mine voids within the vicinity of Cut 7 during the construction was proposed and carried out. A Hold Point was included to permit the results of the construction-stage investigation to be assessed and the design for the remainder of the earthworks in Cut 7 and for stabilisation of the old mine workings to be considered.

5.3 DESIGN OUTCOMES
Several options were initially considered in the early design phase for the mine voids treatment.

- “Do Nothing” – subject to assessment and acceptance of consequences
- Excavate / Collapse / Backfill within areas of shallow workings
- Grouting of the workings and voids – likely to be applicable to both shallow and deeper workings
- Land Bridge – proved to be too costly

Selected options, namely excavate/collapse/backfill and grouting could be assessed further by investigations during construction. Three separate sections along the route within the mine voids area were nominated, based on the design and perceived construction/contractual issues:-

Section A
- <15m Cover
- Excavate / Collapse / Backfill proposed for construction
- Some Grouting based on the contractor’s decision

Section B
- 15 to 30m cover
- Grouting (excavation too deep)
Section C

- Rail Tunnel
- Workings not expected
- Grouting (excavation too deep)

The two design/construction procedures chosen are briefly described as follows.

5.3.1 Excavate/Collapse/Backfill

Bulk excavation was to be carried out to within 5 m above the floor of the workings (determined from the sandstone “marker layer”), i.e. about 2 m to 3 m above the assumed top of workings.

The design of the excavation for this component of the mine voids treatment was based on geometric considerations involving the following components:

- coal seam - depth to top of workings as determined from the investigation and its dip across and along the Bypass alignment,
- natural slope topography and
- an assumed “angle of draw” (35°) from the edges of the treated width across the carriageway.

The last aspect determined a “safe” lateral extent of the treatment so that existing or future subsidence effects in the mine workings remaining outside the treated zone, would not be likely to influence the foundation support and stability of the Bypass carriageway.

The lateral extent of this geometric design was determined on the design cross sections, and the resulting “footprint” of the area to be treated in this manner was established. An example cross section is shown in Figure 5.

![Figure 5: Mine Void Design Cross Section.](image)

At the northern end of the excavate/collapse/backfill zone, where the depth for over-excavation was becoming excessive, an option was provided for the contractor to extend the excavation laterally on the upslope side of the construction (southbound carriageway) and avoid grouting, provided that further geotechnical design assessment of the temporary excavation stability proved to be acceptable.

After the bulk excavation, the mine workings and voids were to be collapsed by any of the following techniques:

- impact
- rock hammering
- vibration
- further bulk excavation

Proof loading of the collapsed workings by impact rolling was initially required as part of the design, for assessment of successful voids treatment, with engineered fill to be constructed above the treated workings to build the construction back up to the design formation level.

However, the method adopted by the contractor was based on excavating the workings and backfilling using end-tipping methods. Deep impact rolling was used initially, to achieve a satisfactory working platform on the collapsed and backfilled workings, with engineered fill construction techniques above.

Requirements for dewatering of the workings and bulk excavation were recognised and included in the specification.
Safe working and local/global slope stability issues for the bulk excavation in the mine voids area were to be determined by the contractor as part of the construction methodology required under the contract.

5.3.2 Mine Void Grouting Design

The following requirements were specified for the mine voids grouting:-

- 95% void volume to be filled
- minimum 2 MPa 28 day grout strength
- thickness of remaining voids <0.3 m
- area of remaining void <5 m²
- wet and dry grouting to be considered
- grout may need to be placed under water
- proving of grouting by re-drilling and second-phase grouting with monitoring of grout acceptance.

6 CONSTRUCTION PHASE

Construction of the bypass was divided into 4 contracts, with the mine void treatment contained within Contract 3 (Earthworks). These works commenced in the year 2000.

In accordance with the specification, a Mine Void Work Methodology Plan was developed. The mine void methodology incorporated a detailed safety plan, which drew on the experience of construction, geotechnical and mining personnel. The safety plan identified varying risk categories for personnel and machinery operating within the mine void area according to the mine workings cover. The safety plan was generated through isopachs of the depth to the base of workings ("Sandstone Marker") as determined from investigation. The cover to the workings was then determined as the depth to the base of workings less 2 m assumed working height. Based on this safety plan, the work was commenced at the southern extent of the mine void area within the Australasian Colliery utilising an Excavate Collapse Backfill operation.

6.1 EXCAVATE/COLLAPSE/BACKFILL

The heavy vegetation across the site limited the visibility of potential ground surface hazards including subsidence features, shafts and sinkholes. This necessitated the clearing of vegetation within the mine void area prior to any machinery entering the area. The clearing was undertaken using manual labour to minimise excessive loading of potentially unstable ground. As subsidence features, shafts and sinkholes were identified during the clearing they were progressively fenced off, to prevent access and to identify these areas as being of high risk to both plant and personnel within entering the area.

Following completion of the clearing, the bulk excavations down to the mine workings commenced. These excavations utilised a large 180T excavator, which eliminated the need for pre-ripping of the overlying rock strata. Where the excavations were at a depth close to the coal workings, a smaller 30T excavator was used as it provided better control to expose workings within the “broken” ground above the workings. During excavation, the safety plan required a mine open cut examiner to be on site at all times. The open cut examiner was responsible for all operations and personnel within the mine void area. Amongst other tasks this included air quality monitoring to assess the risk of carbon dioxide ("black damp") within the excavation.

Figure 6a: Mine void excavation.  Figure 6b: Subsidence and deformation of strata 4 m To 7 m above workings
Figure 6a shows the 30T excavator working in tandem with the 180T excavator loading a haul truck for transport of material to the major fill to the south of the mine void area. Figure 6b shows subsidence features exposed in the western batter of Cut 6.

As the excavations progressed northwards, the height of the excavation face became greater than the reach of the large excavator. To manage this the excavation methodology was reviewed to include a dozer, which operated above the excavation face to progressively reduce the overburden height. Figures 7a and 7b show the excavation methodology schematically.

As predicted, the workings within the Australasian Colliery were relatively dry. However, as the excavations progressed toward the Newcastle Myall Colliery, the minewater within these flooded workings required specific treatment to manage the risk of water breaking out, particularly as the nature of the hydraulic barrier between the two mines was unknown. Prior to encountering the Newcastle Myall Colliery, an excavation was advanced from the ground surface into the lowest point of these workings so that the workings could be dewatered. The minewater pumped from this excavation was treated to correct the pH prior to discharge into the construction site sediment control system. Figures 8a and 8b are photographs of the pump operating at the base of the excavation and an example of the dewatered mine void.

6.2 MINE VOID GROUTING

Mine void grouting was limited to the deeper workings in the northern Newcastle Myall Colliery and in the railway tunnel.

The contractor nominated a fly ash grout with 3% Cement. The grout was applied by drilling percussion holes on a “first pass” 6 m grid. Each of these holes was logged for void encountered and the grout take recorded. This data was plotted in plan to enable assessment of the “first pass” grouting. The “second pass” grouting also followed a 6 m grid offset 3 m from the “first pass” grid. The voids and grout take were also recorded and plotted. The “second pass” grid provided a resultant drill hole grid of 3 m.

The data collected during the drilling and grouting was used to determine the grouting effectiveness, in particular the grout take and voids encountered on the “second pass” drilling grid. Limited areas identified as containing potentially ungrouted void space were re-grouted from preferentially located drill holes.
The total grout consumption within the Newcastle Myall Colliery was 12,881 m$^3$. The Railway Tunnel required 757 m$^3$. Figure 9 shows a grouted mine void (left of photo) exposed at the interface of the mine void grouting and excavate/collapse/backfill treatment. Note the piezometer within the grouted void, and also the ungrouted void (right of the photo). The ungrouted void was grouted later during construction. Inspection of this excavated face showed that grout had locally migrated into open joints as small as 10 mm in width.

![Figure 9: Grouted mine void exposed at Excavate Collapse Backfill interface.](image)

7 CONCLUSION

This case study provides a summary of the processes followed from investigation through to construction, associated with mine void treatment along a section of the West Charlestown Bypass project.

In particular, the risks associated with the mine void treatment were assessed and taken into account in the engineering design and construction specification.

For the particular conditions present along the Bypass route, the outcome of the bypass construction proved the design and construction methodology for the mine voids treatment to be successful.

8 ACKNOWLEDGEMENTS

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8 REFERENCES