APPENDIX F

GEOMORPHOLOGICAL REVIEW OF PAGODAS

P +61 07 3368 2133 | F. +61 07 3367 3629 | W. www.hydrobiology.biz
A. 27 / 43 Lang Parade, PO Box 2151, Toowong, QLD 4066 Australia

Hydrobiology

Bret Leisemann
Chief Development Officer
Coalpac
PO Box 330
Indooroopilly, QLD 4068

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Dear Bret,

Peer Review – Geomorphology of 'Pagodas'

Introduction
As requested, please find herewith a peer review of information and conclusions contained within the report *Ecological Assessment for the Coalpac Consolidation Project – Contracted Project, Response to PAC Review Report (Final Report)*, referred to hereafter as the Response Report.

The review has paid particular attention to chapters 2 and 4 of the above report and considered in particular:

- Definitions used by Cumberland Ecology relating to the definition and description of the pagodas; and
- Appropriateness of the approach used in discussion of pagoda landforms (nomenclature used by Planning Assessment Commission (PAC)).

Qualification to provide this assessment
My experience with reference to this assessment includes:

- Academic (B.Sc (Hons) Environmental Science, Ph.D Fluvial Geomorphology).
- Work experience. Since completing my Ph.D in 1990 I have worked as a consultant on projects relating to fluvial geomorphology, surface hydrology and broader environmental management in Australia, PNG, South East Asia and Africa. For the past 13 years I have worked at Hydrobiology, a consulting company that I co-founded. My CV is attached hereto.

I am a member of the AusIMM and a Chartered Environmental Scientist (M.AusIMM (CP)). I am also a Fellow of the Royal Geographical Society of London and a Chartered Geographer (CGeog).

Background
Pagoda is a term used to describe distinctive rock and associated cliff formations that have formed as a result of the complex weathering of Sandstone. The term pagoda,

according to Washington and Wray (2011) was coined by local interest and conservation groups in the 1980s. Examples of pagodas can be found in the Sydney Basin, including areas immediately adjacent to the Coalpac Consolidation Project (the Project) area where weathering of the Triassic Narrabeen sandstone has occurred. The physiography of the pagodas has been described by Washington & Wray (2011) and was adopted in the Response Report. Washington and Wray (2011) referred to pagodas as being part of a suite of regional sandstone landforms or *pagoda country*, being land that is characterised by these features, and *pagoda complexes* as *...wonderfully intricate, ruinlike, landforms that resemble lost cities and temples...*

Two types of pagodas (based on their shape) have been described by Washington and Wray (2011), platy and smooth. Other descriptions of these features exist in the literature of the Sydney basin. For example, Adamson *et al.* 1983 referred to a '*landscape of rocky towers described locally as minarets*'.

Morphological Processes

Washington & Wray (2011) also described uncertainty with respect to the detail of the processes of Pagoda formation. Processes of weathering are better understood, although acknowledged to be complex. The role of the resistant ironstone banding causing differential rates of aeolian weathering is particularly important in defining the stepped morphology of pagodas while mechanical separation/dissection and vertical incision define the 'pinnacle' morphology.

A variety of other processes affect pagoda morphology at a range of scales as described in the literature. Examples include the interplay of bushfire and faunal activity (Adamson *et al.* 1983), erosional and deposition processes of rainwash, rock and soil creep and bioturbation (with particular reference to sandstone hillslopes (Humphreys & Mitchell 1983)). All of these processes are likely to be variable in time in response to climate cycles and climate change. Young (1982) described block gliding in the Sydney Basin as a process by which separation of sandstone towers from adjacent clifflines could occur.

Geomorphology

Geomorphology describes form and process. From an impact assessment perspective, the geomorphic values of a feature and the risks to those values from the proposed activity need to be considered. The geomorphological values of the pagodas might include aesthetic/recreational (*form*), morphological processes of erosion and deposition (*process*) and ecological (*habitat*) values that are created and supported by these processes.

The definition of SPLs used in the Response Report refers to complexes that include rock formations, cliff faces, dissected gullies (characterised by banded ironstone) and associated rock structures and their attributes. Also referred to are the areas between pagodas that support habitat within these complexes. The report also refers to a

relevant landform dimension of *typically greater than 10 hectares*.

From a geomorphological perspective this is considered to be a reasonable classification of a landform unit in the context of the Project. From an impact assessment perspective it allows the values associated with pagoda complexes to be more clearly defined and accurately mapped (both inside and outside the Project boundary) compared to the more broadly defined *pagoda country* referred to by Washington and Wray (2011).

The SPLs represent agglomerations of morphological features including sandstone cliffs and outcrops but are considered distinct from these features which, in isolation, do not exhibit the specific range of values attributed to the SPLs, in particular, the variety of habitat types, topographic variability, and their striking visual appearance. The *pagoda country* of Washington & Wray (2011) encompasses an area containing both SPLs and sandstone features such as cliffs and outcrops (although it is noted that both the Lidsdale-Newnes and Ben Bullen SPLs extend, in places, beyond the boundaries of the defined *pagoda country* in those areas demonstrating more clearly defined mapping). While the SPLs are intended to represent a geomorphological unit, *pagoda country* represents an area in which these units are found.

Figure 1 demonstrates the difference between an SPL and an area of Sandstone Outcrops (as defined in the Response Report) in the Ben Bullen State Forest. The SPL is a more striking and clearly-defined aggregation that exhibits a more varied and distinct morphology and variety of habitat types compared to the Sandstone Outcrops.

Hydrobiology QLD Pty Ltd
Dr Andy Markham (Director)

Figure 1 SPL (top) and Sandstone Outcrops (bottom) in the Ben Bullen State Forest

References

Adamson, D., Selkirk, P.M., and Mitchell, P., 1983, The Role of Fire and Lyre Birds, in the Sandstone Landscape of the Sydney Basin, in R.W. Young and G.C. Nanson (eds), Aspects of Australian Sandstone Landscapes, ANZGG group special publication no. 1.

Humphreys, G.S., and Mitchell, P.B., 1983, A Preliminary Assessment of the Role of Bioturbation and Rainwash on Sandstone Hillslopes in the Sydney Basin, in R.W. Young and G.C. Nanson (eds), Aspects of Australian Sandstone Landscapes, ANZGG group special publication no. 1.

Washington, H. G. and A. L. Wray. 2011. The Geoheritage and Geomorphology of the Sandstone Pagodas of the North-western Blue Mountains Region (NSW). Proceedings of the Linnean Society of NSW 132:131-143.

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