

MEMORANDUM

To:	██████████, Senior Program Officer -Major Projects and Asset Coordination - Brisbane City Council
From:	Bernhard Wehr, Verterra
CC:	
Date:	9 July 2025
Re:	Verterra memo - Kauri Pine decline
Project:	

The information in this memo is based on detailed soil sampling performed by Brisbane City Council in 2023, comparing “good” to “poor” site (Table 1). A detailed explanation of the soil condition affecting tree health can be found in the “Review of Sherwood arboretum – Kauri pine decline – review and options paper” prepared by Verterra for Brisbane City Council on 28 June 2024 (Verterra 2024).

Earlier soil sampling investigations, although covering a larger area, did not analyse a full suite of soil parameters, hence we cannot determine soil constraints with confidence. Based on the soil and environmental analyses, the decline of Kauri pines is likely caused by more than one factor. We consider two likely causes to be:

1. Shallow water table
2. Low soil pH (acidity)

Table 1: Summary of soil chemical conditions are the good and poor sites at the Sherwood Arboretum Kauri Pine Avenue. Table was taken from Verterra (2024). The comprehensive soil analysis in 2023 only sampled two sites (BH02/23 and BH01/23), hence nearby soil samples from 2016 were also included (BH03/16, BH11/16, BH05/16). Other samples from 2016 were not included since they further away from the 2023 sampling sites.

	GOOD SITES			POOR SITES	
SITE	BH03/16	BH11/16	BH02/23	BH05/16	BH01/23
Mottling	4.0 m	2.0 m	1.7 m	3.5 m	0.2 m
Groundwater	2-3.6 m	No GWL	1.8 m	1.3-3.1 m	3.5
pH1:5 w (to 1 m)		7.0	5.8- 7.3	5.0	5.4-5.5
Al saturation (to 1 m)			0%		20-32%

COMMERCIAL – IN - CONFIDENCE

Based on the soil comparisons, we do not consider salinity or sodicity to be a cause of tree decline. Past and pathogens may be secondary cause of tree decline. A full discussion can be found in our earlier report “Review of Sherwood arboretum – Kauri pine decline – review and options paper” prepared by Verterra for Brisbane City Council on 28 June 2024 (Verterra 2024). To summarise the main points of this report:

- 1) The depth to the water table is shallow (but fluctuating with rainfall, soil clay content, soil compaction and likely also tides). The depth to the water table can be inferred from the soil colour (bluish grey colours indicate permanently wet) and mottling (temporarily waterlogged) (Figure 1). The measured depth to water table ranged from 1.8-3.6 m at the good area, and from 1.3-3.5 m in the poor area, based on the limited samples available. We consider the measured depth to water table a less informative parameter since it depends on weather conditions prior to soil investigations. During rainy periods, the water table will be shallow (close to the surface), whereas the water table will be lower (deeper below the surface) during dry periods. Compaction of soil, or zone with higher clay content, leads to poor drainage and causes perched water tables (Figure 2). We consider soil colour and mottling a more reliable indicator of the water table since it is not influenced by current rainfall but on long-term (months-years) soil water content. Based on measured depth to water table, and soil colour/mottling, there is not a clear difference in hydrology between poor and good areas but local conditions under the trees may be affected by local clay content or compaction, causing a perched water table under some trees but not others (Figure 2).

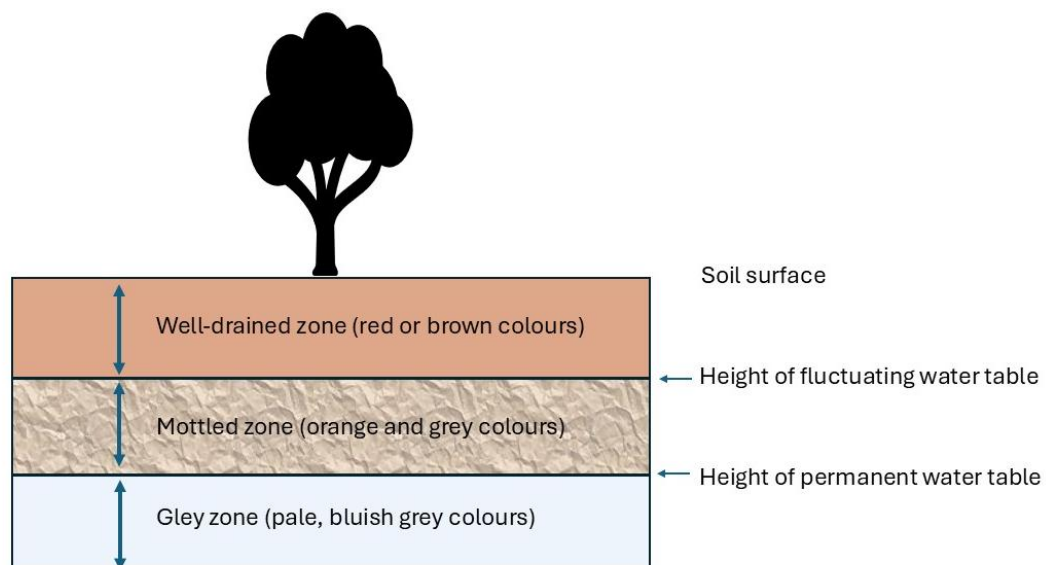


Figure 1. Schematic showing effect of water table depth on soil colours.

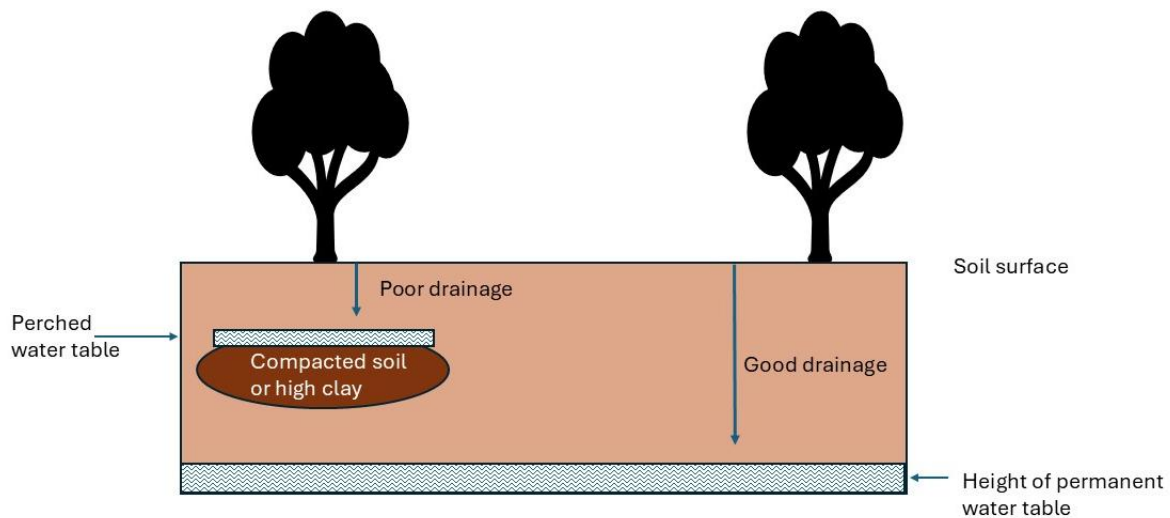


Figure 2. Schematic showing the effect of drainage on the depth to water table.

- 2) Riverine and coastal sediments naturally form pyritic minerals (FeS). These sediments can build up over hundreds to thousands of years. When these sediments are exposed to air (either by excavation, drainage or air-spading) they will oxidise and generate acid, causing low pH. While riverine sediments have only low concentrations of pyritic minerals compared with coastal sediments, they can generate sufficient acid to lower the soil pH. Therefore, lowering the water table by excavation and installation of drainage may expose acid generating sediments to air which can cause low soil pH and would require treatment (see point 3 below).
- 3) Low pH in the top 1 m of soil was observed at the poor site (pH 1.5 water: 5.0-5.5) but not at the good site (pH 5.8-7.3). While the difference in pH between sites may seem minor, the pH is expressed in logarithmic scale. Hence, a one-unit difference in pH is a ten-fold difference in acid concentration. At low pH (pH 1.5 water: < 5.5), Al-containing minerals in the soil (e.g. kaolinite) dissolve (Figure 3) and will release Al^{3+} ions which are highly toxic to plant roots (Wehr et al 2005). Indeed, the measured Al-saturation (i.e. fraction of cation exchange site with Al ions bound to them) was 20-32% at the poor site (Table 1) suggesting Al toxicity as a plausible cause of Kauri decline.

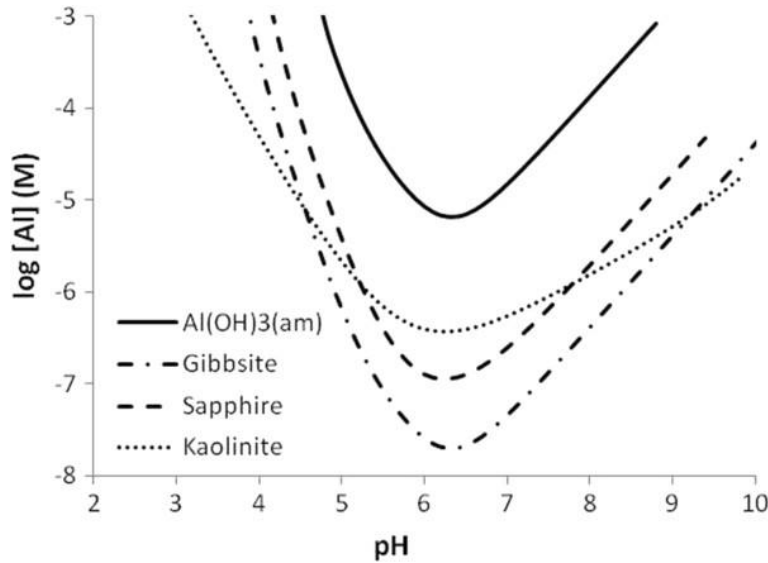


Figure 3. Effect of pH on solubility of Al minerals (from Lutzenkirchen et al 2014)

A schematic presentation of this acidification process is shown in Figure 4. The poor root growth places stress on trees and makes them susceptible to other stresses and pathogens. The Al toxicity is only affecting the roots and is not causing any foliar symptoms. An excavation of the root system of affected trees will likely show brown, stunted and deformed roots.

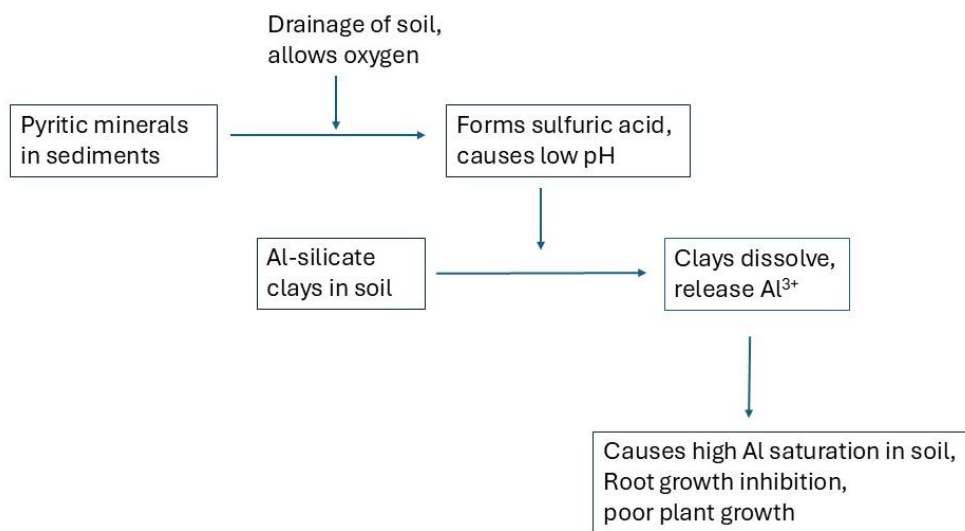


Figure 4. Schematic presentation of the effect of pyritic minerals in soil on root growth inhibition

In conclusion, it is our opinion that the soil conditions at the Kauri Avenue are such that trees on the western side of the Avenue are affected by:

- soil acidity
- and/or waterlogged conditions.

Both conditions cause stress to the trees and lead to their increase susceptibility to pest and pathogen attack.

The soil acidity may have been caused by previous soil disturbance aimed to improve drainage. Draining sediments may lower the soil pH as outlined above. Therefore, we recommend not to disturb/drain the soil unless it has been determined by soil testing that the sediments are not acid-generating. Otherwise, draining the soil will increase the acidity problem.

The soil acidity can be treated with limestone but this requires mixing the affected soil with limestone and replanting. Injection of limestone or surface application show poor effect since limestone does not move in soil.

Rather than excavating and treating the soil, we suggest to consider planting trees species suited to the site conditions.

Possible actions:

1. A detailed soil scanning with dual geometry EM38 could be considered of the Kauri pine avenue and this will give a 3D map of soil variability under the trees. This still needs to be followed up by ground truthing (i.e. soil sampling) to explain the EM38 signal (e.g. is the signal variance caused by clay content, salinity, or water content) and to narrow down possible causes of tree decline.
2. The low pH soil can be treated with limestone to neutralise the pH, but this requires either injection with micronized limestone or excavation of a large volume of soil and mixing with limestone and returning the treated soil. Applying limestone to the soil surface is not likely effective since limestone applied to the soil surface does not move into the subsoil very fast (likely would require decades to reach 1 m depth).
3. Installing drainage or lowering the watertable will expose sediments that may generate acid and lower the pH. This will require extensive sampling and testing of soil to determine acid generating potential and treating a large volume of soil in the vicinity of the trees with limestone to overcome the acid generation potential of the soil. Thus, drainage alone may make the problem worse.

Verterra's core ecological engineering principles give preference to working with nature, i.e., treating soil constraints with minimal intervention or selecting plant species suited to the edaphic and climatic conditions encountered at the site. Rebuilding soil profiles, major drainage earthworks, or ongoing interventions are likely not feasible. We recommend considering other more suited plant species for the site and moving the existing (affected) Kauri pines to higher ground within Sherwood Arboretum.

Further reading:

- Verterra Pty Ltd (2024). Review of Sherwood arboretum – Kauri pine decline – review and options paper. Issued to Brisbane City Council.
- Wehr, JB; Blamey, FPC; Menzies NW (2005) Aluminum. In *Encyclopedia of Soil Science*. 2nd ed. Ed: Lal, R. CRC Press.
- Lützenkirchen, J; Abdelmonem, A; Weerasooriya, R, et al (2014) Adsorption of dissolved aluminum on sapphire-c and kaolinite: Implications for points of zero charge of clay minerals. *Geochemical Transactions* 15:

Answers to questions raised at the Stakeholder meeting 6 June 2025

Can the low pH in soil be addressed?

Adding limestone to soil will increase its pH, but this is not practical since the subsoil (or at least the top 1 m) needs to be treated. Limestone does not move in soil, it needs to be evenly incorporated into the soil, which means excavating the soil and mixing with lime and returning the soil, and then replanting.

Are there other reasons why addressing the pH would not work

You would need to determine that there are no acid generating minerals present in the excavated soil, otherwise the pH will be lower after excavation than before. Good mixing of excavated soil with limestone will be essential. Adding limestone to increase pH is not a controversial process, it is used by farmers extensively, but it requires information how much limestone to add. This requires additional laboratory analyses.

How long will be pH remain low:

As long sulfidic (pyritic) minerals are present in the soil (they occur naturally in riparian/estuarine areas), they will release acid. Once the minerals have been fully oxidised they will no longer release acid. The duration of the acid formation is also a function of the amount of acid forming sediments present in soil, and this is currently unknown.

Are more soil tests required?

The areal extent of the low pH/Al toxicity needs to be determined - it is likely a large area (considering the area with poor trees). This means more soil sampling will be required, preferable to 1.5 m depth and determine the presence of acid-forming (sulfidic) minerals in the soil. Then the amount of limestone needed and the area/volume to be excavated can be determined. One advantage of excavation would be that it would allow to address the drainage issue at the same time.

What would be the effect of earthworks on the site:

The presence of clay in the subsoil causes a perched water table, which sustains the wetland/pond at Sherwood. Draining the area under the Kauri pines will likely also drain the wetland. Draining the site without determining if acid-forming sediments are present will likely make the problem worse.

What is the science behind the acid forming in the soil:

Drainage will expose the potentially acid-forming sediments to oxygen. This will result in release of acid from the sediment and cause low pH. Any soil disturbance (either due to drainage, air spading or excavation) needs to establish the risk of acid forming and this needs to be treated with limestone. Otherwise, the problem will just become bigger.

Why are some trees doing better in the low lying area than other trees?

There are likely areas with compacted soil or high clay, which causes a perched water table. The depth to the clay layer is likely variable, hence some trees will likely be located in areas with shallower water table than other trees. This could be investigated using EM38 to give a 3D image of the rootzone in the Kauri pine avenue. This would still only explain variability between sites, but needs to be followed up with soil sampling for ground truthing (ie. what is causing the variability).

What is the effect of salinity on soil

Salinity causes clay particle to flocculate (stick together). This improves water movement through soil but can cause salt stress in sensitive plants. The sodium ions found in saline soils can bind to clay particles making them sodic. When sodic clays are exposed to fresh water (rainfall), the clay particles disperse, resulting in dense soils with poor drainage.

How deep does soil need to be tested:

Previous soil samples showed acid soil in the top 1 m, the Kauri pine roots will likely grow to 1 m deep (even annual crop plants grow that deep). Evidence of acid forming sediments was found at 6 m depth, so the volume of soil with acid sediments may be considerable.