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Lendlease
Level 14, Tower Three, International Towers Sydney
Exchange Place, 300 Barangaroo Avenue
Barangaroo NSW 2000

Attention
Stewart Verity
Senior Development Manager, Barangaroo South

Dear Sir,

Re: Barangaroo South Stage 1B Deep Soil Zones

We have considered your email dated 1November 2016 with regard to the Planning Assessment Commission consent condition in Concept Plan MOD 8 to provide 2,000 m^2 of 3 m deep soil within the expanded Hickson Park.

This expert opinion is given jointly between Stuart Pittendrigh and Simon Leake Principal Soil Scientist of SESL Australia.

We do not know where the "deep soil zone" concept has come from but in our view it is wrong and demonstrates a fundamental misunderstanding of the structure of tree root systems. Contrary to the popular idea of the "root ball" trees in the great majority of soil types have a "root plate". The root "plate" develops as structural support root spread horizontally through the topsoil, rarely penetrating more than 500 mm. In order to drought-proof" itself the tree will send down "sinker" roots at intervals form the developing root plate. The concept of the "tap root" is also wrong in most soils; this is a juvenile structure only and develops into a "sinker root" in most cases.

The depth to which the sinker roots penetrate depends largely on the availability of water and air. In hard compact clay subsoils subject to periodic water-logging (as is very common on the east coast of Australia) this depth is sometimes as deep as 800mm. Were we to design a higher quality subsoil that is well drained, not subject to water-logging (ie has drainage and aeration installed at the bottom of the profile) and not so compact as to prevent root penetration, this can penetrate as deeply as 1500mm. Below this there is not usually enough oxygen for roots to live. The only exception is very deep sands such as dune and alluvial sands where oxygen can penetrate to depth.

It is our view that a profile depth of 1500 mm is necessary for the largest trees being Ficus species. Following our deliberations we are of the view based on the nominated largest species 1500 mm of soil being 500 mm of topsoil or A horizon and 1000 mm of subsoil B horizon would be adequate depth to establish and sustain the large trees. Given the nature of the compacted fill or concrete underneath drainage would be required, nominally 100mm so the actual soil profile would be 1400 mm deep.

For the past 6 months or so Simon and I have conferred with the landscape design team during the early stages of the emerging site design, plant species selection, soil types and depths to sustain the proposed soft landscape setting for Barangaroo South 1B precinct.

As a result of the successful soft landscape outcomes achieved at Barangaroo Reserve we a satisfied that the soil depths recommended, subject to further specific quality criteria, will meet the requirements to enable the establishment and development of well formed trees and tall understory with their structures and forms typical of the selected species.

These depths are adequate for the large trees provided-
1. There is sufficient lateral extent for an adequate soil volume to be exploited. Usually in turf areas this is available.
2. The number of trees. It is important not to crowd unsustainable numbers of large trees into a small space such that each tree does not have adequate access to sufficient rooting volume. There are guidelines available for judging rooting volume requirements such as Urban (2008) and Leake and Haege (2014).
3. There is adequate distance between stem and hard surfaces or kerbs such that development of the all-important horizontal structural root system is not restricted. The Structural Root Zone of a mature Fig Tree for example with a Trunk Diameter at Ground Level say 1.5 m diameter is estimated at about 3.9 m. radius. This goes to the final placement of trees on the plans.
4. This depth is only adequate if the installed soil meets certain quality criteria. With regard to typical soil characteristics these would be -
    - A layered profile comprising topsoil of higher organic matter, well balanced chemical properties and suitable nutrient content,
    - A subsoil comprising well drained sandy loam with low organic matter and well balanced chemistry.
5. Where depths as shallow as 750 mm occur (which we believe occur in places), our advice would be to choose small trees only. Our suggested optimum from the table below is 900 mm but we believe 700 mm would be just adequate for smaller trees if irrigation is provided and lateral spread varies from 1.83m to 4.83 m. in width.
It is also our view that, provided the above criteria are met, even shallower profiles can be used for small and medium trees. As little as 900mm total (including the drainage layer) would be suitable for small trees in the planting pallet. The following table provides a guide for the species chosen for this project.

Typical mature height	Trunk diameter at ground level mm	Species	Optimal soil depth mm
Small, to 10 m	200-500	*Elaeocarpus eumundii* *Harpullia pendula* *Tristaniopsis laurina* *Waterhousia floribunda'Green Avenue'* *Celtis australis*	750
Medium 10-20 m	500-900	*Angophora costata* *Corymbia gummifera* *Corymbia maculata* *Magnolia grandiflora 'Exmouth'* *Syzygium paniculatum* *Waterhousia floribunda*	750-1000
Large 15-30 m	900-1500	*Ficus microcarpa var.hillii* *Ficus macrophylla*	1500

Since soil depth interacts with total rooting volume and root spread (available surface area) our estimate of these requirements to assist in the design process is as follows.

Typical mature height	Minimum soil volume m^3	Min Radius of SRZ m	Ideal soil area m^2
Small, to 10 m	10	2	9
Medium 10-20 m	18	3	15
Large 15-30 m	25 – 100 (Ficus spp.)	4	35

Barangaroo Reserve has proven to date to be an excellent model for advanced tree planting. With 1500 mm of functional soil depth (including drainage layer) under the largest *Ficus* trees on the Headland Park reducing to 500mm for turf areas. There has been no tree loss of major large species using these soil depths except where drainage was compromised. The sorts of depths indicated in the tables above would be the norm for most projects we work on including Barangaroo, Sydney Olympic Park, Darling Harbour, Pyrmont redevelopment and much of the City of Sydney planting programs.

These sorts of numbers are supported by the literature (Urban (2008) and Leake and Haege (2014)). As early as 1976 Carpenter (1976) was making the following recommendations based on available root ball depth

	Depth inches/ft (mm)
Small shrubs	18-24 ” (450-600)
Large shrubs	24-30 “ (600-750)
Small trees	2 ½ to 3’ (750-900)
Large trees	3 ½ - 4’ (1100-1200)

(After Carpenter 1976).

Summary of Opinion

3 m depth of soil is not necessary for the sustainable growth of even the largest trees chosen for the project and we are not aware of the factual basis upon which this requirement has been adopted. It is our view that half this depth is the normal requirement for the two very large specimens (Ficus microcarpa var. hillii and the Ficus macrophylla). Even lesser depths are needed for the rest of the medium and small trees to be planted on the site.

This opinion is predicated upon certain minimum soil volumes being available for the sustained growth of the trees and advice is presented on those soil volumes to assist the detail design process.

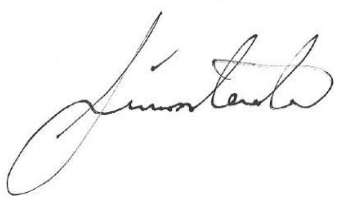
We trust this advice is clear. Should you have any questions regarding the advice please do not hesitate to contact the undersigned.

Yours truly,

Norcue Pty Ltd

Stuart Pittendrigh

Sydney Environment & Soil Laboratory



References

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Leake, S.W and E. Haege (2014) Soils for Landscape Development: Selection, Specification and Validation. CSIRO Publishing, Collingwood VIC.

Urban, J. (2008) Up by Roots. Healthy Soils and Trees in the Built Environment. International Society of Arboriculture. Champaign, Illinois, U.S.