

## Monitoring of Coal Mining Around Large Dams

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### ABSTRACT

Manning Creek Ash Dam has been successfully undermined once, and is currently being undermined again in a second seam. The dam has been monitored closely during each stage of the mining, and there is no evidence of any damage. Maximum vertical ground movements of 0.25 m have been recorded.

A major water supply dam south of Sydney is currently being undermined using a system designed to limit subsidence to about one tenth of the maximum. The mine has implemented an extensive monitoring programme which should provide valuable data in the future on the effect of mining on the overlying strata, including the ground water regime in that strata.

### INTRODUCTION

Coal mining around large dams in NSW requires the approval of the Minister (virtually, the Dams Safety Committee). The Dams Safety Committee (DSC) will generally require a monitoring programme be implemented when approving an application to ensure the validity of the predictions on which the approval was based, and to confirm that no unexpected effects are occurring as mining progresses. Specifications for the monitoring programs are developed by the DSC in consultation with the colliery, and, sometimes, the dam owner. The monitoring is undertaken by the colliery or the dam owner, often with the continued advice and assistance of the DSC. Results are forwarded to the DSC progressively during mining for further analysis.

This paper presents a brief description of two approved layouts. The first of these is interesting because it involves extraction in two seams immediately beneath a reasonable size embankment dam. All evidence to date suggests that the dam has withstood the effects of mining without ill effect. The second case involves extraction beneath the storage of a large water supply dam. While few monitoring results from the second case are available yet, the monitoring programme is extensive and involves a number of interesting projects which should produce worthwhile information in the future.

### MINING BENEATH THE STRUCTURE OF MANNING CREEK ASH DAM - WYEE STATE COAL MINE

Manning Creek Ash Dam is a 12 m high homogeneous earthfill embankment designed to hold wet ash refuse from the local coal fired power station. Loss of stored water from this dam into the mine workings below would, if anything, benefit the

dam owner, so the DSC was not concerned with the effects of mining under the storage of this dam when it reviewed the application. However, a significant failure of the embankment would lead to widespread environmental damage downstream, so the continued stability of the dam was the Committee's chief concern. In addition, the Committee wished to minimise the sterilisation of coal reserves if possible.

As a result, unrestricted mining was permitted under the storage of the dam. However, within a zone under and around the structure of the dam, the extraction ratio was restricted so as to minimise surface subsidence, and therefore the effect on the structure. The proposed mine plan was analysed to determine the likely surface subsidence, and this was used to assess the effect on the structure. The Committee concluded that the structure could withstand the likely mining effects with at most minor surface cracking, and the owner would be able to repair such cracking, together with any depressions, quickly and relatively cheaply (DSC, 1980).

Pre-mining subsidence predictions for the panel and pillar areas were made based on data from the U.K. (National Coal Board data), and suggested that maximum subsidence would be about 0.1 m (Mattes, 1988). Predictions for the total extraction areas were based on local data, and predicted 1.1 m subsidence (Anderson, 1983).

Mining of the Great Northern Seam was undertaken in two phases, separated in time by nearly four years. Following the completion of extraction in the Great Northern Seam, extraction in the Fassifern Seam, about 30 m below the Great Northern Seam, commenced, and is continuing to date. The data presented in this paper refers primarily to the extraction in the Great Northern Seam, although the proposed extent of mining in the Fassifern Seam is shown on Figure 1.

Phase 1 commenced in 1981 in the Great Northern Seam, and involved panel and pillar mining directly beneath the embankment. Pillars 30

m wide were left between 45 m panels. A similar layout was employed during Phase 2, which commenced in mid-1986. A 100 m wide barrier pillar was left between the two areas because of the presence of a strong basaltic dyke (65 MPa (Ives, 1991)) which passes directly under the dam embankment. Outside of these two panel and pillar areas the seam, was totally extracted.

In this area the Great Northern Seam has a very strong conglomerate roof, and a tuffaceous floor which softens as it becomes wet. The combined effect of these is that subsidence creep occurs for some time after the completion of mining. The Great Northern Seam is located at a depth of 170 m, and is about 3 m thick.

The Committee required the colliery and the dam owner to undertake various monitoring programs. These included surface subsidence and strain monitoring (in the form of surveys, inclinometer readings, crack measurements, and daily visual inspections) of the embankment and surrounding areas, as well as routine ground water monitoring and in-seam water monitoring.

#### Subsidence results

Figure 2 shows the profile of subsidence over the embankment. The effect of the limited extraction ratio on the surface subsidence can be clearly seen, with the subsidence reduced from a maximum in the total extraction area of nearly 0.6 m, to about 0.25 m over the panel and pillar area. Note that the actual subsidence over the panel and pillar area is significantly more than that predicted. This is likely due to the lack of local data on which to base the prediction, and the continued subsidence creep due to the punching of the pillars into the soft floor.

Figure 3 shows the subsidence with time over the embankment at two points (over a panel and pillar area, and over a pillar), and over an area of total extraction. The effect of the subsidence creep can be seen be the continued subsidence after the completion of Phase 1 for nearly four years. There is no obvious end to the subsidence at the end of Phase 2, which is a result of continued extraction in the Great Northern Seam outside of the approval area having an effect on the subsidence in this area (Reid, 1990).

#### Other monitoring results

None of the other monitoring systems have shown any significant response as a result of the mining activity. In particular, the extensive surface strain measurements taken over a ten year period generally do not show clear trends. This is believed to be as a result of the construction of the survey pegs, the expansive nature of the surface soils, the

survey methods used, and the initial design of the survey lines. Briefly, the pegs were not substantial enough, the soils are effected substantially by changes in soil moisture, insufficiently accurate measurement techniques were employed on occasion, and the bay lengths have been shown to be too long to offer any useful information.

Regular inspections of the embankment were undertaken during mining, and none of these showed any apparent surface cracking.

#### Conclusions from Phase 1 and Phase 2 mining.

The conclusion drawn from the monitoring to date is that the dam has withstood the mining induced ground movements without any ill effects. While loss of storage was not a concern to the DSC, it was noted that despite the extensive extraction beneath the storage no inflows into the workings occurred (Reid, 1991).

#### Further mining

The colliery has subsequently commenced mining in the Fassifern Seam, and this, too, consists of two phases. Firstly, a longwall panel has been extracted immediately upstream of the embankment. Secondly, two longwall panels will be extracted in the abutment of the dam. Early results indicate that extraction of the first longwall has resulted in additional subsidence of only 0.01 m over the embankment. There has been no evidence of reworking of the old workings, although it is considered that this is a reasonable possibility. There has also been no reports of cracking of the embankment, either (Reid, 1993).

#### PANEL AND PILLAR MINING BENEATH A LARGE WATER SUPPLY DAM

In the Southern Coalfield large reserves of high quality coking coal coincidence with the Water Board's Southern Catchment. There are several of Sydney's major water supply dams in this area. One of these is a 94,000 ML dam which supplies the growing Campbelltown area with water. Several collieries have reserves beneath the storage of this dam, and one of these has recently commenced large scale extraction beneath the storage. Figure 4 shows the general layout of the workings.

The mining area is located more than three km from the structure of the dam, so that no significant mining effects are expected at the dam wall. However, the value of the storage is such that the mining layout has been designed to minimise surface subsidence, and thereby ensure the integrity of the storage. The panels are about 100 m wide, and the pillars are 60 m wide.

The 2.5 m high Bulli Seam is being mined at a depth of 340 to 400 m. Maximum surface subsidence is expected to be of the order of 130 mm. By way of comparison, unrestricted mining in this area would generally produce surface subsidence of around 1.5 m

An extensive surface and sub surface monitoring programme has been developed, and all but implemented, which includes: surface subsidence and strain measurements; ground water monitoring; surface and seam level geological and geophysical surveys; in-situ strain monitoring; and sub-surface vertical strain monitoring. A brief description of each of these follows.

#### Surface subsidence and strain monitoring.

The dam owner and the colliery are undertaking surveys of ground movements at the surface. These include: traditional subsidence and strain survey lines over the panels; "high quality" survey lines which have been designed to withstand non-mining ground movements; EDM (electronic distance measurement) surveys over survey lines and individual markers to give ground movement vectors; and "tectonic" surveys over large distances to determine absolute locations and to isolate any large scale rigid block movements. The latter is to be done with both GPS (global positioning system) and conventional EDM techniques.

The "high quality" survey lines basically consist of survey stations constructed to resist soil and other natural movements (they are either well grouted in or are drilled and grouted into stable rock). The "tectonic" surveys are particularly useful in the Southern Coalfield because of the strength of the Hawkesbury Sandstone, which typically occurs at the surface in this area. This strong rock causes subsidence effects to extend out beyond the normal range, and therefore survey controls need to be brought in from well outside the area of mining.

#### Ground water monitoring

Four boreholes have been installed at two sites, with seven electric (vibrating wire) piezometers and two open standpipe piezometers monitoring four horizons between 80 m and 250 m above the seam. Both sites are located over the centres of panels, where maximum surface subsidence is expected to occur. It is hoped that these piezometers will show that a hydraulic connection does not develop between the overlying strata and the mine workings.

#### Surface and seam level geological and geophysical surveys

It is the Committee's belief that most of the risk of an inrush into the workings will be minimised provided no significant geological features are encountered in the workings. To determine if this is the case, ISS (in-seam seismic) surveys are undertaken ahead of any workings. Should this method highlight any critical features, the mining layout can be modified to accommodate these. After the development work for the panels has been completed, but before final extraction, detailed seam level geological surveys are undertaken, together with further geophysical studies such as RIM (radio imaging method) if necessary to improve the prediction. Any critical features determined at this stage may result in the abandoning of all or part of a panel.

The decision to abandon a panel would be made in conjunction with an analysis of the surface geological maps. These maps are at 1:2,000 scale and focus on local structural geology. These maps may suggest the vertical extent of the geological feature. Other uses for surface geological maps are for determining possible causes of errors in surface subsidence surveys, and for locating other monitoring sites.

#### In-situ strain monitoring

One of the more innovative monitoring programs implemented as part of this proposal is for in-situ strain monitoring. This involved adapting the borehole strain devices developed by the University of Queensland for use in California as earthquake "alarms" as relative strain tools. Three tools were deployed, two in the area of mining, and one close to the dam wall as a control. These tools are capable of measuring in nano strain.

The tools are located in sites that are analogous to both the dam wall and the bottom of the reservoir, so that realistic estimates of the effects at these sites can be made on the basis of the readings.

#### Sub surface strain monitoring

Each of the three in-situ strain holes also includes a vertical extensometer, as well as a tilt meter, to provide a vertical component to the monitoring sites.

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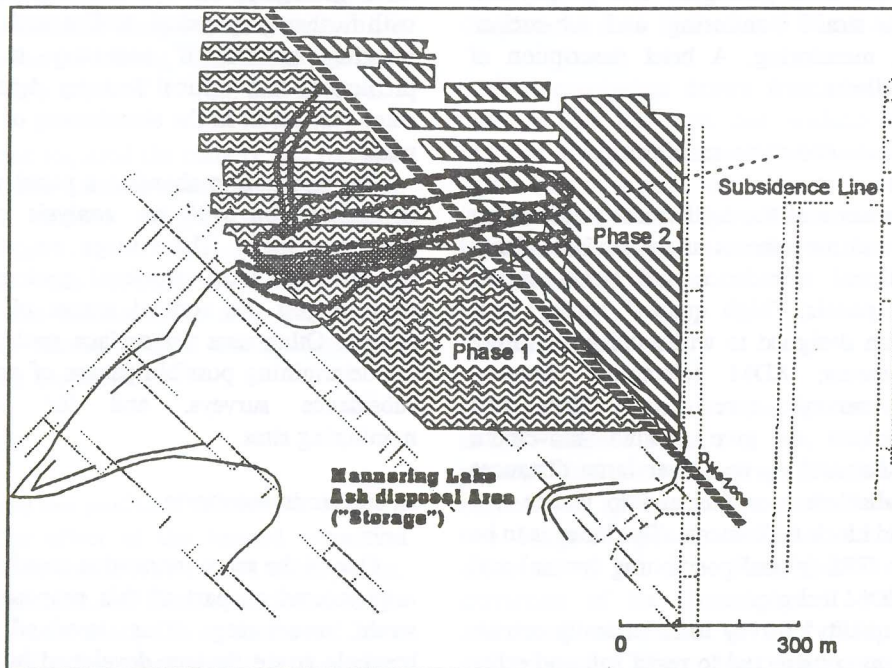


Figure 1. Extraction in the Great Northern Seam beneath Mannering Creek Ash Dam. Grey lines show current workings in the Fassifern Seam

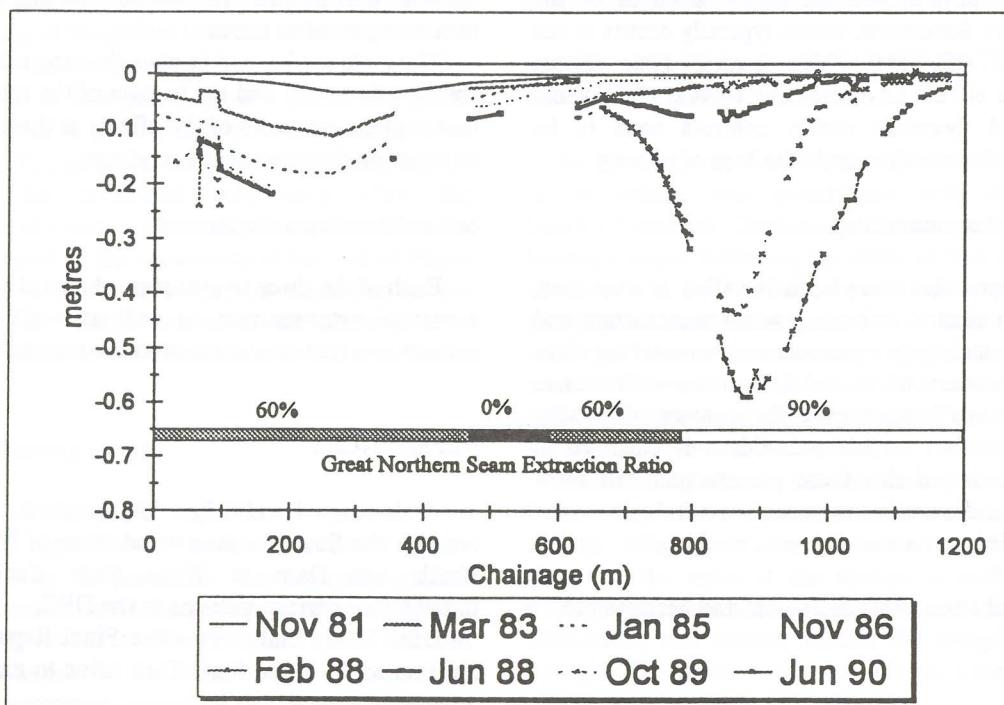


Figure 2. Subsidence over Mannering Creek Ash Dam embankment as a result of mining in the Great Northern Seam

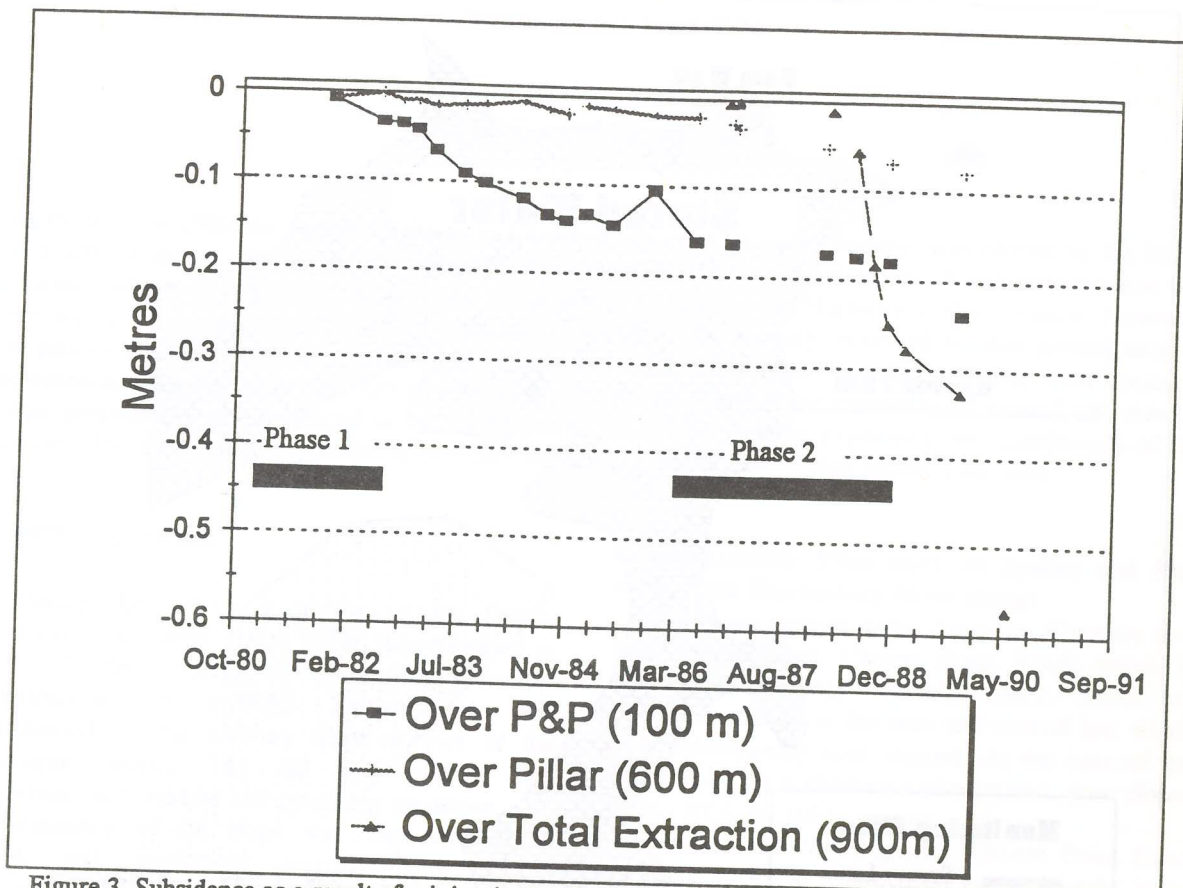


Figure 3. Subsidence as a result of mining in the Great Northern Seam at Mannering Creek Ash Dam. Phase 1 and Phase 2 refer to the areas drawn on Figure 1.

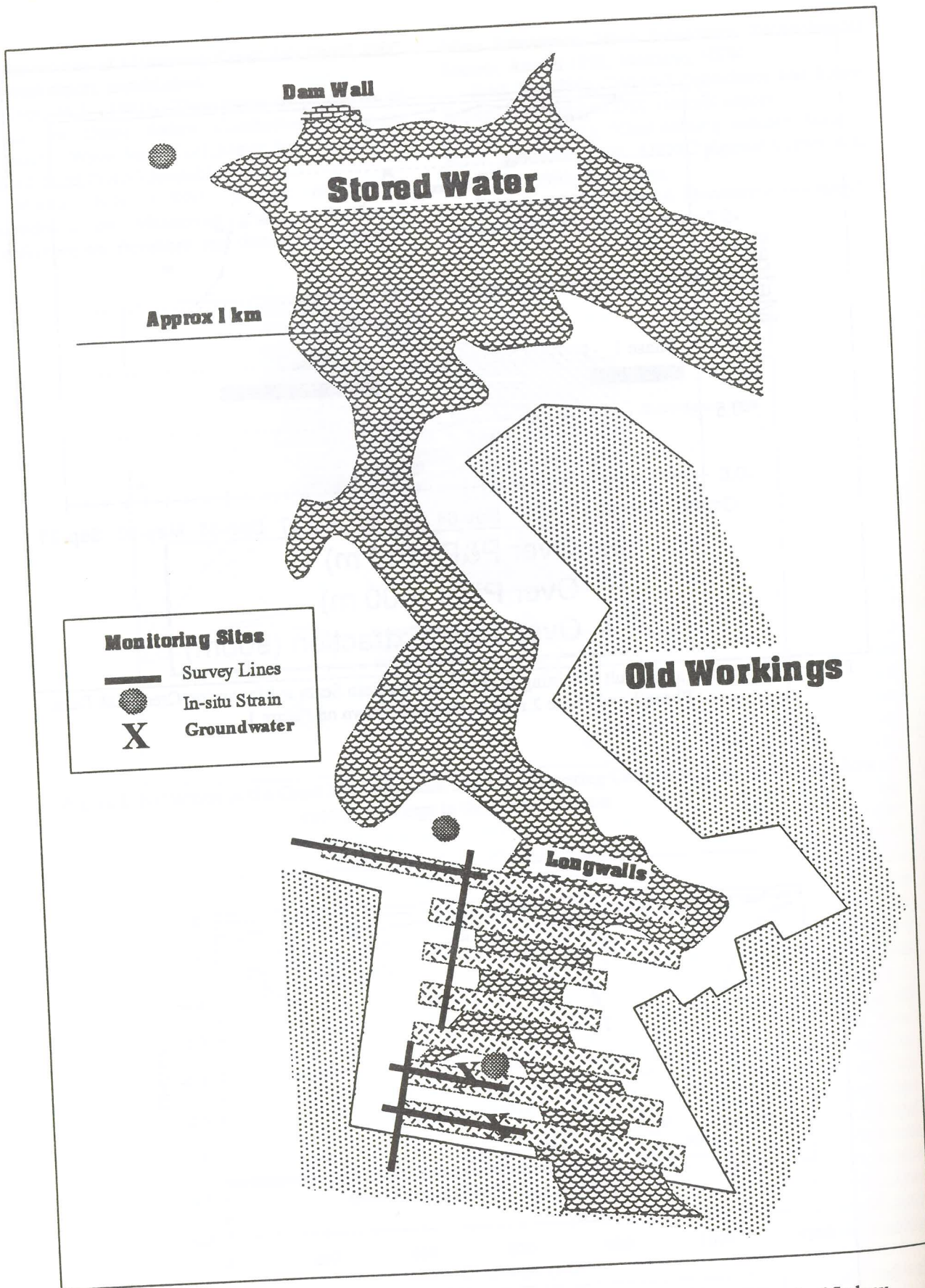


Figure 4. Proposed coal mining layout beneath the storage of a large water supply dam south of Sydney.