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Related information

- Alteration of habitat following subsidence due to longwall mining as a key threatening process - fact sheet

Alteration of habitat following subsidence due to longwall mining - key threatening process declaration

NSW Scientific Committee - final determination

The Scientific Committee, established by the Threatened Species Conservation Act, has made a Final Determination to list Alteration of habitat following subsidence due to longwall mining as a KEY THREATENING PROCESS in Schedule 3 of the Act. Listing of key threatening processes is provided for by Part 2 of the Act.

The Scientific Committee has found that:

1. Longwall mining occurs in the Northern, Southern and Western Coalfields of NSW. The Northern Coalfields are centred on the Newcastle-Hunter region. The Southern Coalfield lies principally beneath the Woronora, Nepean and Georges River catchments approximately 80-120 km SSW of Sydney. Coalmines in the Western Coalfield occur along the western margin of the Sydney Basin. Virtually all coal mining in the Southern and Western Coalfields is underground mining.

2. Longwall mining involves removing a panel of coal by working a face of up to 300 m in width and up to two km long. Longwall panels are laid side by side with coal pillars, referred to as "chain pillars" separating the adjacent panels. Chain pillars generally vary in width from 20-50 m wide (Holla and Barclay 2000). The roof of the working face is temporarily held up by supports that are repositioned as the mine face advances (Karaman *et al.* 2001). The roof immediately above the coal seam then collapses into the void (also known as the goaf) and a collapse zone is formed above the extracted area. This zone is highly fractured and permeable and normally extends above the seam to a height of five times the extracted seam thickness (typical extracted seam thickness is approximately 2-3.5 m) (ACARP 2002). Above the collapse zone is a fractured zone where the permeability is increased to a lesser extent than in the collapse zone. The fractured zone extends to a height above the seam of approximately 20 times the seam thickness, though in weaker strata this can be as high as 30 times the seam thickness (ACARP 2002). Above this level, the surface strata will crack as a result of bending strains, with the cracks varying in size according to the level of strain, thickness of the overlying rock stratum and frequency of natural joints or planes of weakness in the strata

(Holla and Barclay 2000).

3. The principal surface impact of underground coal mining is subsidence (lowering of the surface above areas that are mined) (Booth *et al.* 1998, Holla and Barclay 2000). The total subsidence of a surface point consists of two components, active and residual. Active subsidence, which forms 90 to 95% of the total subsidence in most cases, follows the advance of the working face and usually occurs immediately. Residual subsidence is time-dependent and is due to readjustment and compaction within the goaf (Holla and Barclay 2000). Trough-shaped subsidence profiles associated with longwall mining develop tilt between adjacent points that have subsided different amounts. Maximum ground tilts are developed above the edges of the area of extraction and may be cumulative if more than one seam is worked up to a common boundary. The surface area affected by ground movement is greater than the area worked in the seam (Bell *et al.* 2000). In the NSW Southern Coalfield, horizontal displacements can extend for more than one kilometre from mine workings (and in extreme cases in excess of three km) (ACARP 2002, 2003), although at these distances, the horizontal movements have little associated tilt or strain. Subsidence at a surface point is due not only to mining in the panel directly below the point, but also to mining in the adjacent panels. It is not uncommon for mining in each panel to take a year or so and therefore a point on the surface may continue to experience residual subsidence for several years (Holla and Barclay 2000).

4. The degree of subsidence resulting from a particular mining activity depends on a number of site specific factors. Factors that affect subsidence include the design of the mine, the thickness of the coal seam being extracted, the width of the chain pillars, the ratio of the depth of overburden to the longwall panel width and the nature of the overlying strata; sandstones are known to subside less than other substrates such as shales. Subsidence is also dependent on topography, being more evident in hilly terrain than in flat or gently undulating areas (Elsworth and Liu 1995, Holla 1997, Holla and Barclay 2000, ACARP 2001). The extent and width of surface cracking over and within the vicinity of the mined goaf will also decrease with an increased depth of mining (Elsworth and Liu 1995).

5. Longwall mining can accelerate the natural process of 'valley bulging' (ACARP 2001, 2002). This phenomenon is indicated by an irregular upward spike in an otherwise smooth subsidence profile, generally co-inciding with the base of the valley. The spike represents a reduced amount of subsidence, known as 'upsidence', in the base and sides of the valley and is generally coupled with the horizontal closure of the valley sides (ACARP 2001, 2002). In most cases, the upsidence effects extend outside the valley and include the immediate cliff lines and ground beyond them (ACARP 2002).

6. Mining subsidence is frequently associated with cracking of valley floors and creeklines and with subsequent effects on surface and groundwater hydrology (Booth *et al.* 1998, Holla and Barclay 2000, ACARP 2001, 2002, 2003). Subsidence-induced cracks occurring beneath a stream or other surface water body may result in the loss of water to near-surface groundwater flows. If the water body is located in an area where the coal seam is less than approximately 100-120 m below the surface, longwall mining can cause the water body to lose flow permanently. If the coal seam is deeper than approximately 150 m, the water loss

may be temporary unless the area is affected by severe geological disturbances such as strong faulting. In the majority of cases, surface waters lost to the sub-surface re-emerge downstream. The ability of the water body to recover is dependent on the width of the crack, the surface gradient, the substrate composition and the presence of organic matter. An already-reduced flow rate due to drought conditions or an upstream dam or weir will increase the impact of water loss through cracking. The potential for closure of surface cracks is improved at sites with a low surface gradient although even temporary cracking, leading to loss of flow, may have long-term effects on ecological function in localised areas. The steeper the gradient, the more likely that any solids transported by water flow will be moved downstream allowing the void to remain open and the potential loss of flows to the subsurface to continue. A lack of thick alluvium in the streambed may also prolong stream dewatering (by at least 13 years, in one case study in West Virginia, Gill 2000). Impacts on the flows of ephemeral creeks are likely to be greater than those on permanent creeks (Holla and Barclay 2000). Cracking and subsequent water loss can result in permanent changes to riparian community structure and composition.

7. Subsidence can also cause decreased stability of slopes and escarpments, contamination of groundwater by acid drainage, increased sedimentation, bank instability and loss, creation or alteration of riffle and pool sequences, changes to flood behaviour, increased rates of erosion with associated turbidity impacts, and deterioration of water quality due to a reduction in dissolved oxygen and to increased salinity, iron oxides, manganese, and electrical conductivity (Booth *et al.* 1998, Booth and Bertsch 1999, Sidle *et al.* 2000, DLWC 2001, Gill 2000, Stout 2003). Displacement of flows may occur where water from mine workings is discharged at a point or seepage zone remote from the stream, and in some cases, into a completely different catchment. Where subsidence cracks allow surface water to mix with subsurface water, the resulting mixture may have altered chemical properties. The occurrence of iron precipitate and iron-oxidising bacteria is particularly evident in rivers where surface cracking has occurred. These bacteria commonly occur in Hawkesbury Sandstone areas, where seepage through the rock is often rich in iron compounds (Jones and Clark 1991) and are able to grow in water lacking dissolved oxygen. Where the bacteria grow as thick mats they reduce interstitial habitat, clog streams and reduce available food (DIPNR 2003). Loss of native plants and animals may occur directly via iron toxicity, or indirectly via smothering. Long-term studies in the United States indicate that reductions in diversity and abundance of aquatic invertebrates occur in streams in the vicinity of longwall mining and these effects may still be evident 12 years after mining (Stout 2003, 2004).

8. The extraction of coal and the subsequent cracking of strata surrounding the goaf may liberate methane, carbon dioxide and other gases. Most of the gas is removed by the ventilation system of the mine but some gas remains within the goaf areas. Gases tend to diffuse upwards through any cracks occurring in the strata and be emitted from the surface (ACARP 2001). Gas emissions can result in localised plant death as anaerobic conditions are created within the soil (Everett *et al.* 1998).

9. Subsidence due to longwall mining can destabilise cliff-lines and increase the probability of localised rockfalls and cliff collapse (Holla and Barclay 2000, ACARP 2001, 2002). This has occurred in the Western Coalfield and in some areas of the Southern Coalfield

(ACARP 2001). These rockfalls have generally occurred within months of the cliffline being undermined but in some cases up to 18 years after surface cracking first became visible following mining (ACARP 2001). Changes to cliff-line topography may result in an alteration to the environment of overhangs and blowouts. These changes may result in the loss of roosts for bats and nest sites for cliff-nesting birds.

10. Damage to some creek systems in the Hunter Valley has been associated with subsidence due to longwall mining. Affected creeks include Eui Creek, Wambo Creek, Bowmans Creek, Fishery Creek and Black Creek (Dept of Sustainable Natural Resources 2003, *in lit*.). Damage has occurred as a result of loss of stability, with consequent release of sediment into the downstream environment, loss of stream flow, death of fringing vegetation, and release of iron rich and occasionally highly acidic leachate. In the Southern Coalfields substantial surface cracking has occurred in watercourses within the Upper Nepean, Avon, Cordeaux, Cataract, Bargo, Georges and Woronora catchments, including Flying Fox Creek, Wongawilli Creek, Native Dog Creek and Waratah Rivulet. The usual sequence of events has been subsidence-induced cracking within the streambed, followed by significant dewatering of permanent pools and in some cases complete absence of surface flow.

11. The most widely publicised subsidence event in the Southern Coalfields was the cracking of the Cataract riverbed downstream of the Broughtons Pass Weir to the confluence of the Nepean River. Mining in the vicinity began in 1988 with five longwall panels having faces of 110 m that were widened in 1992 to 155 m. In 1994, the river downstream of the longwall mining operations dried up (ACARP 2001, 2002). Water that re-emerged downstream was notably deoxygenated and heavily contaminated with iron deposits; no aquatic life was found in these areas (Everett *et al.* 1998). In 1998, a Mining Wardens Court Hearing concluded that 80% of the drying of the Cataract River was due to longwall mining operations, with the balance attributed to reduced flows regulated by Sydney Water. Reduction of the surface river flow was accompanied by release of gas, fish kills, iron bacteria mats, and deterioration of water quality and instream habitat. Periodic drying of the river has continued, with cessation of flow recorded on over 20 occasions between June 1999 and October 2002 (DIPNR 2003). At one site, the 'Bubble Pool", localised water loss up to 4 ML/day has been recorded (DIPNR 2003). Piezometers indicated that there was an unusually high permeability in the sandstone, indicating widespread bedrock fracturing (DIPNR 2003). High gas emissions within and around areas of dead vegetation on the banks of the river have been observed and it is likely that this dieback is related to the generation of anoxic conditions in the soil as the migrating gas is oxidised (Everett *et al.* 1998). An attempt to rectify the cracking by grouting of the most severe crack in 1999 was only partially successful (AWT 2000). In 2001, water in the Cataract River was still highly coloured, flammable gas was still being released and flow losses of about 50% (3-3.5 ML/day) still occurring (DLWC 2001). Environmental flow releases of 1.75 ML/day in the Cataract River released from Broughtons Pass Weir were not considered enough to keep the river flowing or to maintain acceptable water quality (DIPNR 2003).

12. Subsidence associated with longwall mining has contributed to adverse effects (see below) on upland swamps. These effects have been examined in most detail on the Woronora Plateau (e.g.

Young 1982, Gibbins 2003, Sydney Catchment Authority, *in lit*.), although functionally similar swamps exist in the Blue Mountains and on Newnes Plateau and are likely to be affected by the same processes. These swamps occur in the headwaters of the Woronora River and O'Hares Creek, both major tributaries of the Georges River, as well as major tributaries of the Nepean River, including the Cataract and Cordeaux Rivers. The swamps are exceptionally species rich with up to 70 plant species in 15 m2 (Keith and Myerscough 1993) and are habitats of particular conservation significance for their biota. The swamps occur on sandstone in valleys with slopes usually less than ten degrees in areas of shallow, impervious substrate formed by either the bedrock or clay horizons (Young and Young 1988). The low gradient, low discharge streams cannot effectively flush sediment so they lack continuous open channels and water is held in a perched water table. The swamps act as water filters, releasing water slowly to downstream creek systems thus acting to regulate water quality and flows from the upper catchment areas (Young and Young 1988).

13. Upland swamps on the Woronora Plateau are characterised by ti-tree thicket, cyperoid heath, sedgeland, restioid heath and *Banksia* thicket with the primary floristic variation being related to soil moisture and fertility (Young 1986, Keith and Myerscough 1993). Related swamp systems occur in the upper Blue Mountains including the Blue Mountains Sedge Swamps (also known as hanging swamps) which occur on steep valley sides below an outcropping claystone substratum and the Newnes Plateau Shrub Swamps and Coxs River Swamps which are also hydrologically dependent on the continuance of specific topographic and geological conditions (Keith and Benson 1988, Benson and Keith 1990). The swamps are subject to recurring drying and wetting, fires, erosion and partial flushing of the sediments (Young 1982, Keith 1991). The conversion of perched water table flows into subsurface flows through voids, as a result of mining-induced subsidence may significantly affect the water balance of upland swamps (eg Young and Wray 2000). The scale of this impact is currently unknown, however, changes in vegetation may not occur immediately. Over time, areas of altered hydrological regime may experience a modification to the vegetation community present, with species being favoured that prefer the new conditions. The timeframe of these changes is likely to be long-term. While subsidence may be detected and monitored within months of a mining operation, displacement of susceptible species by those suited to altered conditions is likely to extend over years to decades as the vegetation equilibrates to the new hydrological regime (Keith 1991, NPWS 2001). These impacts will be exacerbated in periods of low flow. Mine subsidence may be followed by severe and rapid erosion where warping of the swamp surface results in altered flows and surface cracking creates nick-points (Young 1982). Fire regimes may also be altered, as dried peaty soils become oxidised and potentially flammable (Sydney Catchment Authority, *in lit*.) (Kodela *et al*. 2001).

14. The upland swamps of the Woronora Plateau and the hanging swamps of the Blue Mountains provide habitat for a range of fauna including birds, reptiles and frogs. Reliance of fauna on the swamps increases during low rainfall periods. A range of threatened fauna including the Blue Mountains Water Skink, *Eulamprus leuraensis*, the Giant Dragonfly, *Petalura gigantea*, the Giant Burrowing Frog, *Heleioporus australiacus*, the Red-crowned Toadlet, *Pseudophryne australis,* the Stuttering Frog *Mixophyes balbus* and Littlejohn's Tree Frog, *Litoria littlejohni,* are known to

use the swamps as habitat. Of these species, the frogs are likely to suffer the greatest impacts as a result of hydrological change in the swamps because of their reliance on the water within these areas either as foraging or breeding habitat. Plant species such as *Persoonia acerosa, Pultenaea glabra, P. aristata* and *Acacia baueri* ssp. *aspera* are often recorded in close proximity to the swamps. Cliffline species such as *Epacris hamiltonii* and *Apatophyllum constablei* that rely on surface or subsurface water may also be affected by hydrological impacts on upland swamps, as well as accelerated cliff collapse associated with longwall mining.

15. Flora and fauna may also be affected by activities associated with longwall mining in addition to the direct impacts of subsidence. These activities include clearing of native vegetation and removal of bush rock for surface facilities such as roads and coal wash emplacement and discharge of mine water into swamps and streams. Weed invasion, erosion and siltation may occur following vegetation clearing or enrichment by mine water. Clearing of native vegetation, Bushrock removal, Invasion of native plant communities by exotic perennial grasses and Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands are listed as Key Threatening Processes under the Threatened Species Conservation Act (1995).

The following threatened species and ecological communities are known to occur in areas affected by subsidence due to longwall mining and their habitats are likely to be altered by subsidence and mining-associated activities:

Endangered Species	
Epacris hamiltonii	a shrub
Eulamprus leuraensis	Blue Mountains Water Skink
Hoplocephalus bungaroides	Broad-headed Snake
Isoodon obesulus	Southern Brown Bandicoot
Petalura gigantea	Giant Dragonfly
Vulnerable species	
Acacia baueri subsp*. aspera*	
Apatophyllum constablei	
Boronia deanei	
Cercartetus nanus	Eastern Pygmy Possum
Epacris purpurascens var*. purpurascens*	
Grevillea longifolia	
Heleioporus australiacus	Giant Burrowing Frog
Ixobrychus flavicollis	Black Bittern
Leucopogon exolasius	
Litoria littlejohni	Littlejohn's Tree Frog
Melaleuca deanei	
Mixophyes balbus	Stuttering Frog
Myotis adversus	Large-footed Myotis
Persoonia acerosa	
Potorous tridactylus	Long-nosed Potoroo
Pseudophryne australis	Red-crowned Toadlet
Pteropus poliocephalus	Grey-headed Flying Fox
Pterostylis pulchella	
Pultenaea aristata	
Pultenaea glabra	
Tetratheca juncea	
Varanus rosenbergi	Rosenberg's Goanna

Endangered Ecological Communities
Genowlan Point *Allocasuarina nana* Heathland
Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion
O'Hares Creek Shale Forest

Shale/Sandstone Transition Forest

Species and populations of species not currently listed as threatened but that may become so as a result of habitat alteration following subsidence due to longwall mining include:

Acacia ptychoclada	
Almaleea incurvata	
Darwinia grandiflora	
Dillwynia stipulifera	
Epacris coricea	
Grevillea acanthifolia subsp. *acanthifolia*	
Hydromys chrysogaster	Water rat
Lomandra fluviatilis	
Olearia quercifolia	
Pseudanthus pimelioides	

16. Mitigation measures to repair cracking creek beds have had only limited success and are still considered experimental (ACARP 2002). Cracks less than 10 mm wide may eventually reseal without active intervention provided there is a clay fraction in the soil and at least some water flow is maintained. Cracks 10-50 mm wide may be sealed with a grouting compound or bentonite. Cracks wider than 50 mm require concrete (ACARP 2002). Pattern grouting in the vicinity of Marhnyes Hole in the Georges River has been successful at restoring surface flows and reducing pool drainage following fracturing of the riverbed (International Environmental Consultants 2004). Grouting of cracks also appears to have been relatively effective in Wambo Creek in the Hunter Valley. Installation of a grout curtain in the Cataract River, however, has been only partially successful and it was concluded in 2002, after rehabilitation measures had taken place, that the environment flows released from Broughtons Pass Weir by the Sydney Catchment Authority were insufficient to keep the Cataract River flowing or to maintain acceptable water quality (DIPNR 2003). Mitigation measures themselves may have additional environmental impacts due to disturbance from access tracks, the siting of drilling rigs, removal of riparian vegetation, and unintended release of the grouting material into the water. Furthermore, even measures that are successful in terms of restoring flows involve temporary rerouting of surface flows while mitigation is carried out (generally for 2-3 weeks at each grouting site). Planning for remediation measures may also be hampered by the lack of predictability of some impacts, and difficulties gaining access to remote areas where remedial works are needed. The long-term success of mitigation measures such as grouting is not yet known. It is possible that any ongoing subsidence after grouting may reopen cracks or create new ones. Further, it is not yet known whether the clay substance bentonite, which is often added to the cement in the grouting mix, is sufficiently stable to prevent shrinkage. Grouting under upland and hanging swamps that have no definite channel is probably not feasible.

17. Empirical methods have been developed from large data sets to predict conventional subsidence effects (ACARP 2001, 2002, 2003). In general, these models have proved more accurate when predicting the potential degree of subsidence in flat or gently undulating terrain than in steep topography (ACARP 2003). A major issue identified in the ACARP (2001, 2002) reports was the lack of knowledge about horizontal stresses in geological strata, particularly those associated with river valleys. These horizontal stresses appear to play a major role in the magnitude and extent

of surface subsidence impacts. The cumulative impacts of multiple panels also appear to have been poorly monitored. The general trend in the mining industry in recent years toward increased panel widths (from 200 up to 300 m), which allows greater economies in the overall costs of extraction, means that future impacts will tend to be greater than those in the past (ACARP 2001, 2002).

18. In view of the above the Scientific Committee is of the opinion that Alteration of habitat following subsidence due to longwall mining adversely affects two or more threatened species, populations or ecological communities, or could cause species, populations or ecological communities that are not threatened to become threatened.

Dr Lesley Hughes
Chairperson
Scientific Committee

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