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Ms Madeleine Foley
Principal Council Officer
General Purpose Standing Committee No 5
Parliament House
Macquarie Street
SYDNEY NSW 2000

Our Ref: Z12/15281
File: ESP-070.02.003
Date: 30 January 2012

Dear Ms Foley

INQUIRY INTO COAL SEAM GAS

Thank you for the opportunity provided to Wollongong City Council to appear as a witness at the Coal Seam Gas Inquiry on Friday 9 December 2011. Following is the additional information requested by the Committee in relation to this Inquiry.

Transcript

As requested, I have attached a copy of the transcript of our evidence with the relevant (three) amendments.

Question taken on notice

At the Hearing, Wollongong City Council committed to providing a response to the following question:

The Hon. Rick Colless: Have you got any idea how many coalmines would be operating in that (the Wollongong Local Government) area?

The response to this question is:

There are 4 coal mines operating within the Wollongong Local Government Area, these being:

1. Metropolitan Coal – located at Helensburgh;
2. Gujarat NRE 1 – located at Russell Vale;
3. Dendrobium – located at Mount Kembla; and
4. NRE – Wongawilli – located at Wongawilli.

Supplementary question

A supplementary question was sent to Wollongong City Council on 15 December 2011:

Can you provide any evidence for the following statement on p 2 of the Wollongong City Council submission: 'Surface or groundwater losses have been reported in places where CSG or other mining activities are taking place.' (Mr MacDonald)

The response is:

The statement was made in reference to the concerns about surface and ground water loss at the Thirlmere Lakes in NSW and the potential role of coal mining operations in the vicinity. This issue has been the subject of an ongoing investigation including a study undertaken by the NSW

Office of Water. A copy of this report is attached (downloaded from the internet). Reference to this situation was made, as it adds to community concern that similar situations could potentially arise with coal seam gas mining.

Witness Feedback Questionnaires

A copy of the Witness Feedback Questionnaires will be provided separately.

Thank you again for the opportunity to appear before the General Purpose Standing Committee No. 5. I look forward to the outcomes of the deliberations of this Committee.

Please contact me should you require further information.

This letter is authorised by

Renee Campbell
Manager Environmental Planning & Strategy
Wollongong City Council
Direct Line (02) 4227 7331

Attach/2.

NSW GOVERNMENT | Office of Water

Thirlmere Lakes groundwater assessment

Leading policy and reform in sustainable water management

Publisher

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The NSW Office of Water is a separate office within the Department of Environment, Climate Change and Water. The Office manages the policy and regulatory frameworks for the State's surface water and groundwater resources to provide a secure and sustainable water supply for all users. The Office also supports water utilities in the provision of water and sewerage services throughout New South Wales.

Thirlmere Lakes groundwater assessment
December 2010

ISBN 978 0 7313 3467 4

This report may be cited as:

Russell G.N., Green R.T., Spencer J., Hayes J. (2010) *Thirlmere Lakes groundwater assessment*, NSW Office of Water, Sydney

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Executive summary

The NSW Office of Water has undertaken an assessment of the possible causes of water level decline reported for Thirlmere Lakes in recent times.

Various lines of evidence have been considered to establish the likely cause of the reported water level declines. These have included consideration of Tahmoor Colliery operations, long-term rainfall records, broader catchment river flow data and regional groundwater levels. No hydrology data exists for the lakes themselves.

Long-term rainfall analysis using rainfall residual mass curve plots has indicated that there is an ongoing decline in rainfall over the lakes and a considerably wider area. This rainfall decline has not ceased following the end of the drought in eastern Australia, but is persisting at the current time in terms of impacts on water resources. Prolonged and consistent rainfall is required to counteract the long-term drying effects of ongoing below average rainfall over the last ten years and reverse this trend.

River flow data from gauges located throughout the upper Hawkesbury-Nepean catchment show a decline in runoff in recent years. Cumulative flow plots of gauging data indicate that river flows for the upper Hawkesbury-Nepean, as well as adjacent catchments, have been in decline for the last ten years. This is an expected outcome of the drought; however the declining trend does not yet appear to have been reversed, even with the substantial rainfall over the broader catchment areas in the second half of 2010.

Long-term groundwater level records for the NSW Government monitoring bore network in the Southern Highlands, approximately 15 km from Thirlmere Lakes, show a reduction in recharge to both shallow and intermediate aquifers corresponding to the declining rainfall trend. This monitoring bore network is far removed from the areas of current longwall mining, and is considered to provide data representative of background conditions. In this location prolonged water level lowering is apparent in the monitoring record which also confirms the trend of reduced recharge over at least the last ten years.

Groundwater monitoring undertaken by Tahmoor Colliery reflects behaviour consistent with the expected subsurface impacts of longwall mining and the movements associated with conventional subsidence. The short-term data indicates substantial drops in the groundwater levels above longwall mining associated with progression of longwall panels. The record also shows recovery of water levels consistent with the restoration of groundwater pressures after subsidence has occurred and mining has moved on to other parts of the lease.

As identified from mine plans supplied by Xstrata, the closest proximity of longwall mining to the Lakes was of the order of 660 m. This is more than double the distance within which mine-induced subsidence would be expected. It is accepted that far field fracturing can occur outside of the angle of incidence but there was no evidence of such fracturing found in the field. If any fracturing caused by mining does exist in the sandstone below the Lakes it is expected to be minor in nature and not materially affect the groundwater flows into the Lakes in a measurable way.

Whilst there is a lack of data on the Lakes themselves, by using what local and region hydrology data is available it is concluded that the most likely cause of the reported water level declines in Thirlmere Lakes is due primarily to the prevailing climatic conditions. Specifically, the continuing declining trend in rainfall, established during the recent severe drought, appears to be still impacting on surface water runoff and recharge to groundwater. This trend needs to be reversed by extensive and protracted rainfall events before recovery in flows, and therefore lake levels, will be observed.

As a result of this investigation, there was no evidence to suggest that mine fracturing or subsidence has affected the water levels in Thirlmere Lakes in any substantial way.

1 Introduction

1.1 Setting

Thirlmere Lakes are situated approximately 90 kilometres southwest of Sydney, and about 10 kilometres southwest of Picton (Figure 1). They are a series of five lakes distributed within a horseshoe bend along Blue Gum Creek, a tributary of Little and Warragamba Rivers and a feeder creek for Lake Burragorang.

The system comprises the following lakes in descending order.

- Lake Gandangarra
- Lake Werri Berri
- Lake Couridjah
- Lake Baraba
- Lake Nerrigorang

Each of these is a shallow, mostly perennial and elongated fresh water body that together cover an area of approximately 50 hectares. The lakes are perched above alluvial unconsolidated sediments that are underlain by consolidated sandstones typical of the Sydney region.

1.2 Issues/objectives

This report has been undertaken to assess the groundwater conditions in the vicinity of Thirlmere Lakes.

Concerns have been raised in the public and parliament that the longwall mining has impacted the water levels in the lakes, despite the long interval between the panels being extracted and the current declines.

The Thirlmere Lakes are located near to the Tahmoor Colliery which extracted coal from longwall panels in close proximity to the lakes between 1999 and 2001, and 2002 to 2004.

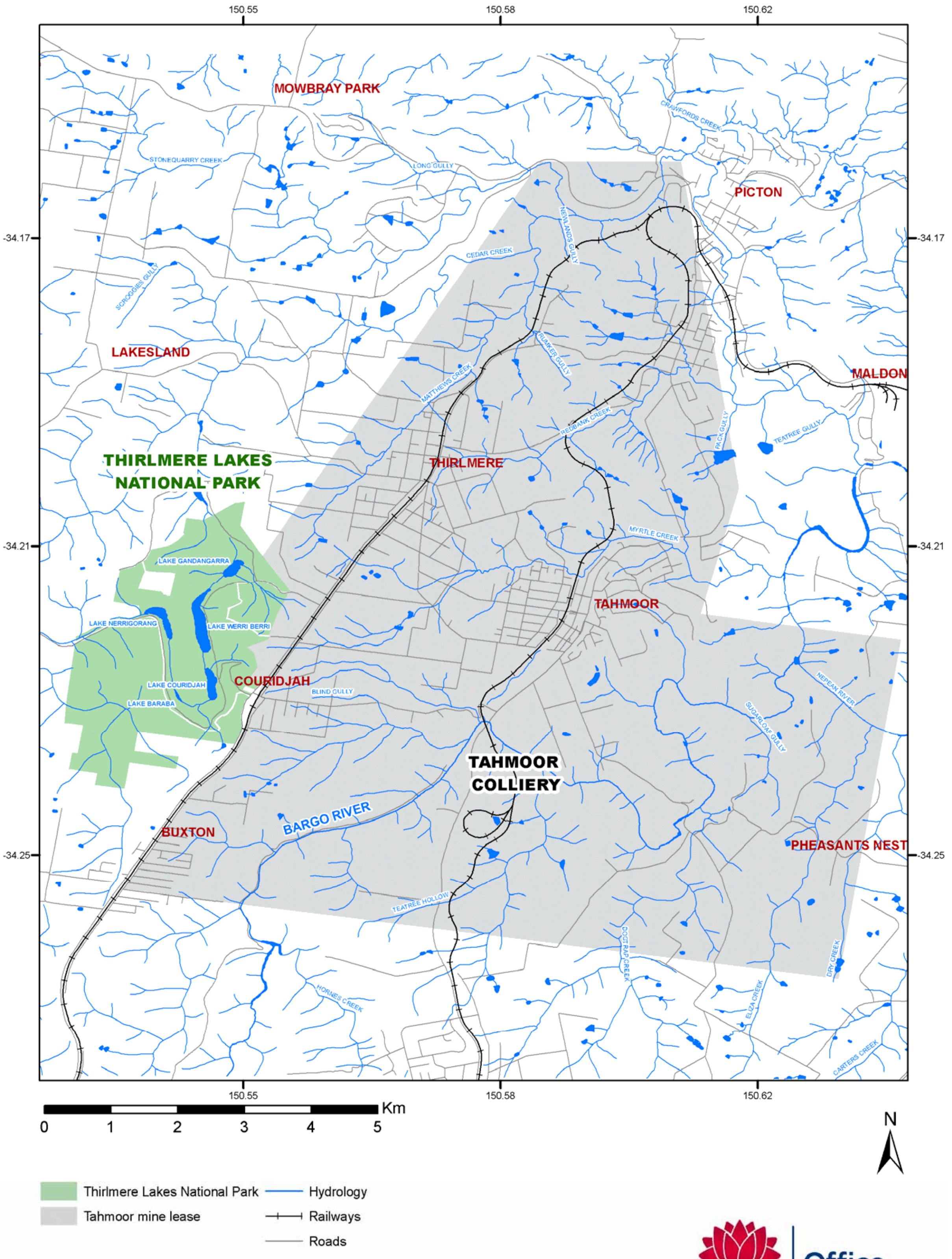
Water levels in the lakes are not measured.

Recent heavy rainfall follows the prolonged severe drought experienced throughout eastern Australia between 2001 and 2010.

The lakes are situated within a shallow creek meander at the head of a catchment in elevated terrain and are reliant on antecedent rainfall to maintain water levels.

The objective of this report is to provide an assessment, based on geological evidence and hydrogeological theory, as to whether longwall mining may have impacted on water levels in Thirlmere Lakes.

Figure 1 Localities and features in the vicinity of Thirlmere Lakes



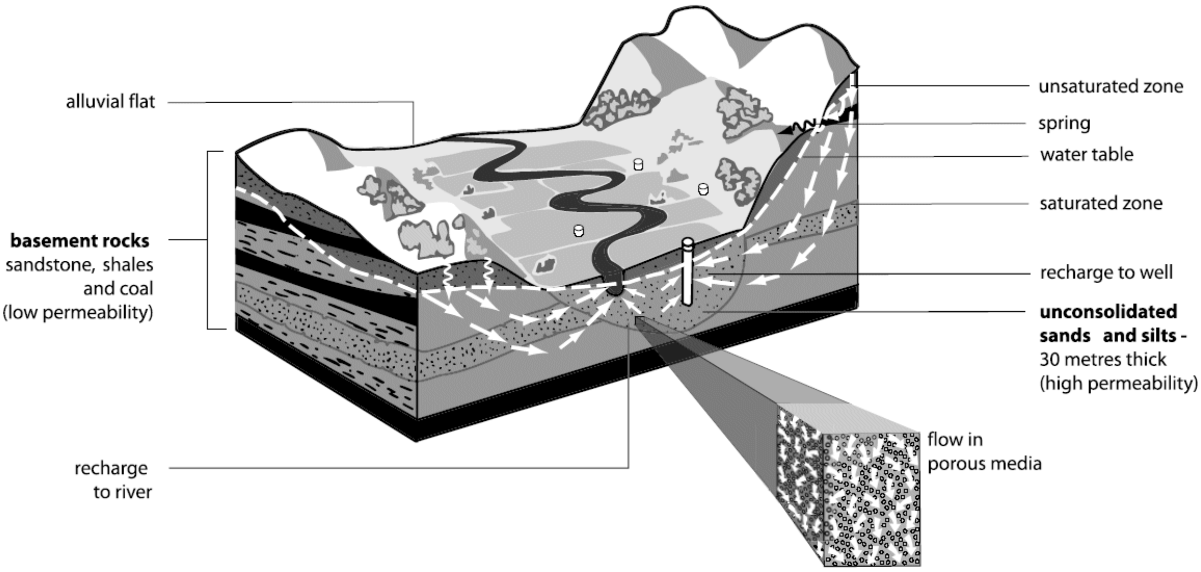
2 Background

2.1 Data sources

This report investigates the aquifer surrounding the Thirlmere Lakes system due to the concern surrounding the low water levels in the lakes. No consideration has been given to groundwater quality issues in relation to this report, as the issue is relevant to groundwater levels, river flow and climate.

Groundwater discharge occurs in many upland river systems as baseflow. The baseflow component of river flow is typically sourced from the surrounding aquifers (Figure 2). This conceptual model shows two aquifer types with an alluvial aquifer underlain by a porous rock aquifer. Both of these aquifers would provide groundwater baseflow to the local river. This report will analyse if a similar type of conceptual groundwater flow system exists at Thirlmere Lakes.

Figure 2 Schematic of unconsolidated shallow alluvial aquifer system, underlain by a porous rock aquifer



Limited data was available from the Thirlmere Lakes area as there is no monitoring of groundwater or surface water currently undertaken in the National Park area.

Information was obtained from the NSW Office of Water regional monitoring bore network in the Southern Highlands (being the closest NSW Government monitoring to the lakes) and the state wide databases administered by the agency. The databases include:

- Groundwater Data System (GDS) – This database includes physical information relating to licensed groundwater works such as drilling depth, date of completion, construction method and materials used.
- HYDSTRA – This database includes time series (i.e. continuous or semi-continuous) measurements of surface water flow data and groundwater level data.
    - Sydney Catchment Authority river gauging data (monitoring from SCA catchments).
    - NSW Office of Water river gauging data (monitoring from other catchments).
    - NSW Office of Water groundwater monitoring data (monitoring from NSW Government bore network in the Southern Highlands)

- Licensing Administration System (LAS) - This database allows the management of groundwater licence conditions and entitlements.

The following external publications were reviewed in order to write this report.

- NSW National Park Plan of Management.
- Published journal and symposium articles.
- Xstrata Coal subsidence management plans, monitoring reports and supplied data.

In addition, a field visit to the lakes was undertaken by a Senior Hydrogeologist from the NSW Office of Water to gain an understanding of the physical setting in which the Thirlmere Lakes are situated.

2.2 Legislative controls

The *Draft Water Sharing Plan for the Greater Metropolitan Groundwater Sources 2010*, which includes the Hawkesbury-Nepean, Shoalhaven and Illawarra areas was recently released for public exhibition. The Thirlmere Lakes area falls within the Sydney Basin Nepean Porous Rock Groundwater Management Unit.

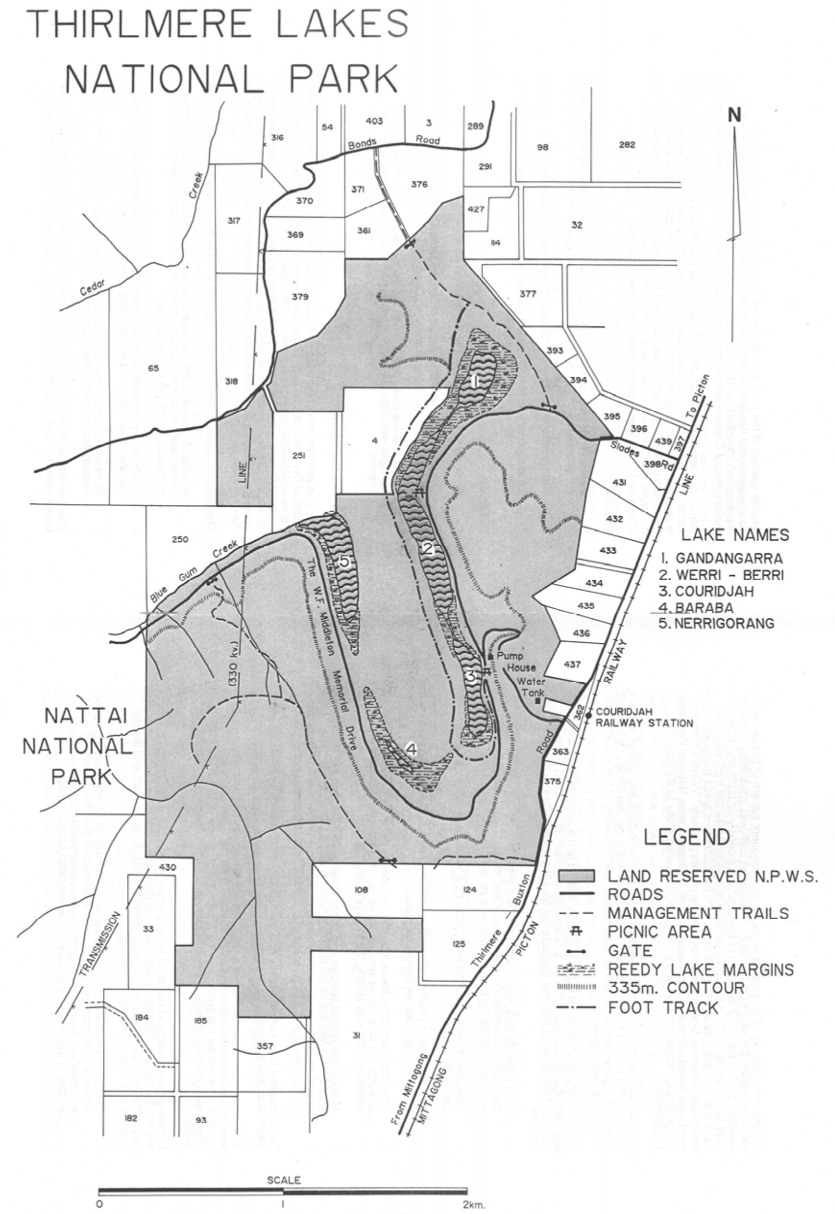
Only where water sharing plans are in place does the *Water Management Act 2000* apply and replace the *Water Act 1912*. Currently groundwater management is still occurring under the *Water Act 1912*, which requires all groundwater pumpers including mines to have a water license.

3 Thirlmere Lakes

3.1 Historical overview

Following their discovery in around 1798, the lakes were considered briefly as a supply option in the 1867 Royal Commission to Inquire into the Water Supply for the city of Sydney and Suburbs, but were of insufficient volume to meet the predicted demand. Subsequently the lakes were utilised as water supply for steam engines running along the Main Southern Railway to Mittagong and a pumping station was constructed adjacent to Lake Couridjah for that purpose. Prior to the town of Picton sourcing its water supply from a dam on the Bargo River, there was a proposal to pipe water from the lakes along the railway easement. However, the water supply proposal was discounted as the lakes were not considered a reliable source of supply. It has since been reported that the lakes became almost completely dry during the 1902 drought, and again during the 1928 drought, and that lake levels have been at least 4 m lower in the past than at present (NSW NPWS 1997).

Figure 3 Thirlmere Lakes National Park map illustrating individual lakes (NSW NPWS 1997)



The lakes have historically been used for a variety of recreational activities. High impact activities such as water skiing were allowed throughout the 1950s and resulted in modification to the creek as well as neighbouring lands. To improve access to the lakes a road was constructed during this period, and a channel was excavated to link several lakes and increase the extent of the water body for skiing. Herbicide use along the banks removed natural vegetation to achieve improved lake frontage access as well as more pleasing visual aesthetics (Atkinson, 2000).

The lakes were initially protected by the establishment of a state park in 1972 under the *National Parks and Wildlife Act 1967* (NSW). The Thirlmere Lakes National Park (Figure 3) was subsequently established in 1974 under the *National Parks and Wildlife Act 1974* (NSW); the park reserve encompassing an area of 627 hectares. The operation of the park was brought into coordination with the adjoining Nattai National Park and several other reserves in 1997 under a comprehensive Plan of Management (NSW NPWS 1997).

The National Park was subsequently included within the Greater Blue Mountains World Heritage Area (listed in December 2000). In recognition of the environmental sensitivity of the lakes, the NSW National Parks and Wildlife Service now only encourage low impact uses such as walking, swimming, canoeing and picnicking.

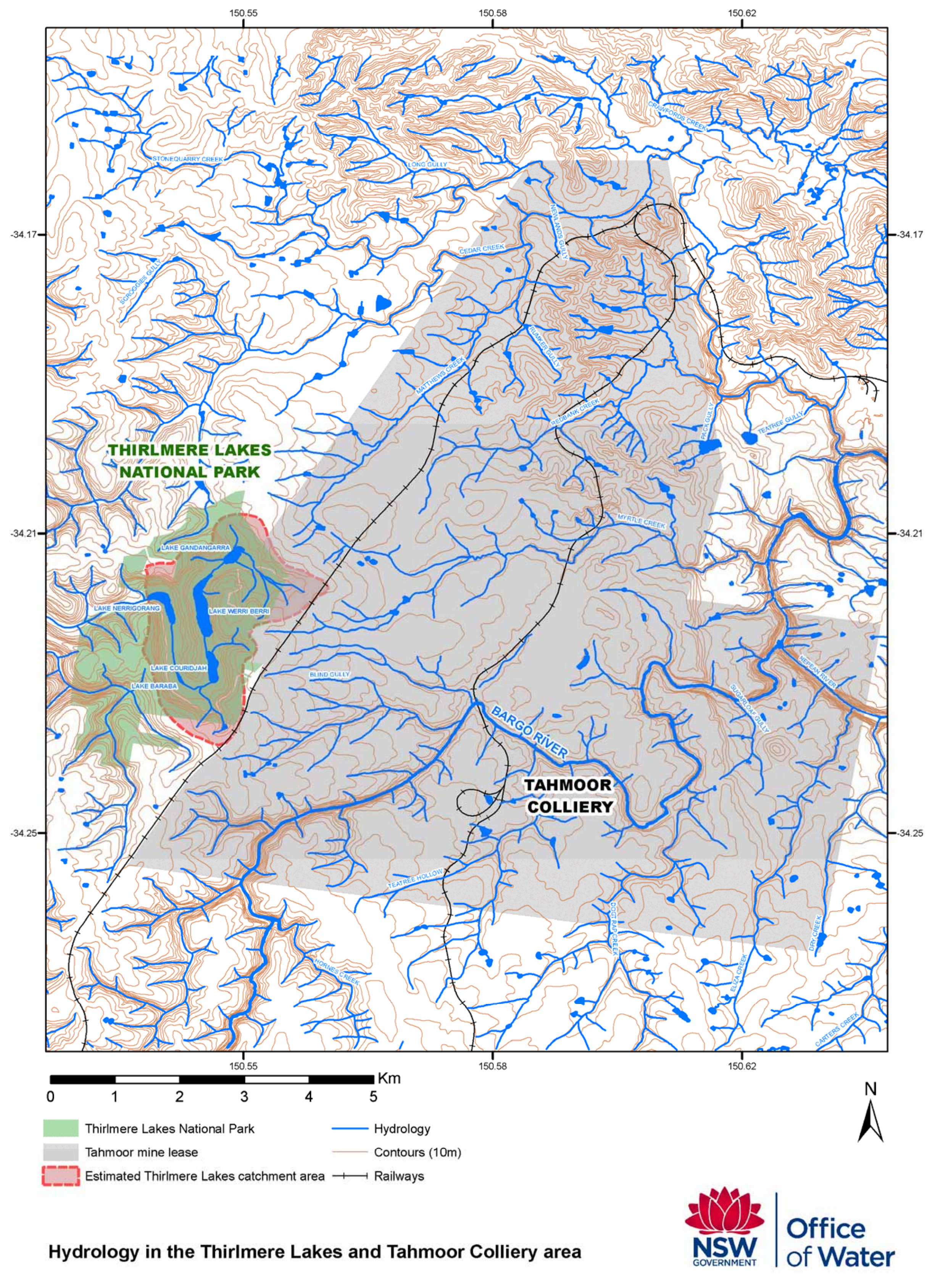
3.2 Lakes hydrology

The five lakes are located within an entrenched valley meander whose formation has been attributed to the tectonic downwarping of the neighbouring countryside (NSW NPWS 1997). This resulted in the elevation of the valley (and lakes) relative to the surrounding sandstone landscape and the development of the unique characteristics and species associated with the lakes system.

The lakes drain to Blue Gum Creek, and thence to Little River, ultimately discharging via Warragamba River into the water supply reservoir of Lake Burragorang. The water in the lakes is retained by the barrier forming the downstream outlet to Blue Gum Creek which is only overtopped occasionally. The lake levels and consequently the flow in Blue Gum Creek are closely associated with prevailing rainfall (NSW NPWS 1997).

The lakes have been identified as having low sedimentation rates (Atkinson, 2000), which prevented the evolution of the water bodies into sediment-filled depressions in the landscape. Lakes of similar geomorphological origin, size and setting have been infilled due to higher rates of sediment deposition. The low rates of deposition at Thirlmere are likely to be the result of the limited catchment area (Figure 4) of the lakes. Due to the small catchment, sediment loads contributed to the lakes in surface runoff are generally minor.

Figure 4 Thirlmere Lakes hydrological setting

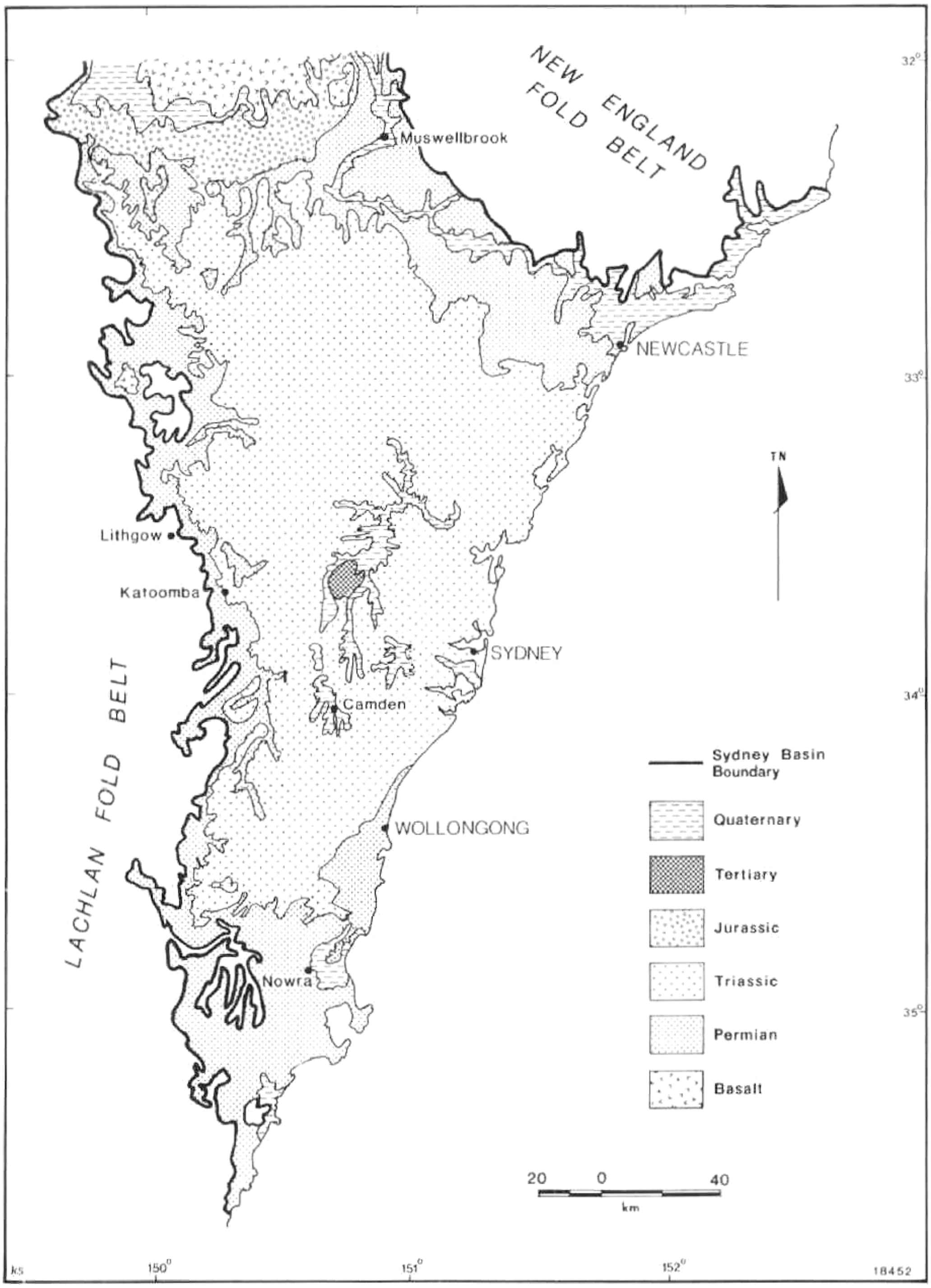


4 Geological setting

4.1 Introduction

Thirlmere Lakes area is located within unconsolidated sediments in an incised valley within the Hawkesbury Sandstone unit. The Hawkesbury Sandstone is part of the greater Sydney Basin geological structure (Figure 5).

Figure 5 Simplified geology of the Sydney Basin (modified from Jones and Clark 1991)



4.2 Sydney Basin

The Sydney Basin is a broad sedimentary basin within which consolidated strata of Permo-Triassic age overly a basement of early to middle Palaeozoic rocks (Moffitt 2000). The southern and western edges of the basin are clearly defined by the boundaries between the older basement rocks and the younger basin sediments. The northern boundary of the Sydney Basin is less well defined, and continuation of the sedimentary sequence occurs to the north within the Gunnedah Basin. Together, these are often incorporated into a larger regional feature, the Sydney-Gunnedah Basin (Figure 6).

The underlying basement rocks comprise folded Ordovician (<480 million years) to Silurian (< 440 million years) age metasediments together with Devonian (< 415 million years) intrusives. The upper surface of the Palaeozoic rocks represent the bottom limit of the Permo-Triassic sediments and their surficial exposures to the west and south form the margin of the basin (Figures 7 and 8).

Above the basement, Permian (<270 million years) and Triassic (<225 million years) sedimentary rocks were laid down across broad areas (refer Figure 5), forming predominantly horizontally bedded layers. These basin sediments were subsequently uplifted and downwarped by post-depositional tectonic activity, creating substantial relative differences in elevation. As part of the deformation, broad anticlinal, synclinal and monoclinal folding occurred and faulting along a generally northwest trend developed (Merrick 2007).

The Permian Illawarra Coal Measures and overlying Triassic Narrabeen Group and Hawkesbury Sandstone units are the rock types of interest in this report as they underlie the Thirlmere Lakes area.

Figure 6 Sydney-Gunnedah Basin structural relationship (Bembrick *et. al.* 1980)

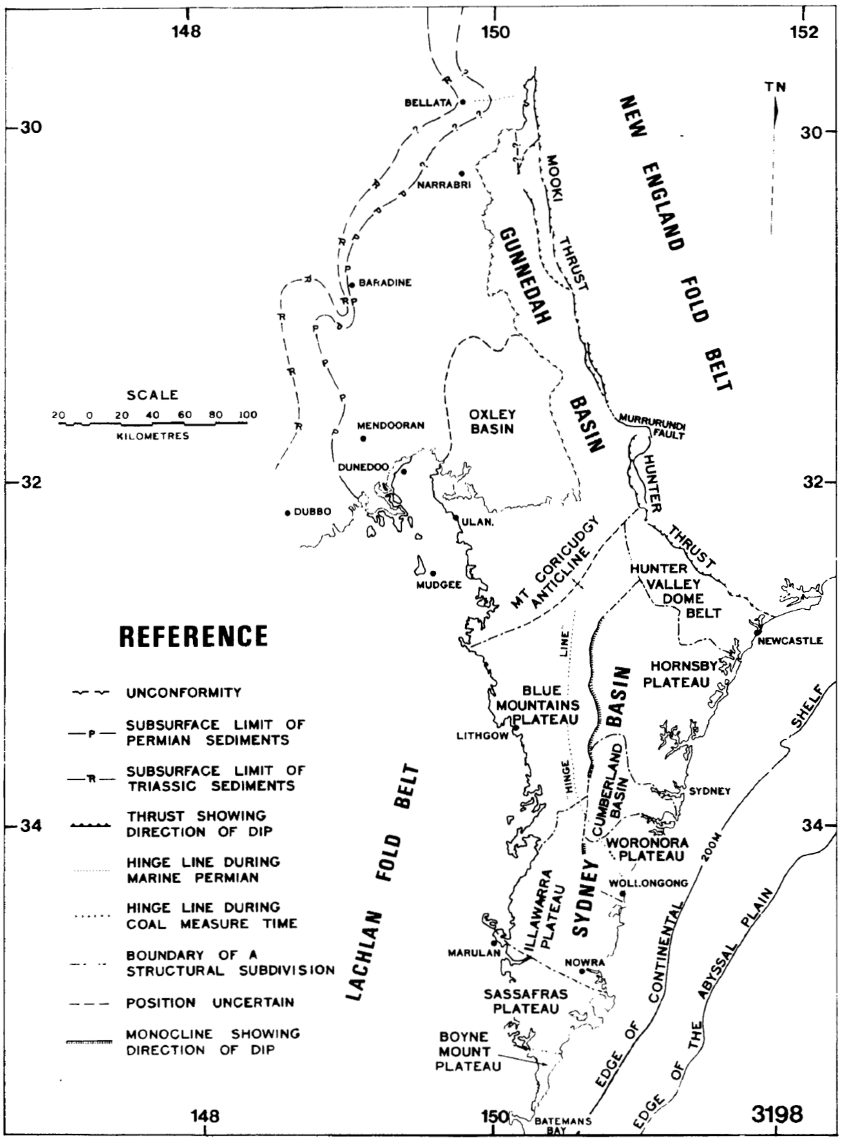


Figure 7 South to north section of the Sydney Basin (Branagan and Packham 2000)

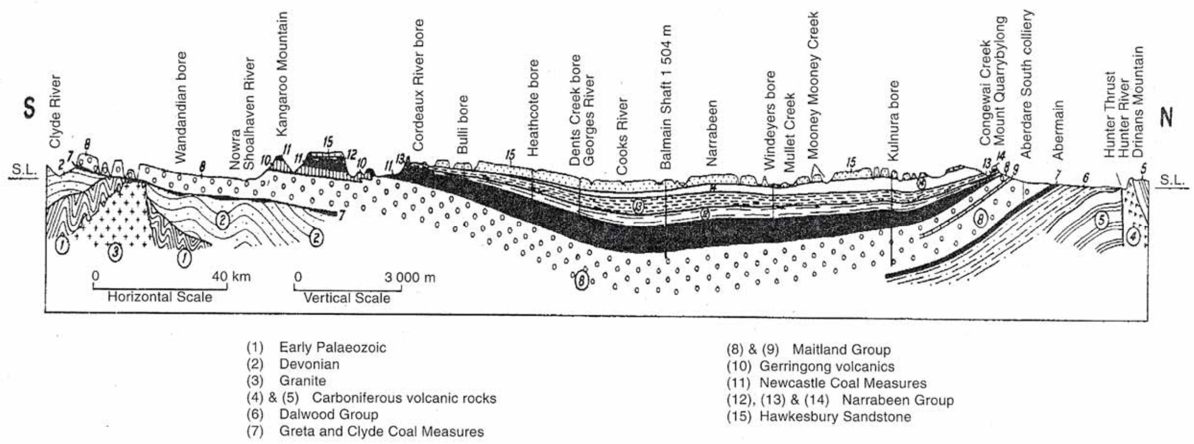
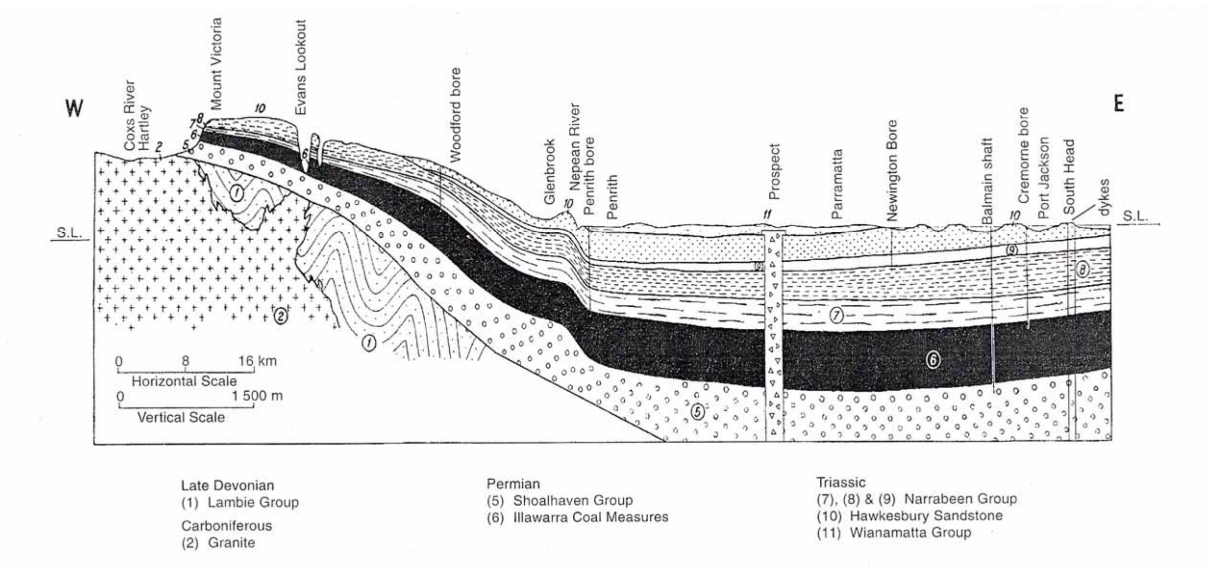


Figure 8 West to east section of the Sydney Basin (Branagan and Packham 2000)

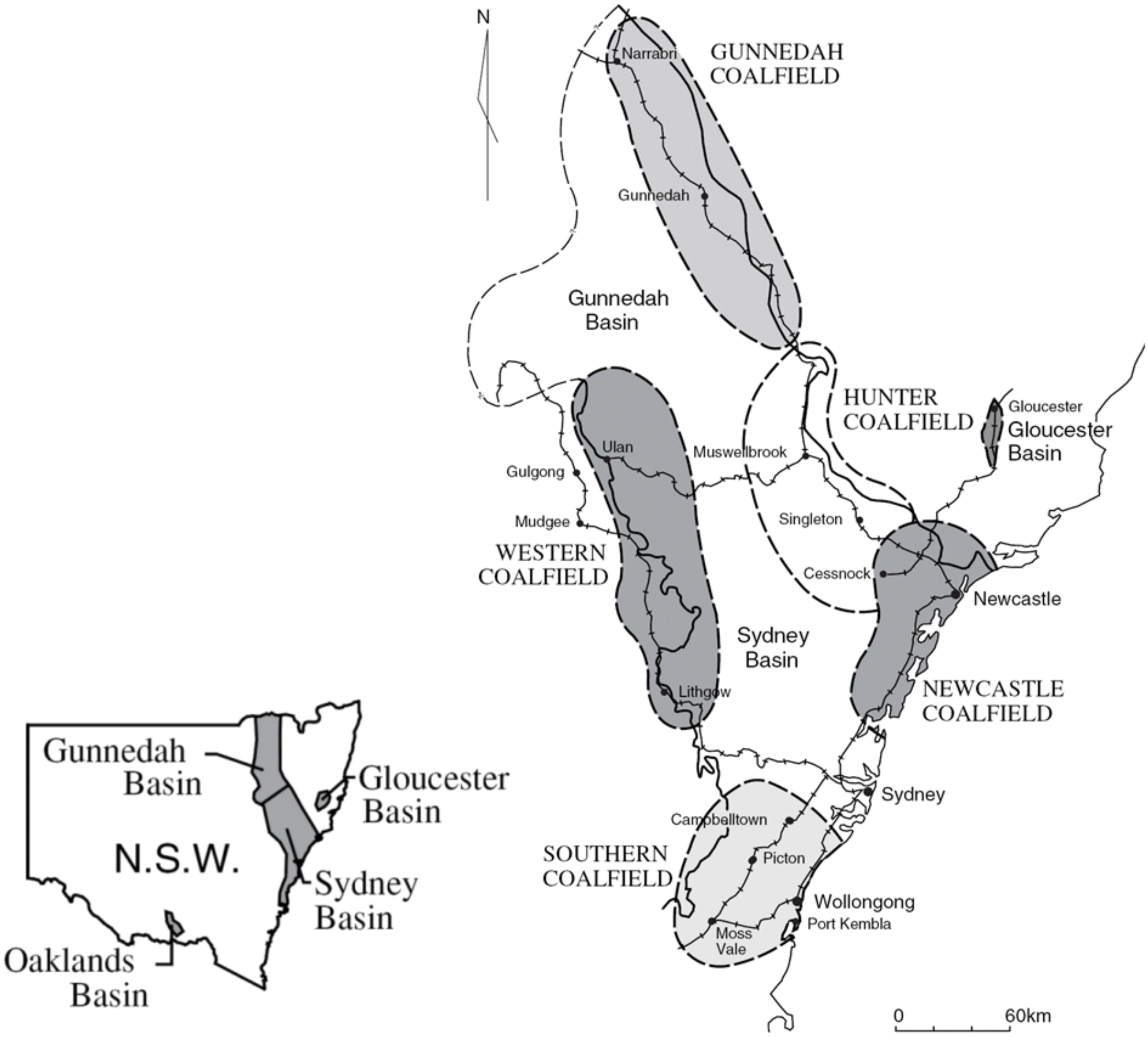


4.3 Southern Coalfield

4.3.1 Location

The Southern Coalfield is one of the five major coalfields within the Sydney-Gunnedah Basins (Figure 9). Each of these coalfields (Gunnedah, Hunter, Newcastle, Western and Southern Coalfields) was developed to extract coal from the Permian strata, which generally comprises individual seams interbedded with sandstone and shale layers. In combination, these form the coal measures targeted by mining.

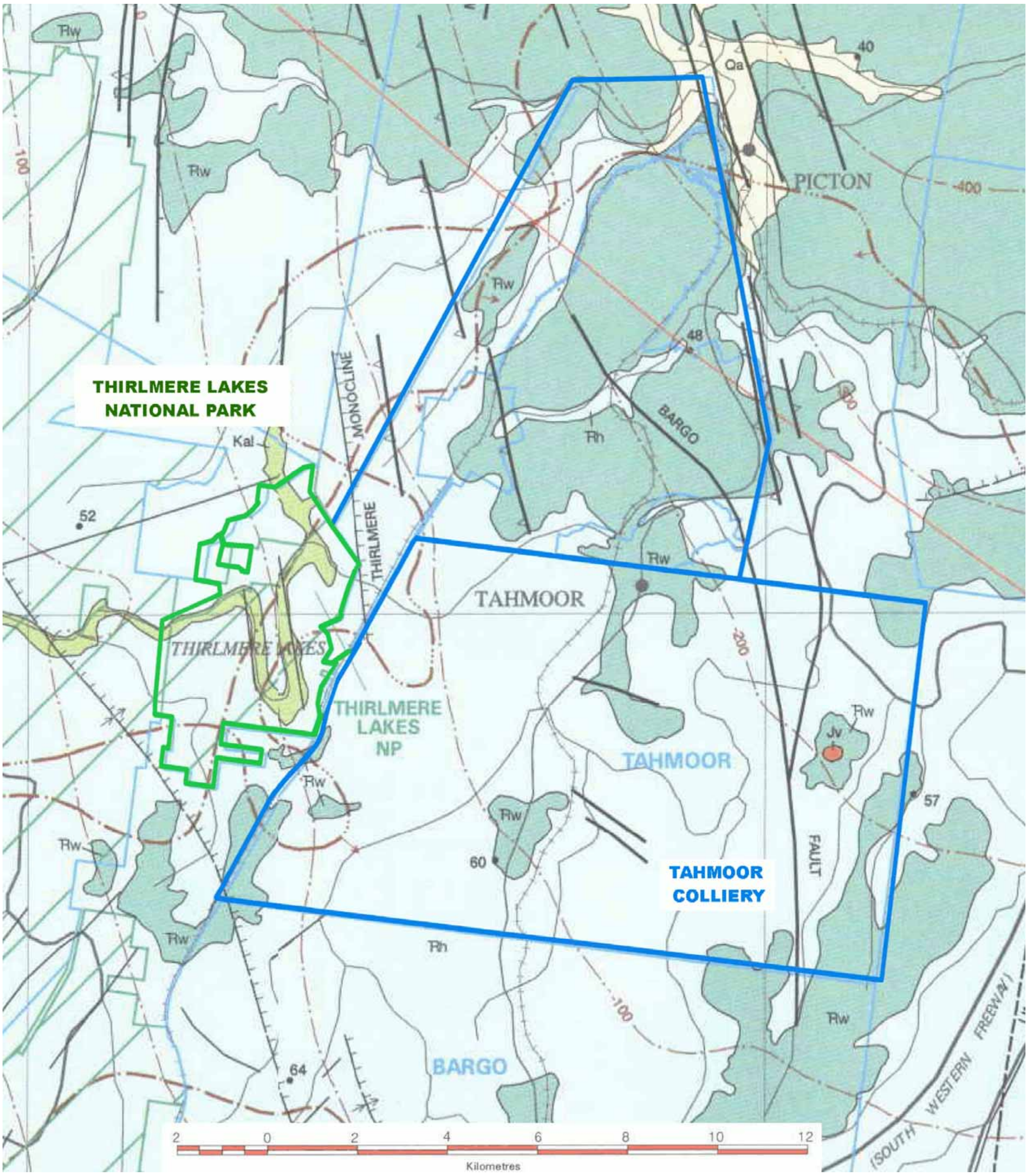
Figure 9 Southern Coalfield location map (modified from Holla and Barclay 2000)



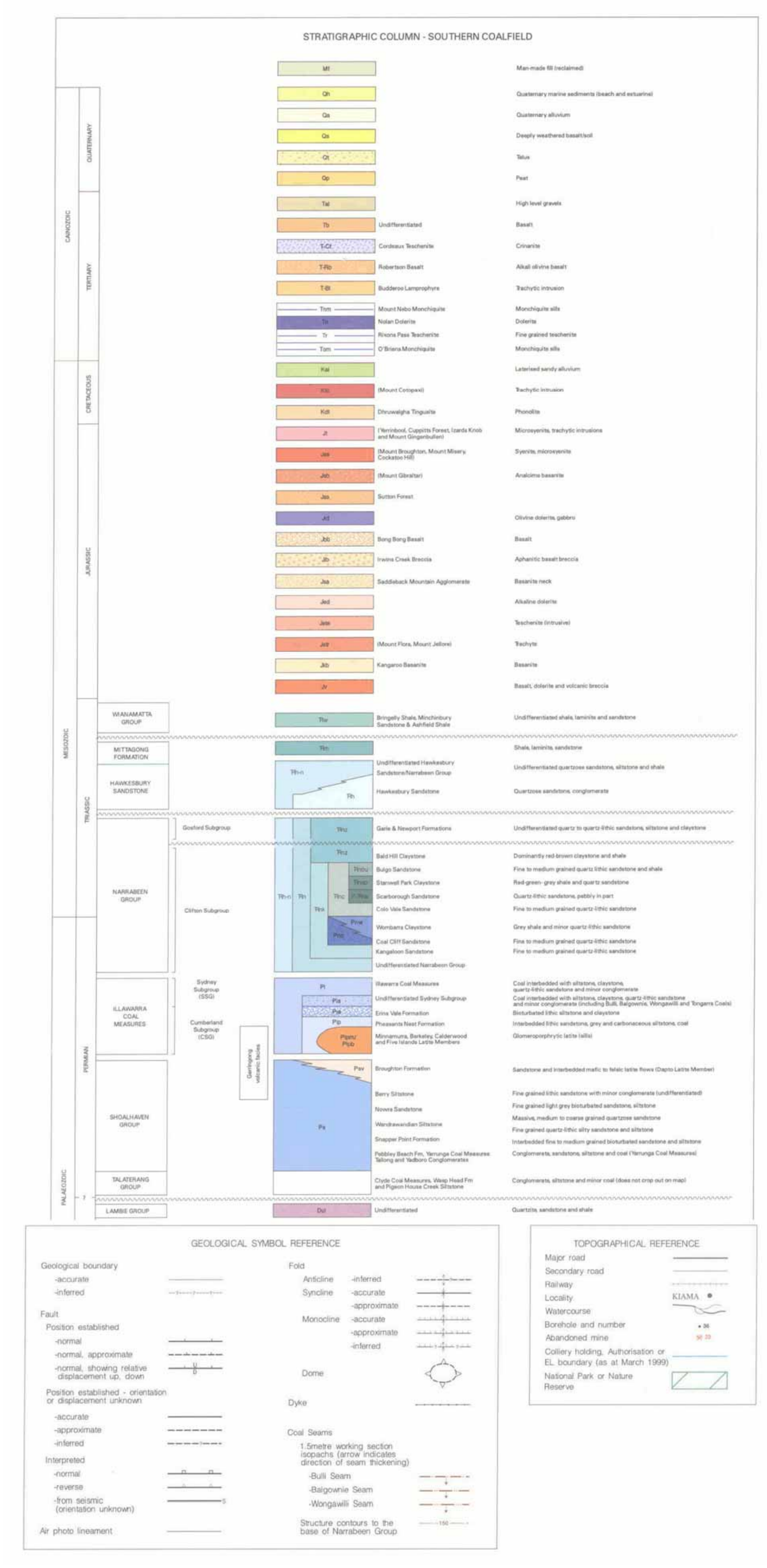
4.3.2 Lithological descriptions

Geological mapping conducted by the Geological Survey of NSW was recently revised for the Southern Coalfield. The geology of the Thirlmere area is dominated by surficial exposure of Triassic Hawkesbury Sandstone, with discrete outcrops of Wianamatta Group shale forming capping strata in some locations (Figure 10). Thirlmere Lakes are situated above an alluvial channel deposit overlying the Hawkesbury Sandstone.

Figure 10 Mapped geology of the Thirlmere Lakes area (modified from Moffitt 1999)



Geological legend for this map is reproduced on the following page


STRATIGRAPHIC COLUMN - SOUTHERN COALFIELD
GEOLOGICAL SYMBOL REFERENCE
Geological boundary
-accurate
-inferred
Fault
Position established
-normal
-normal, approximate
-normal, showing relative displacement up, down
Position established - orientation or displacement unknown
-accurate
-approximate
-inferred
Interpreted
-normal
-reverse
-from seismic (orientation unknown)
Air photo lineament
Fold
Anticline
-inferred
Syncline
-accurate
-approximate
Monocline
-accurate
-approximate
-inferred
Dome
Dyke
Coal Seams
1.5metre working section isopachs (arrow indicates direction of seam thickening)
-Bulli Seam
-Balgownie Seam
-Wongawilli Seam
Structure contours to the base of Narrabeen Group
TOPOGRAPHICAL REFERENCE
Major road
Secondary road
Railway
Locality
KIAMA
Watercourse
Borehole and number
Abandoned mine
Colliery holding, Authorisation or EL boundary (as at March 1999)
National Park or Nature Reserve

The following geological formations detail the differing geology surrounding and underlying the Thirlmere area.

4.3.2.1 Illawarra Coal Measures

The Permian Illawarra Coal Measures have been described as interbedded sandstone, siltstone, claystone and coal layers with minor tuff and conglomerate horizons as well as intrusions. In the centre of the Sydney Basin, the coal measures are recorded as having a thickness of in excess of 500 m. Near the western margin of the basin, the coal measures are only a few metres in thickness, and are entirely absent in some localities to the southwest (e.g. Wingello and Penrose).

The coal measures are subdivided into the basal Cumberland Subgroup and the overlying Sydney Subgroup.

4.3.2.2 Narrabeen Group

The Permo-Triassic Narrabeen Group is subdivided into two subordinate groups; the Clifton Subgroup and the Gosford Subgroup. The basal Clifton Subgroup is characterised by: light grey quartz-lithic sandstone units (Coal Cliff Sandstone); sandstone and conglomerate channel deposits (Scarborough Sandstone); pebbly sandstone (Bulgo Sandstone); and green to chocolate brown claystones (Wombarra Claystone, Stanwell Park Claystone, Bald Hill Claystone). The overlying Gosford Subgroup includes the characteristic marker horizon of the Garie Formation and the Newport Formation. The Garie Formation comprises cream pelletal claystone that grades upwards to a grey, fossiliferous, slightly carbonaceous claystone. The Newport Formation consists of light grey fine grained sandstone, interbedded with siltstones and minor claystones that have distinct dark grey to cream to purple colour variations.

4.3.2.3 Hawkesbury Sandstone

The Triassic Hawkesbury Sandstone is a major cliff-forming unit throughout the Southern Coalfield, and is particularly represented in the topography of the Illawarra Escarpment. This unit ranges in thickness from typically around 120 m in some locations to a maximum of 230 m in drilled core samples. The formation comprises predominantly quartzose sandstone, with less frequent intervals of siltstone and fine sandstone laminite, siltstone horizons and claystone bands. The sandstone exhibits variable grainsize between very fine to very coarse, but is most typically medium grained, and ranges from moderately to poorly sorted.

Two depositional sandstone units are recognised within the formation; a ‘sheet sandstone facies’ and a ‘massive sandstone facies’ (Conaghan 1980). Intercalated thin mudstone and siltstone horizons have also been identified as ‘mudstone facies’. The sheet sandstone facies are distinguished by pronounced cross-bedding within horizons between a few centimetres and 5 m in thickness. The sandstone forming these facies is quartzose, generally medium to very coarse grained and with small rounded quartz pebbles. The massive sandstone units are generally lighter in colour than the sheet sandstone facies, being fine grained and more friable when exposed in outcrop. Because of their finer grainsize, higher clay content and less abundant chemical cement, these units tend to be recessive in outcrop and prone to honeycomb weathering. The depositional formation of the entire Hawkesbury Sandstone sequence has been attributed to the cyclical recurrence of the mudstone, sheet sandstone and massive sandstone facies (Conaghan 1980).

4.3.2.4 Mittagong Formation

The Triassic Mittagong Formation is a thin (around 2 m thick) sandstone, siltstone and laminite horizon that overlies the Hawkesbury Sandstone. It shares common characteristics with the upper parts of the underlying Hawkesbury Sandstone, as well as those of the basal section of the overlying Wianamatta

Group shales. As a result, the limits of the bounding units are difficult to distinguish in drill cuttings unless cored holes are employed.

4.3.2.5 Wianamatta Group

The Triassic Wianamatta Group comprises the basal Ashfield Shale, the Minchinbury Sandstone and the Bringelly Shale. The Ashfield Shale is a dark grey to black fossiliferous siltstone, grading to a laminite toward the top of the unit. The Minchinbury Sandstone is a thin persistent mappable horizon that separates the basal shale from the overlying shale strata. This unit is a quartz-lithic sandstone that is up to 6 m in thickness. The overlying Bringelly Shale contains minor carbonaceous claystone at the basal section, however the predominant strata comprise claystone, siltstone, laminite and sandstone.

4.3.2.6 Unconsolidated sediments

The Tertiary and Quaternary unconsolidated sediments of the Sydney region are typically along major water courses and coastal embayments. These sediment deposits commonly include gravel, sands, silts, clays and peats as distinct layers or mixed horizons, with varying degrees of cementation. In the Southern Coalfield, the distribution of these unconsolidated sediments is extremely limited due to the generally steep topographic relief and the dynamics of the incised river and creek valleys that prevents significant local deposition. However, moderate areas of Tertiary sedimentation are observed along some water courses where low topographic relief or geological factors provide a favourable environment for deposition. Thirlmere Lakes sit on a thin veneer of unconsolidated sandy sediments.

5 Hydrogeology

5.1 Background

Significant regional aquifers within the Sydney Basin are hosted by Triassic strata (Hawkesbury Sandstone and Narrabeen Group sandstones). Groundwater accumulates in porous zones (‘sheet sandstone’ units, refer to previous sections) within the sandstone rock mass, and generally flows down the prevailing dip of the strata. That is, the direction of groundwater movement is generally toward the central basin area. Overprinting by faulting, fracturing and fissuring enhances the permeability of these rock units on various scales and is significant in improving the transmissivity of the strata generally.

The Bald Hill Claystone forms a regionally significant aquitard, separating the Hawkesbury Sandstone from the underlying Bulgo Sandstone. Under normal circumstances, this unit forms a barrier to vertical groundwater movement between the two aquifers.

5.2 Field inspection

An inspection of the Thirlmere Lakes National Park was undertaken by a Senior Hydrogeologist from the NSW Office of Water, and observations made of the lakes and their setting (examples at Figure 11, Figure 12 and Figure 13).

The Hawkesbury Sandstone ridge around Thirlmere Lakes was inspected. Typical fine to coarse Hawkesbury Sandstone with examples of cross bedding, jointing and horizontal layering was observed (Figure 14 and Figure 15). The sandstone in part on the exposure is massive with fractures showing some minor groundwater seepage and significant weathering occurring in some parts such as where overhangs or caves were visible. This sandstone unit underlies the lake sequence however weathering of the unit produces unconsolidated sands which may have contributed to the alluvium on the edge and most probably the base of the lakes.

The inspection of the lake beds themselves showed them to have low water levels, and in some areas wetland vegetation appeared to have died back, exposing the lake bed sediments (Figure 16). Areas that were in close proximity to water (or underwater) could not be inspected due to the boggy conditions as this was a non-intrusive site walkover only. As such, no augering, drilling, nor excavation was undertaken to identify the nature or thickness of the sediments under the lakes. The observations made identified unconsolidated sediments varying from fine to coarse sands, silty sands and clays (Figure 17). In addition, some areas were covered with substantial coverage of organic matter (Figure 18). Both Lake Werri Berri and Lake Couridjah were observed to have significant sandy sequences on the lake edge. This is in contrast to parts of Lake Gandangarra, Lake Baraba and Lake Nerrigorang, which appeared to have more clayey and organic material forming their lake beds. One particular lake bed showed large mud cracks which is typical of the drying of clays (Figure 19). In the absence of intrusive investigation, it is unclear whether sand underlies this clayey sequence.

The sandstone ridge country was seen to be discharging water (Figure 20) which was assumed to be the result of springs associated with sandstone aquifers that outcrop above the lakes. Some of these ridge discharges were observed to be discharging a flow of the order of 1 L/s or less. This water ultimately ends up in the lakes or within the alluvium which is in addition to the intermediate sandstone aquifer base flows that may be occurring. It is not known when the last rainfall occurred in the vicinity of the lakes, and therefore no assessment of the permanency of the springs and associated gully flows could be made.

Figure 11 Lake Gandangarra (7 December 2010)

Figure 12 Lake Werri Berri (7 December 2010)

Figure 13 Lake Couridjah (7 December 2010)

Figure 14 Typical sandstone outcrop approximately 5 m in height

Figure 15 Photo of jointed sandstone

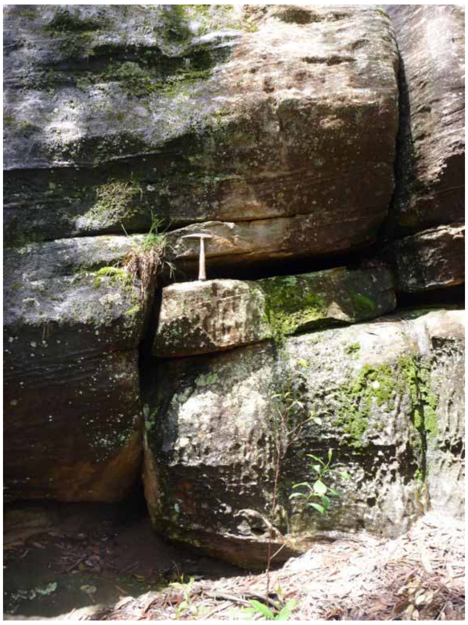


Figure 16 Die back of vegetation along lake bed

Figure 17 Unconsolidated sand

Figure 18 Organic lake bed sediment

Figure 19 Mud cracks at lake with reduced water level

Figure 20 Upland gully discharge from spring in perched sandstone aquifer

5.3 Conceptual groundwater flow systems

The conceptual groundwater flow systems that are considered to be operating in the lakes surrounds have been classified as a local flow regime (Figure 21) and a broad regional flow environment (Figure 22), described as follows.

- **Shallow**. Minor perched sandstone aquifers occur sporadically and are evident on the hill slopes above the Lakes Hawkesbury Sandstone aquifer. Springs discharge locally to creeks which flow to the Lakes area. Groundwater occurs beneath the Lakes in sandy alluvium. This is recharged from Lake seepage and rainfall as well as a small component from the underlying sandstone.
- **Intermediate**. Hawkesbury Sandstone porous rock aquifer. Although no bores were drilled in the National Park, the topography and geology indicate that local flow over prints a regional flow system. The Hawkesbury Sandstone typically has groundwater levels ranging from approximately 10 to 50 m below the land surface. A groundwater divide is thought to exist between Thirlmere Lakes and Tahmoor Colliery to the east. Locally some discharge from the sandstone passes into the Lakes.
- **Deep**. A deeper aquifer system also occurs but does not affect the Lakes. The Narrabeen Group and Illawarra Coal Measures are located beneath the regional Bald Hill Claystone which acts as an aquitard to groundwater flow.

Figure 21 Conceptual groundwater flow systems at Thirlmere Lakes

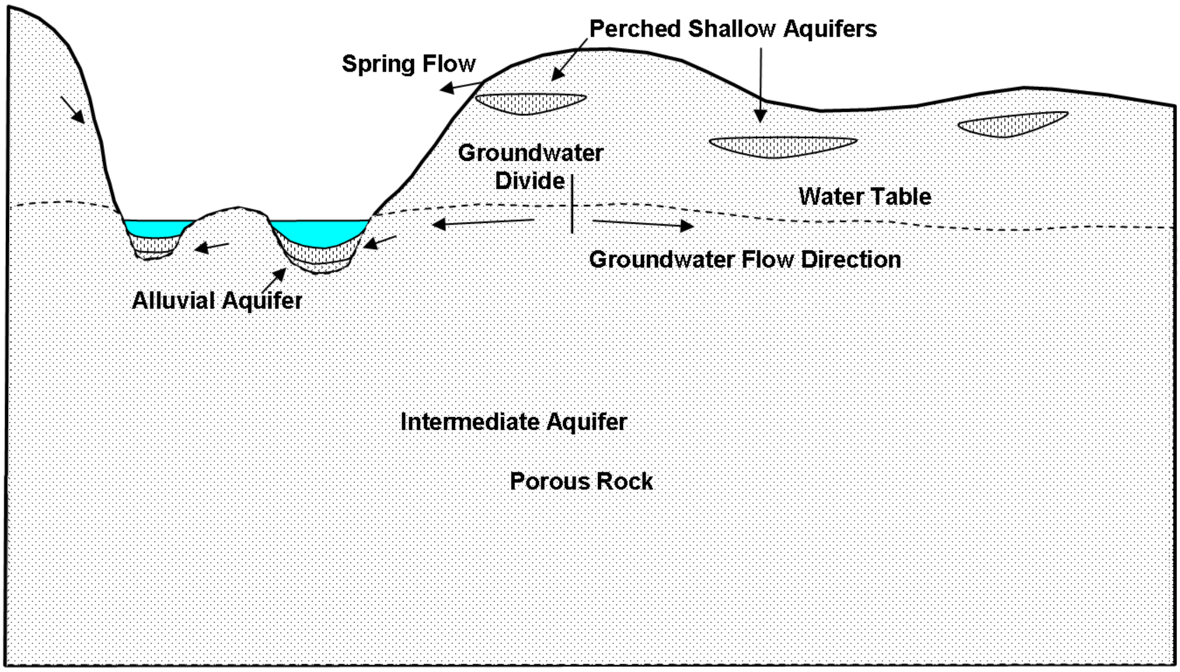
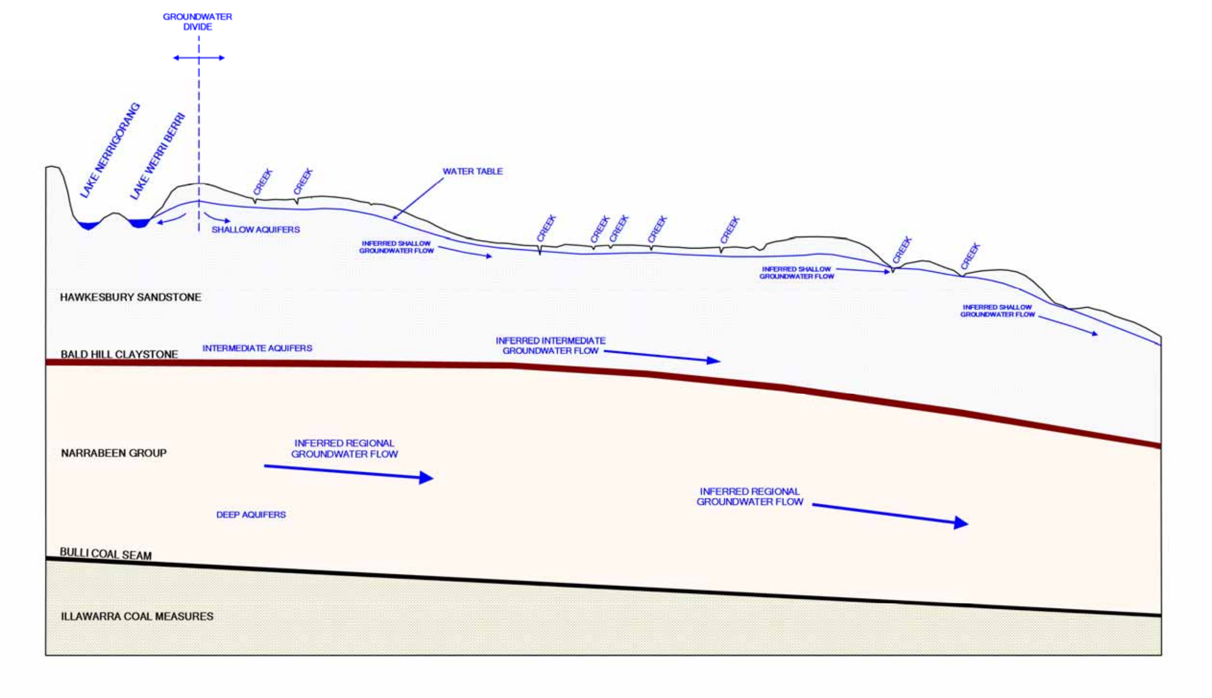


Figure 22 Conceptual regional groundwater flow systems



Recharge varies from year to year depending on climatic conditions. Major recharge occurs during wet decades.

The Thirlmere Lakes alluvial sequence is very sandy and is more rapidly recharged in rainfall events than the surrounding sandstone. Recharge occurs direct from several sources; rainfall, seepage from the Lakes and from discharge from the sandstone.

5.4 Rainfall

It is important to consider the rainfall local to the Thirlmere Lakes as they are situated in the headwaters of the Little River catchment (refer Figure 4) and precipitation is likely to be the primary source of replenishment for the water bodies. Similarly, rainfall recharge is significant in groundwater level behaviour within the sandstone, as discussed in the previous section.

Reduced rainfall is likely to impact on the lakes directly, as the inflows from surface water runoff will be greatly diminished.

Rainfall records for Picton, Thirlmere and Buxton weather stations (in close proximity to the lakes), as well as the Moss Vale weather station (in close proximity to NSW Government monitoring bores) have been considered for the period between 2000 and 2010 (Table 1). The records for Picton and Thirlmere are generally incomplete (as observed by the number of months of recorded data indicated), however, there is sufficient information to suggest that for most of the years in the period selected the area received below average rainfall. This correlates well with the records for Buxton and Moss Vale, which are considerably more complete, and which also demonstrate below average rainfall for most of the years in the period under consideration. It is also apparent from the data presented for Thirlmere and Buxton that there is considerable variation in rainfall over relatively short distances.

Table 1 Comparison of annual rainfall recorded at Picton, Thirlmere and Moss Vale weather stations 2000-2010

Year	Picton (068052)	No. months	Thirlmere (009648)	No. months	Buxton (068166)	No. months	Moss Vale (068045)	No. months
2000	567.0	11	481.8	9	671.8	12	725.8	12
2001	522.5	9	489.8	11	690.6	12	800.1	12
2002	451.6	9	651.3	12	695.8	12	547.1	12
2003	671.6	12	461.7	6	728.0	12	766.7	12
2004	702.9	12	261.8	3	674.6	12	578.6	12
2005	610.7	11	591.3	7	940.6	12	867.1	12
2006	403.6	11	300.1	10	348.2	9	609.1	12
2007	1019.0	12	790.8	10	997.6	12	1053.3	12
2008	750.8	12	732.1	12	884.4	12	806.6	12
2009	559.1	12	729.9	11	587.6	12	611.4	12
2010	554.3	9	314.7	7	596.0	9	621.0	10
Average	803.9		814.4		852.8		961.9	

5.5 Rainfall residual mass

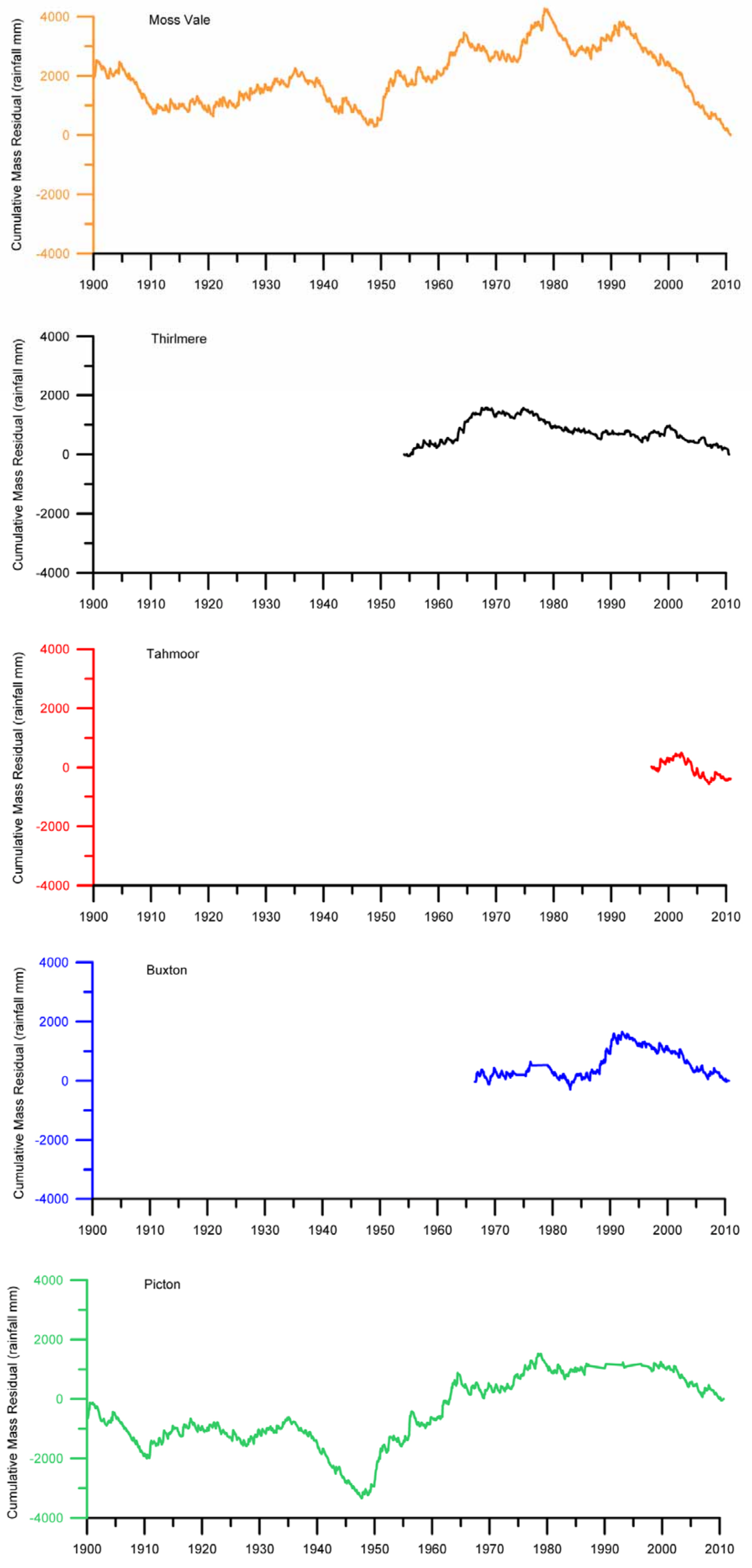
To better understand the effect of rainfall on the area monthly rainfall residual mass curves were developed for the weather stations (Figure 23). A monthly rainfall residual mass curve is the cumulative mean deviation from monthly rainfall plotted against time. The specific values of the cumulative mean deviation are less significant than the slope or trend of the plot. A positive slope in the curve indicates a continuous period of above average rainfall conditions whilst a negative slope indicates a continuous period of below average rainfall conditions. The graphs highlight the variability of rainfall across the area.

Although the periods of record for the individual weather stations vary markedly, the recent (post 2000) trends in each of the rainfall residual mass curves presented indicate consistent negative slopes for all of the plots. This is consistent with the prevalence of drought conditions for the period and implies that a substantial rainfall deficit has developed during that time.

At Picton, the residual rainfall mass curves represent significant droughts are represented on the plots from the period of about 1905 to 1910 and another in the 1930s to the 1940s. The graphs also illustrate that there was significant rainfall up until around 1980. Although there is a data gap from the late 1980s to the 1990s, it is apparent that there is a steady moderate decline in rainfall from 2000 to 2010. Other weather station graphs show similar trends, however, it should be noted that the Moss Vale weather station, where there is a more complete data set, significant decline started in the mid 1990s and is continuing. The shorter term data from Thirlmere, which started in the 1950s shows there has been a low to moderate decline in rainfall since the 1970s. It appears around 2000 that some additional rainfall briefly moderated the trend before another minor decline. The plot for the Tahmoor Colliery weather station, which has the shortest period of record, is also showing a minor, but persistent, decline in rainfall since 2004. Buxton records show moderate declines since the early 1990s that are ongoing.

The implications of such reduced rainfall are that the soil moisture levels will be naturally depleted due to the prolonged dry weather. This means that a substantial amount of rainfall may be required to restore the moisture store before recharge of the groundwater system will commence. Until the soil moisture levels are restored to pre-drought condition, there is likely to be a reduced volume of surface water runoff contributing to the recharge of the lakes.

Figure 23 Rainfall residual mass curves for Moss Vale, Thirlmere, Tahmoor (mine), Buxton and Picton weather stations



5.6 Regional groundwater monitoring

The NSW Office of Water maintains a series of seven groundwater monitoring bores at five sites throughout the Southern Highlands, centred around Moss Vale. The nearest bore is located near Mittagong approximately 15 km to the southeast of Thirlmere Lakes. Groundwater levels are being monitored in order to assess aquifer dynamics such as recharge processes and observing extraction impacts. The installation and construction of these bores in 1998 was undertaken to establish monitoring in an area of significant groundwater extraction. This area was subsequently embargoed in 2004.

Table 2 NSW Government Southern Highlands monitoring bore summary (modified from Willing 1998)

Bore no	Site	Depth (m bgl)	Slotted interval (m bgl)	WBZ* depth (m bgl)	WBZ* elevation (m AHD)	Estimated yield (L/s)	SWL at completion (m bgl)	SWL at completion (m AHD)
GW075032/1	Berrima STP	31	24-29	24	654	0.35	15.5	662.78
GW075032/2	Berrima STP	91	73-88	73	605	1.5	25.5	652.68
GW075033/1	Burrawang Pumping Station	36	30-35	30	662	0.8	20.2	672.80
GW075033/2	Burrawang Pumping Station	101	89-99	89	603	2.0	19.8	672.70
GW075034	Bong Bong Reserve	101	90-100	90	570	1.5	24.6	635.41
GW075035	Boxvale Walking Track car park	91	74-89	74	574	1.4	25.8	622.45
GW075036	Cunningham Park	85	73-83	70	590	1.1	43.6	616.68

* WBZ – Water Bearing Zone

Whilst these bores are several kilometres removed from the Thirlmere Lakes, they are useful in defining the regional groundwater behaviour that has occurred as a result of the prolonged drought. The monitoring records from these bores have previously been used for a review of the level of groundwater development across eight parishes in the Southern Highlands (Pritchard, *et. al.* 2004). Two NSW Office of Water groundwater hydrographs, rainfall and residual mass are shown in Figure 24 and Figure 25 at Berrima (GW075032/1 and GW075032/2) and near Mittagong (GW075035) respectively.

Figure 24 Hydrographs of groundwater levels from NSW Government monitoring bores GW075032/1 and GW075032/2 in the Southern Highlands

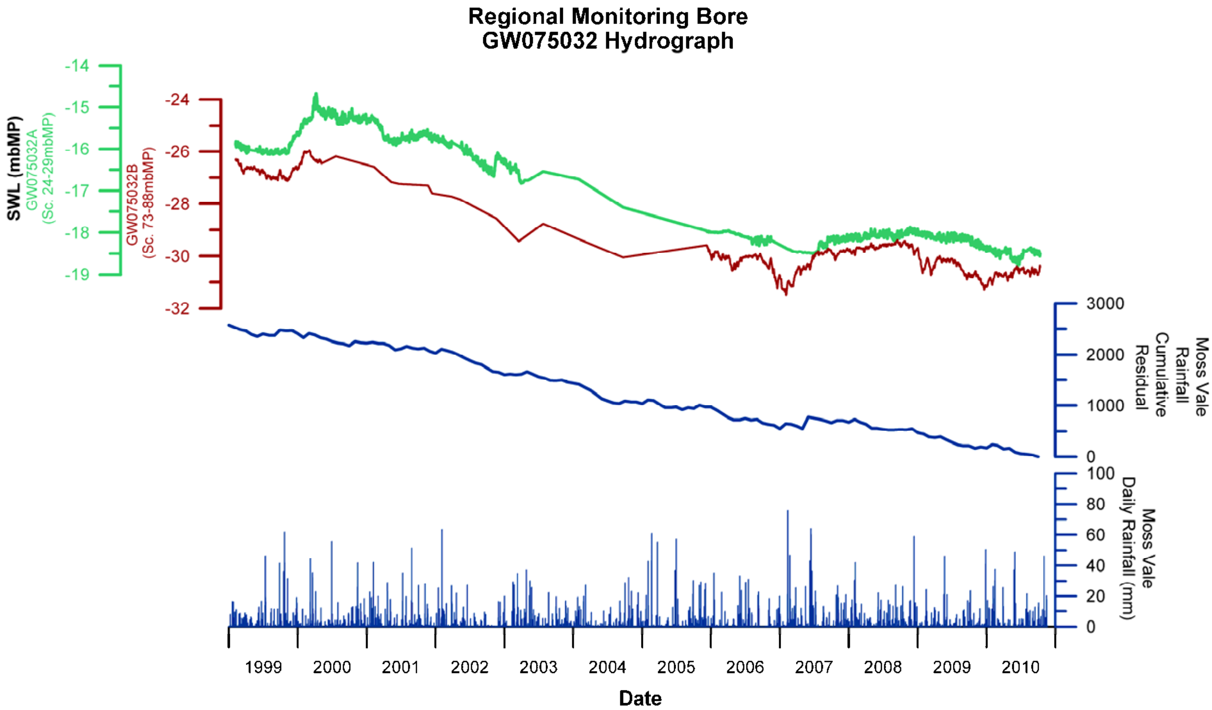
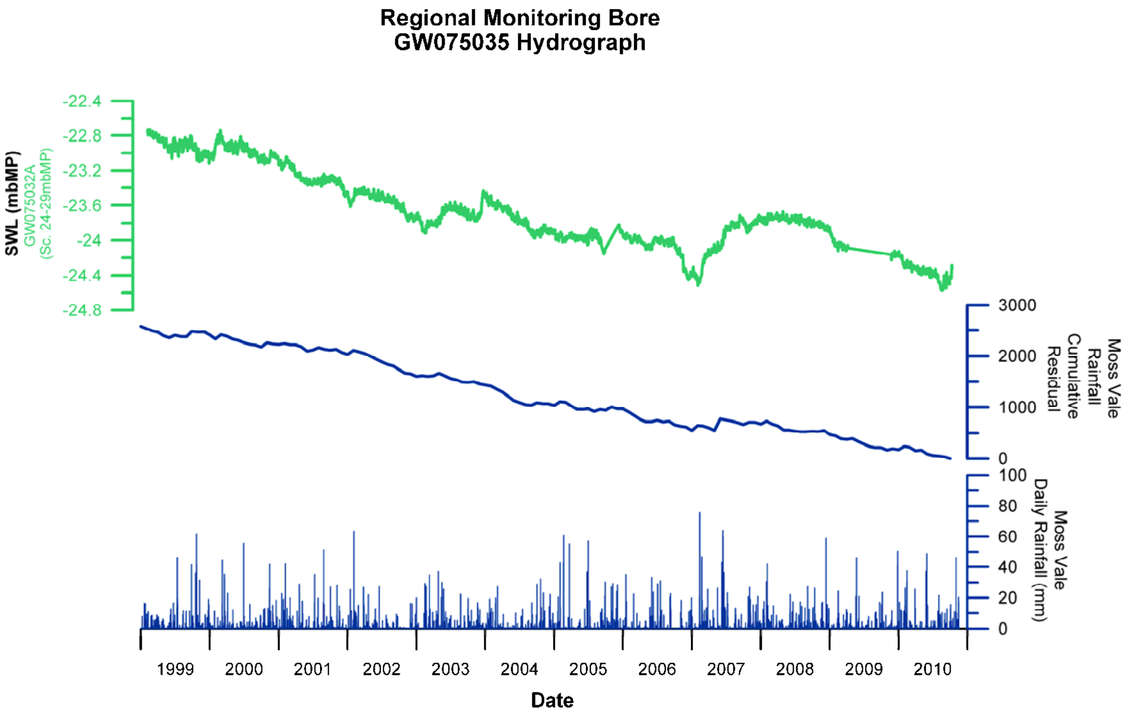


Figure 25 Hydrograph of groundwater levels from NSW Government monitoring bore GW075035 in the Southern Highlands



Both shallow and deep water levels are shown and exhibit a rise in water level when recharge occurs or a decline in water level which represents discharge. Discharge may represent groundwater discharge to springs or rivers, and in some instances declines can represent extraction from pumping bores. The hydrographs at Berrima show typically natural conditions in the water table. There has been a decline in the water levels of around 4 m for the shallow aquifer (around 25 m below ground level) and 5 m in the deep aquifer (around 80 m below ground level). This decline is considered natural because the residual mass curve shows there has been a similar trend in rainfall over the period of monitoring for both bores. The hydrograph from the monitoring bore near Mittagong (closest to Thirlmere Lakes) also shows continuing decline in association with reduced rainfall of almost 2 m (deep aquifer at approximately 80 m). Typically the majority of the monitoring bores are showing a similar gradual decline in water levels due to declining rainfall, except were significant extraction is occurring that affects the hydrograph.

It is apparent from the hydrographs presented for the NSW Government monitoring bores that rainfall recharge is important in maintaining the range of groundwater levels typically observed. Climatic influences are significant.

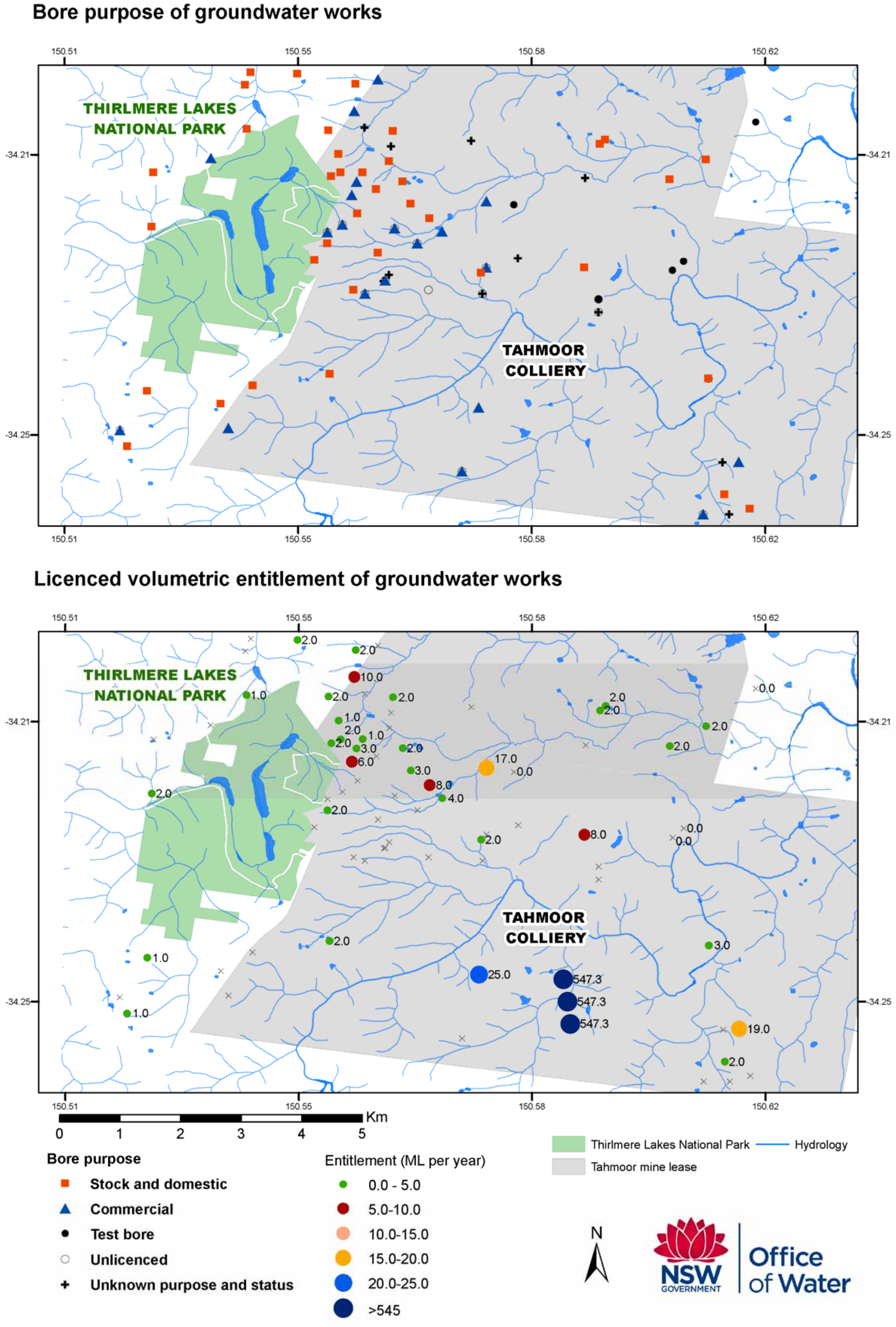
It is anticipated that any potential discharge from the shallow groundwater system that might supplement the lakes storage would also be likely to have reduced.

5.7 Groundwater works

A search of the groundwater works database administered by the NSW Office of Water resulted in information relating to 77 groundwater works for an adopted study area between Thirlmere Lakes and Tahmoor Colliery (summary data for these works is provided in Appendix A). The majority of the works within the study area are of open hole construction; that is, every individual water bearing zone intersected by the bore contributes some proportion of the yield.

Most of the bores in the adopted study area have been drilled for stock and domestic supplies (Figure 26). Entitlements attached to bore licences in the area range from 1 ML/year up to 19 ML/year, corresponding to domestic and commercial purposes. Typically groundwater access licences are used either for irrigation or poultry farming. The largest extraction licence within the investigation area is that of the Tahmoor Colliery, with a combined allocation of 1,642 ML/year used for mine dewatering. The three extraction locations used by the mine are illustrated on Figure 26.

Figure 26 Distribution of groundwater works in the vicinity of Thirlmere Lakes by licensed purpose and by entitlement



6 Longwall mining

In order to assess the impacts of coal mining on the region, a review of Xstrata Coal's groundwater monitoring data and reports was provided to the NSW Office of Water.

6.1 Mining process

The Southern Coalfield is the sole source of premium quality hard coking coal in NSW, with extraction principally occurring from the Bulli seam (the uppermost seam in the Illawarra Coal Measures) at depths greater than 400 m below the land surface. Longwall mining is the preferred extraction method due to the depth of overburden and the resource recovery efficiencies associated with that approach.

The longwall coal mining method requires the development of a series of underground longwall panels, typically 200-250 m wide, 1,500-4,000 m long and 2-5 m thick. Detailed drilling and seismic investigations are typically undertaken in advance of mining to design the location and layout of the panels. Once the design has been established, gas within the coal and surrounding strata must be removed to make the operating environment safe, a process which takes approximately 3 months. A vacuum may be applied to holes drilled into the respective strata from the surface to encourage the drainage of hazardous gases (methane, carbon dioxide, nitrogen, ethane and other hydrocarbons) if the inherent pressure is insufficient to achieve degassing. Continuous mining equipment is then installed below ground to extract coal for the construction of access roadways and ventilation tunnels.

'First workings' are established with the excavation of a network of underground roadways and headings to create rectangular coal blocks suitable for panel extraction. Subsequent to the excavation of main headings and pillars (Figure 27), longwall equipment is installed and extraction of the panel commences. The longwall machinery travels back and forth across the coal face, shearing a slice from the seam with each pass. The coal is transported via conveyor to the operating shaft for removal to the surface. The overburden near the mining face is prevented from collapse by hydraulic roof supports, which are progressively moved forward as the longwall advances. After the roof supports have been relocated, the overburden behind the mining face is allowed to collapse into the void, creating a cavity infilled with fractured rubble (or 'goaf'). This process is known as 'retreat mining' and typically progresses at a rate of about 50-60 m per week.

To maximise the recovery of the coal resource, longwall panels are usually designed to be close together, separated by unmined remnant coal supports ('chain pillars') which are intended to limit the magnitude of overburden collapse. Where the mined longwall panels are narrow and the rocks above the mined seam are competent, the support from the pillars may prevent the roof from collapsing. However, it is generally more economically viable to extract wide panels (up to 230-250 m), which results in a degree of roof collapse (Figure 28).

Figure 27 Typical longwall mining panel layout (OEC 1998)

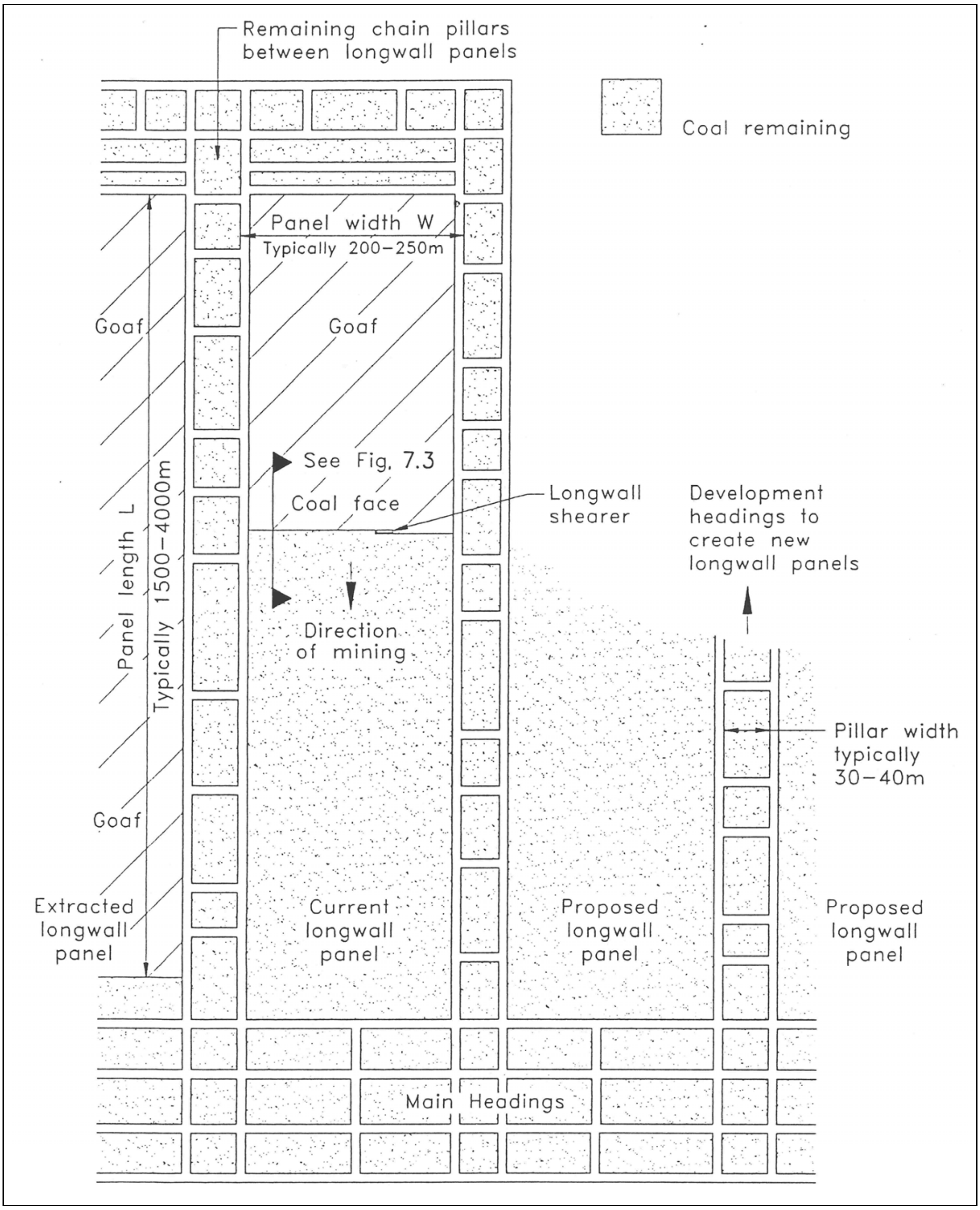
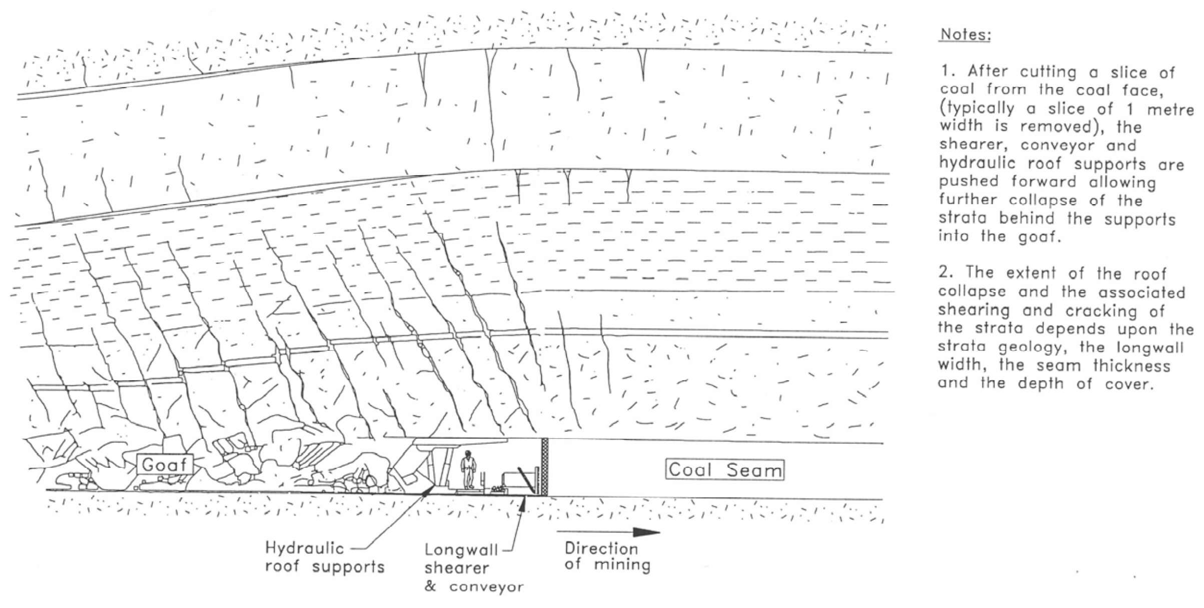


Figure 28 Typical longwall operation sectional diagram (OEC 1998)



6.2 Mining induced subsidence

Once the overburden has collapsed into the goaf, the strata above loses support and sags to fill the void beneath. As this slumping of strata progresses upward, the affected width increases so that at the surface an area considerably larger than the extracted panel of coal undergoes settlement. The angle at which the subsidence spreads out towards the surface is referred to as the 'angle of draw' (illustrated longitudinally along a panel in Figure 29 and laterally across a panel in Figure 30) and is typically 10-40 degrees from the vertical, depending on a variety of parameters (such as the strength of the overlying strata). Subsidence at the surface progresses at about the same speed that the coal face is mined, and ground movement is generally completed within 12 months after the longwall face has passed. The depression formed at the surface is typically elongated in the direction of the mined longwall panel and is referred to as a 'subsidence trough'.

The angle of draw is usually used to define the limit of mining influence outside an extraction panel (Holla and Barclay 2000). A commonly adopted subsidence cut-off value of 20 mm is used to define the limit of mining influence. This cut-off value eliminates surface movement associated with other factors, such as soil moisture changes, climatic variations and water table fluctuations that have been found to occur in areas remote from the Southern Coalfield.

Figure 29 Subsidence effects of longwall mining: along panel orientation (OEC 1998)

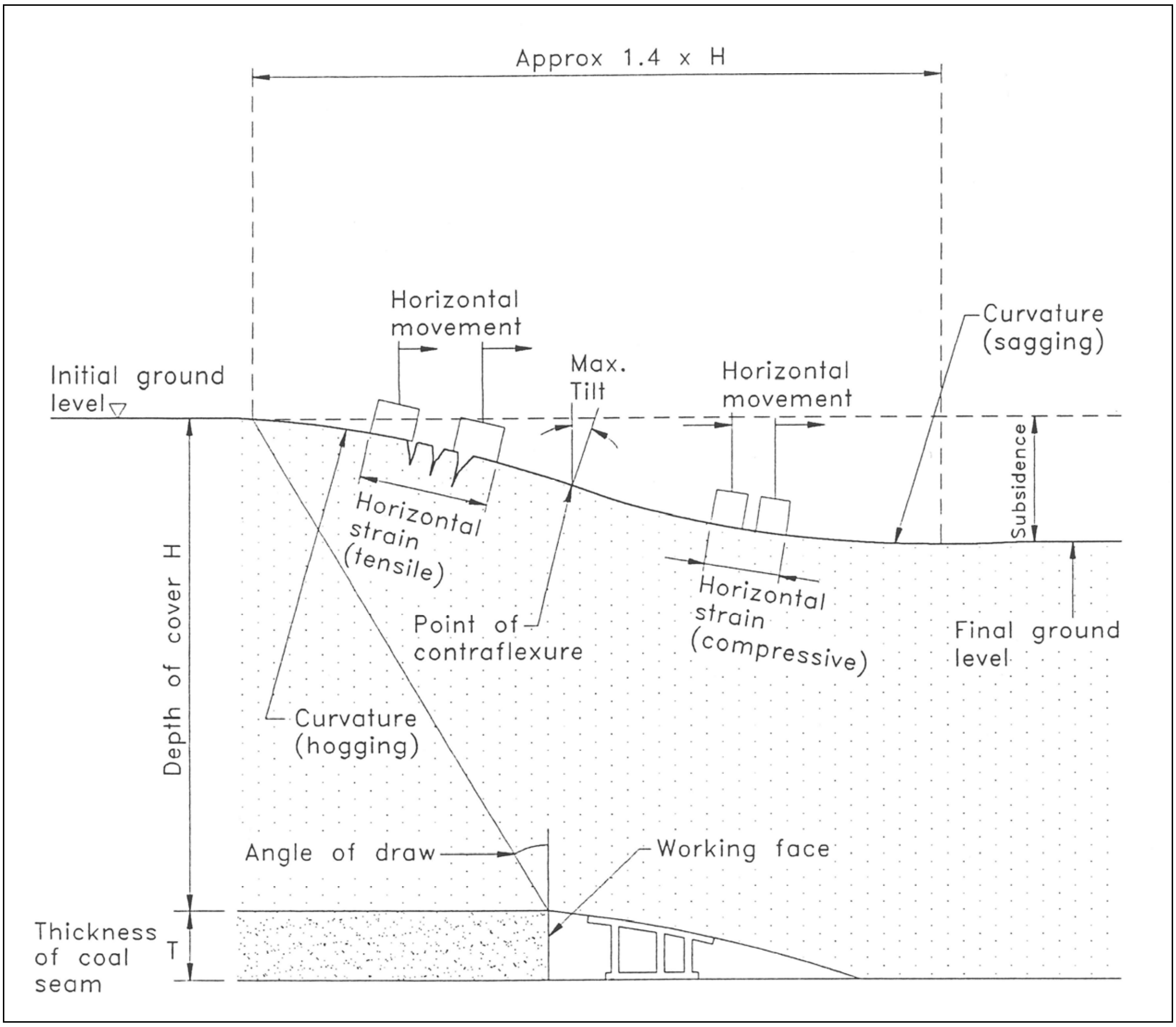
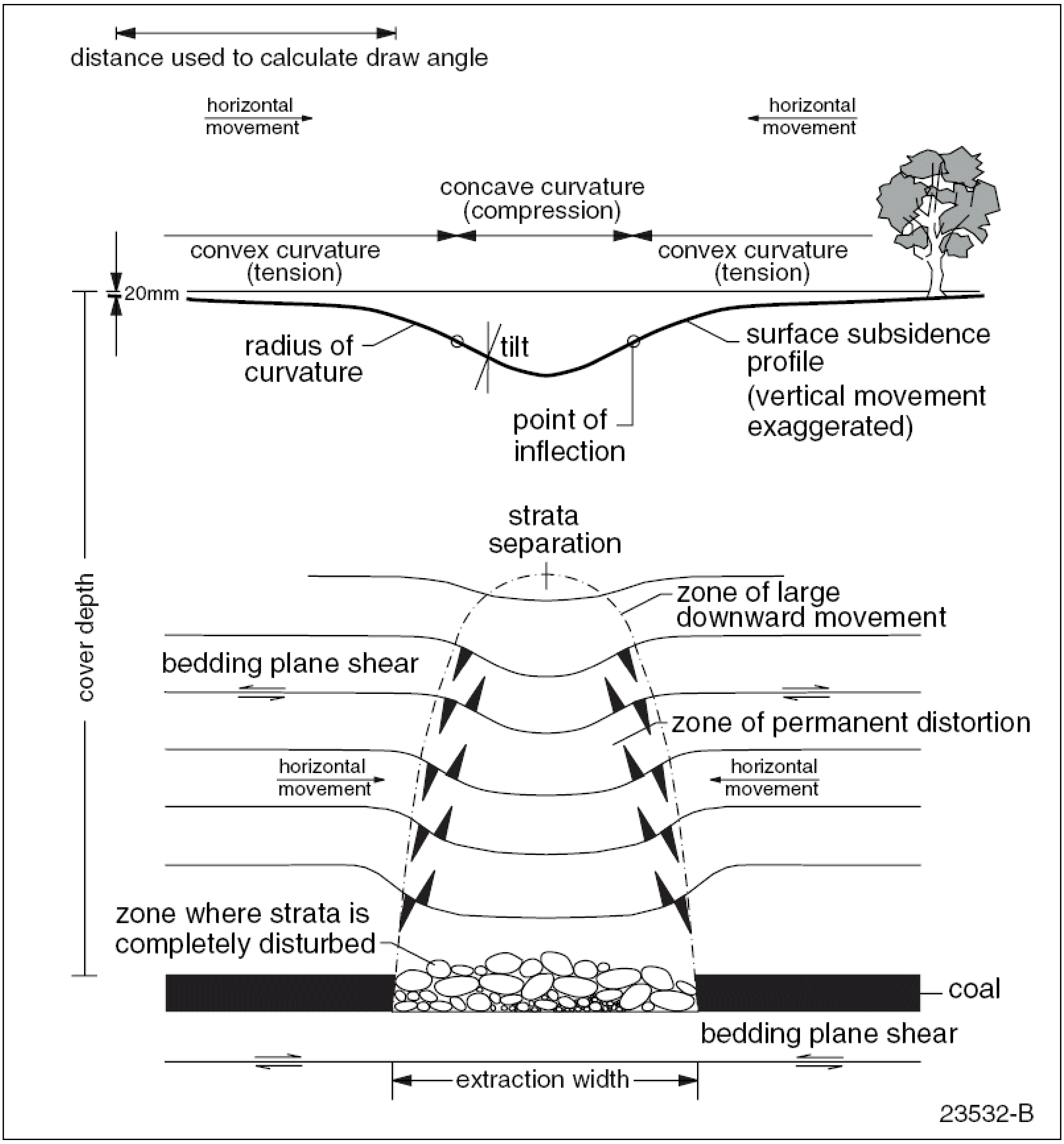


Figure 30 Subsidence effects of longwall mining: across panel orientation (Holla and Barclay 2000)



6.3 Tahmoor Colliery ownership history

The Tahmoor Colliery is an established coal mining operation in the Bargo River catchment. Following geological exploration in the early 1970s, the southern area mining lease was granted to Clutha Development Pty Ltd. Mine planning and development commenced in 1975 and coal was first produced commercially by bord and pillar extraction in 1979. In 1986, the company changed its name to BP Coal Australia Pty Ltd and the first longwall mining equipment was introduced to the colliery. In 1989 CRA Ltd (previously Conzinc Riotinto of Australia Ltd) acquired Tahmoor mine from BP Coal Australia. Expansion of the colliery into the Tahmoor North area was approved in 1995 with strict conditions on subsidence controls around residential properties. The wholly owned subsidiary of CRA, Kembla Coal and Coke Pty Ltd, managed the mine until it was purchased by Austral Coal Ltd in 1997.

Subsequently the mine was purchased by Centennial Coal Company Ltd in 2004. Xstrata Coal Pty Ltd purchased the colliery in 2007 and is the current operator.

Currently Xstrata Coal operates within two coal mining leases; the southern lease area (situated between Tahmoor, Buxton and Bargo) and the Tahmoor North Underground Extension (between Tahmoor, Thirlmere and Picton).

6.4 Pillar extraction

Limited pillar extraction was carried out at Tahmoor Colliery between 1981 and 1987 (Table 3). This extraction was carried out during the ownership of Clutha and BP Coal, and was mostly undertaken prior to the establishment of the longwall operations. The extent of the pillar extraction was limited to the vicinity of the mine drift and main east headings within the southern lease area.

Table 3 Pillar extraction records for the southeastern part of southern lease area (data supplied by Xstrata Coal)

Panel No.	Start date	Finish date	Comments
100	March 1981	March 1986	Includes 101 Panel, 102 Panel, 103 Panel
300	March 1986	March 1987	Includes 301 Panel, 302 Panel, 303 Panel
200	December 1981	June 1986	Includes 201 Panel, 202 Panel, 203 Panel, 204 Panel, 200 Panel

6.5 Longwall operations

The progression of mining is represented as a series of snapshots in Appendix B.

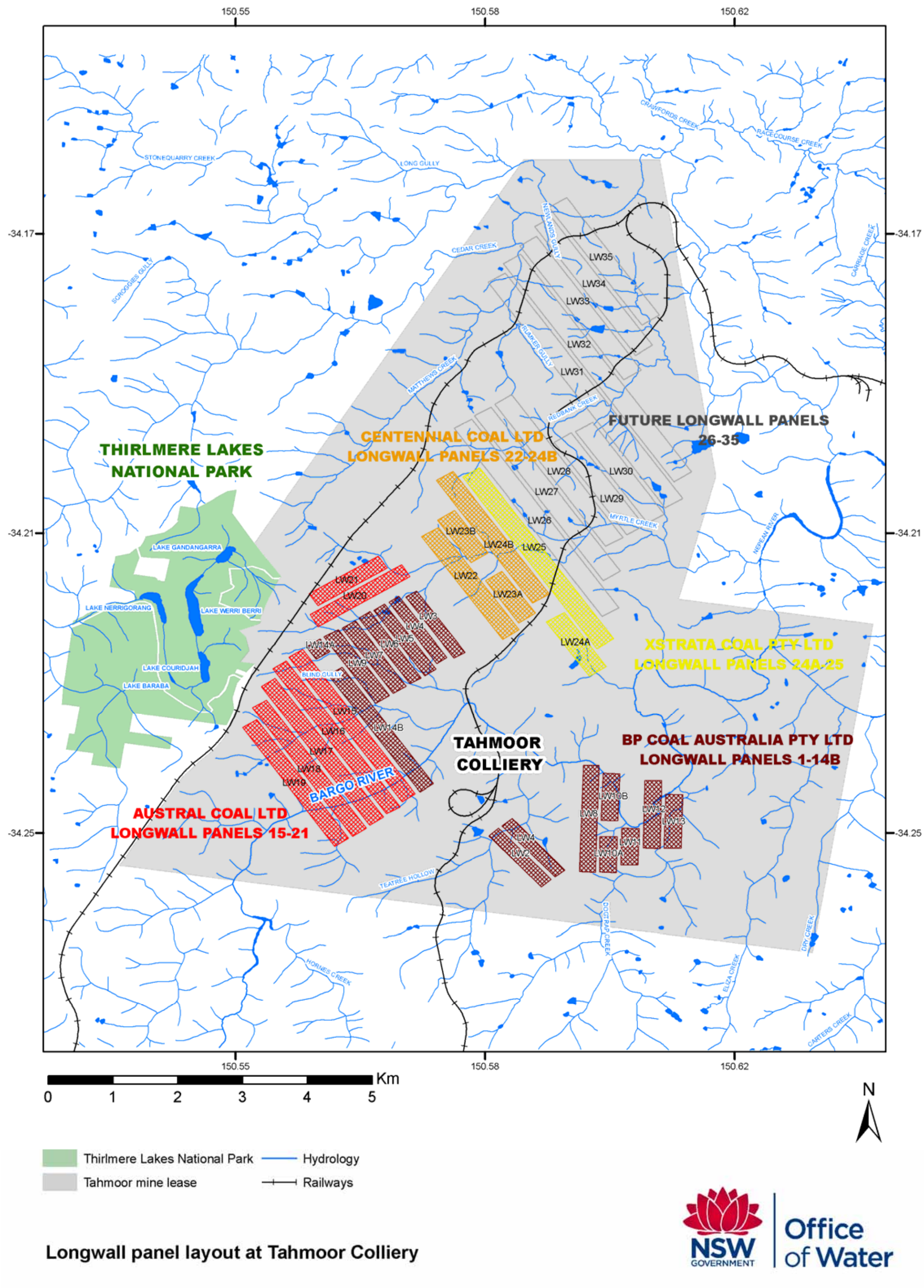
Longwall mining (Table 4, Figure 31) commenced within the southern lease area with two panels extracted in close proximity to the mine drift by BP Coal in 1987 (LW1 and LW2). Longwall operation then moved to the northwest of the southern lease, where five panels were extracted between 1988 and 1991 (LW3 to LW7). The longwall returned to the southeast of the lease area in 1991 (LW8) and, apart from a single panel (LW9) to the northwest, continued extraction in that general location until 1994 (LW10A/B to LW13). Subsequently the longwall was relocated back to the northwest where two parts of a panel (LW14A/B) were mined by BP Coal from 1995 to 1996.

Table 4 Longwall panel extraction records for the southern and northern lease areas (data supplied by Xstrata Coal)

Panel No.	Operator	Panel length (m)	Start date	Finish date	Extraction duration (days)	Goaf width (m)
1	BP Coal Australia Pty Ltd	1053	02-MAR-1987	19-JUL-1987	139	
2		1035	17-AUG-1987	26-NOV-1987	101	
3		1113	21-MAR-1988	16-NOV-1988	240	
4		1111	04-FEB-1989	09-MAY-1989	94	
5		1174	05-JUN-1989	25-OCT-1989	142	
6		1201	04-DEC-1989	21-APR-1990	138	
7		1197	16-JUL-1990	28-JAN-1991	196	
8		1634	17-APR-1991	12-NOV-1991	209	
9		1226	06-DEC-1991	14-JUN-1992	191	
10A		554	27-JUL-1992	14-NOV-1992	110	
10B		716	04-DEC-1992	31-MAR-1993	117	
11		556	17-MAY-1993	09-AUG-1993	84	
12		1034	10-SEP-1993	03-JUN-1994	266	
13		831	08-JUL-1994	11-NOV-1994	126	
14A		215	31-JAN-1995	12-MAY-1995	101	235.7
14B		2151	16-JUN-1995	22-MAY-1996	341	235.7
15	Austral Coal Ltd	2707	27-JUN-1996	07-AUG-1997	406	235.5
16		2677	08-SEP-1997	02-DEC-1998	450	235.4
17		2556	16-FEB-1999	24-MAY-2000	463	238.6
18		2360	22-JUN-2000	06-SEP-2001	441	238.6
19		2177	03-OCT-2001	19-JUL-2002	289	238.6
20		1419	30-SEP-2002	26-MAY-2003	238	238.6
21		1079	12-SEP-2003	29-MAR-2004	199	238.6
22	Centennial Coal Company Ltd	1877	31-MAY-2004	27-JUL-2005	422	282.0
23A		776	14-SEP-2005	21-FEB-2006	160	283.0
23B		771	22-MAR-2006	26-AUG-2006	157	283.0
24B		2260	13-OCT-2006	02-OCT-2007	354	283.0
24A	Xstrata Coal Pty Ltd	983	15-NOV-2007	18-JUL-2008	246	283.0
25		3585	22-AUG-2008			

Austral Coal commenced longwall extraction of five panels (LW15 to LW19) between 1996 and 2002, continuing the general progression to the southwest of the southern lease area. The longwall was then relocated to the extreme northwest of the southern lease, where two panels were extracted (LW20 and LW21) between 2002 and 2004. This was approximately 1.8 km from Lake Werri Berri. It is during the period of mining of panels LW17, LW18 and LW19, between February 1999 and July 2002, that the longwall operation was the closest to the Thirlmere Lakes (660, 700 and 820 m, respectively from Lake Couridjah).

Figure 31 Tahmoor Colliery lease areas and longwall panels layout



Longwall extraction expanded into the northern lease area under ownership of Centennial Coal, commencing with three panels that crossed the lease boundary (LW22, LW23A/B and LW24B) between 2004 and 2007. The extraction of these panels moved progressively to the northeast, passing from the southern lease area into the northern lease area. Subsequently, Xstrata Coal completed the extraction of one panel (LW24A) and commenced the mining of the adjacent longwall (LW25), continuing the progression to the northeast and further away from the lakes.

6.6 Groundwater monitoring

Groundwater information was provided by Xstrata Coal for the Tahmoor Colliery area. Groundwater monitoring bores drilled by the mining company have groundwater level data that has been collected since 2004. In addition to their own monitoring bores, the company has engaged consultants to collect groundwater data from surrounding bore users as shown in Table 5 and Figure 32. This also shows the bore depth and salinity of groundwater. The following discussion involves the continuous groundwater level monitoring of the Xstrata Coal bores (Figures 33 to 40).

Table 5 Construction details for piezometers and bores monitored by Xstrata Coal (modified from Geoterra 2010)

Bore no.	Registered no.	Date	Depth	SWL (m)	Aquifer (m)	Yield (L/s)	Purpose
P1		2004	48		18-20	0.8	Monitoring
P2			150				Monitoring
P3			100				Monitoring
P4	GW067570	1988	85			0.2	Domestic
P5	GW063525	1954/1990	76/91		60-66, 70-91	1.0	Domestic, stock, irrigation
P6	GW042788	1976	148		105-135	1.5	Agriculture
P7							Monitoring
P8							Monitoring
	GW105254	2003	163	80	113-156	0.7	Domestic
	GW107918	2007	60	42.5	40-48	2.2	Domestic
	GW109010	2008	169	89		0.8	Domestic, stock
	GW109224	2008	132	60		1.0	Domestic
	GW008548	1947	65.5	28		0.5	Irrigation
	GW010496	1954	40.6	28.6	33-36	0.8	Irrigation
	GW013282						Irrigation
	GW018568	1961	63.3	39.6	45-63	1.1	Domestic
	GW029143	1968	73	44	40-73		Agriculture
	GW035753	1972	142	24.3	30-32, 71-138	3.2	Irrigation
	GW037860	1969	137	36.5	39-134	2.3	Domestic
	GW038060	1974	123	37.2	49-107	3.0	Domestic
	GW049796	1980/2005	61/125	24.6	37-58	0.8	Agriculture
	GW047416	1979	64	34.3	38-46, 59-61	1.5	Domestic
	GW060238	1985/2004	41/48	30.7	30-35	1.7	Irrigation

Figure 32 Location of monitoring piezometers maintained by Tahmoor Colliery

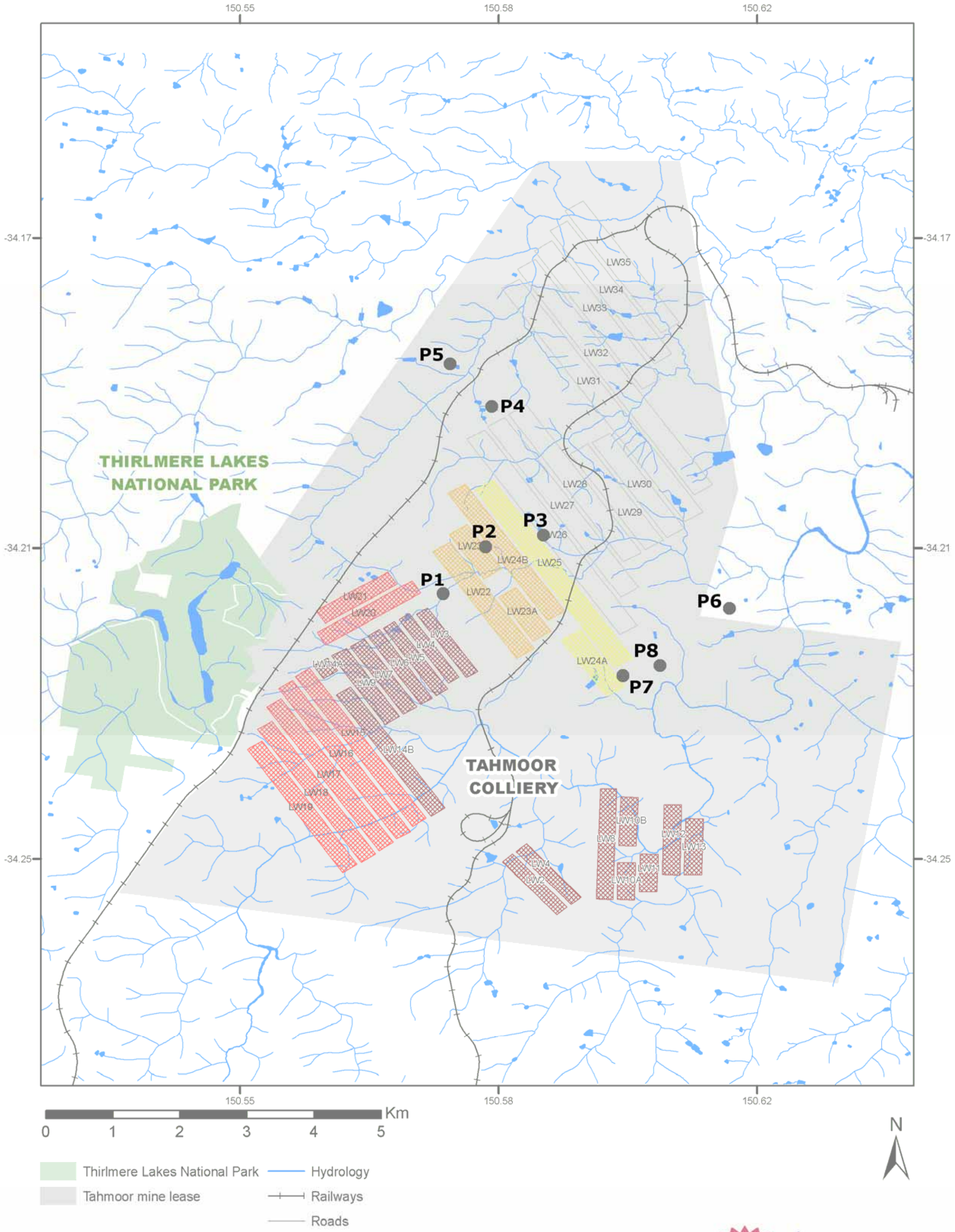


Figure 33 Hydrograph for piezometer P1 (over main roadway first workings)

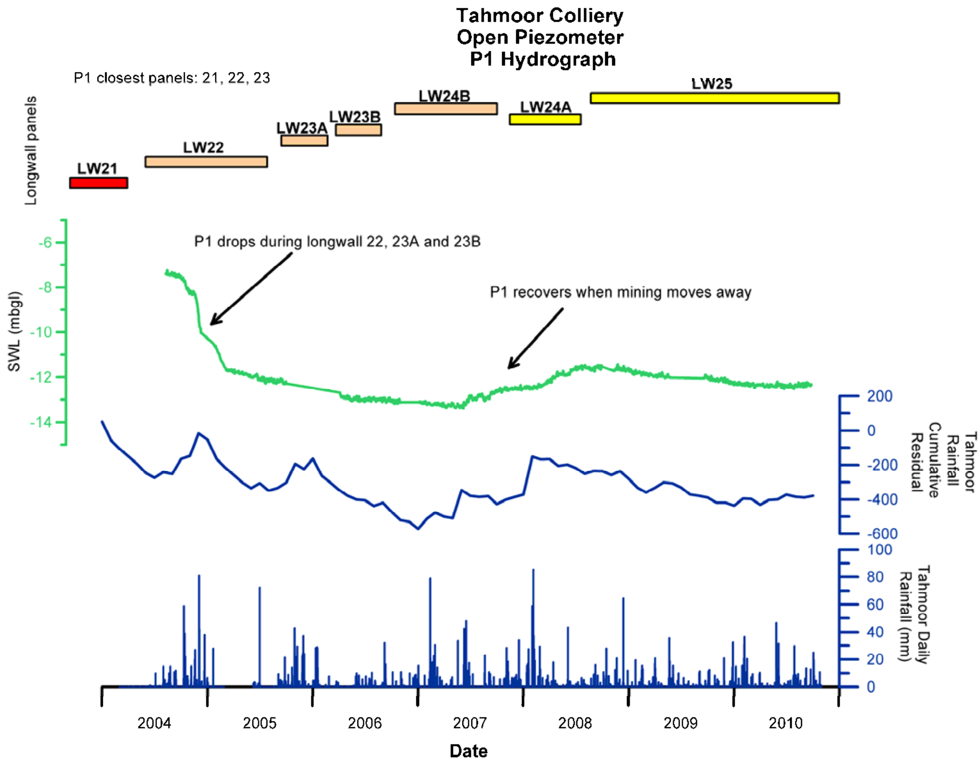


Figure 34 Hydrograph for piezometer P2

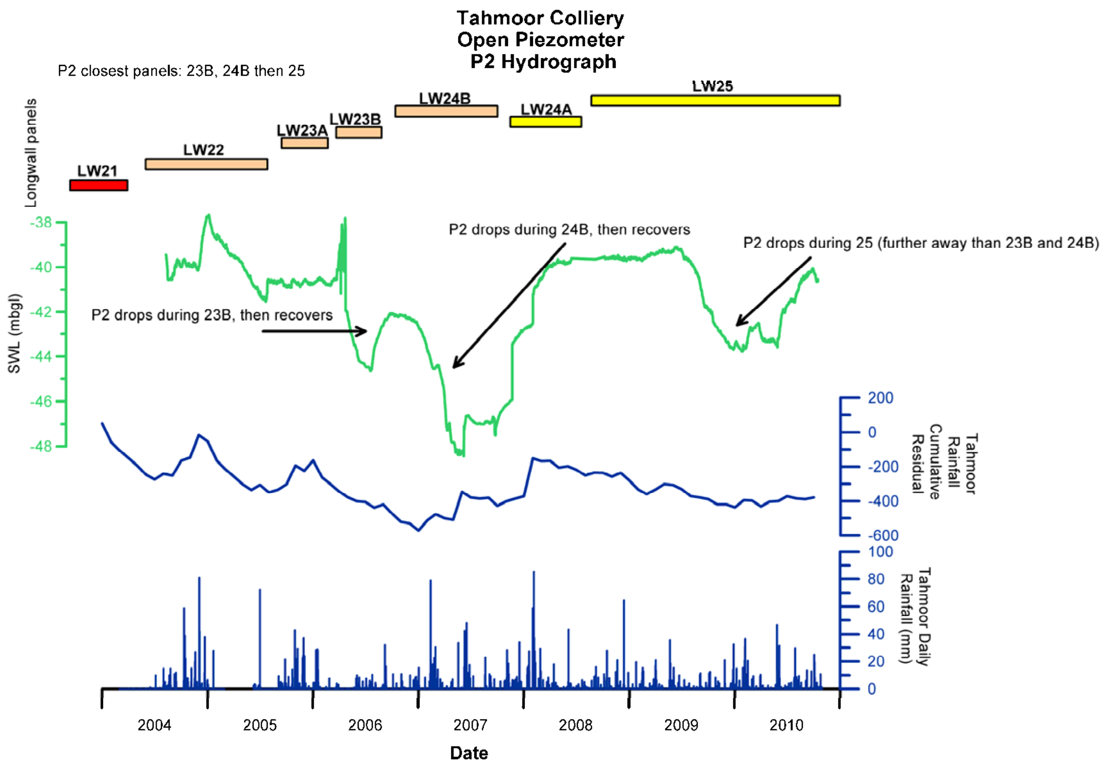


Figure 35 Hydrograph for piezometer P3 (over chain pillar between LW25 and LW26)

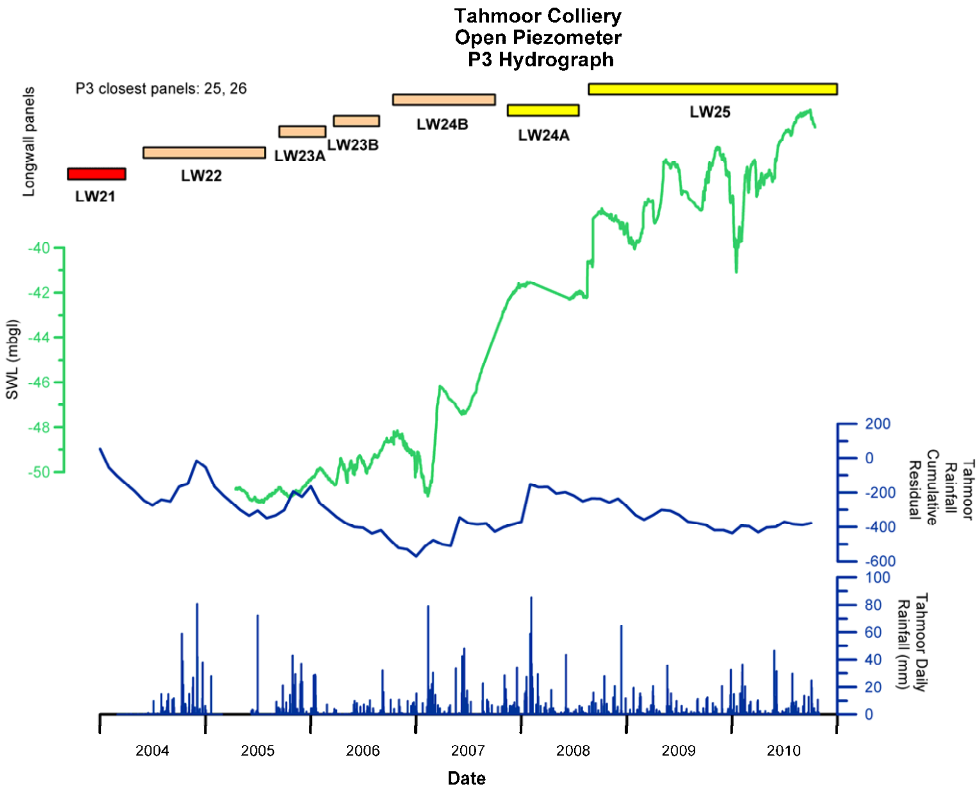


Figure 36 Hydrograph for piezometer P4

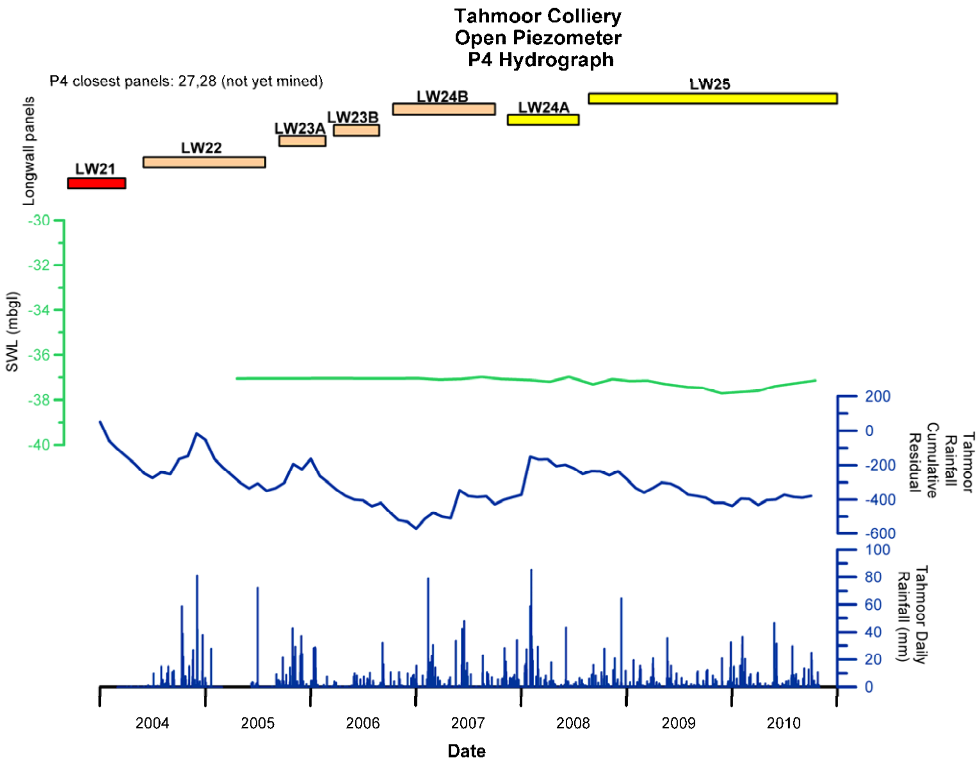


Figure 37 Hydrograph for piezometer P5

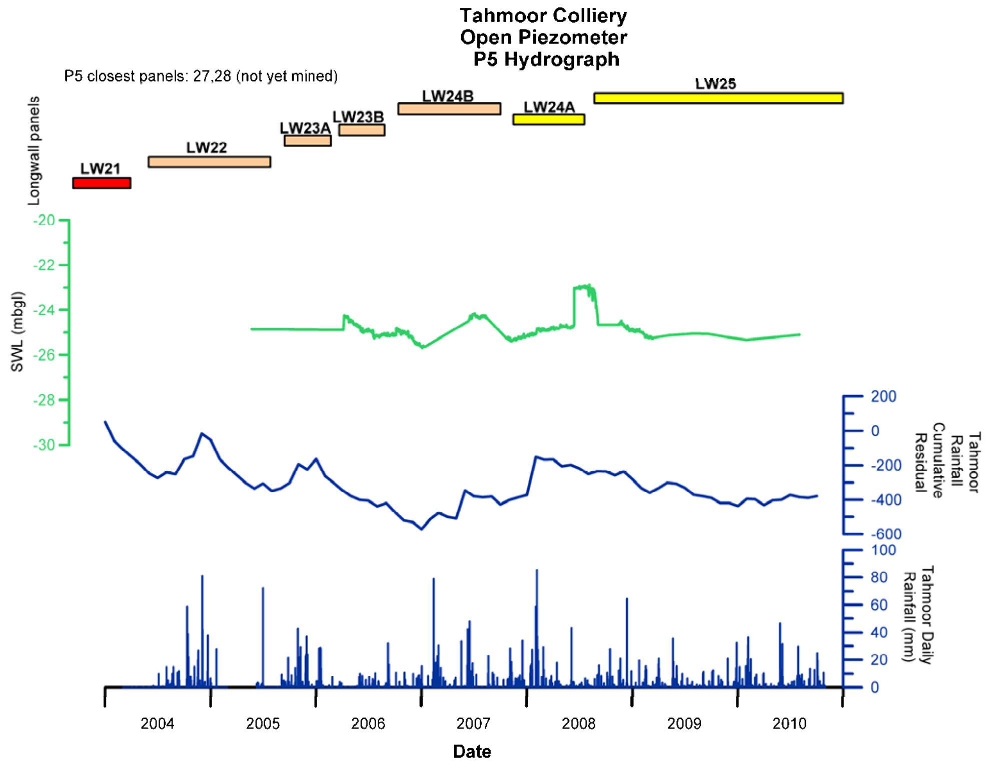


Figure 38 Hydrograph for piezometer P6

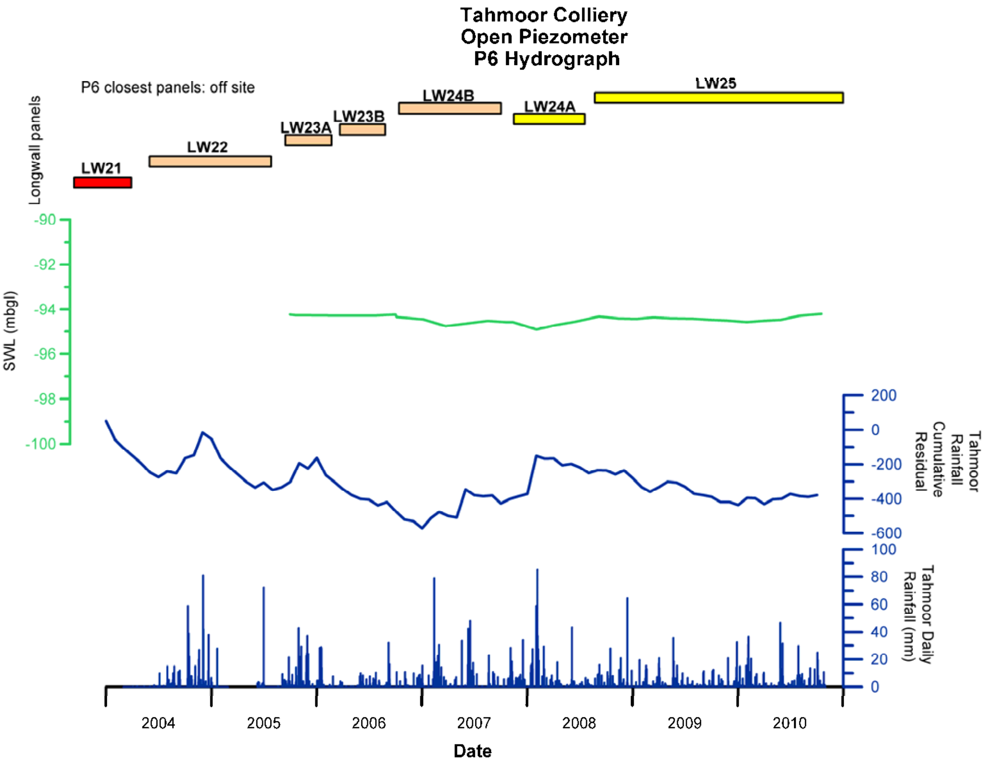


Figure 39 Hydrograph for piezometer P7

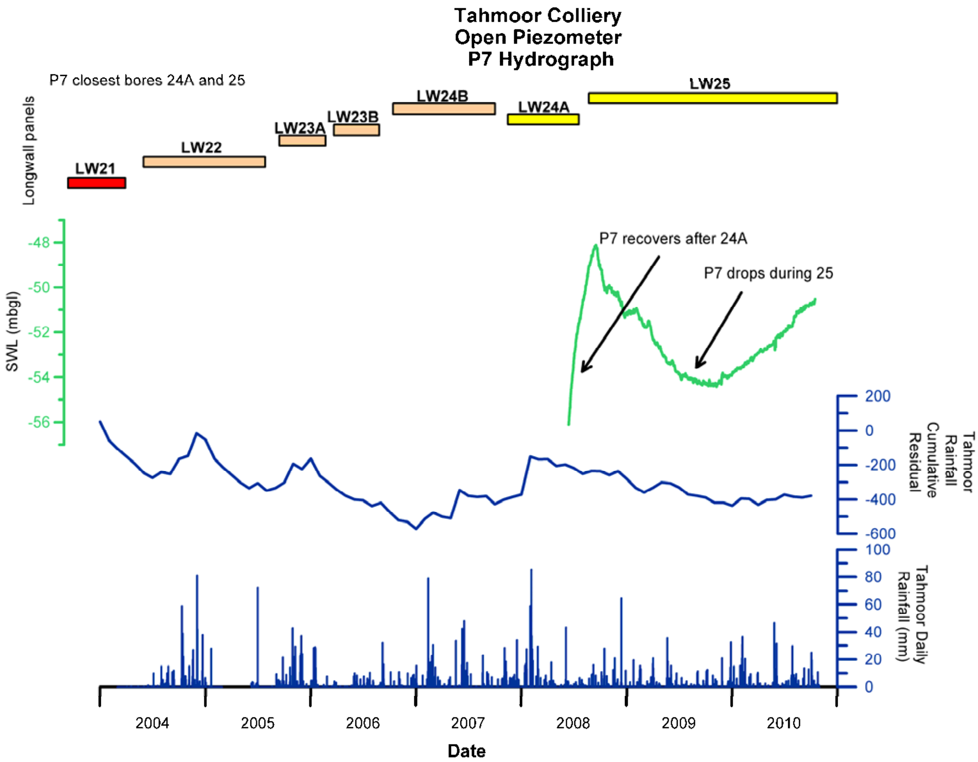
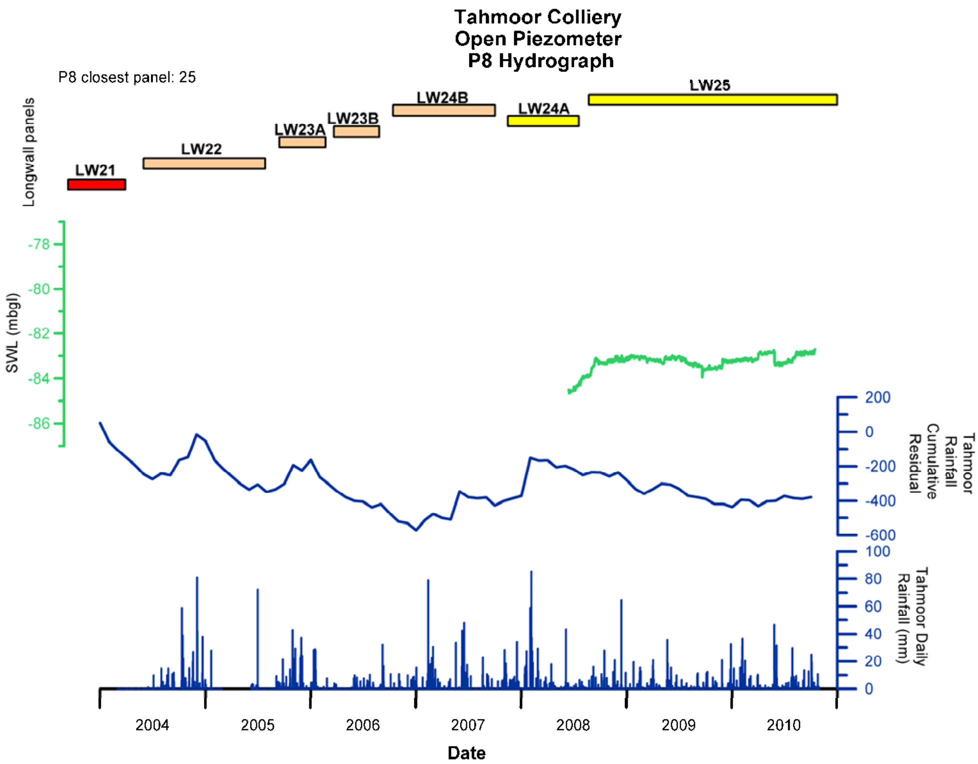


Figure 40 Hydrograph for piezometer P8



A discussion of results follows:

- The hydrograph for piezometer P1 (depth 48 m) shows a drop in water level (approximately 5.5 m) associated with longwall mining during 2004 which continued until early 2007 when a slight recovery was apparent (0.75 m rise) as the longwall moved away. It is assumed that water levels have remained at a lowered level due to the need for ongoing dewatering of the headings and roadways situated beneath P1, that provide access to the current (and future) longwall panels.
- The hydrograph for piezometer P2 (150 m depth) shows declines (up to 10.3 m) due to the mining of panels LW23B, LW24B and LW25. It can be seen in the figure that the water level drops when a new panel is dewatered and is followed by recovery in water levels until another panel is dewatered in the vicinity.
- The hydrograph for P3 (depth 100 m) shows a distinct recovery response (a rise of 14.6 m). The cause of this is not clear, as the piezometer is situated above the chain pillar separating the current longwall panel (LW25) as well as the next block to be mined (LW26).
- The hydrograph for piezometer P4 (85 m depth) shows minimal variation in water level to date (a decline of 0.09m). This piezometer is located away from the current mining panel and dewatering may not have yet commenced in the area of the bore.
- The hydrograph for piezometer P5 (91 m depth) also shows a slight decline (0.48 m) and so does not appear to be impacted by mine dewatering. This piezometer is also is located away from the current mining panel.
- The hydrograph for piezometer P6 (148 m depth) shows minimal water level variation (a decline of 0.17 m) and is located between proposed longwall panels LW26 to LW 30 and the Nepean River.
- The hydrograph for piezometer P7 (100 m depth) shows recovery after extraction of panel LW24A, and then a decline (a lowering of 4.84 m) likely to be associated with the dewatering of panel LW25. The water levels currently appear to be recovering as mining moves away from the bore location.
- The hydrograph for piezometer P8 (105 m depth) shows a gradual recovery in water level (a rise of 1.23 m)since 2008.

6.7 Mine water make

Dewatering of the mine workings at Tahmoor currently takes place from three underground pick-up locations - ‘Pit Bottom’, ‘No. 3 Shaft’ and ‘Mid-drift’ as shown in Table 6. From these, groundwater is pumped to the surface at the ‘Pit’ via pipes – ‘Line 1’, ‘Line 2’ and ‘Line 3’. These pipes are licensed by the NSW Office of Water with licence numbers 10BL602333, 10BL602337 and 10BL602336 respectively. Note that the dewatering works are not bores as such.

From the ‘Pit’ water travels through a series of dams to control water quality. Water then either evaporates, is pumped from the dams for reuse on site, or discharged via ‘LPD1’ and disposed of via Tea Tree Hollow into Bargo River and thence into the Nepean River.

Previously, a fourth pick-up location was in use – ‘No. 2 Shaft’. Water from here was pumped to the surface and discharged via ‘LPD2’. Since 1999, water collected here has been transferred to ‘Pit Bottom’ and is now pumped to the surface via this location and discharged via ‘LPD1’.

Table 6 Mine dewatering locations (data provided by Xstrata Coal)

Site	Pick-up locations	Licence no.	Groundwater work no.
Line 1	Pit bottom, mid-drift	10BL602333	GW111044
Line 2	Pit bottom (and previously No. 2 Shaft)	10BL602337	GW111045
Line 3	No. 3 Shaft	10BL602336	GW111046

Dewatering volumes at the mine have been measured only since 1995 as shown in Table 7. Water extracted from the mine was estimated weekly from 16/04/1995 until 24/06/2001 and daily from 01/07/2001 until 30/04/2002 as the volume pumped from each pick-up location and discharged via 'LDP1' and 'LDP2'. This was calculated by multiplying each pump's running hours by the estimated flow rates of the pumps. On the 13/06/1999, all water was diverted from 'No.2 Shaft' to 'Pit Bottom'. All water extracted from this point on leaves through 'LDP1' and 'LDP2' is no longer used.

Table 7 Construction details for piezometers and bores monitored by Xstrata Coal (modified from Geoterra 2010)

From	To	Location	Estimated flow rates	Discharge point
16-APR-1995	27-DEC-1998	Pit bottom	1 pump @ 22 L/s	LDP1
16-APR-1995	27-DEC-1998	No. 2 Shaft	1 pump @ 13 L/s	LDP2
16-APR-1995	27-DEC-1998	No. 3 Shaft	1 pump @ 22 L/s	LDP1
16-APR-1995	27-DEC-1998	Mid-drift	1 pump @ 18 L/s	LDP1
01-JAN-1999	24-JUN-2001	Pit bottom	2 pumps @ 25 L/s each	LDP1
01-JAN-1999	24-JUN-2001	No. 2 Shaft	1 pump @ 18 L/s (reporting to pit bottom)	LDP1
01-JAN-1999	24-JUN-2001	No. 3 Shaft	1 pump @ 25 L/s	LDP1
01-JAN-1999	24-JUN-2001	Mid-drift	1 pump @ 15 L/s	LDP1
01-JUL-2001	30-APR-2002	Pit bottom	2 pumps @ 25 L/s each	LDP1
01-JUL-2001	30-APR-2002	No. 2 Shaft	1 pump @ 18 L/s (reporting to pit bottom)	LDP1
01-JUL-2001	30-APR-2002	No. 3 Shaft	1 pump @ 25 L/s	LDP1
01-JUL-2001	30-APR-2002	Mid-drift	1 pump @ 18 L/s	LDP1

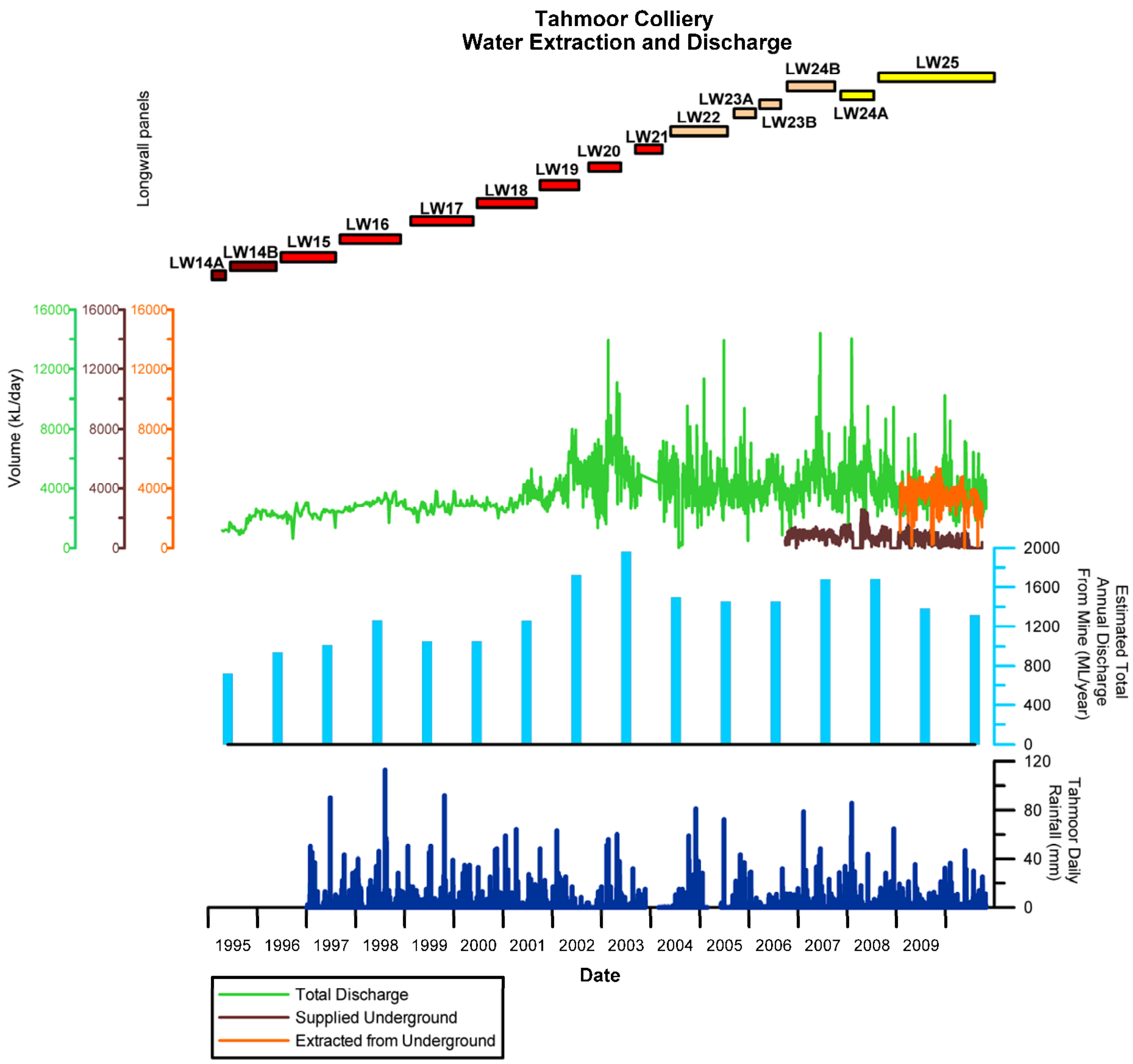
From 01/05/2002 until 2010 water extracted from the mine was no longer directly measured or estimated as water came out of the mine. Discharge via 'LPD1' was instead directly calculated or measured. This volume of discharge was estimated until flow meters were installed on 02/07/2002.

This type of measurement gives an indication of dewatering volumes, but does not allow for water lost to evaporation or seepage from the dam, or for water reused on site. Measurement of the amount of water pumped from the dams for reuse on site commenced in September 2006. Direct measurement of dewatering volumes as water was extracted from the mine workings, as well as of volumes discharged from the dams and volumes reused onsite began in January 2009.

This variability of data creates difficulty in assessing variability in dewatering volumes over the mine's life. Also, as measurement from 2002 to 2009 took place as water was discharged from the dam, relationships between factors such as rainfall, the mining of particular sections, such as under Bargo River, or when goaf areas were larger cannot be identified. Discharge from the dam can occur at a more steady rate than can dewatering, which must keep the mine workings dry and vary depending on rainfall, and variable hydrogeology around the current mine workings.

Groundwater extraction from the Tahmoor Colliery and discharge for the period from 1995 onwards is shown in Figure 41.

Figure 41 Mine water make at Tahmoor Colliery



7 Catchment surface water flows

Cumulative flows are given in Figure 42 to Figure 49. There are no sites in the direct vicinity of the Lakes so data from a range of sites in the general area and in adjacent catchments is presented.

What all these plots show is that the flows in all sites for the period post about 1992 (except for a small period during 1998/99) have been below the average flow for the period of data shown. They are comparable to the monthly rainfall residual mass curves discussed in Section 5.5 that were used to explain groundwater level behaviour.

The cumulative discharge plots display a running total of the differences from the average value for the period being shown.

How does one interpret a CUSUM plot:

- Suppose that during a period of time the values are all above average. The amounts added to the cumulative sum will be positive and the sum will steadily increase. A segment of the cumulative discharge plot with an upward slope indicates a period where the values tend to be above average. Likewise a segment with a downward slope indicates a period of time where the values tend to be below the average.
- The closest gauging station is located at Little River (Figure 42), approximately 10 kilometres from Thirlmere Lakes. This plot exhibits the same overall decline in river flow that the other plots show.

Figure 42 Little River cumulative discharge plot

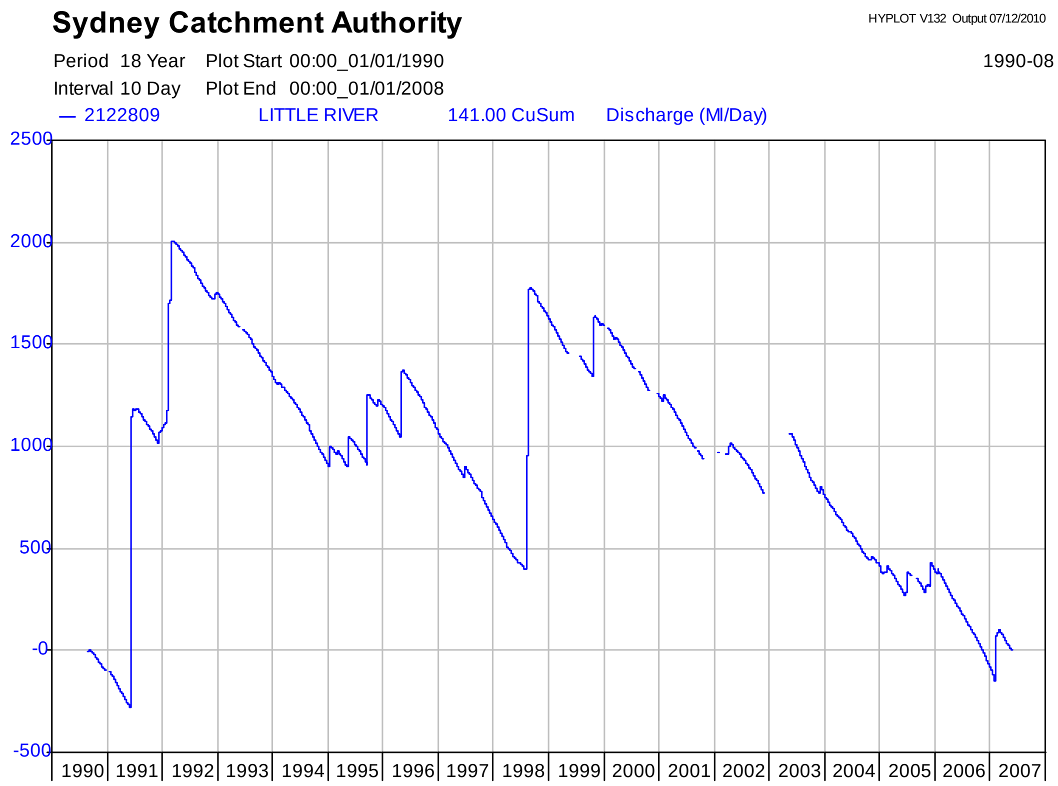


Figure 43 Nepean River (at Camden Weir) cumulative discharge plot

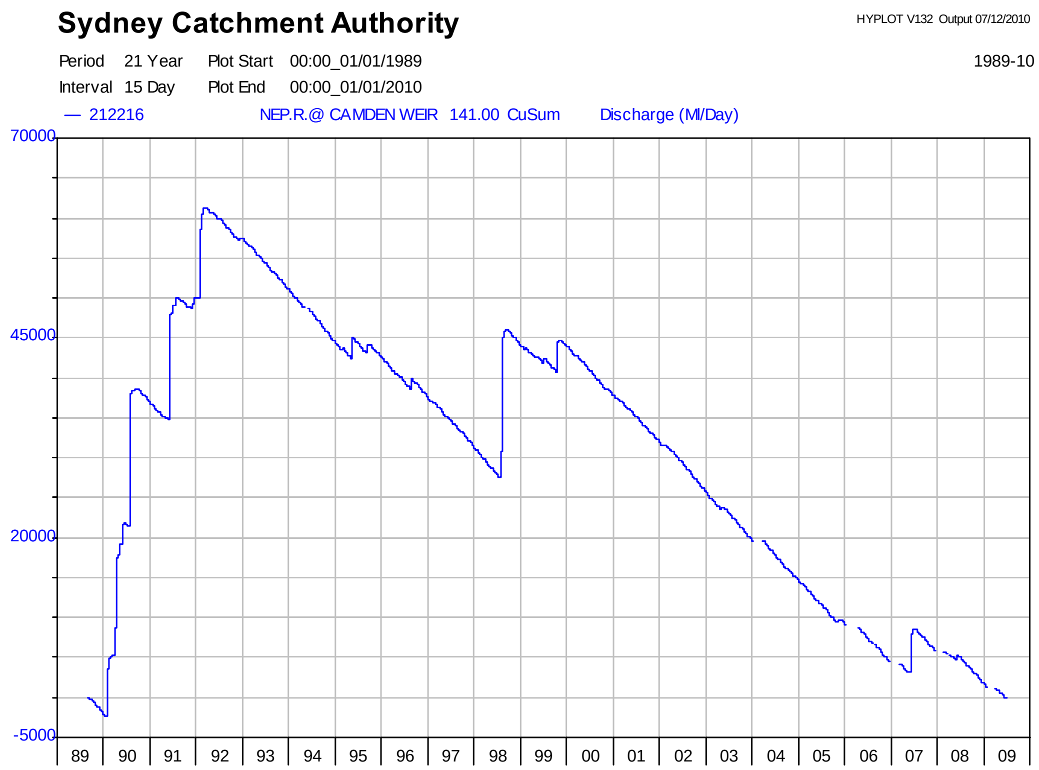


Figure 44 Nepean River (at Maldon Weir) cumulative discharge plot

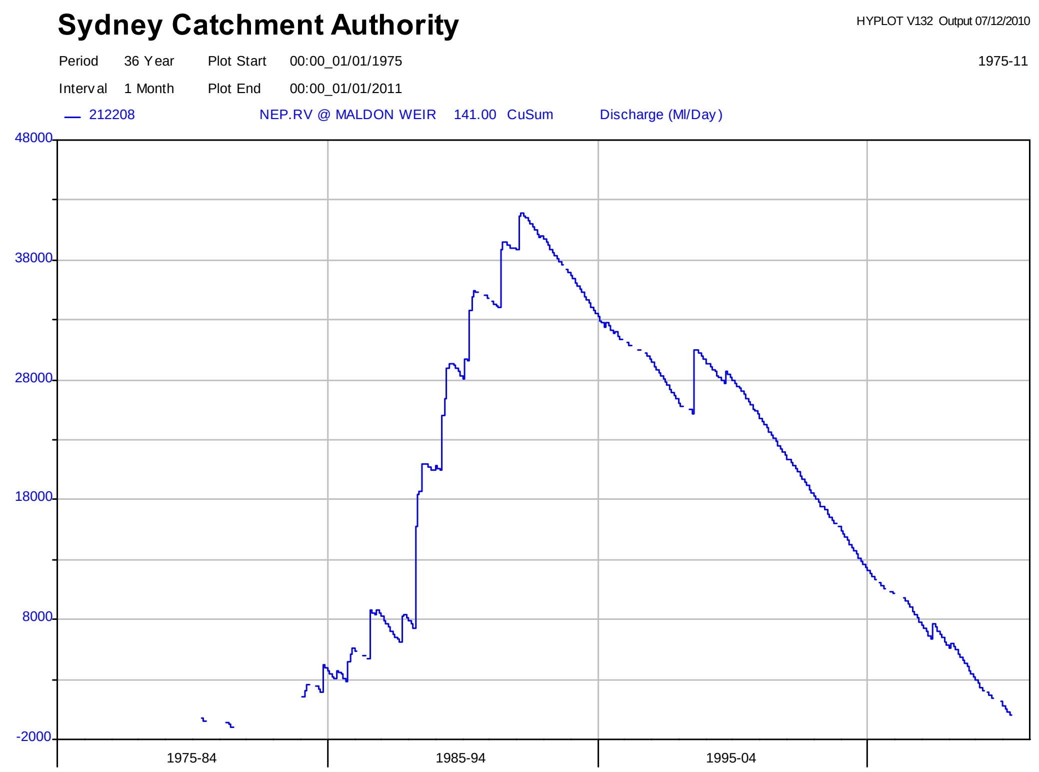


Figure 45 Nepean River (at Pheasants Nest) cumulative discharge plot

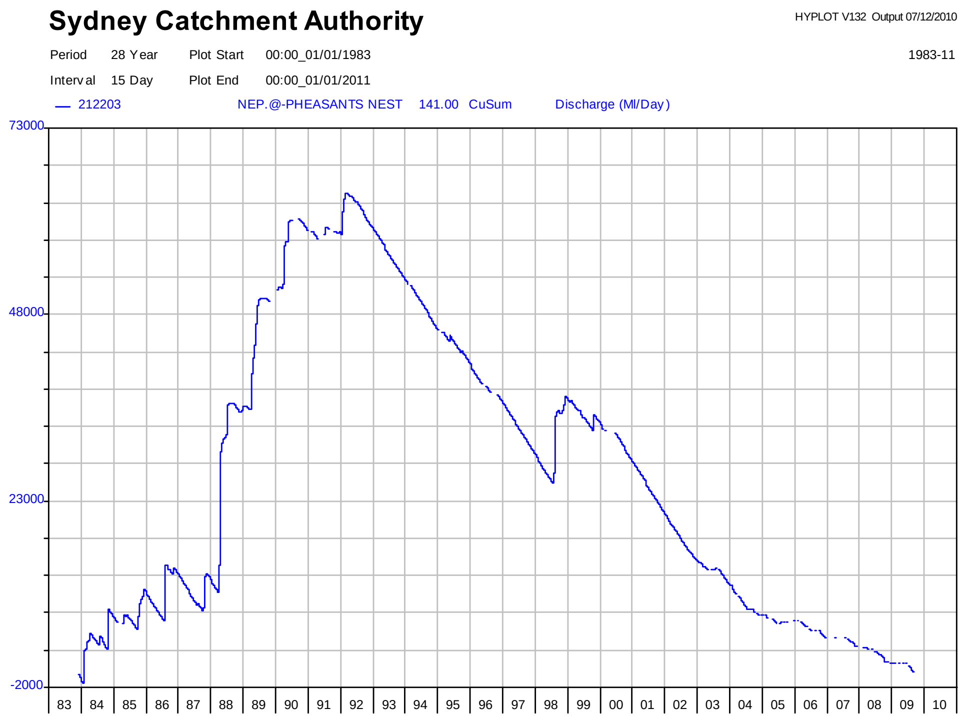


Figure 46 Nattai River (at the Causeway) cumulative discharge plot

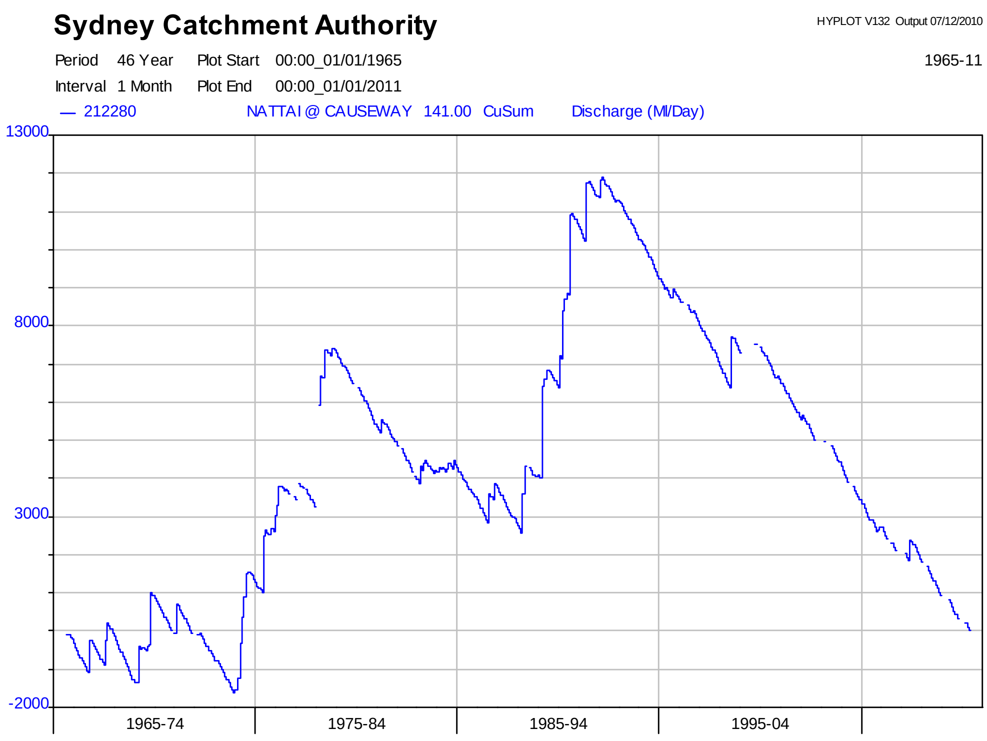


Figure 47 South Creek (at Mulgoa Road) cumulative discharge plot

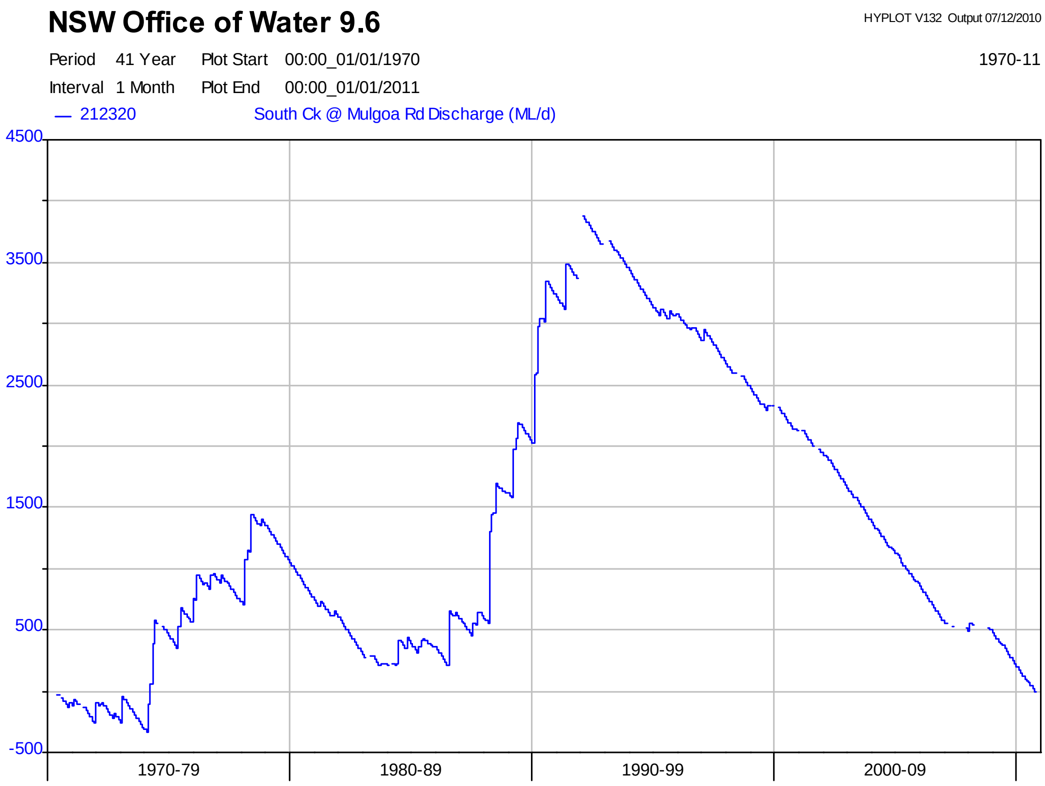


Figure 48 Macquarie Rivulet cumulative discharge plot

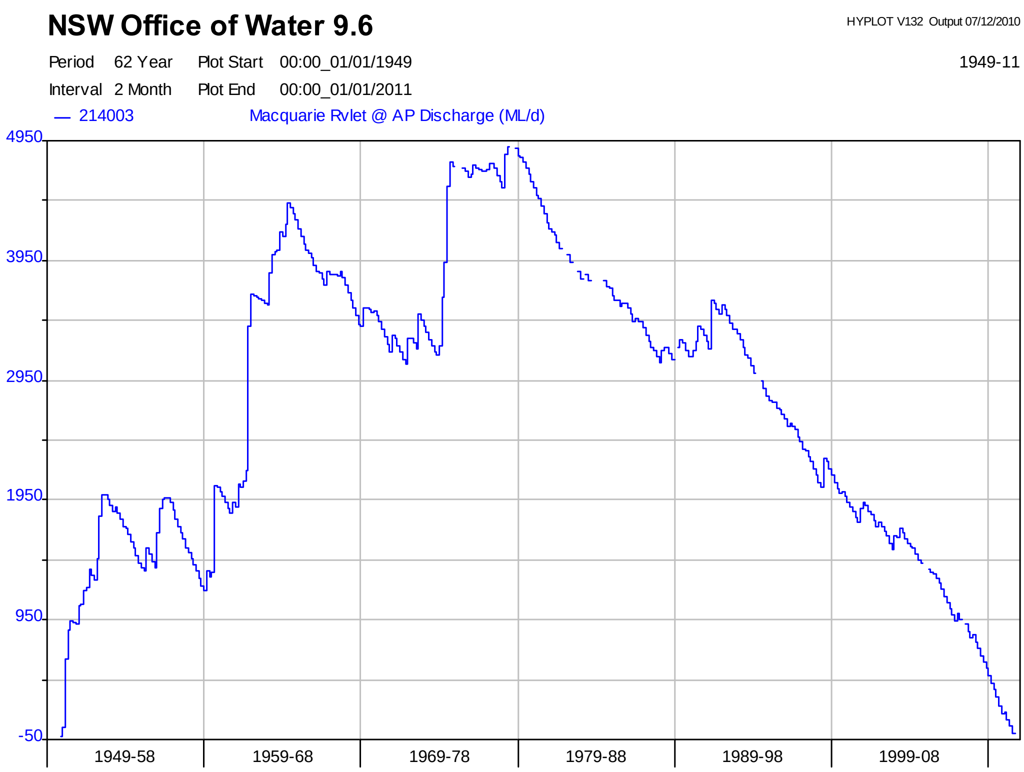
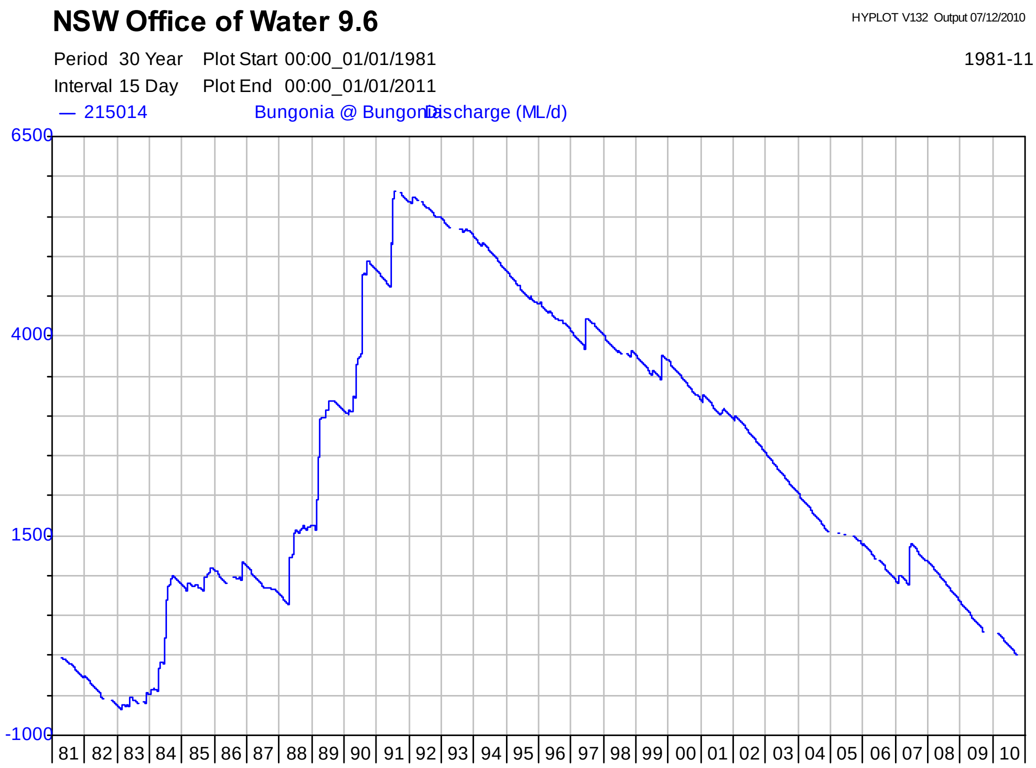


Figure 49 Bungonia Creek (at Bungonia) cumulative discharge plot



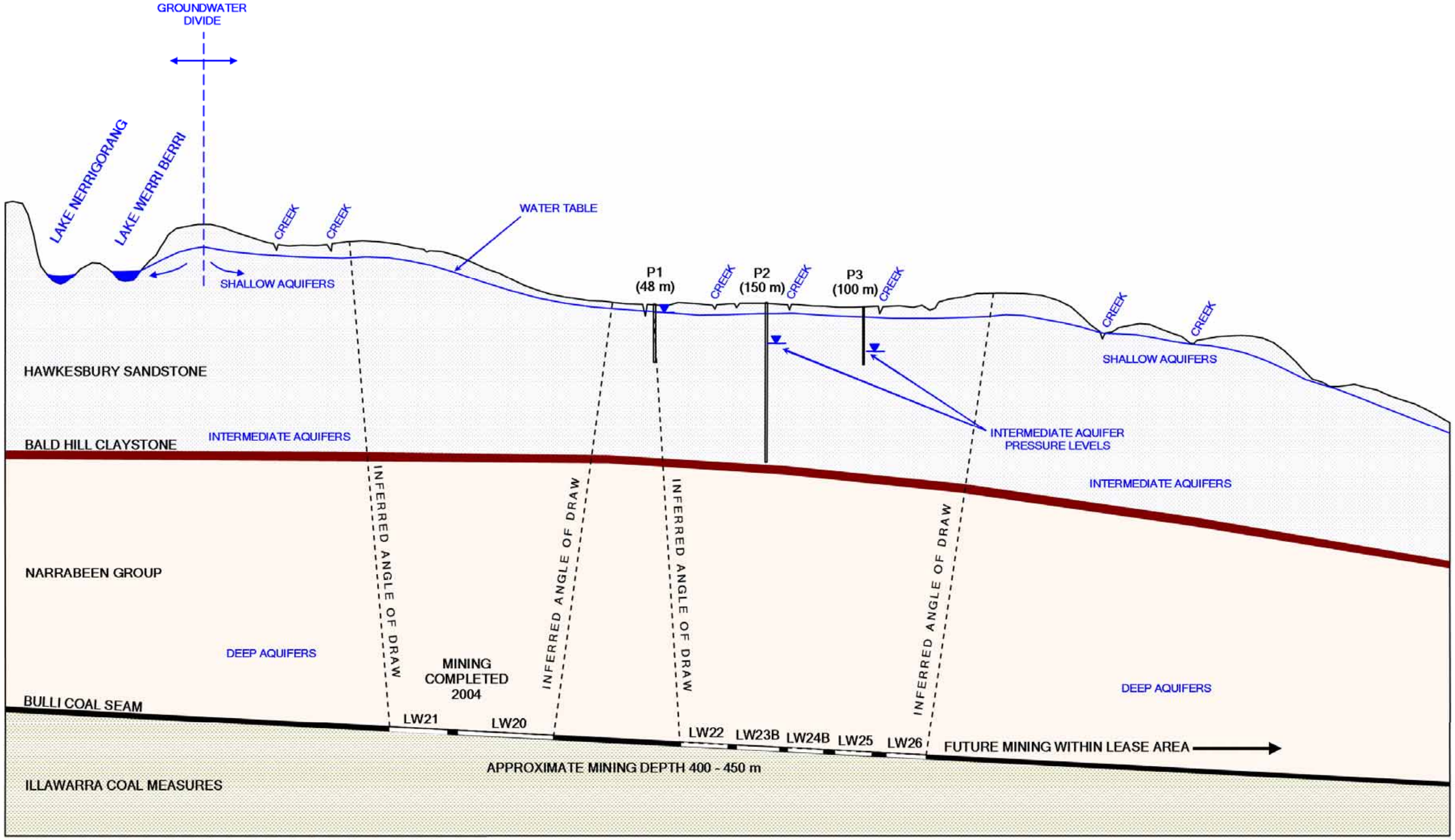
8 Discussion

As there is little or no baseline information available to review from the Lakes themselves, the accurate determination of the probable causes of the recent low Lake levels is made more difficult. In lieu of direct evidence that could inform any analysis, multiple lines of evidence have been considered to identify the probable cause of water level declines in the Lakes.

It is apparent from the consideration of surface water flows that the runoff within the Upper Hawkesbury-Nepean Catchment has been depleted for some time (refer Section 7). This suggests that the available surface water is reduced below long-term averages across the catchment as a whole and would have serious implications for the availability of water for the Lakes as well. Despite recent rain events, the longer term climate has been one of declining rainfall over at least the last decade. The cumulative lack of rainfall recharge to the lakes that has developed over time will not be counteracted by several short-term events. A more prolonged trend of increasing rainfall will be needed to re-establish soil moisture levels, runoff rates and storage volumes. The long term residual rainfall mass data illustrates this continuing decline since the 1990s (refer Section 5). The NSW Office of Water monitoring bores in the Southern Highlands show similar climate driven declines in groundwater level (refer Section 5). Groundwater levels have dropped some 2 to 4 m since 1998 in the intermediate depth aquifers.

Concern over subsidence issues from mining was examined in detail. In reference to the longwall mining (refer Section 6), groundwater level impacts have been observed above the mined panels. The longwall mining areas are shown on the regional conceptual groundwater regime (Figure 50). Most of the groundwater impacts have been observed above the mined areas. The lakes are shown to be outside the angle of incidence where most vertical and horizontal movement occurs. Also subsidence has been shown to be exacerbated beneath sites with medium to high topographic relief (Holla and Barclay 2000). This is not the situation at Thirlmere Lakes. As identified from mine plans supplied by Xstrata, the closest proximity of longwall extraction to the lakes was of the order of 660 m. This is more than double the distance within which mine-induced subsidence would be expected, and further reduces the likelihood that longwall extraction has impacted on the lakes. It is accepted that far field fracturing can occur outside of the angle of incidence but there was no evidence of such fracturing found in the field. If any fracturing caused by mining does exist in the sandstone below the Lakes it is expected to be minor in nature and not materially affect the groundwater flows into the Lakes in a measurable way.

Figure 50 Regional conceptual groundwater regime and mining (vertical exaggeration applied)



9 Conclusions

As a result of this investigation, there was no evidence to suggest that mine fracturing or subsidence has affected the water levels in Thirlmere Lakes in any substantial way. The most likely cause of the declines is the recent long term dry period where rainfall and runoff have been below average. Likewise the minor groundwater inflow into the Lakes from the underling sandstones would have been reduced as a result of lower groundwater levels. These groundwater levels are low mostly because of the lack of recharge in recent years. Mining impacts, if they occur at all on the Lakes, are unlikely to be measurable because of the dominance of other processes. The NSW Office of Water can only conclude that the drier than normal weather is impacting on surface water flows as well as groundwater levels, and it is these factors separately, or in combination, that have resulted in the reported decline in lake levels.

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Appendix A – Groundwater works summary data

Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW008537				1947	65.5							Open hole	
GW008548				1947	65.5							Open hole	
GW010496				1954	40.7		0.76			268.8			
GW010584				1954	50.0		0.99	'501-1000'		282.5 267.3	0.13 0.99		Sandstone with minor shale
GW010654				1954	39.6		0.63	'0-500'		290.5 279.8 269.7	 0.63	Open hole	
GW011200	10BL602381 (ACTIVE)	DOMESTIC FARMING STOCK	3.0	2008	61.0	30	3.0	130	283	243	3.0	Open hole	Sandstone
GW011234	10BL004280 (CANCELLED)	DOMESTIC POULTRY STOCK IRRIGATION		1955	52.4		1.14	'501-1000'		270.4 262.0 253.3	0.04 0.25 1.14	Cased hole	Sandstone
GW011299	10BL004419 (CANCELLED)	STOCK DOMESTIC IRRIGATION		1955	61.0		0.76	'501-1000'		289.8	0.76	Open hole	Sandstone with minor shale
GW012611	10BL005514 (CANCELLED)	DOMESTIC IRRIGATION STOCK		1945	50.2		0.11					Open hole	
GW012612	10BL005324 (CANCELLED)	IRRIGATION DOMESTIC STOCK			57.9		0.11					Open hole	
GW013282	10BL006233 (CANCELLED)	NOT KNOWN			18.3								
GW018568	10BL012007 (ACTIVE)	DOMESTIC STOCK		1961	63.4		1.14	'0-500'		294.2 287.8 280.2	0.0 0.32 1.14	Open hole	Sandstone

Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW022245	10BL014739 (ACTIVE)	DOMESTIC STOCK		1943	146.3		0.25			251.1	0.25	Open hole	Sandstone and shale
GW024623	10BL019186 (CANCELLED)	POULTRY		1950	91.4		0.04			408.8	0.04	Open hole	
GW028859	10BL023205 (ACTIVE)	DOMESTIC	1.0	1968	45.7		1.14			299.2	1.14	Open hole	Sandstone
GW029143	10BL023286 (ACTIVE)	DOMESTIC INDUSTRIAL	6.0	1968	73.2		0.76			291.8 278.7 269.8	0.30 0.45 0.76	Open hole	Sandstone with minor shale
GW031294	10BL023035 (CANCELLED)	IRRIGATION STOCK		1969	90.2		1.52			253.9 234.1 232.9	0.06 0.25 1.52	Open hole	Sandstone with minor shale
GW032443	10BL023692 (CANCELLED)	DOMESTIC IRRIGATION		1966	130.1		1.26	'Good'		296.6 283.8 249.1 242.4 222.9 212.2	0.04 0.91 1.26	Open hole	Sandstone with minor shale
GW033916	10BL026503 (ACTIVE)	WASTE DISPOSAL		1971	108.2		0.08			346.8	0.08	Open hole	Sandstone with minor shale
GW034518	10BL139545 (ACTIVE)	DOMESTIC STOCK		1970	76.2		0.5			292.6 259.3	0.06 0.47	Open hole	Sandstone
GW034687	10BL027100 (CANCELLED)	NOT KNOWN			6.0							Well	
GW035753	10BL106242 (CANCELLED)	STOCK DOMESTIC IRRIGATION		1972	142.0		3.16			268.2 227.3 208.4 205.4 187.0 161.0	0.51 0.76 1.52 3.16	Open hole	Sandstone with minor shale
GW037289	10BL030565 (CANCELLED)	IRRIGATION DOMESTIC STOCK		1973	137.2		4.55			283.2 248.4 220.7 188.4	0.04 0.51 1.26 4.55	Open hole	Sandstone

Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW037742	10BL030327 (SUSPENDED)	IRRIGATION		1972	112.8		1.52			287.7 235.9	0.25 1.52	Open hole	Sandstone with minor shale
GW037860	10BL102484 (ACTIVE)	DOMESTIC STOCK		1969	137.1		2.27			276.0 262.6 226.7 203.5 182.2	0.13 0.38 0.63 2.27	Open hole	Sandstone with minor shale
GW037932	10BL030210 (ACTIVE)	IRRIGATION STOCK		1972	95.10		0.53			331.0 292.6	0.10 0.53	Open hole	Sandstone with minor shale
GW038060	10BL030824 (LAPSED)	IRRIGATION		1974	122.5		3.03			288.3 233.1	0.25 3.03	Open hole	Sandstone with minor shale
GW038074	10BL029771 (CANCELLED)	TEST BORE			60.9			'Salty'					
GW042537	10BL142370 (ACTIVE)	DOMESTIC STOCK		1975	121.9		2.3			289.6 230.4	0.15 2.27	Open hole	Sandstone with minor shale
GW042825	10BL133647 (ACTIVE)	DOMESTIC STOCK		1976	114.6		0.13			338.2 316.5 272.3		Open hole	Sandstone with minor shale
GW043154	10BL100445 (ACTIVE)	DOMESTIC		1968	48.8		2.27			282.2		Open hole	Sandstone
GW047416	10BL159306 (ACTIVE)	DOMESTIC STOCK	2.0	1979	64.0	24	0.8	'Good'	307	293.0 272.0	0.80 0.70	Open hole	Sandstone
GW049796	10BL107520 (ACTIVE)	DOMESTIC STOCK FARMING		1980	61.0		0.8	'Good'		290.4	0.80	Open hole	Sandstone with minor shale
GW053449	10BL133741 (ACTIVE)	DOMESTIC STOCK		1981	105.0		1.3	'Fresh'		224.9 195.0	0.20 1.30	Open hole	Sandstone with minor shale
GW057274	10BL124173 (ACTIVE)	STOCK		1982	115.0								
GW059311	10BL138212 (ACTIVE)	DOMESTIC		1982	51.8		0.56	'0-500'		289.0 261.2	0.06 0.56	Open hole	Sandstone
GW060205	10BL132681 (ACTIVE)	IRRIGATION		1985	50.0		1.0	'Fresh'		270.1 255.7	0.60 1.00	Open hole	Sandstone

Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW060238	10BL600598 (ACTIVE)	DOMESTIC STOCK	2.0	2004	48.0		1.7	30		312.0	1.70	Cased hole	Sandstone
GW062068	10BL603188 (ACTIVE)	DOMESTIC STOCK	2.0	1986	150.0			'1001-3000'				Open hole	Sandstone and shale
GW070245				1992	97.5		1.9	'0-500'		212.3 197.5 195.0	0.45 0.60 1.90	Open hole	
GW070979					48.0	10	1.7		302	284.0 282.0 272.0	0.20 0.10 1.70	Open hole	
GW072432	10BL156205 (ACTIVE)	DOMESTIC		1994	76.0		1.9	10		244.0 242.0 240.0	0.60 1.10 1.90	Open hole	Sandstone
GW073018				1992	53.3		2.1	'Good'		234.0	2.10	Open hole	Sandstone
GW073406				1952	63.0		0.68						
GW101026	10BL157002 (CANCELLED)	DOMESTIC	3.0	1992	45.7		0.80	200		216.0	0.80	Open hole	Sandstone
GW010247	10BL158315 (ACTIVE)	DOMESTIC STOCK	2.0	1998	42.0		1.1	94		278.5	1.10	Open hole	Sandstone with minor shale
GW102344	10BL158620 (ACTIVE)	IRRIGATION	19.0	1998	110.0	29	2.1	500	241	230.0 209.0 172.0	0.20 0.50 2.10	Cased hole	Sandstone with minor shale
GW102390	10BL159030 (ACTIVE)	DOMESTIC STOCK	2.0	1999	114.5		3.0	156		270.5 251.0 230.5 229.0	0.80 0.50 0.40 3.00	Open hole	Sandstone with minor shale
GW102439	10BL159262 (ACTIVE)	DOMESTIC STOCK	2.0	1998	115.0	72	0.8	200	267	267.0 245.0 236.0	0.13 0.20 0.50	Cased hole	Sandstone with minor shale
GW102483	10BL156727 (ACTIVE)	MONITORING BORE		1995	21.6								
GW102630	10BL159385 (ACTIVE)	DOMESTIC	1.0	1999	43.0		2.0	30		287	2.0	Cased hole	Sandstone

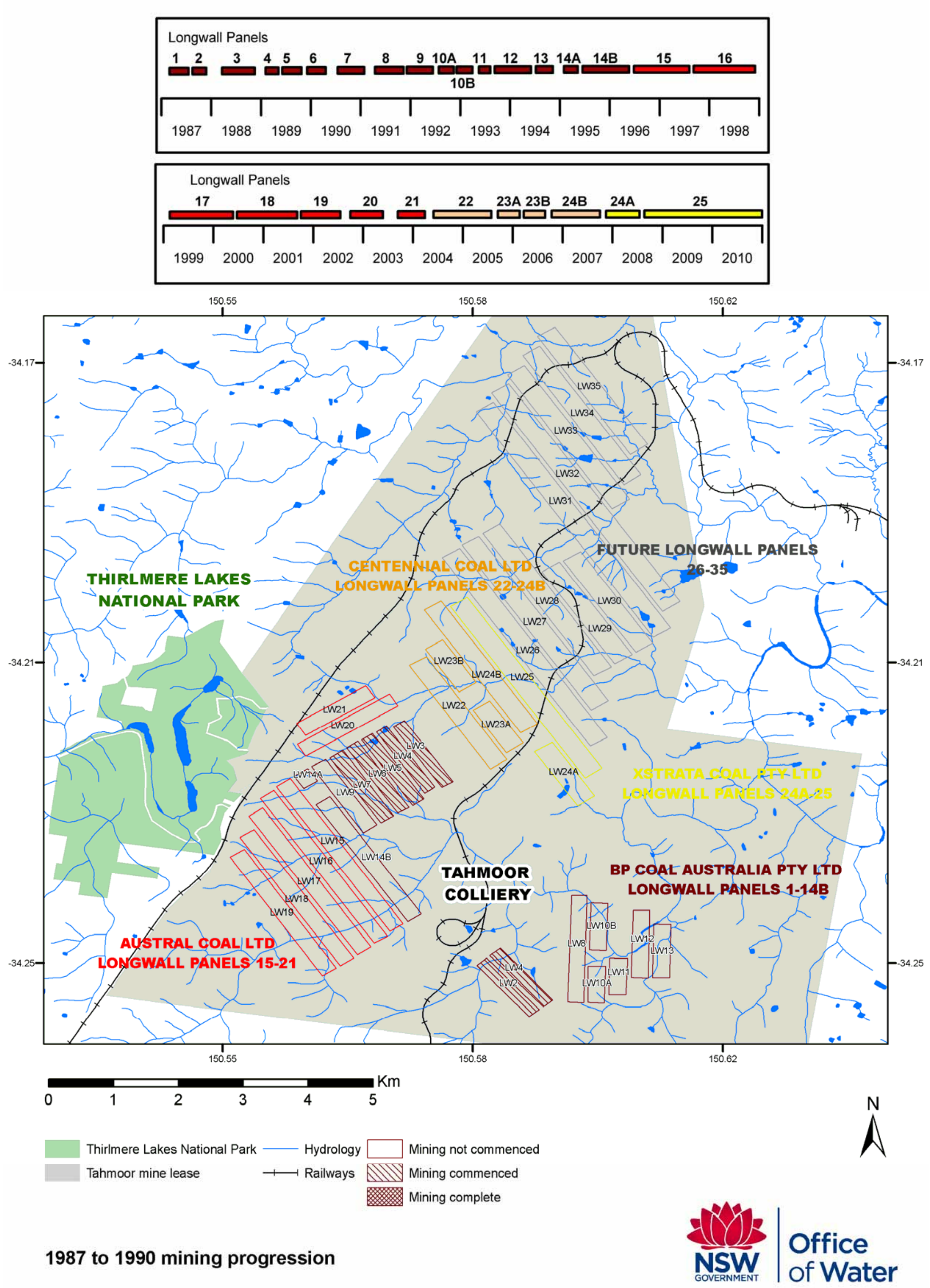
Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW104077	10BL160370 (ACTIVE)	DOMESTIC STOCK	2.0	2001	48.0		0.4	70		279.0 270.0 268.0	0.10 0.20 0.41	Cased hole	Sandstone
GW104659	10BL163397 (ACTIVE)	RECREATION	25.0	2003	132.0	51	1.0	450	240	214.5 198.5 193.0 181.5	0.60 1.00 0.60 0.80	Open hole	Sandstone with minor shale
GW104720	10BL161464 (ACTIVE)	DOMESTIC STOCK	2.0	2003	91.0	54	1.7	110	278	274.0 252.0	0.30 1.70	Open hole	Sandstone
GW105145	10BL157150 (ACTIVE)	DOMESTIC STOCK	8.0	1952	67.0	45			256			Open hole	
GW105148	10BL157090 (ACTIVE)	DOMESTIC STOCK	8.0	1995	120.0	33	0.6	500	242	224.4 191.5 163.7 158.7	0.60 0.40 0.50 0.30	Open hole	Sandstone with minor siltstone
GW105236	10BL160397 (ACTIVE)	DOMESTIC STOCK	2.0	2001	73.0	14	2.2	'Good'	292	264.0 242.0 236.0	0.35 1.00 2.20	Open hole	Sandstone
GW105246	10BL162110 (ACTIVE)	DOMESTIC STOCK	1.0	2003	120.0	71	0.2	203	254	276.5 236.0 225.5 215.0	0.15 0.45 0.20 0.20	Open hole	Sandstone with minor shale
GW105254	10BL162211 (ACTIVE)	DOMESTIC STOCK	2.0	2003	163.0	80	0.7	169	210	177.0 165.0 159.0 141.0 135.0	0.30 0.20 0.33 0.67 0.50	Open hole	Sandstone with minor shale
GW106281	10BL163582 (ACTIVE)	MONITORING BORE		2004	48.0	11	0.25		277	276.0 270.0	0.05 0.25	Open hole	Sandstone
GW107525	10BL165563 (ACTIVE)	IRRIGATION DOMESTIC	3.0	1950	145.0		0.5					Open hole	
GW107918	10BL164820 (ACTIVE)	DOMESTIC STOCK	2.0	2005	60.0	20	2.2	'Fair'	211	191.0	2.20	Cased hole	Sandstone

Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW108981	10BL602105 (ACTIVE)	RECREATION	17.0	2008	175.0	48	0.8	180	243	262.0 213.0 184.0 166.0 156.0 142.0 136.0	 0.25 0.75 0.25 0.28 0.28 0.50	Open hole	Sandstone with minor shale
GW109010	10BL601785 (ACTIVE)	DOMESTIC STOCK	2.0	2008	169.0	89	0.8	0.69	197				
GW109032	10BL109032 (ACTIVE)	DOMESTIC	1.0	2008	132.0	20	0.8	140	404				
GW109153	10BL164630 (ACTIVE)	DOMESTIC STOCK	1.0	2008	60.0								
GW109203	10BL602318 (ACTIVE)	IRRIGATION DOMESTIC	10.0	2008	91.0	30	1.6	0.23	285	279.0 249.0 237.0 231.0	 1.60 0.40 0.20	Cased hole	Sandstone with minor shale
GW109224	10BL164076 (ACTIVE)	DOMESTIC STOCK	2.0	2008	132.0	60	1.0		189				
GW109630	10BL602627 (ACTIVE)	IRRIGATION	4.0	2007	102.0	30	1.0	'Fresh'	269	257.0 221.0 209.0	0.22 1.00 1.00	Open hole	Sandstone
GW110435	10BL602501 (ACTIVE)	MONITORING BORE		2008	100.0	55	0.8	1000	200	160.0		Cased hole	Sandstone with minor mudstone
GW110436	10BL602502 (ACTIVE)	MONITORING BORE		2008	105.0	85	0.1	822	173	168.0	0.10	Cased hole	Sandstone
GW110523	10BL600965 (ACTIVE)	DOMESTIC STOCK	2.0	2009	85.0		1.8	0.27		300.0 272.0 258.0 252.0 246.0 240.0 234.0 232.0	0.20 0.25 0.31 0.41 0.25 0.24 0.56 1.78	Cased hole	Sandstone

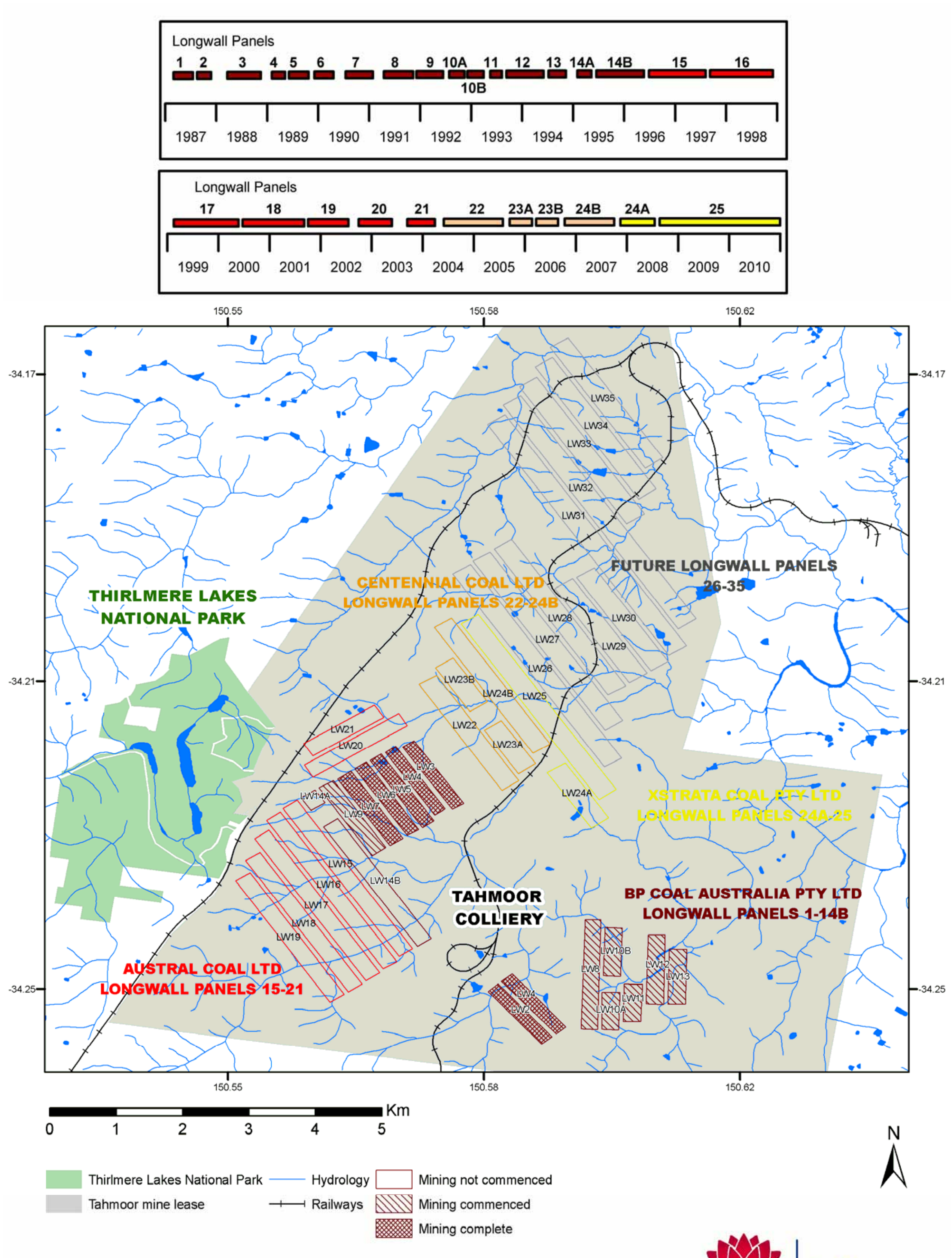
Bore ID	Licence	Purpose	Entitlement	Date	Depth (m)	SWL (m)	Yield (L/s)	Salinity (mg/L)	SWL (m AHD)	Water bearing zones (m AHD)	WBZ yields (L/s)	Construction	Lithology
GW110669	10BL603394 (ACTIVE)	DOMESTIC STOCK	2.0	2010	132.0	66	0.6	300	275	233.0 227.0 221.0	0.15 0.45 0.60	Open hole	Sandstone with minor shale
GW111044	10BL602333 (ACTIVE)	DEWATERING	547.3	2010	420.0							Mine shaft	
GW111045	10BL602337 (ACTIVE)	DEWATERING	547.3	2010	420.0							Mine shaft	
GW111046	10BL602336 (ACTIVE)	DEWATERING	547.3	2010	420.0							Mine shaft	
GW111047	10BL600332 (ACTIVE)	DOMESTIC STOCK	2.0	2006	120.0							Open hole	Sandstone

Note: Licences 10BL602333, 10BL602337 and 10BL602336 have a conjunctive entitlement of 1,642 ML/annum for mine dewatering at Tahmoor Colliery

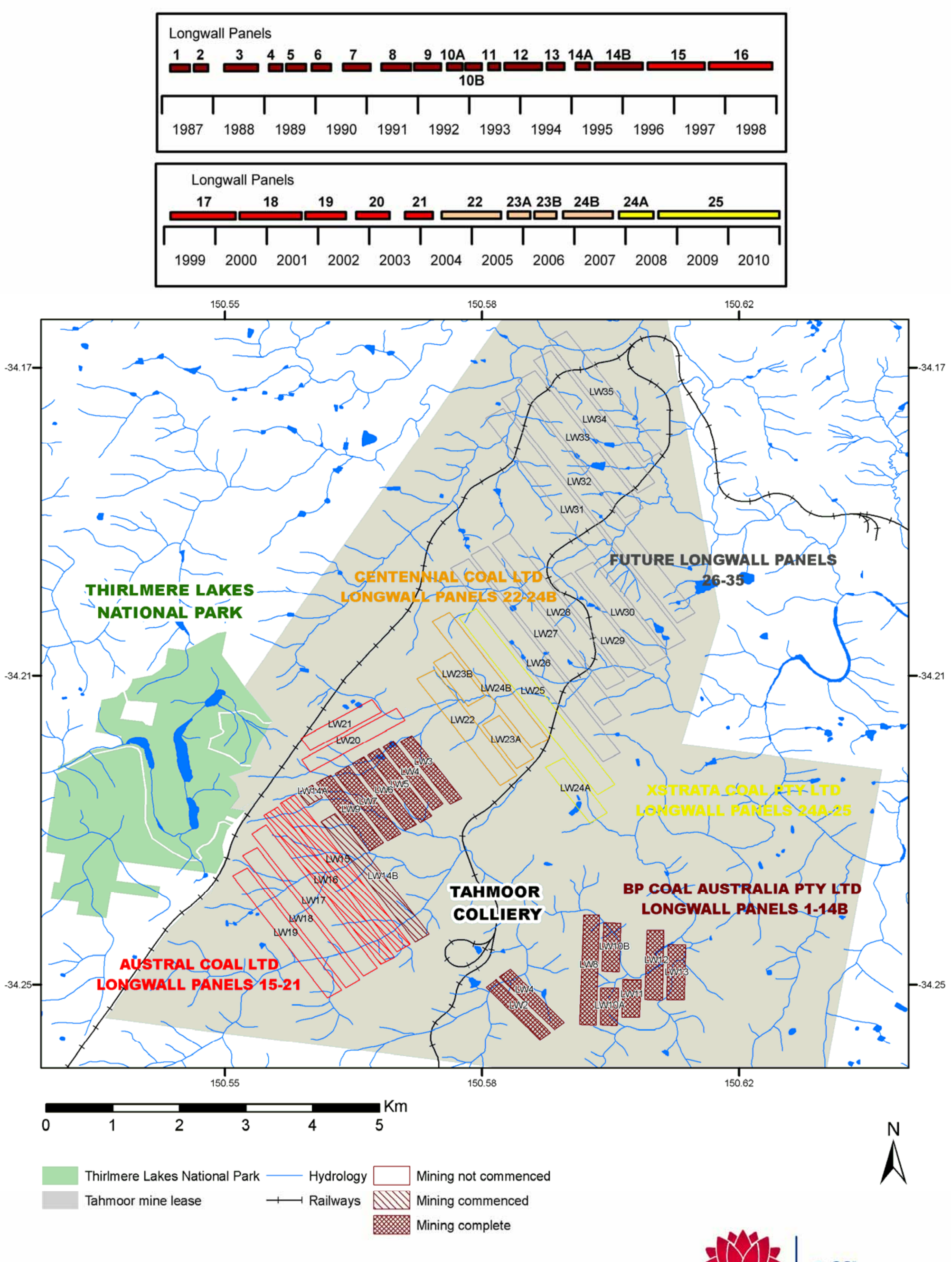
Appendix B – Longwall mining progression



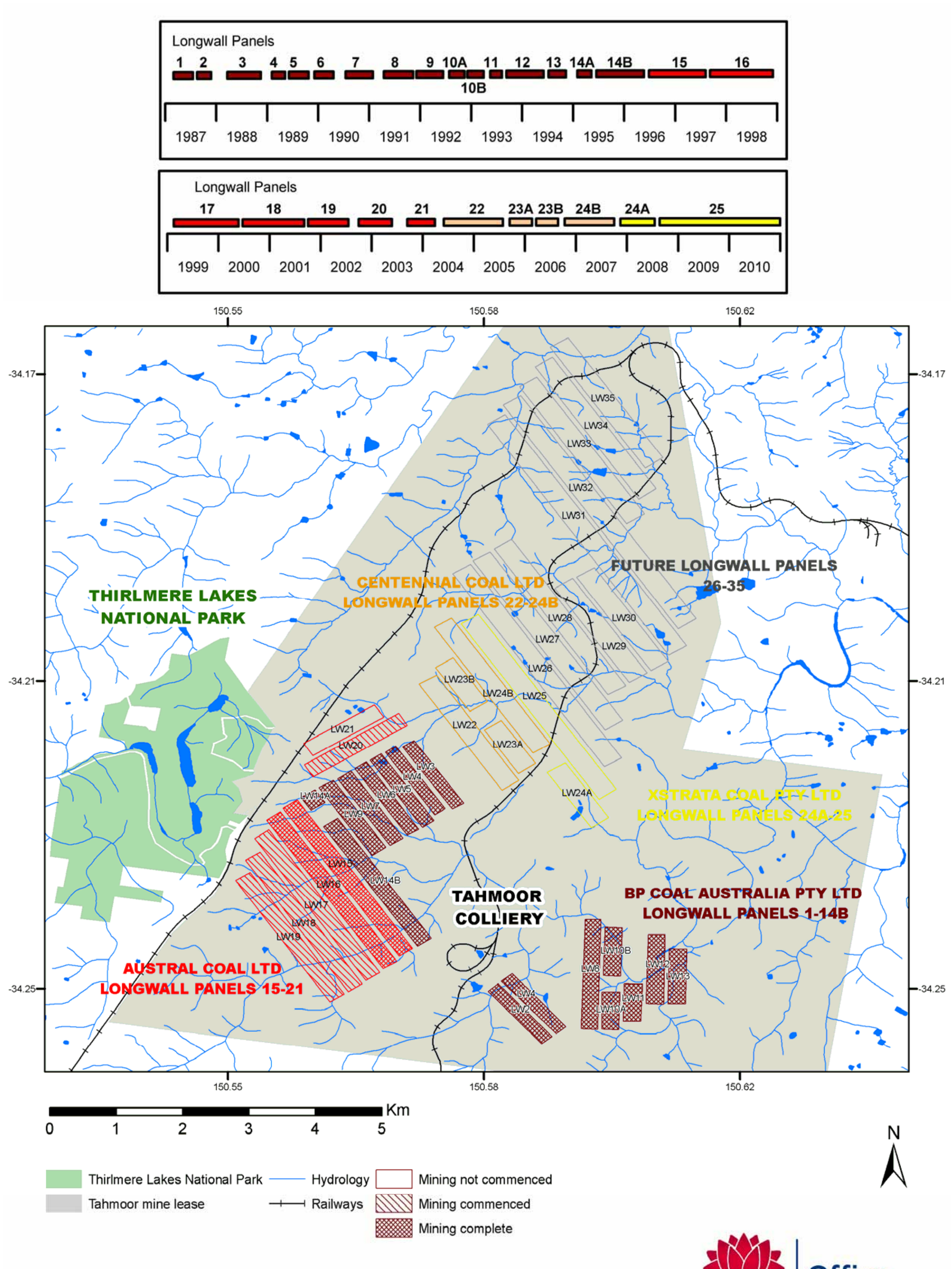
1987 to 1990 mining progression



1991 to 1994 mining progression

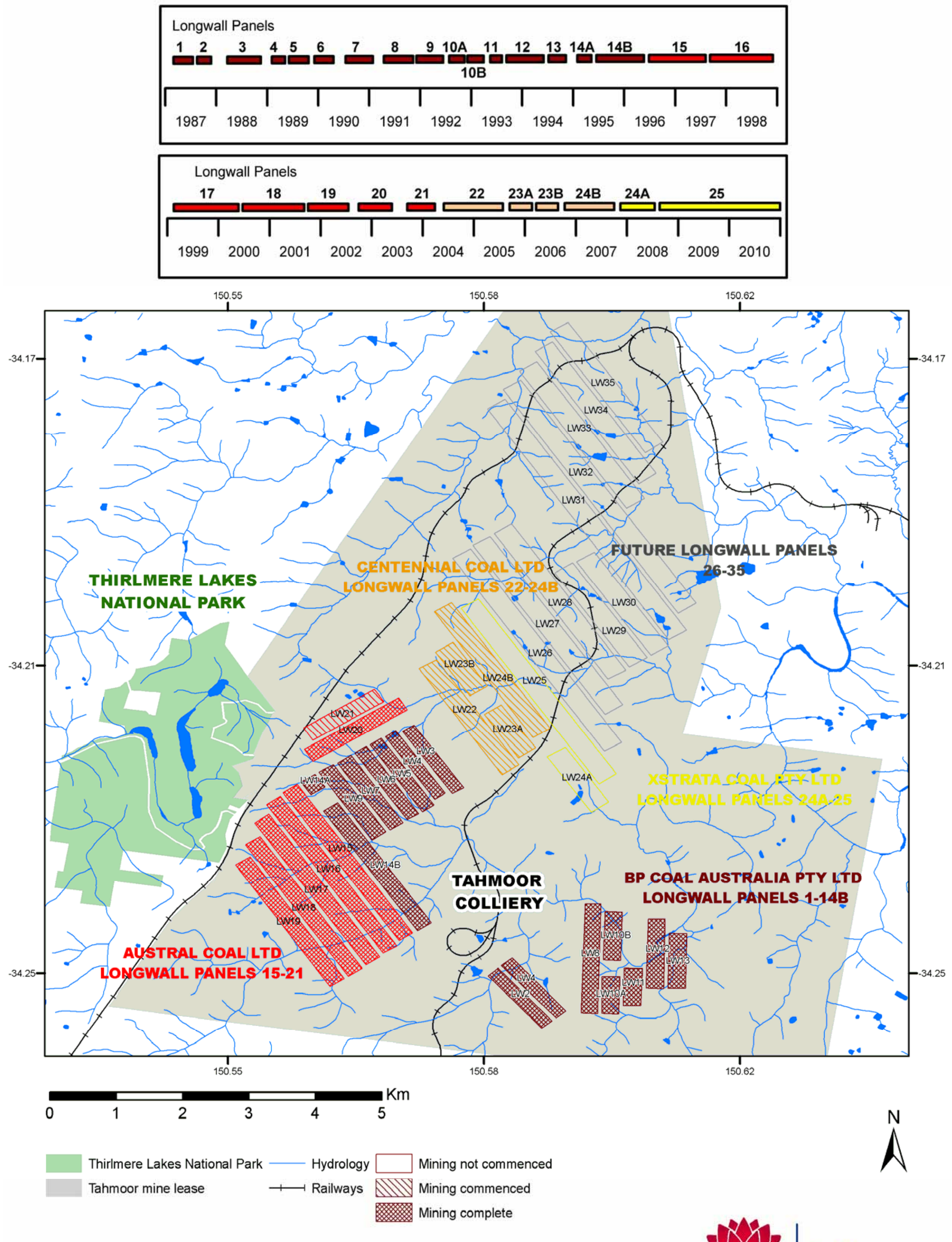


1995 to 1998 mining progression

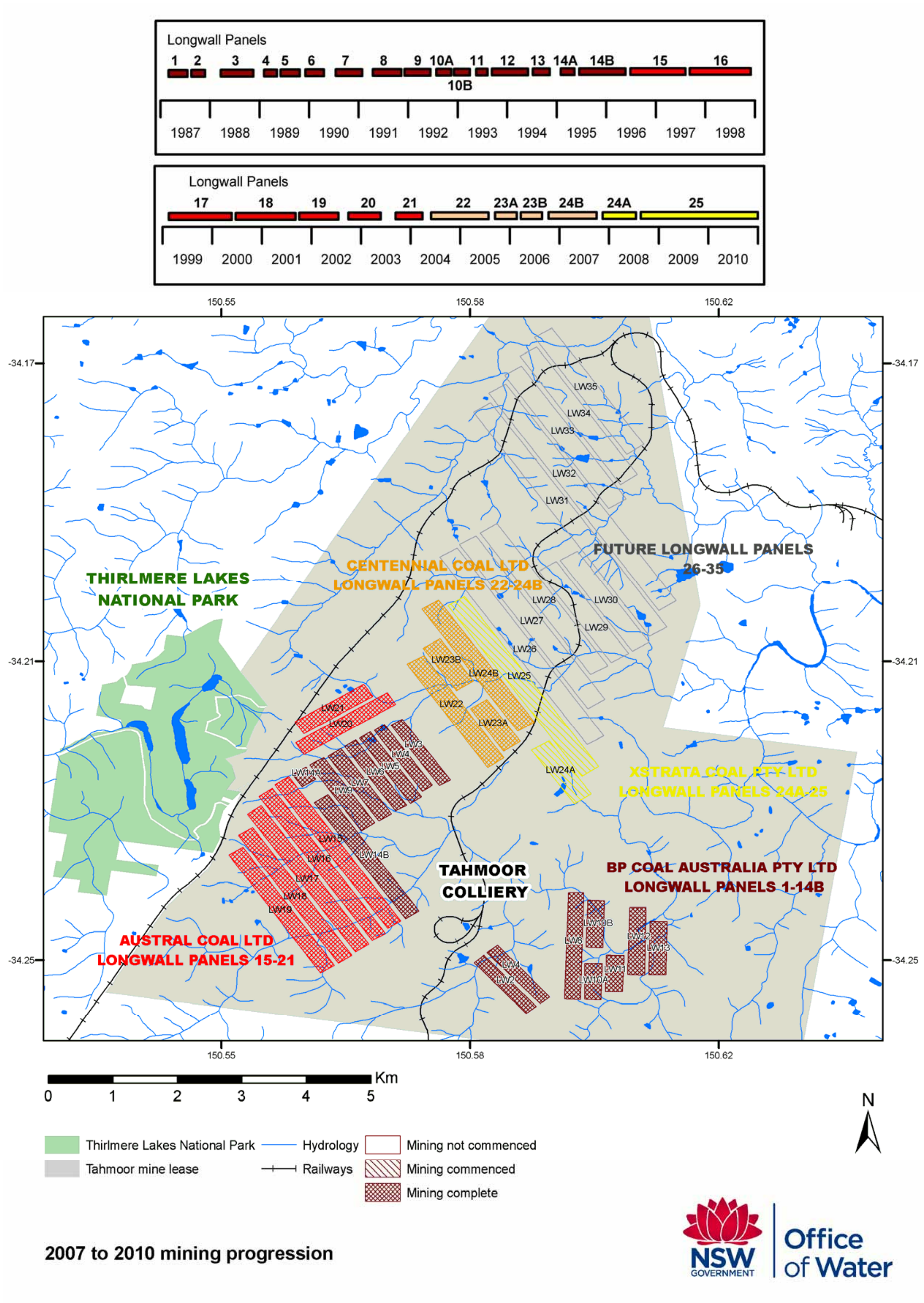


1999 to 2002 mining progression

NSW GOVERNMENT Office of Water



2003 to 2006 mining progression



Longwall Panels
1 2 3 4 5 6 7 8 9 10A 11 12 13 14A 14B 15 16
10B
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
Longwall Panels
17 18 19 20 21 22 23A 23B 24B 24A 25
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
150.55
150.58
150.62
-34.17
-34.21
-34.25
THIRLMERE LAKES NATIONAL PARK
CENTENNIAL COAL LTD LONGWALL PANELS 22-24B
FUTURE LONGWALL PANELS 26-35
XSTRATA COAL PTY LTD LONGWALL PANELS 24A-25
TAHMOOR COLLIERY
BP COAL AUSTRALIA PTY LTD LONGWALL PANELS 1-14B
AUSTRAL COAL LTD LONGWALL PANELS 15-21
LW35
LW34
LW33
LW32
LW31
LW30
LW29
LW28
LW27
LW26
LW25
LW24B
LW23B
LW23A
LW22
LW24A
LW21
LW20
LW19
LW18
LW17
LW16
LW15
LW14B
LW14A
LW10B
LW10A
LW13
LW12
LW11
LW8
LW4
LW2
Km
0 1 2 3 4 5
N
Thirlmere Lakes National Park
Tahmoor mine lease
Hydrology
Railways
Mining not commenced
Mining commenced
Mining complete
2007 to 2010 mining progression
NSW GOVERNMENT
Office of Water