**Dendrobium Extension Project (SSD 8194) –**

**Independent Planning Commission (IPC), Public Hearing**

**Independent expert report:** Professor David Keith

**Date of submission to Public Hearing:** 2 December 2020

**Background:** I am Professor of Botany and Deputy Director of the Centre for Ecosystem Science at UNSW Sydney. I am a nationally and internationally regarded ecosystem scientist with specialist interests in in ecosystem dynamics, bushfire ecology, biodiversity risk assessment and Australian vegetation. Upland swamps are one of my research specialities, and I have worked on them on the Woronora Plateau for more than 35 years, having published multiple peer-reviewed papers on their ecology and dynamics. A summary of my Curriculum Vitae is appended below.

I presented recent findings of relevant research on upland swamps to assist the IPC in their deliberations on the Dendrobium Extension Project (SSD 8194). I have provided a copy my presentation to the Commission as a microsoft Powerpoint file and pdf. This report provides supplementary information on key issues identified in my presentation, and should be read with reference to the presentation.

As author of this expert report, I acknowledge that I have read and agree to comply with Part 31 Division 2 of the Uniform Civil Procedure Rules 2005 (NSW) and the Expert Witness Code of Conduct.

**Importance of upland swamp ecosystems**: Upland swamps are a type of peat-accumulating wetland known internationally as mires or bogs. These ecosystems are extensive across boreal latitudes and some temperate regions of the northern hemisphere (Keith et al. 2020). In the southern hemisphere, they have a much more restricted distribution due to the limited area of climatically and geomorphically suitable habitat for their development. Nonetheless, the upland swamps in Australia, and the Woronora Plateau in particular, are globally significant because they contain a highly diverse and endemic flora and fauna, with many species found nowhere else in the world or in the surrounding (dryland) landscape (Keith & Myerscough 1993).

In addition to their biodiversity values, upland swamps are critical to landscape function and supply of ecosystem services to the regional human population. The swamps occupy headwater valleys and thus

- absorb large volumes of water after rainfall events,
- gradually release high quality water filtered through organic sediments
- contribute to sustained flows to: i) streams and their aquatic habitats; ii) metropolitan water storages servicing Australia's largest city; and iii) recreational waterways.
- contribute to flood mitigation
- contribute to carbon sequestration from the atmosphere through accumulation of peaty sediments.

In recognition of threats posed by underground coal mining, climate change and other factors (Keith et al. 2013, Appendix 2), Coastal Upland Swamp, found on the Woronora Plateau and within the Dendrobium Extension Project area, is listed as an Endangered Ecological Community under NSW and Commonwealth legislation.

**Research studies in upland swamps**: Our research at UNSW and collaborating institutions aims to understand the factors influencing ecosystem sustainability and change in upland swamps in order to inform sustainable management. The case study presented to the IPC on 2 December 2020 seeks specifically to diagnose the evidence, causes, effects and mechanisms of ecosystem collapse so that such outcomes may be avoided in the future through appropriate planning and management measures. The study is based on a designed landscape experiment in upland swamps on the Newnes plateau, which was burnt in the 2019-2020 bushfires. The experiment enables quantitative comparison of the observed post-fire vegetation regeneration in swamps that had been undermined by longwall coal extraction with that in unmined reference swamps (see Powerpoint presentation slide 7 for summary of details). It also includes contextual data on soil moisture monitored at the same mined and reference sites since 2015, during and after the coal extraction process and in the lead up to the 2019-20 bushfires. The study is currently being prepared for publication in an international peer-reviewed scientific journal, and builds on our previously published work.

**Research findings**: The data show very strong evidence of ecosystem collapse in swamps that were undermined by longwall coal extraction, while unmined reference swamps regenerated rapidly after the fire. The observed symptoms of ecosystem collapse include (see Powerpoint presentation slides 8-11 for summary of data):

- extensive and deep combustion and consumption of peat in mined swamps, compared to minimal peat loss in reference swamps;
- shorter and sparser vegetation regrowth in mined swamps, than in reference swamps;
- very low regenerating plant biomass in mined swamps, on average 43 times less than in regenerating reference swamps;
- fewer plant species in post-fire vegetation of mined swamps than in reference swamps;
- marked differences in plant species composition between mined swamps and reference swamps.

These marked changes were preceded by more subtle symptoms in the mined swamps prior to the fires, such as reduced soil moisture and selective death of some water-dependent plant species.

The soil moisture data (see Powerpoint presentation slide 13 for summary of data) show progressive drying of mined swamps in the years leading up to the 2019-20 bushfires. In comparison, the unmined reference swamps retained high levels of soil moisture, even during the 2019 drought immediately prior to the fires. At that time (Sept 2019), there were large differences in soil moisture between mined and unmined swamps.

In summary, pre-fire drying of swamp soils caused by mining rendered their peaty sediments in a highly flammable state. Extensive and deep combustion of those sediments resulted in death of plant regenerative organs and seedbanks, and conversion of the coherent peat base and dense root mat into an unconsolidated highly erodible deposit of mineral sand and silt. These features (peat base, root mat, regenerative organs and seedbanks) survived fire in the reference swamps and supported rapid and abundant regeneration. In contrast, regenerative processes failed in mined swamps, and the collapse of those ecosystems is associated with loss of their biodiversity values and hydrological functions.

The observed changes cannot be explained by drought or fire, individually or in combination, because all mined and reference swamps experienced the same local climatic drought conditions and all were burnt at similar severity by the 2019-220 bushfires. We conclude that hydrological changes caused by longwall coal extraction weakened the natural resilience of upland swamps to fire, resulting in ecosystem collapse.

Upland swamps exhibited a lagged response akin to widely recognised 'extinction debts' (Tilman et al. 1994). This phenomenon occurs when environmental change renders habitat unsuitable or insufficient for persistence of species, with the extinction outcomes lagging years or decades after the causal environmental change. The soil moisture data show the environmental change and underlying functional transformation of the ecosystem after mining. Initial plant deaths were indicative of the early phase of a trajectory towards ecosystem collapse, which was accelerated and realised more rapidly through failure of post-fire regeneration when fire inevitably occurred.

**Reversibility of ecosystem collapse**: The evidence strongly indicates that mining-related ecosystem collapse of upland swamps is irreversible over long time frames. The evidence supporting this conclusion may be summarised as follows:

- changes undergone by mined upland swamps before and during their collapse are structural. They involve a fundamental breakdown in the features and feedback processes that sustain the ecosystem, its biodiversity and its functions (see Powerpoint presentation slide 5 for an illustration of these critical features and processes). Increased permeability of the substrate caused by mine subsidence means that the headwater valleys are no longer able to maintain the water surplus that sustains the positive feedbacks between the development of dense swamp vegetation and peat accumulation.
- The soil moisture data from our Newnes study (slide 13) and from our other studies on the Woronora plateau (Mason et al. in review) indicate that water balance in upland swamps continues to decline in the years after longwall coal extraction beneath them.
- Basal carbon dates for upland swamps on the Woronora Plateau extend up to 17,000 years (Young 2017), indicating an extended period of swamp development and sediment accumulation and, potentially centuries or millennia to re-establish a functional ecosystem when conditions are suitable.
- Future climates are projected to be warmer with higher evapotranspiration and more variable rainfall patterns (IPCC, Bureau of Meteorology), conditions that are less suitable for upland swamp development than climates of the recent past (e.g. 20th century).
- A review of rehabilitation methods and outcomes for groundwater-dependent swamps as well as streams and water bodies commissioned by the Commonwealth government found that "no strategies - other than changes in mine plan layout - have been proven to effectively mitigate longwall mining impacts", and that "existing remediation techniques are unproven and appear insufficient without destruction of the surface environment" (Commonwealth of Australia 2014).

**Avoidance of ecosystem collapse**: The only viable option for sustaining upland swamps in mining landscapes is through mine designs that avoid impacts by excluding longwall extraction of coal seams from the projected footprint of upland swamps and a suitable buffer zone. This is because ecosystem collapse is irreversible, and the benefits of narrow longwall panels are uncertain. The currently proposed mine designs for Dendrobium Extension involve panel widths (305 m) which are large relative to most other mines in the Sydney geological basin, and much larger than those shown previously to cause subsidence impacts (e.g. subsidence above panels 160 m wide in the Metropolitan colliery caused substantial hydrological change in surface features). Narrowing proposed longwall panels may reduce conventional subsidence effects, but this could be offset to an unknown degree by unconventional subsidence effects, even though upland swamps are located on relatively flat terrain within shallow headwater depressions. Unconventional subsidence effects occur predominantly in incised valleys (cf. shallow headwater depressions) and are largely independent of panel width. This suggests that more certain benefits, in terms of reduced risk of ecosystem collapse, may be obtained by investments in mining exclusion zones beneath swamps and associated buffer zones, or possibly with bord and pillar extraction methods, rather than investments in narrower longwall panels Although costs of alternative mine designs with narrower longwall panels have been assessed, design options with additional exclusion zones or bord and pillar have apparently not been evaluated in similar detail and warrant further consideration.

**Relevance of research on Newnes plateau to the Dendrobium Extension Project:** Upland swamps on the Newnes plateau and Woronora plateau share many features that underpin their hydrological and ecological functions, and also share some species in common, despite a number of species being unique to each region. The outcomes of the research on Newnes plateau swamps are directly applicable to upland swamps on the Woronora plateau for several reasons:

- Mined swamps in both regions show the same pre-fire symptoms of a trajectory towards ecosystem collapse after longwall mining (substantial reduction in soil moisture, limited retention of groundwater, selective death of vegetation). At Newnes, these symptoms predisposed swamps to accelerated collapse after bushfire. The Woronora plateau is similarly prone to bushfires (major fires in 1968/69, 1980-81, 1990-91, 2001-02, 2013-14) and a similar outcome of collapse may be expected after the next substantial fire event.
- The three essential features for development of upland swamps are common to both regions: 1 Wet climate; 2 Flat terrain; 3 Impermeable substrate (see slide 5).
- In both regions, the substrate is sandstone, with relatively minor differences in stratigraphic structure that do not greatly affect overall hydrological conditions through differences in permeability. Both types of sandstone support development of upland swamps, both have structural joints in the sandstone that may be opened into cracks by mining-related subsidence.
- Swamps are similarly located in shallow headwater valleys and have a similar range of sediment depths (maximum values recorded are 4.15 m and 5.2 m for Woronora and Newnes, respectively).
- Similar levels of waterlogging are evident in both regions. Prolonged near-surface water in depression axes indicates groundwater-dependence of functionally intact unmined swamps, , and transient near-surface water in depression axes indicates rainfall dependence of subsidence-affected swamps (see Powerpoint presentation slide 13 for Newnes; Mason et al. in review for Woronora).
- Mining practices are similar, with longwall panel widths narrower at Newnes (261 m) than proposed in the Dendrobium Extension project (305 m).

In essence, swamps in both regions conform to the functional model shown in slide 5 of the Powerpoint presentation, and therefore both are prone to similar mechanisms of ecosystem collapse through the erosion of resilience to bushfires by longwall mining and more gradual collapse in the prolonged absence of fire as extinction debt is realised.

## References


Commonwealth of Australia. (2014) Temperate highland peat swamps on sandstone: evaluation of mitigation and remediation techniques, knowledge report, prepared by the Water Research Laboratory, University of New South Wales, for the Department of the Environment. Commonwealth of Australia, Canberra.

Keith, D. A. and Myerscough, P. J. (1993). Floristics and soil relations of upland swamp vegetation near Sydney. *Australian Journal of Ecology* ***18,*** 325-344.

Keith, D.A., Ferrer-Paris, J.R., Nicholson, E. and Kingsford, R.T. (2020). *IUCN Global Ecosystem Typology v2.0: Descriptive profiles for Biomes and Ecosystem Functional Groups.* IUCN, Gland.

Keith D. A., Rodríguez, J. P., Rodríguez-Clark, K. M., Nicholson E., Aapala, K., Alonso, A., Asmussen, M., Bachman, S, Basset, A., Barrow, E. G., Benson, J. S., Bishop, M. J., Bonifacio, R., Brooks, T. M., Burgman, M. A., Comer, P., Comín, F. A., Essl, F., Don Faber-Langendoen, D., Fairweather, P. G., Holdaway, R. J, Jennings, M., Kingsford, R. T., Lester, R. E., Mac Nally, R.,, McCarthy, M. A., Moat, J., Oliveira-Miranda, M. A., Pisanu P., Poulin, B., Regan, T. J., Riecken U, Spalding, M. D., Zambrano-Martínez, S. (2013) Scientific foundations for an IUCN Red List of Ecosystems. *PLoS ONE* **8**(5), e62111.

Mason et al. (in review) Persistent effects of underground longwall coal mining on freshwater wetland hydrology. *Science of the Total Environment*.

Tilman, D., May, R., Lehman, C. et al. (1994) Habitat destruction and the extinction debt. Nature 371, 65–66. https://doi.org/10.1038/371065a0

Young A. (2017) Upland swamps in the Sydney region. Dr Ann Young, Thirroul.

# Professor David Keith

Centre for Ecosystem Science, School of Biological, Earth & Environmental Sciences UNSW Sydney

**BS(Hons)  University of Sydney; PhD University of Sydney (Sydney)**

## Areas of Expertise

David is one of Australia's leading ecologists, with expertise in ecosystem dynamics, plant population biology, design of field experiments, surveys and monitoring, vegetation science, restoration ecology, ecological modelling, threatened species conservation science, biodiversity risk assessment, bushfire planning and management for landscapes. Specific interests include research to support sustainable ecosystem management for biodiversity conservation and human well-being.  He has authored more than 200 peer-reviewed scientific publications, including two seminal books on Australian vegetation. In recognition of scientific excellence, David is recipient of the 2019 NSW Premier's Prize for Environmental Science, the 2017 Clarke Medal for natural sciences, the 2015 Eureka Prize for Environmental Science, and the 2013 Australian Ecology Research Award.

## Relevant Projects

A sample of recent and current relevant projects:

- Review of species and ecosystem responses to fire  (2020)
- Understanding the long-term ecological dynamics  (1989-2020)
- Design of ecological restoration projects (2002-2020)
- Recovery of rainforest and peatland ecosystems after the 2019-2020- bushfires
- Ecosystem risk assessment protocols (2012-2020)

## Selected recent publications

Keith, D. A., Auld, T. D., Barrett, S., English, V., Gallagher, R., Gray, R., van Leeuwin, S., Allen McIlwee, Mitchell, D., Tozer, M. G., Williams, R. J., Yates, C., Neldner, J., Buchan, A., White, M. D., Rogers, D., West, A., Seddon, J., Simpson , C. C. (2020) Terrestrial Ecological Communities in Australia: initial assessment and management after the 2019-20 bushfires. Report to the Wildlife and Habitat Bushfire Expert Panel and the Australian Department of Agriculture, Water and Environment. Centre for Ecosystem Science, University of NSW, Sydney.

Keith, D.A., Ferrer-Paris, J.R., Nicholson, E. and Kingsford, R.T. (2020). *IUCN Global Ecosystem Typology v2.0: Descriptive profiles for Biomes and Ecosystem Functional Groups.* IUCN, Gland,

Watson JEM, Keith DA, Strassburg BBN, Venter O, Williams B, Nicholson E (2020). Set a global target for ecosystems. Nature 578(7795), 360-362

Keith, D. A. (2017) Australian vegetation. Cambridge University Press, Cambridge.

Mason, T. J., Keith, D. A. & Letten, A. D. (2017). Detecting state changes for ecosystem conservation with long-term monitoring of species composition. *Ecological Applications* **27**, 458-468..

Keith D. A. (2012). Functional traits: their roles in understanding and predicting biotic responses to fire regimes. In: 'Flammable Australia: fire regimes, biodiversity and ecosystems in a changing world*.*' second edition (Eds. R. A. Bradstock, R. J. Williams and A. M. Gill), pp97-125. CSIRO, Melbourne.Keith, D. A., Akçakaya, H. R., Thuiller, W., Midgley, G. F. Pearson, R. G., Phillips, S. J., Regan, H. M., Araújo, M. B. and Rebelo, T. G. (2008). Predicting extinction risks under climate change: coupling stochastic population models with dynamic bioclimatic habitat models. Biology Letters 4, 560-563.

Keith, D. A., Holman, L., Rodoreda, S., Lemmon, J. and Bedward, M. (2007). Plant Functional Types can predict decade-scale changes in fire-prone vegetation. *Journal of Ecology* **95**, 1324-1337.

Keith, D. A. (2004). Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT. NSW Department of Environment and Conservation, Sydney.