Global Urban Forest
Soil Health • Tree Health

MCGREGOR COXALL

Source: https://shaping.banyule.vic.gov.au/C107

Water & Soil Health Assessment Report

Proposed TreeTops Adventure Park, Yarra Flats, Ivanhoe East, VIC
February 2021

Report Prepared for:

Dr Andrew Lees, President

Riverland Conservation Society of Heidelberg Inc. (Friends of Yarra Flats Park)

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Report Prepared by:

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Concerns blurb for Victorian Panel Hearing:

The Treetops project proposes to utilise the trees as load bearing infrastructure. Duty of care around risk and fit for purpose use and assessment of the trees for this application must be considered. Current standards of Visual Tree Assessment (VTA) are subjective and do not assess any below ground components of trees to be considered reliable. An accurate assessment of 'whole of organism' tree health status, above and below ground is required to satisfy a risk assessment. Particularly below ground as the root mass and surrounding soil health provide the foundations for stability of each tree. If this environment is compromised, it should be considered that load bearing applications applied to the trees in this environment is of high risk of failure.

Site Soil Health indicators and investigations by GUF suggest poor soil health conditions at the site have led to soil borne disease and Tree Decline. A desktop environment assessment by Owen Richards of McGregor Coxall (McGC), supports the poor health conditions indicated by GUF. This assessment suggests the urbanised landscape restricts passive infiltration of rainfall/runoff reducing the extent and volume of baseflow subsurface water (groundwater) flows that may otherwise occur naturally. Assessment of proposed billabong recharging methods identified risks of groundwater mounding, restricting the distribution of subsurface water across the wider area soil strata.

Billabongs are an ephemeral system which recharge naturally by expressing baseflow subsurface water. The Yarra Flats Park is within a High Potential Groundwater Dependent Ecosystem (GDE) incorporating Aquatic GDEs (rivers, springs, wetlands) and Terrestrial GDEs (vegetation). The types of Inflow Dependent Ecosystems (IDEs) that exist in the Yarra Flats area predominantly include Terrestrial IDEs (an ecosystem reliant on subsurface water in addition to rainfall e.g., soil moisture). Groundwater dependent ecosystems (GDEs) are defined as 'ecosystems that need access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services'. GDEs include a broad range of environments and can be highly specialised, possessing unique characteristics that 'separate' them from other ecosystems. The dependence of GDEs on groundwater varies from seasonal or episodic, to continual. They can range in size from a few metres to many square kilometres. Groundwater dependent terrestrial vegetation (Phreatophytes): Phreatophytes do not rely on the surface expression of water for survival but depends on the subsurface presence of groundwater, often accessed via the capillary fringe (i.e. the subsurface water just above the water table that is not completely saturated). Phreatophytes include both deep and/or shallow rooted vegetation communities. Forests and woodlands can rely on groundwater for survival, particularly in areas of shallow groundwater. The degree of groundwater dependence can vary, the literature indicating seasonal variability in both the quantity of groundwater used and the relative importance of groundwater as a water source.

The health of these ecosystems and encompassing soil strata is at significant risk of decline (if not already) without this subsurface water cycle.

Abstract

Urban Forestry around the world is investing in ambitious projects that can be described as Green Infrastructure consisting of 'green assets' such as trees, parks and gardens that provided functional value. When integrated with stormwater management approaches consisting of 'blue assets' such as raingardens, bio-retention, and infiltration systems, Blue-Green (Living) Infrastructure emerges. Living Infrastructure incorporating natural systems that provide sustainable triple bottom line (3BL) 1) ecological, 2) amenity and 3) economic benefits associated with integrated urban greening and stormwater management. This means trees can be viewed as Living Infrastructure and should be viewed as being no different from Grey Infrastructure (buildings, roads, and other urban constructions) investment that provides essential services. Design, construction, and maintenance of Grey Infrastructure is structured and complex and this is also true for Living Infrastructure.

The TreeTops Adventure Park [The Project] proposed at Yarra Flats Park [The Site] provides an example where the standard industry approach in assessing trees visually requires much more detail to obtain an informed position as to its impact and risk of development. The Project goes another step further in utilising individual tree structure from which to create landings, platforms and hang apparatus from. This proposed use significantly increases the tree assessment requirements and must include a whole of systems approach, above and below ground knowledge and assessment of Soil and Plant Health.

In 2018 Matthew Daniel and Owen Richards came together after identifying synergies within respective disciplines attributed to failing urban green assets. Their collaborative insights and assessment of several project sites has defined a new method, the Integrated Water & Soil Regenerative Method (IWSRM). The IWSRM is a collaborative method where specialist Arboriculturists and Environmental Engineers communicate, measure, and provide evidence-based knowledge and assessment of specific site natural system function. Matthew and Owen have identified that Urban Water Cycle and Plant and Soil Health are interconnected and in many cases are damaged beyond self-repair, ultimately deemed unsustainable in a changing climate. This leaves trees prone to a plethora of plant Health Care issues including poor canopy function, root development and pathogen activity. This has a cascading effect on natural system health status reducing the capacity of Living Infrastructure to maintain or improve health status, provide microclimates, retaining moisture to cool cities and increasing soil carbon to clean air.

The effective integration of the two typically siloed disciplines 1) Arboriculture and 2) Environmental Engineering within the IWSRM has shown to be able to maximise 3BL benefits and climate adaptiveness of bespoke Living Infrastructure Solutions. Arboriculture is the industry tasked with individual tree management. It is primarily focused on risk mitigation and applies a subjective human interpretation in assessing the tree and referred to as Visual Tree Assessment (VTA). Environmental Engineering incorporates assessment of the water cycle to determine most practicable, fit for purpose management solutions primarily focused on risk mitigation to the environment and community.

The combined expert opinions presented in this report provide a basis to support the argument that greater detail in assessment, development, and management of Urban Forest projects is required when natural systems and land use types are combined.

Based on the Qualitative Assessment of Plant and Soil Health and Water Cycle the development of land in Yarra Flats Park, for an outdoor recreation facility -TreeTops Adventure Park - covered by proposed Banyule Planning Scheme Amendment C107 must be halted as it relies on ill-informed assessments of the site and the trees. Further assessment and bespoke mitigation solutions could be identified to rejuvenate the Yarra Flats Park ecosystem which may, in turn, support progressing the development of the Site.

Executive Summary

Global Urban Forests (GUF) submits this Arboriculture - Specialist # (Quantified Plant and Soil Health Assessment Report regarding the Banyule Planning Scheme Amendment C107 - development of land in Yarra Flats Park **[the Site]**, Ivanhoe East for an outdoor recreation facility TreeTops Adventure Park **[The Project]**

This GUF report has been commissioned by Riverland Conservation Society of Heidelberg Inc. (Friends of Yarra Flats Park) The Author has completed a desktop analysis of site history, Critical Analysis of the: ***ARBORICULTURAL TREE HEALTH & HAZARD ASSESSMENT [2018 update] by Advanced Treescape Consulting requested by Ecoline Pty Ltd prepared by Russell Kingdom*** **[Kingdom, 2018]** and completed an independent specialist Basic Site Soil Health Assessment and Soil Health Sampling Regime on Tree # 1.

A multidiscipline Approach is also included with specialist assessments of historic and current civil infrastructure impact to the ephemeral water cycle of the Site and how that relates to plant and soil health of trees involved in the The Project.

This information is used in an evidence-based approach of site assessment and compared to the Arboriculture industry **Visual Tree Assessment (VTA)** to identify a detailed and holistic **Quantified Assessment of Plant and Soil Health**. Current Arboriculture Industry standards for VTA do not include quantified assessments of Soil Health. See Appendix A.

The purpose is to conduct an independent critical analysis of Kingdom (2018) as to the impact of The Project from a current and future site plant and soil health perspective, a view based on Applied Science. This method considers an objective assessment of the health status of Soil and Plant Heath concerning an individual tree (Tree # 1). A specialist area of investigation using pathological and clinical measures and methods of inquiry of the sciences concerned with Plant and Soil Health and function and capable of providing a robust metric analysis. This is to determine an accurate indication of Plant and Soil Health of individual trees identified in Kingdom (2018). GUF Plant and Soil Health Asssessment in more detail, see Appendix, B and C.

GUF has considered the standard Arboriculture Visual Tree Assessment used in Kingdom (2018) and then outlined a Quantified Assessment of Plant and Soil Health. The outcome is The Project exploits individual trees to provide support apparatus and do not consider appropriate knowledge, assessment, management, and risk of the entire site dynamics, that must include the trees root system, soil health, and potential risk of plant pathogens and toxins that will affect individual tree health status, longevity, and stability.

A quantified approach provides a reliable set of metrics for baseline measures of key variables that are used to optimize plant and Soil Health knowledge and management. This is essential in providing advanced and targeted support of Living Infrastructure (trees).

GUF Investigations reveal poor soil health is common in Urban Environments around the world including Australia. See Appendix, D. These Poor Soil Health conditions cannot provide the essential supporting medium (soil Health) to maintain optimized Living Infrastructure (Trees). Stressors are rapidly increasing through Historic Impact, Urbanization, and Climate Change. GUF has developed methods that embrace the complexities of natural systems and investigated sophisticated methods of sensing ecosystem health, monitor biodiversity and environmental conditions via a Multidiscipline Approach including but not limited to, Independent Laboratory Analysis, evolving open source technology, and collaborative sensing platforms to develop knowledge and management capabilities in Urban Forestry and Regenerative Biodiversity.

The author argues that the PLANNING SCHEME AMENDMENT C107 does not consider the true environmental impact of The Project. Complex historic and current Plant and Soil Health impacts, site requirements of ongoing regenerative management, and individual monitoring of Living Infrastructure have not been adequately assessed in Kingdom (2018)

[The Project] reliance solely on the subjective misleading analysis of the tree health in [Kingdom 2018] exposes risk. GUF recommends the PLANNING SCHEME AMENDMENT C107 be abandoned due to an inaccurate assessment of the [The Site].

Based on the authors review of Kingdom (2018) and including the GUF Plant and Soil Health Specialist - Basic Site Assessment and soil sampling and testing regime to confirm CO_2 Respiration, the Author has formed a clear and confident position in refusal to accept [Kingdom, 2018] assessment of the trees and site and deems it inaccurate and misleading.

The current health status and potential future Impact to trees from [The Project] have not been considered in its entirity in [Kingdom, 2018]. The GUF Quantified approach has identified risks, based on unknown current Plant and Soil Health and poor site conditions that may become causative agents of potential tree defect at [The Site]. These below ground factors have not been addressed, understood, planned for or measured in [Kingdom 2018]. It fails to provide Plant Health Care Protocols required for best practice management for an ecotourism venture such as [The Project], where trees are used as structures. [Kingdom 2018] fails to adequatly assess below ground tree components and required advanced tree care.

GUF assessed the proposed site at a concentration point of (Tree # 1) where the impact would be greatest due to the congregation of participants and construction activities. See figure 3. A more extensive Quantified Assessment was not possible due to the budget constraints of the Riverland Conservation Society. A Basic Soil Health Assessment was applied to compare against the Visual Tree Assessment in order to show how soil health measures improve site assessment and overall management of Living Infastructure (trees).

Basic Soil Health conditions were assessed as (poor) based on these initial indicators:

- **Soil Compaction** - (Penetrometer)
- **Soil Moisture** - (% probe @ 7 cm / 50 cm)
- **Soil CO_2 respiration** - (24 hr chamber burst)

GUF Soil Health Investigations have identified multiple current Soil Health impacts on Individual Tree # 1, Contrary to [Kingdom 2018].

Highly elevated Soil Compaction was detected onsite (sample # 1 - 8/1/2021) within Tree # 1 Tree Protection Zone (TPZ) Approx 11 M Radius:

The Soil Compaction Result Average - 900 PSI @ 14 cm. indicates soil compaction is highly elevated. 6 x Soil Compaction (Penetrometer) samples were collected in an array including areas of walking track and areas of Noxious weed growth. 5 pedestrians passed the author on the track adjacent to the root flare during the 45 min survey. This pedestrian volume contributes to pathogen distribution potential.

GUF argues there is a major historic and current Soil Health impact on individual trees that require attention. Historic Animal Agriculture, Landfill, The Millennium Drought, general management (Weed/Pathogen), public landuse (high pedestrian access), recent environmental water releases are all contributing factors that have caused poor soil health conditions to combine and develop into detectable measures in Yarra Flats Park in 2021.

Included in this report are examples of localised consistent poor soil health causing two trees to fail in 2020 from Root Plate Failure see: section 7. Evidence of Poor Soil Health contributing to (Root Plate Failure) provide examples to support the argument that a more sophisticated approach to Tree Assessment is required in Urban Forestry, especially in this case where trees are used as primary support structures to attach human participants to.

The author argues that the PLANNING SCHEME AMENDMENT C107 does not consider the true environmental impact of the development, the complexities regarding ongoing management and monitoring of Living Infrastructure utilised as key components in The Project and how these translate into risk.

The Acceptable Level of Risk and Hazard Assessment outlined in Kingdom (2018) is deemed ill-informed regarding Tree Health, as Soil Health has not been measured.

This is due to the reliance on standard Arboriculture Visual Tree Assessment and the lack of recognising the tree root system and soil health conditions supporting these visual indicators.

The standard Arboriculture Visual Tree Assessment (VTA) is a subjective exercise in determining tree health it is designed primarily to assess risk and does not measure health indicators. VTA does not contain metrics capable of informing a multivariable health status matrix, that is required for an accurate quantified scientific assessment of tree health and function. Based on Kingdom (2018) The Authors argue The Project falls short to adequately consider:

1. Fit for purpose design and management of the project and how it relates to health and function status of key individual Living Infrastructure assets (Trees 1 -58, Kingdom, 2018) that support the apparatus for The Project.
2. A detailed assessment of plant and soil health applied science including Environmental Engineer Assessment of the regions water cycle from a historic and augmented perspective, and how that relates to plant and soil health metrics. This is required to determine the most fit for purpose, practicable biophiloc design, responsive to the individual environment and geological characteristics, along with future management such as regenerative methods/ protocols and risk abatement to plant and soil health.
3. Acceptable level of Risk regarding current and future health and function status of individual Living Infrastructure assets (Trees 1 – 58, Kingdom, 2018) and potential endemic or developing tree health defects e.g. Pathogen activity.
4. Adittional close proximity Tree Health impacts resulting in (tree root plate failure) caused by suspected poor soil health conditions associated with Melbourne Water works to install a billabong. See figure 7,8 and 9.
5. Plan to obtain a pre – works comprehensive baseline of plant and soil health status of individual living infrastructure assets (Trees 1 -58, Kingdom 2018)
6. Plan to optimise tree health and function in the aim of reducing the risk of potential endemic or developing tree health defects.

The Project appears to exclusively rely on a Visual Tree Assessment provided in Kingdom (2018) to assess the Site. These standard methods are inadequate to inform entire knowledge of Tree Health.

A Quantified Plant and Soil Health Assessment is required for [The Project] to determine current Tree Health and the environmental impact of [The Project] over time, and required level of specialist methodology to effectively monitor and manage individual living infrastructure assets (trees), entirly.

In respect to the Site's impact on the water cycle , Environmental Engineering ground truthing is required to confirm the Site specific geological/hydrogeological characteristics. This will inform a bespoke biophilic design and water cycle restoration approaches to maximise triple bottom line (3BL) sustainable benefits across the three pillars of 1) envionmental, 2) social, and 3) economics.

CONTENTS

1 Introduction

Global Urban Forest (GUF) has been engaged by Riverland Conservation Society of Heidelberg Inc. (Friends of Yarra Flats Park) to provide a preliminary Arboriculture Quantified Plant and Soil Health Assessment Report in response to the Banyule Planning Scheme Amendment C107 - development of land in Yarra Flats Park, Ivanhoe East for an outdoor recreation facility TreeTops Adventure Park.

As part of this assessment, GUF was asked to give a critical review of **Kingdom (2018) from a Plant and Soil Health perspective that includes Water Cycle daynamics accociated with The Site.**

The Site for The Project is located within Yarra Flats Park as shown in Figure 1.

Figure 1 Yarra Flats Park proposed TreeTop Development Location

The proposed development area and TreeTop Activity area is shown in Figure 2.

Figure 2 Proposed Development Site Boundary and TreeTop Activity Area (Source: https://shaping.banyule.vic.gov.au/C107)

(Source: update 18-183 (16-37) TreeTop Yarra Flats 2018 update.docx ADVANCED TREESCAPE CONSULTING)

Matthew Daniel conducted a desktop analysis of information provided by Dr. Andrew Lees including (Historic knowledge and photographic evidence of nearby tree root plate failure in Yarra Flats Park. Additionally, a site inspection was conducted, (sample # 1 - 8/1/2021) to gather further plant and soil health data. This information is used in an Evidence-based approach of site assessment and compared with a Visual Tree Assessment contained in Kingdom (2018).

Ecotourism ventures such as The Project must fully evaluate potential environmental impact to limit the destruction of natural assets and associated cultural heritage. It is also essential to maximize the knowledge of the natural systems associated with a venture and assist best practice management by demonstrating a duty of care to all stakeholders. Advanced monitoring of biodiversity, including Living Infrastructure is essential. See (Appendix A, Innovative New Technologies.)

Urban forest

The urban forest comprises all trees and other living infrastructure (including soil and water) contained within the urban footprint (see definition). It applies to both the public and private realms (e.g., streets, parks, residential blocks, road/pathway corridors, universities, schools, open spaces, etc). The urban forest provides important benefits to our urban ecosystem including shade, habitat and habitat connectivity, carbon storage, oxygen, removal of air and water pollution, reduced stormwater run-off as well as aesthetic value and enjoyment.

Living infrastructure

Living infrastructure refers to all of the interconnected ecosystems within an urban catchment, including the 'green infrastructure' of trees, gardens, green walls and roofs, parks, reserves, and open spaces, and the 'blue infrastructure' of our water bodies including lakes, wetlands, and waterways.

Source *CANBERRA'S LIVING INFRASTRUCTURE PLAN: COOLING THE CITY 2019.*

Figure 3 shows the individual trees within the proposed development Activity Area.

Located in the center of the image is a tree with a platform surround (Administration Area). This tree was identified for the basic Site Soil Health Assessment and is referred to herein as Tree#1.

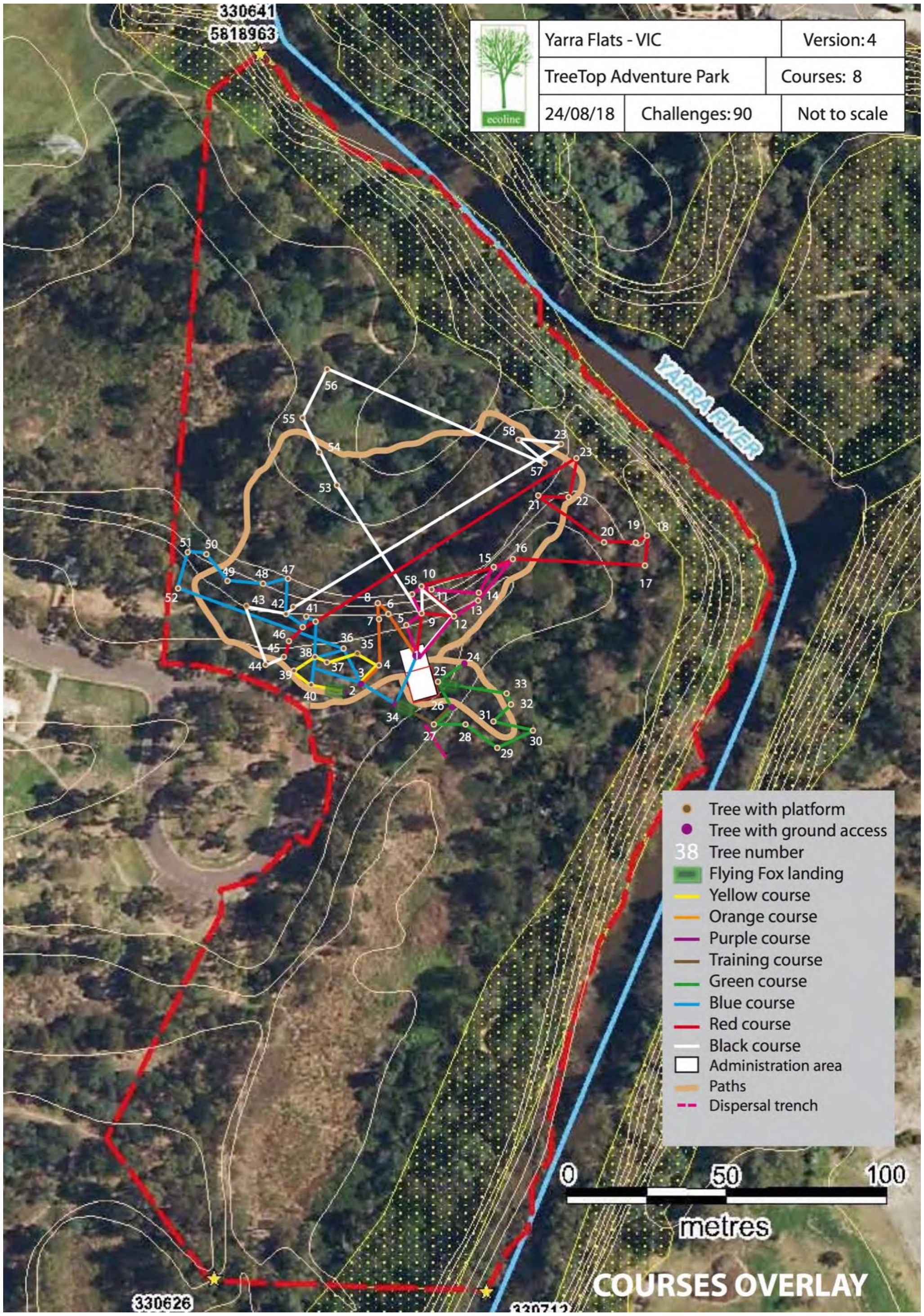

Figure 3 Proposed TreeTop Activity Course and Tree linkages

2 Purpose

The Purpose of this report is to evaluate The Project and its impact to biodiversity from a holistic perspective that includes plant and soil health and Water Cycle dynamics at The Site.

Novel techniques and methods based on applied science supplied by the specialist authors, are compared to standard industry practice, and reporting in Arboriculture and Civil Engineering. This exercise highlights that greater detailed assessments are required for developments where Living Infrastructure is highly valued and promoted in Green Infrastructure strategy. For further detail, see Appendix E.

3 Approach

The Author conducted a site inspection on 8th January 2021 and applied the standard Visual Tree Assessment (VTA). Then, a more detailed plant and soil health assessment was conducted on Tree # 1 and included metrics:

- 6 x Soil sample - App – Based Oursci LLC sensor (CO_2 Respiration)
- 6 x Soil Sample - App Based OurSci LLC Sensor (Soil Spectrum)
- 6 x Site measure (instrument) - Soil Moisture Array @ depth 0 – 40 cm
- 6 x Site measure (instrument) - Soil Compaction Array (Penetrometer)

Metrics obtained in the GUF Basic Soil Health Assessment, demonstrate where a standard Visual Tree Assessment fails to determine an accurate understanding of the below-ground fundamental and functional plant and soil health characteristics of trees. See (Appendix B, Quantifying Plant and Soil Health)

The GUF Assessment of [The Site] identify risk to The Project, as the structural integrity and future sustainability of tree health can be questioned, as site Soil Health conditions were determined poor, contrary to kingdom, (2018), and requires further investigation.

Kingdom, (2018) underestimates risk as it lacks detailed metrics to confirm below ground health status of the trees in [The Project].

4 Method of Assessment

Appendix B, C and D detail the innovative new technologies and quantification methods used in this assessment in part.

Soil Compaction was measured with a standard Penetrometer. These instruments measure PSI pressure at depth in the soil.

Note: This is an indication of Soil compaction. Penetrometers were designed to be used in agricultural soils at field capacity. This must be considered when interpreting data. Penetrometers are a useful field instrument to assist Soil Health

Investigations in Urban Forestry as they are relatively nondestructive. The method requires an interpretation by an experienced soil specialist. This method is more appropriate in the initial phase of plant and soil health investigation as it can allow for an intuitive three-dimensional understanding of soil compaction and medium the root system is growing in. e.g., detection of subsurface compaction layers. Further site assessment methods for soil compaction can include: Soil Bulk Density Assessment in combination with Penetrometer arrays within the TPZ.

The penetrometer soil compaction measures within the TPZ of Tree#1, identified highly elevated surface soil compaction and detectable subsurface compaction layers, a possible result of historic impact or fill.

Soil Moisture was measured at 7 cm and 50 cm using a digital, moisture % probe, and augur and tape measure. Soil moisture and compaction are interconnected and can be antagonistic. For example, it is common in Urban Forestry in Australia to find highly elevated soil compaction leading to soils becoming hydrophobic.

App-Based Sensor – CO_2 Respiration (Microbiome indicator) This soil respiration kit measures the amount of soil CO_2 evolved from a soil 24 hours after rewetting. This is a soil health test that measures the CO_2 Production from activity of soil microbes. These tests are used in GUF Quantified Soil Health Assessments to compare against Laboratory Direct Microscopy ground truthing baselines.

App-Based Sensor – Soil Reflectance (Nutrient) The reflectometer uses NIR/Vis spectroscopy to measure soil 'darkness', which is often correlated with soil organic matter, which impacts the availability of soil nutrients.

GUF has demonstrated on projects such as **Hume City Council / MIT Quantifying Urban Forest Soil Health** (refer to Appendix B) **where** both the reflectometer and soil respiration kit showed strong relationships to important soil nutrients (N, P, K) and total C. a useful cost-effective means of quantifying remediation activity effectiveness and future monitoring of soil carbon content.

5 Results

Results of the plant and soil health data have been determined through undertaking a basic site survey applying a Visual Tree Assessment and using field instruments and soil sampling array techniques. Soil CO_2 Respiration and Soil Reflectance were measured from the site survey samples 48 hrs. after sampling using low-cost App – Based Sensors developed by GUF and OurSci. Soil CO_2 measures indicate poor soil Microbiome levels @ Tree #1. when compared to GUF investigations quantifying soil health. see Appendix B, D and G.

5.1 Visual Assessment

A photograph of the south eastern side of Tree#1 trunk (base) is shown in Figure 4.

Figure 4 Photograph of Tree#1 trunk

The image of Tree #1 shown in Figure 4 indicates evidence of kino production induced canker activity, overlooked in Kingdom, 2018.

5.2 Soil Compaction (penetrometer)

A penetrometer was used to obtain a reliable compaction metric within the TPZ of Tree#1 and investigate detectable subsurface compaction layers resulting from historic impact or fill. Soil health metrics were obtained from six [6] samples per calculated TPZ.

As a rule, healthy soil compaction should be below 300 psi @ at least 400 mm depth to support healthy root growth. This optimal value is rare in Urban Forestry due to Historic impact, current management, and development design process. Deeper soils greater than 400mm are preferable depending on the size of the tree and the root: shoot ratio required to support the entire tree mass and vascular system.

Table 1 lists the soil compaction and moisture characteristics measured at the Site.

Table 1 Site measured Soil Compaction and Soil Moisture

5.2.1.1.1 SOIL COMPACTION - PENETROMETER	5.2.1.1.2 SOIL MOISTURE % - PROBE @ DEPTH 7 CM & 40 CM
900 PSI @ 14 cm	23% @ 7 cm - 19 % @ 50 cm

Results in Table 1 generally indicate that this location is of poor Soil Health and fundamental soil functions are restricted - 900 psi @ 14cm, is three times the best practice standard and would require remediation and management.

5.3 Plant and Soil Health Sensing Data

Plant and soil health data was assessed via App-Based Sensors, CO_2 respiration and Soil Spectrometry.

Soil Samples collected around the TPZ of Tree#1 were analysed using a cost-effective method of 24 hr. CO_2 chamber burst. This assessment resulted in the final measure of CO_2 in the chamber after a 24-hr. period at a consistent temperature as listed in Table 2.

Table 2 Soil sample CO2 Respiration chamber burst.

CO2 PPM RESPIRATION CHAMBER BURST
Baseline – 456 ppm
Final – 3142ppm

Based on GUF investigations on Victorian soils where independent laboratory analysis of soil biology was cross-referenced against the CO_2 sensor data; it can be suggested the single soil sample indicates poor soil biological activity. poor soil biology activity will restrict healthy root growth including suppression of pathogens. Soil Microbiome is a critical component in healthy soils.

For reference projects displaying similar data outcomes, refer to:

- Appendix B - *Quantifying Tree and Soil Health - Hume City Council, Global Urban Forest (GUF), Massachusetts Institute of Technology (MIT) - Australian Ground Truth Study 2019 - 2020*
- Appendix *D - State of the Urban Forest Soil Microbiome 2018 – 2020 Analysis of GUF Soil Health Data*
- *Appendix H – Allnutt Park Phytophthora Remediation Project 2019*

Figure 5 Screenshot of CO2 App Respiration Assessment

Figure 5 presents a CO_2 respiration burst @ 24 hrs. of 3142 PPM. This indicates poor soil biological activity.

5.4 Soil Reflectance

Soil Reflectance is a valuable monitoring metric when combined with a ground-truthing Independent Laboratory Soil Assessment of Total, Available and Exchangeable Nutrients, but alone these metrics cannot be interpreted. The purpose to include this measure in this report without a ground-truthing survey is to demonstrate the required process of evaluating soil health parameters to establish fit for purpose Living Infrastructure status. Soil spectrometry samples have a 1-minute sample process, so the author decided to include this measure. As an example. These metrics are valuable over time as they will inform a larger Soil Health global community database currently being built by GUF.

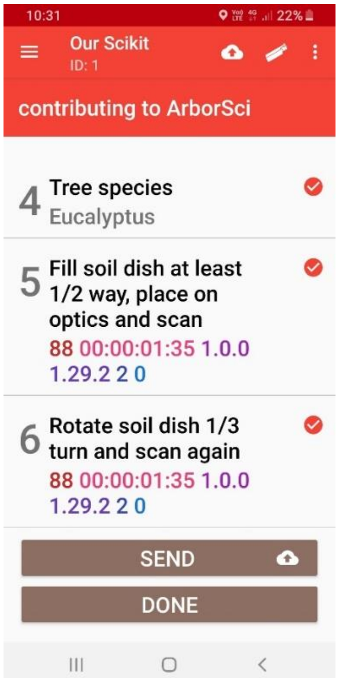

Figure 6 - Screenshot of App-Based sensor of Soil Reflectance (Nutrient indicator)

6 Evidence of Poor Soil Health contributing to (Root Plate Failure)

In December 2020, two [2] tree **Root Plate Failures** occurred nearby the Site on either side of the Annulus Billabong within Yarra Flats Park. This area is part of Melbourne Water - Lower Yarra billabong environmental water releases.

Water will be released from the main branch of the Yarra River, or from alternative sources – like harvested and treated stormwater – where available.

In 2020/21, water for the environment is proposed to be delivered to the following billabongs:

- *Yering Backswamp, Yering*
- *Annulus Billabong, Yarra Flats Park – Heidelberg Source: Melbourne Water*

This case of major tree failure is concerning as it identifies the historic and current poor plant and soil health conditions at Yarra Flats Park becoming causative agents to tree defects. This example identifies the importance of obtaining more sophisticated assessments of environmental conditions and impact on living infrastructure in Urban Forest development.

It appears from the photographic evidence that the root plate failure has occurred from a combination of historic poor soil health, anaerobic conditions forming due to soil compaction, low soil permeability, and potential pathogens such as *Phytophthora* and *Pythium* species being transported to the Site from sources such as stormwater, pedestrian access, and landfill. Further detail on pathogens and poor soil health Investigations by GUF in Victoria, see Appendix F, G and H.

This example of tree failure poses a clear link of risk to the Tree Tops Adventure Park proposal as this area of Yarra Flats Park has the same historic impacts of Animal Agriculture, Land Fill, and Storm Water Catchment Augmentation. A clear example of requiring a more sophisticated and scientific approach of assessing the Quantifying Plant and Soil Health before the exploitation of Living Infrastructure (Trees 1 – 58, Kingdom 2018). It is also an example of oversimplifying environmental projects and not considering the historic and current impacts on soil health before works. Injecting environmental water flows into areas of poor soil health may lead to anaerobic soil conditions forming and soil pathogens flourishing. It also has an unknown impact on the tree endemic soil Microbiome consortia.

6.1 Identified Tree Failure #1

Figure 7 - Images Tree Failure #1 - December 9th, 2020

Figure 7 indicate poor soil health conditions, poor root: shoot ratio, and root development. Blackened necrotic roots indicate anaerobic soil conditions Image Source – Dr. Andrew Lees

Figure 8 – Images Tree Failure #1 – December 9th, 2020

Figure 8 indicates (yellow circle) the tree had a poor root: shoot ratio, and an active functioning canopy with little signs of dieback. browned off grass area where recent flooding occurred is defined by browned off margin.

Figure 9 – Image Tree Failure #1 , October 2020.

Figure 9 recorded before falling event and indicates flooding of the tree 13 October 2020 before failure in 2021. Source – Dr. Andrew Lees.

Figure 10 – Image Indicates the 2 x Tree Failure Sites. Source Dr. Andrew Lees.

6.2 Identified Tree Failure #2

A desktop analysis provides an inferior analysis of tree defects after the event has occurred. Although in this case, they provide an excellent example of the limits in a Visual Tree Assessment to determine the health and function of the root system in Soil. The Images provide visual evidence of Tree Failure # 2:

1. *Basidiomycete* fungi activity in the crown of the root flare with signs of white fungal mycelia present in heartwood tissue. See Figure 11, #1 and figure 12.
2. Fungal decay in the Critical Root Zone area, see figure 11, 12.
3. Canker activity on new wound wood tissue. See figure 11 # 3.
4. Canopy Health appear to have been good at the time of failure as figure 14 shows no signs of dieback and has green leaves still attached within the entire canopy.

Figure 11 – shows this tree root plate failure was caused by basidiomycete fungal decay in the late stages of destroying the structural integrity of the critical root system of the tree. In retrospect, this tree may not have been condemned by an Arborist while standing when grading with a Visual Tree Assessment. In all fairness, the fungal activity is hidden from the expert eye underground and within wood tissue. Identification of Pathogens is impossible from these symptoms without laboratory analysis. What may have been an indication of Pathogen activity at the time before failure would be the signs of canker activity on new wood tissue causing Kino production see figure 11 .3.

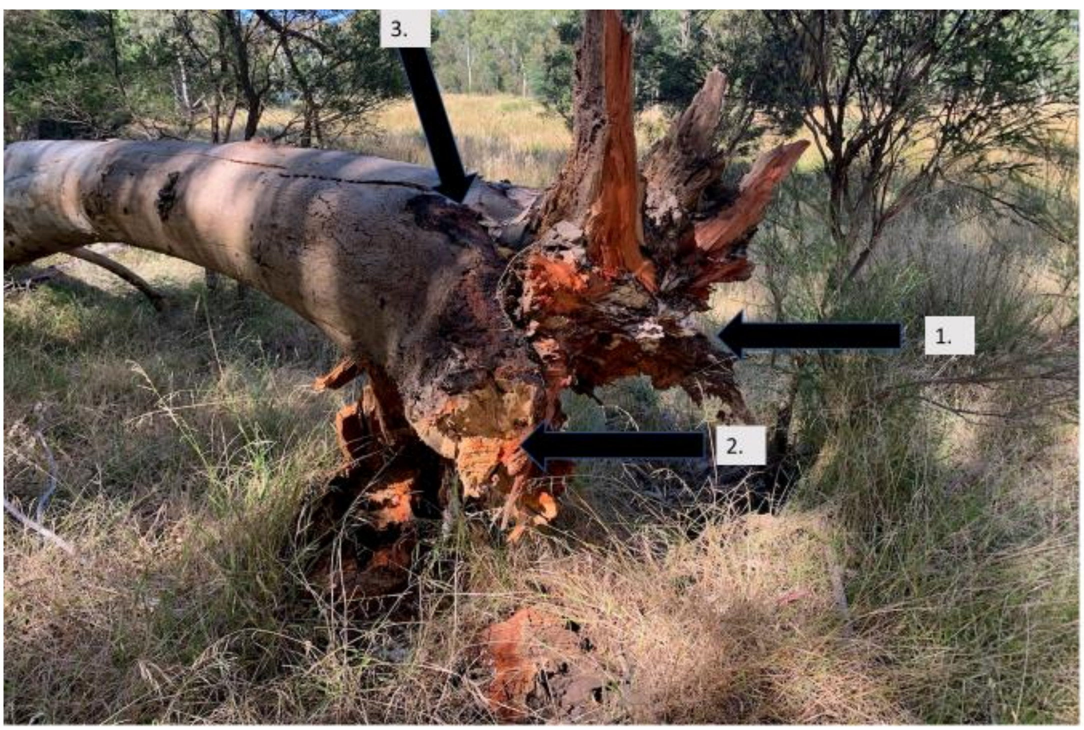

Figure 11 – December 14th 2020.

Figure 11 Shows 1., Fungal Mycelia active in root flare heartwood .2., Decayed wood in root flare 3., Canker activity.

Figure 12 – December 14, 2020

Figure 12 shows well developed and active Basidiomycete activity in the heartwood crown of the root flare.

Figure 13 - December 14, 2020

Figure 13 indicates structural root failure caused by Basidiomycete fungal activity.

Figure 14 - December 14, 2020,

Figure 14 Image indicates in the yellow circle that the tree appeared to have an active canopy at the time of structural root plate failure.

7 Yarra Flats Region Environment and Water

This section of the report (by Owen Richards) assesses the water story, the historic (Aboriginal) environment and the current augmentation, subsequent impact, and function of civil Infrastructure on environmental water flows and how that relates to the Yarra Flats Park region and subsequently impacts the Site.

7.1 Introduction

The water cycle is widely overlooked in the assessment of soil and tree health. All living organisms require water for survival. Water helps to transport oxygen, minerals, nutrients, and waste products to and from the (biological) cells, and the chemical reactions that occur during this cycle help maintain soil carbon.

Water links and maintains all ecosystems on the planet. The main function of water is to propel plant growth; provide a permanent dwelling for species that live within it or provide a temporary home or breeding ground for multiple amphibians, insects, and other water-birthed organisms; and provide the nutrients and minerals necessary to sustain physical life. As nature's most important nutrient, people need water to survive.

Looking at the planet from space, if the Earth were hypothetically a body, then water would be its lifeblood. Like air, sunlight, and food, without water, there would be no life on the planet.

When humans change an ecosystem without thought to maintaining its natural balance, the cycle of life in the ecosystem can skew to one side or other and disrupt the delicate equilibrium necessary to sustaining the community. Some species may die off, and others may thrive, but in the end, the symbiotic relationships begin to break down and the ecosystem dies (Sciencing, 2021).

Urbanisation, grey infrastructure, and agriculture are some of the key drivers of Climate Change. We continue to assess and mitigate these drivers individually and wonder why there is negligible progress towards restoring nature's balance.

This section of the report assesses the water cycle and its impacts on soil and tree health within the Site and investigates:

- the pre-European natural water cycle, related environment, and biodiversity;
- the geology at the Site and the surrounding region;
- the impacts on the water cycle post-European establishment;
- general regenerative approaches towards restoring ecosystem health; and
- introduction of the Integrated Water & Soil Regenerative Method (IWSRM).

7.2 Background

In its natural state, the environment poses little flooding and pollution risk with as little as 10% of rainfall becoming runoff. Depression storage retains surface flows. Significant losses occur through infiltration and transpiration. The waterways within these natural environments, generating little runoff, are ephemeral. An ephemeral creek is a waterway that flows only during and after precipitation (WikiPedia. 2021. Ephemeral stream).

Increasing urbanisation and agriculture has dramatically changed the natural landscape with the introduction of hard, impervious surfaces such as roads, carparks, building structures, and engineered fill in urban centres; whilst in respect to agriculture: reduced biodiversity, soil damage, compaction (increasing soil bulk density) and reduction in plant and root growth and soil water holding capacity.

Where once the natural earth exhibited as little as 10% surface runoff, 40% evaporation / transpiration, 25% infiltration to shallow groundwater tables and 25% deep infiltration to aquifers as shown in Figure 15 now exhibits as much as 90% runoff with as little as 10% natural (loss) processes as shown in Figure 16 (Richards 2017).

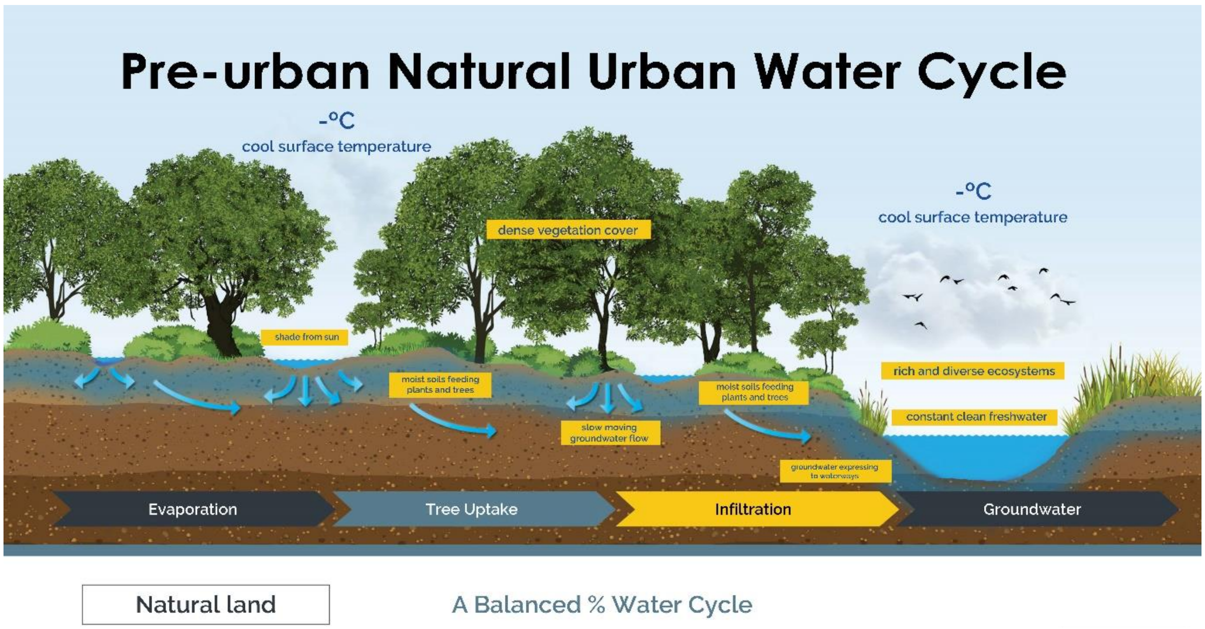

Figure 15 Natural Water Cycle.

In these natural state ephemeral environments, frequent, low-volume rainfall infiltrates into the ground where it lands. Surface overland flows are prevalent during significant rainfall events where the ground is saturated and excess runoff is generated. These are the key water cycle characteristics that were exhibited across the pre-European Yarra Flats region.

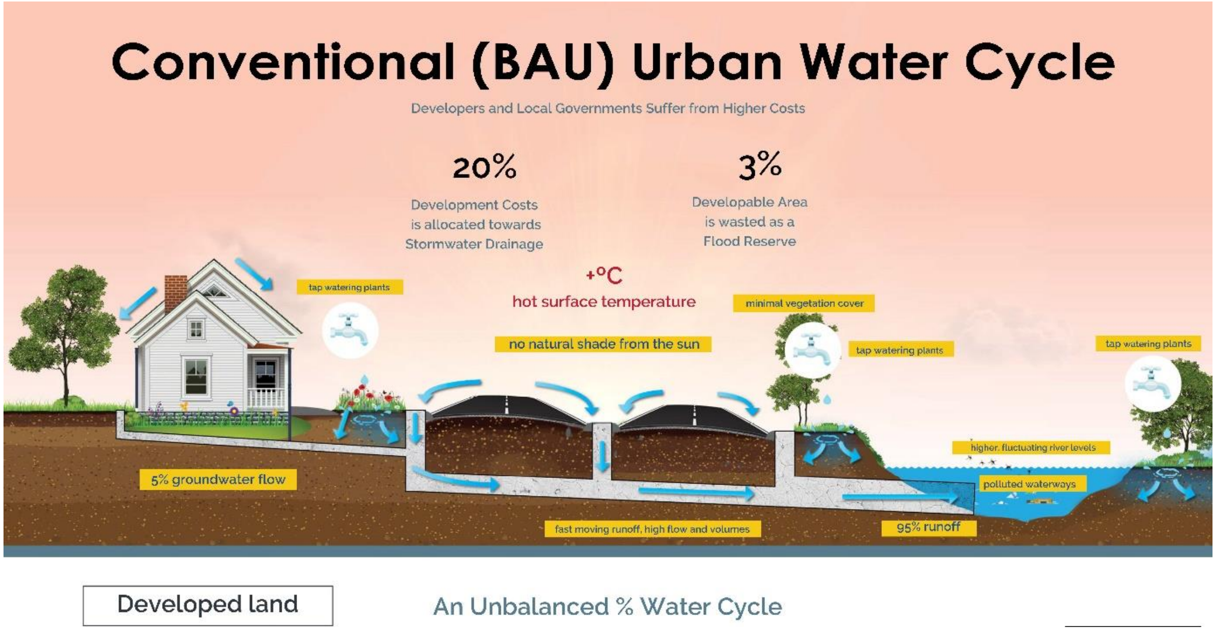

Figure 16 Conventional Developed (Urbanised) Urban Water Cycle

Through urbanisation, areas of the natural (pervious) environment are replaced with constructed impervious surfaces whilst in farming and agriculture, areas of the natural (biodiverse) environment are stripped and replaced with singular species crops or grazing livestock which undergo compaction from machinery or stock tread.

Conventional urbanisation and agriculture have critically increased problems such as:

- flash flooding;
- receiving environment stormwater pollution and management problems;
- heat island effects with subsequent increased energy consumption;
- groundwater depletion and increased water security risk;
- increasing urban tree fall risk;
- increased erosion, nutrient run-off, and landslides; and
- reduced long term crop yields and productivity, even more so following drought.

These problems are becoming more prevalent, frequent, and increasing at a magnitude of scale.

Mitigation approaches currently only target individual problems and 'band-aid 'the issues. These façade approaches only lead to irreversible detrimental impacts in future.

An understanding of the natural environment function, its characteristics and composition can aid in more effectively rejuvenating and regenerating these environments so severely impacted from these human activities.

7.3 Pre-European Landscape

The Wurundjeri-willam people of the Kulin nation are the traditional owners of the land in this region. The Wurundjeri's connection to land is underpinned by cultural and spiritual values vastly different to those of the Europeans. The Wurundjeri did not 'own 'the land in the European sense of the word, but belonged to, or were 'owned by 'the land. The land provided all the Wurundjeri needed – food, water, medicine, shelter – and they treated it with the respect due to such a provider (Agora, 2013).

The moment Europeans arrived in the area they began changing the land to suit the European way of life. For most settlers, the driving force was land ownership. For at least some of these settlers, underlying this drive was an imperial belief in British superiority combined with a desire to 'civilise '(Agora, 2013).

The illustration of Figure 17 depicts the rich biodiversity that once dominated this region's landscape.

Figure 17 Illustration of Wurundjeri people camping alongside a billabong. (source: ToMelbourne.com.au)

The rich river flats drew attention from pastoralists, market gardeners and orchardists soon after Melbourne was established in 1835. The first land sales occurred in 1838 and Heidelberg was already well settled by 1841 with timber cutters at work, dairy farmers along the creeks and gentleman farmers on larger estates.

The Yarra Flats Park comprised land that was originally the properties of the Charterisville and Hartlands estate.

The natural vegetation of the area was soon displaced by the trees and plants of England. Small farmers moved in, growing first wheat then, later, oats, potatoes, vegetables, barley, lucerne, maize and hops and establishing market gardens, orchards, and vineyards (SMH, 2021).

Evidence of the Yarra Flats pre-European environment biodiversity has been mostly depicted through artists impressions such as the 1873 oil on canvas painting by William Ford, shown in Figure 18. It should be noted that the artists impression illustrated in Figure 17 could be considered an accurate representation of the extremely diverse pre-European Yarra Flats Landscape. In particular upon comparison to artists impressions of other Australian landscapes, such as the stark comparison of North Esk river near Launceston, shown in Figure 19 and Figure 20.

Figure 18 Yarra Flats 1873, WILLIAM FORD 1823-1884 (Source: https://www.invaluable.com/auction-lot/william-ford-1823-1884-yarra-flats-1873-oil-on-ca-53-c-2c447b2bec)

Figure 19 North Esk river near Launceston: 1809 as painted by John William Lewin (source: Mitchell Library, SLNSW, PXD 388/6)

Figure 20 North Esk river near Launceston: 2008 (source: Bill Gammage)

The area and distribution of the various forest types has reduced significantly, largely because of land clearing for agriculture and urban development as European settlement proceeded. Prior to European settlement and subsequent urbanisation, the total area of forest in Victoria was 19,983,000 hectares, representing 88% of the State (Woodgate & Black, 1988).

This rich biodiverse landscape is a stark contrast to the post agricultural landscape of the Yarra Flats Park region shown in Figure 21.

Figure 21 Aerial Photo (1931) of the Yarra Flats and surrounding region (source: http://www.friendsofyarraflatspark.org.au)

Urbanisation, agriculture, and farming throughout the region has significantly altered the natural water cycle and subsequently detrimentally impacted ecosystem health. This was further exacerbated in the 1860's when droughts and floods forced many farmers off the land. No regenerative processes followed. The landscape was abandoned, left broken with dairy farming become the primary agricultural use in the years afterwards.

7.4 Geology

The regional geology encompassing Yarra Flats Park is shown in Figure 22. Yarra Flats Park is situated within Quaternary geology of Recent to Pleistocene periods and consists of low-level alluvium and beach sand (Qra) deposits.

The surrounding geology consists of massive siltstones with interbedded sandstones and shales with some fine to coarse sand and gravel pockets throughout Heidelberg.

Although these deposits vary in thickness, formation, and materials, they are grouped together by similar hydrogeological processes (VVG, 2021). This regions geology supports infiltration and passive aquifer recharge.

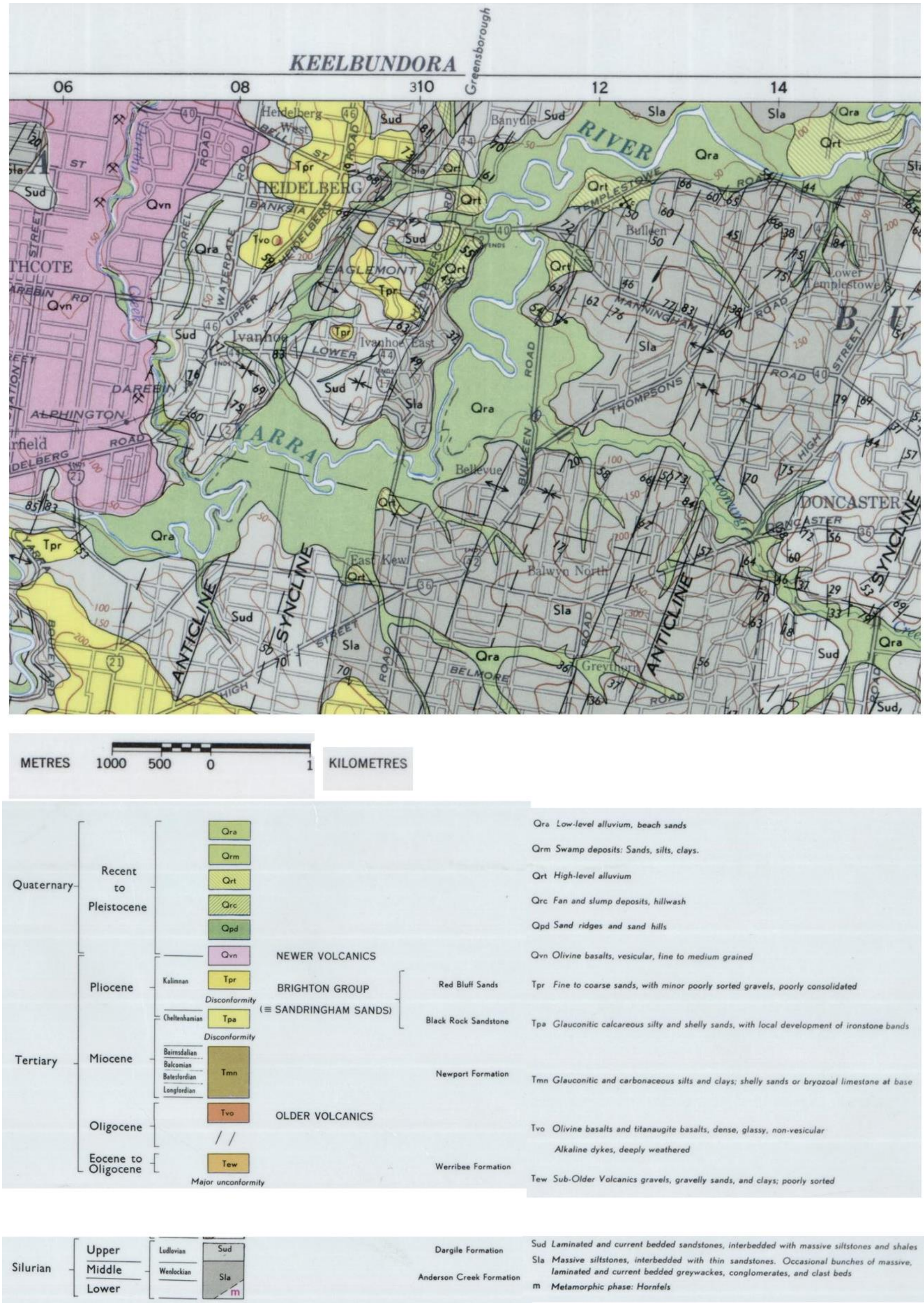

Figure 22 Geology of Heidelberg (source: Geological Survey of Victoria, Ringwood, No.849 Zone 7)

7.5 Groundwater

Groundwater is water that is found under the ground. It is stored in and can flow through discrete layers known as aquifers which are discrete layers of fractured rock, gravel, sand, or limestone that exhibits enough porosity to hold and convey water. Groundwater is generated primarily from surface water from rainfall or other water bodies which incorporate porous substates that promote percolation through the ground to the water table (SRW, 2011).

The soils in these flood plains mainly comprise of fine sand, silt, and clays. The extent of pore spaces is reduced with finer sand deposits, reducing infiltration rates to underlying groundwater (aquifer) systems. Refer to the following section for further groundwater discussion.

Where localised clay deposits exist, rainwater which infiltrates down to these less porous materials becomes perched. It infiltrates to deeper levels over a much longer period. As a result, long periods of rainfall can generate significant perching of groundwater and saturate the surrounding soils.

Groundwater moves at varying rates through the unconsolidated deposits in local flow systems that generally develop at shallow depths below the ground surface. Compared to stream flow, groundwater may take tens, hundreds, or thousands of years to move the same distance through an aquifer (SRW, 2011).

The groundwater systems of the Yarra Flats region, shown in Figure 23, are supported by the geology which promote infiltration and passive aquifer (groundwater) recharge. Note, however, groundwater aquifers that are thick can dissipate infiltrating water. Alternatively, aquifers with low thickness are less able to dissipate the water. The maximum height of a mound tends to decrease as the thickness of the aquifer increases (MPCA, 2021). The location of the thicker aquifer located west of Heidelberg is consistent with the sand and gravel deposits (Tpr) and would exhibit high infiltration rates under natural water cycle conditions. Whereas the thinner aquifer within the Yarra Flats plain would exhibit much lower infiltration rates which is supported by the geology and subsequent waterlogging.

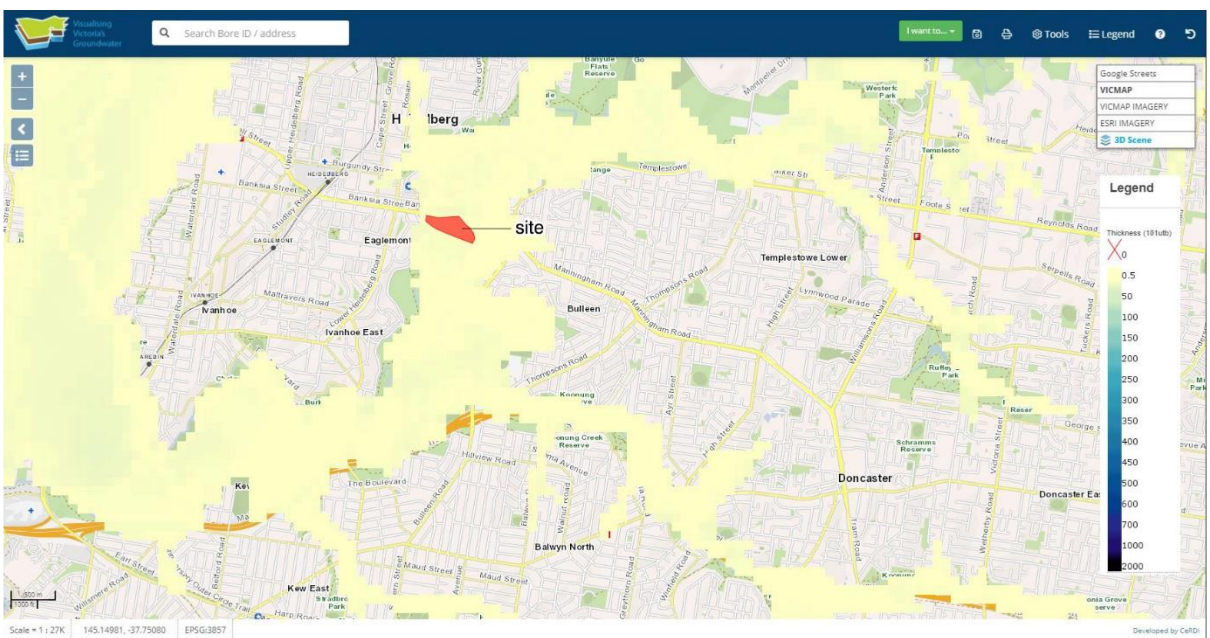

Figure 23 Yarra Flats region groundwater systems

The extensive bores in the region, shown in Figure 24, support the historic reliance on groundwater for water supplies.

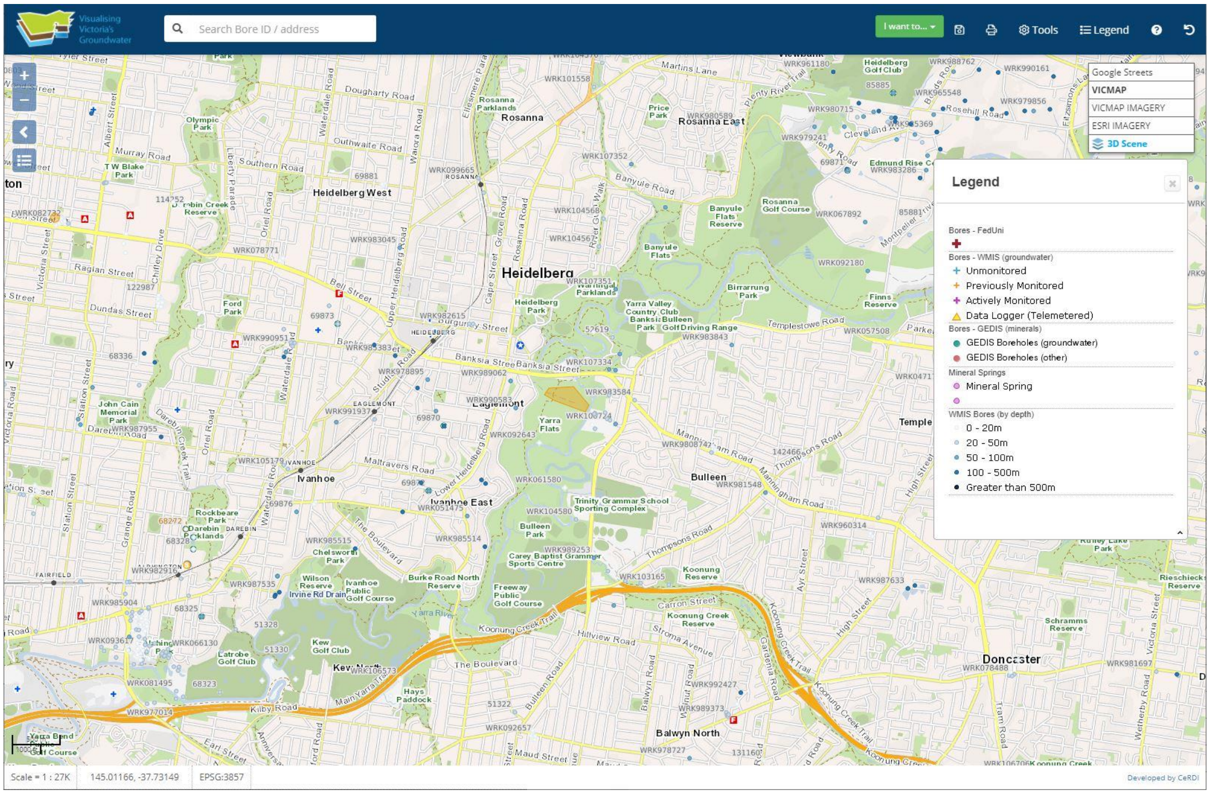

Figure 24 Yarra Flats region Groundwater bores

Water can move in both directions between an aquifer and surface water feature (eg. billabongs, lakes, and streams). Some surface water environments, in particular billabongs, rely on recharge from groundwater, known as baseflow, to stay healthy and survive. These types of environments are referred to as Groundwater Dependent Ecosystems (GDE) (SRW, 2011). The groundwater cycles through GDE as depicted in Figure 25.

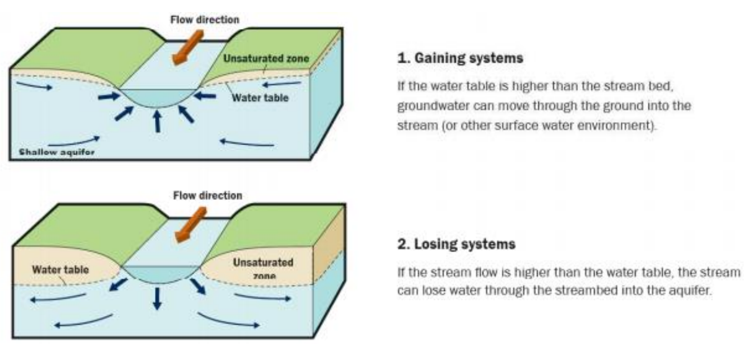

Figure 25 GDE groundwater flow cycle (source: SRW 2011)

In general, changes in the water (cycle) balance resulting from land-use change has (significantly) increased frequency and volumes of stormwater discharges during **all** rainfall events resulting in soil water logging (VVG, 2021). Combined with the geology and soils consisting of finer particles, a low hydraulic gradient occurs, supporting only slow-moving groundwater in the saturated alluvial plain. Furthermore, as stormwater is conveyed and discharged to end of line systems, such as the stormwater wetlands in Yarra Flats Park shown in Figure 26, these systems generate significant groundwater mounding and saturation of the surrounding soils. This in turn significantly exacerbates waterlogging.

Mounding can occur in areas where infiltrating water intersects a groundwater table and the rate of water entering the subsurface is greater than the rate at which water is conveyed away from the infiltration system (Susilo, 2009).

Centralised stormwater collection systems consisting of constructed wetlands, infiltration basins and even waterways (with directly connected stormwater outlets) have far greater groundwater mounding impacts because the stormwater volumes are accumulated and concentrated into a small area at orders of magnitude greater than other approaches. For example: a 10,000 m3 detention basin will result in 10 m groundwater mounding calculated using *Hantush (1967) to compute the transient watertable rise (height of groundwater mound) beneath rectangular and circular recharge areas (infiltration basins or ponds).* End of line surface infiltration sump systems (vegetated) generate 1 m mounding per 1000 m3 of stormwater (Richards, 2019).

Figure 26. Yarra Flats Park Water Systems (source: Friends of Yarra Flats Park)

If the groundwater mound reaches the base of the water body, then the hydraulic gradient (direction of water movement) shifts from vertical to horizontal and significantly slows the movement of water through the soil. This may be a considerable factor within the Yarra Flats Park with the number of stormwater systems, outlets, constructed wetlands and current billabong recharging schemes. The image of Figure 27 shows River Water discharging rapidly into the Bolin Bolin billabong.

Figure 27. Bolin Bolin Billabong restoration (source: VEWH)

The interconnectivity of groundwater mounds from concentrated discharges of these water systems may significantly impede infiltration, resulting in more frequent waterlogging. This could detrimentally impact ecosystem health through the imbalance of water volumes, oxygen, minerals, and nutrients and increase water security risk through reduced aquifer recharge.

7.6 Impacts of urbanisation and agriculture on the Yarra Flats Water Cycle

7.6.1 Urbanisation

Urbanisation over the highly porous geology of the sand and gravel (Tpr) deposits, refer Figure 22, has prevented infiltration. The impervious (reflective) surfaces consisting of pavement, roof, compacted engineered soils etc. immediately generate runoff. Here an imbalance in the natural water cycle occurs as the environment loses its ability to absorb rainwater. The rainwater is instead accumulated and channelised over these impervious surfaces, like a river, increasing in volume and velocity the further it flows.

In the urban context, to mitigate flood risk to urban areas, properties and life, the land is graded to assist in draining these reflective surfaces. Pit and pipe drainage systems are adopted to assist in mitigating frequent storm flood risk, typically for the five [5] year Average Recurrence Interval (ARI). Unfortunately, pit and pipe drainage systems are impractical and un-economical for all storm events greater than the typical 5-year ARI and up to and including the major 100-year ARI storm events. Subsequently, the road reserves are designed as (major storm) flood corridors to convey the flood risk to a designated area within the urban area. Typically, all stormwater is concentrated into a waterway, detention or wetland area at the bottom of a hill (Figure 16 and Figure 26).

The major challenge with conventional pit and pipe underground drainage systems is what is known as 'daylighting', which is discharging flows back to the existing (natural) surface.

- Pipes require grade to function; and
- Pipes require cover to protect from collapsing.

The longer a pipe run, the deeper the pipe. Unless drainage pipe runs are daylighted intermittently (by distributed detention systems), the pipes can become very deep. In dense urban areas, distributed (surface) detention systems are uncommon due to the lack of land area set aside for such purposes, particularly where land values are a premium. Therefore, as underground drainage pipe runs become very long, they are subsequently very deep. The limited space for major storm detention systems in the road reserves forces the detention systems to the lowest lying part of the urban area. Significant import of fill is also generally required to tilt the landscape and promote drainage along road corridors, but also to provide depth (and cover) for underground drainage pipes (and other utilities such as sewer reticulation) so that they can daylight to a detention basin that is not excessively deep. If the design solution restricts detention basin depth, the design engineer will require more surface area at an even further location downstream, resulting from the additional accumulation of runoff volumes. Regardless of the design outcome, the area designated for the detention reserve is significantly altered from its natural, pre-developed condition. The construction and function of a detention basin requires as much 'clear' open space as possible.

7.6.2 Agriculture

Farming and agriculture is the most prevalent activity within the Yarra Flats region since European establishment. The combination of grazing and wet pastures usually causes varying degrees of damage to vegetation and soils (AV, 2021). In relation to pasture damage, stock treading:

- buries and fouls herbage, reducing pasture utilisation; and
- creates bare space, which can be invaded by weeds.

In relation to soil damage, stock treading:

- makes the soil surface rough, resulting in management problems.
- destroys soil structure and pore space, which reduces infiltration rates and further compounds the poor drainage of the soil;
- kills earthworms.
- increases the risk of erosion and nutrient run-off; and
- causes soil compaction (increasing soil bulk density), which further reduces plant and root growth and the water-holding capacity of the soil. New Zealand research has shown infiltration rates to be 10 times slower in compacted soils. The connection system between soil pores is damaged, which results in reduced aeration and water storage (AV, 2021).

The advent of high intensity (extreme) rainfall has been identified as a dominant trigger for erosion and landslides in rural agricultural areas and urban centres established in undulating topography (Dahlhaus, 2003). The extreme rainfall generates significant overland and subsurface stormwater flows, as well as erosion and landslides. Compacted areas of bare earth generate runoff which flows directly into the subsoil via surface cracks, rabbit burrows, or old root holes. Impervious surfaces such as compacted surfaces, roads and structures act to convey stormwater to concentrated discharge locations. Subsequently, this develops potential for the formation of slurries that flow beneath the soil, which can rapidly flow to the surface forming a tunnel. These tunnels continue to enlarge during subsequent wet periods and eventually reach a point where the roof collapses resulting in potholes and erosion gullies (DPIPWE, 2020). Figure 28 shows an example of tunnel erosion identified within the Site.

Figure 28 Tunnel erosion identified at the Site.

The soils impacted by tunnel erosion generate additional risk to tree fall through the creation of large soil cavities resulting in reduced root mass stability.

7.7 Impact on vegetation

In the Yarra Flats region, the local geology and soil profile has a direct correlation to the extent of water retention and subsequent vegetation species. Plant species exist within ecosystems, which require specific volumes, surface water depths and constituents of water sources to survive. Root zones of vegetation target various depths within soil profiles to ensure these specific water sources can be retrieved. Augmentation of the natural water cycle within urban growth areas detrimentally impacts water-sensitive native flora throughout the growth area, altering:

- water constituents.
- location of surface water retention.
- surface water depths; and
- groundwater flows.

The European establishment, urbanisation and agriculture practices within complex and diverse native environments such as the indigenous Yarra Flats region has detrimentally impacted on these ecosystems, altering:

- surface water and groundwater volumes;
- concentration of surface water and groundwater volumes into predetermined areas;
- runoff water temperatures; and
- land surface temperatures.

These detrimental changes to the natural environment are common throughout BAU urban development and conventional farming practices.

8 Regenerative Approaches

8.1 Sustainable Urban Water Cycle through Source Control Stormwater Management

Recognition of adverse effects of urbanisation has led to a progression of evolving stormwater management strategies, each of which has attempted to minimise impacts of urban runoff on the flow regime of receiving watercourses. While these efforts have resulted in reduction of some impact, research has shown that the current state of practice with respect to stormwater management is often not sufficient to mitigate the hydraulic and environmental impacts of land use change and urban development on the water cycle and environment.

Examination of the premise behind current management strategies clearly reveals the need for a paradigm shift in stormwater management practice. While end-of-pipe solutions have been effective to a degree in reducing flood flow and water quality impacts, current science points to the need for a water balance approach that promotes additional source and conveyance controls to minimize the increase in runoff generated from urban landscapes and reduce impacts to receiving watercourses and the aquatic habitats that they support. The runoff volume control implied by this approach is often difficult or impossible to achieve only with end-of-pipe solutions and, in that context, source controls involving retention and infiltration mechanisms (as close to where rainfall lands as practicable) become an essential component for the stormwater treatment train (Novatech 2007).

The contemporary approach to stormwater management promotes 'source control stormwater management' as the fundamental philosophy towards maintaining ecosystem health and reducing the impacts to receiving environments. This very effectively mimics the natural pervious water cycle within mostly impervious environments. In China, this is referred to as a 'Sponge City'. Basically, absorbing rainwater as close as practicable to where it lands, and integrating the water source into the urban water cycle. The result is almost equal natural-state processes within urban environments, generating a sustainable natural urban water cycle as illustrated in Figure 29.

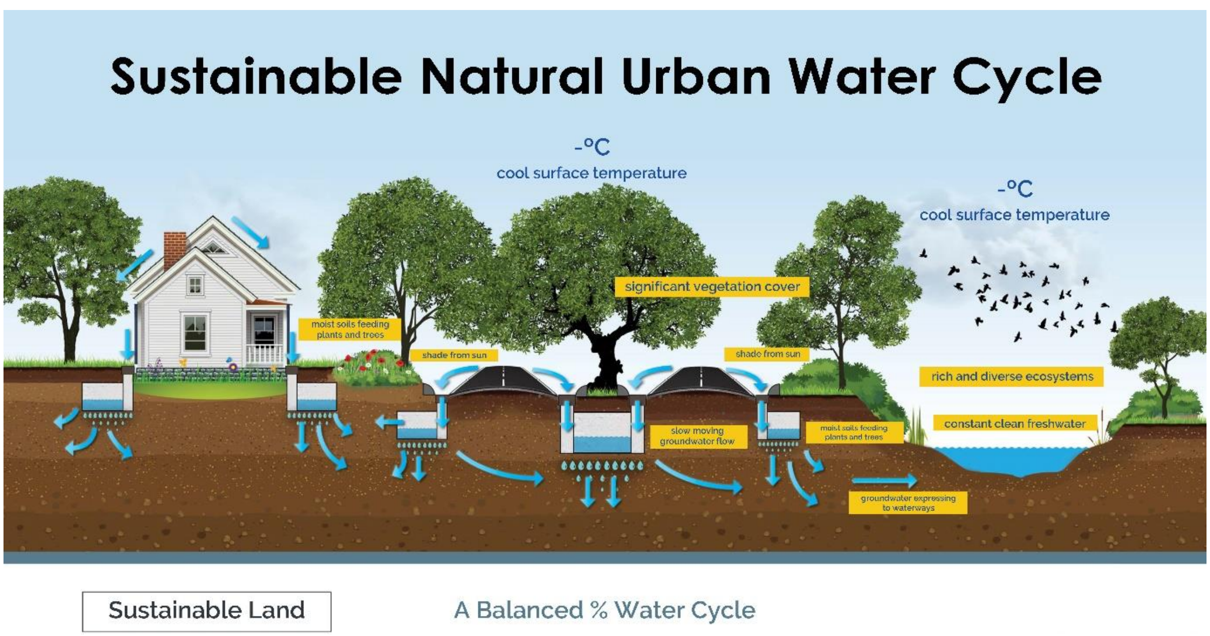

Figure 29 Sustainable Natural Water Cycle.

The application of source-control stormwater management compared with conventional conveyance and detention systems, can:

- Most practicably 'mimic' the natural hydrology (within a mostly impervious urban environment);
- Reduce altered state processes and increase natural state processes within the urban water cycle; and
- Maintain existing ecosystem flora health and function.

Source control for stormwater management enables more practicable and achievable ways of 'mimicking' the pre-urban natural water cycle. By applying 'fit for purpose' and individual drainage solutions responsive individual environmental conditions can maximise triple bottom line (3BL) benefits of:

1. Economic costs;
2. Social / development amenity; and
3. Environmental outcomes.

Source control for stormwater management promotes the development of many small, distributed stormwater management systems. Each individual stormwater management system is designed specifically responsive to local individual environmental and geological conditions. For example:

- Where the natural hydrological processes exhibit depression/retention storage, underground voids can be applied to effectively replicate the displaced volumes resulting from the constructed impervious surfaces;
- Where the natural hydrological processes exhibit greater surface water flows, over depression storage, the extent of underground voids can be reduced to effectively replicate the natural water cycle process;
- Where the natural hydrological processes exhibit infiltration, at-source infiltration systems can be applied to effectively replicate the pre-urban volumes lost through infiltration processes; and
- The assessment of the natural environmental conditions may identify areas of reflective rock geology or impermeable layers, even free draining soil, or a combination of these. Where existing conditions exhibit impermeable layers, hybrid drainage systems can be applied to effectively replicate the horizontal flow of stormwater. These hybrid drainage systems may consist of short lengths of conveyance infrastructure combined with underground or surface detention, even infiltration systems responsive to natural horizontal flows, depression storage and infiltration losses, respectively.

The reliance on one facet of stormwater management infrastructure (*i.e.* just conveyance systems) will <u>not</u> 'mimic' the natural hydrological regime. Designs must consider any combination of 'fit for purpose' infrastructure that will achieve triple bottom line benefits and deliver optimum results.

8.2 Sustainable Rural Water Cycle through Natural Sequence Farming

Natural Sequence Farming (NSF) is a method of landscape regeneration devised by the Australian farmer, Peter Andrews, during the 1970's (Wikipedia, 2021). The NSF method is a way of restoring degraded, deforested, eroded or salinated land to full fertility. It uses major earth works to copy natural water courses, thereby controlling floods, restoring ground cover, preventing soil erosion, and restoring fertility (PA, 2021)

NSF is a whole of landscape approach, that focuses on the movement of water and nutrients from the top of the hills to the lowest points of the floodplain, forestry to aquaculture. Natural Sequence Farming is all about managing the entire landscape, not just bits and pieces of it (FF, 2021).

"Our land is severely dehydrated. We know our bodies cannot work unless they're hydrated, we know plants and animals can't work unless they are hydrated. But our land is dehydrated", Mr Cootes (Australian Story, 2015).

Using rocks, fallen trees and other natural debris, a weir is constructed across the creek, not to stop the water from flowing through, but to slow the water down. It then has a chance to seep into the landscape on either side, rather than gushing down the creek system and straight out to sea, taking important nutrients with it. This is why Mulloon Creek is still running, even though there has been little rain. That water, which was stored in the landscape, is now seeping back into the creek.

When farmers across the eastern seaboard are suffering through a drought that some consider the worst in living memory, the NSF landscapes are still rich and abundant in life.

"It's alive with fungus and bacteria, earthworms, and they're all processing that organic matter and that litter. All you need to do is have a look under that brown stubble on the surface, and you can see plenty of resilience that will help this farm burst into life again in the spring. All we've done is reproduced what was a natural process in Australia's landscapes", Mr Andrews (Australian Story, 2015).

NSF is considered Sponge City Concepts and/or Water Sensitive Urban Design (WSUD) of rural landscapes. It follows the same fundamental philosophy and generates the same 3BL benefits.

It has been introduced into this document based on the predominant historical land use across the Yarra Flats region and the respective degenerative processes which have detrimentally impacted the environment.

9 Integrating disciplines for new design methods

Awareness of the issues presented in this document and the appropriate mitigation approaches are becoming more prevalent, however, and particularly in relation to soil health and the water cycle, there is no evidence of Arboriculture and Environmental Engineering disciplines coming together in any other circumstances.

“Green” assets (soils, trees, parks and gardens) effectively integrated with “blue” assets (WSUD) can achieve maximum 3BL objectives, including ecological and amenity, as well as reducing risk and impacts associated with failing systems and environments as shown in Figure 30.

The development of mitigation solutions must be bespoke and responsive to local individual environment characteristics. Only this approach will ensure that the most fit for purpose approaches are implemented to most effectively, and practicably reintroduced the natural water cycle within these urban environments.

In 2018 Matthew Daniel and Owen Richards came together after identifying synergies within respective disciplines attributed to failing urban green assets. Their collaborative insights and assessment of a number of project sites has defined a new method, the Integrated Water & Soil Regenerative Method (IWSRM), represented in Figure 30. The IWSRM is a collaborative method where specialist Arboriculturists and Environmental Engineers communicate, measure, and provide evidence-based knowledge and assessment of specific site natural system function. Matthew and Owen have identified that Urban Water Cycle and Plant and Soil Health are interconnected and in many cases are damaged beyond self-repair, ultimately deemed unsustainable in a changing climate. This leaves trees prone to a plethora of plant Health Care issues including poor canopy function, root development and pathogen activity. This has a cascading effect on natural system health status reducing the capacity of Living Infrastructure to improve health status and provide microclimates, retaining moisture to cool cities and increasing soil carbon to clean air.

This collaboration with Global Urban Forest is the first of its kind, integrating Arboriculture (soil and plant health) and Environmental Engineering (water and blue-green infrastructure).

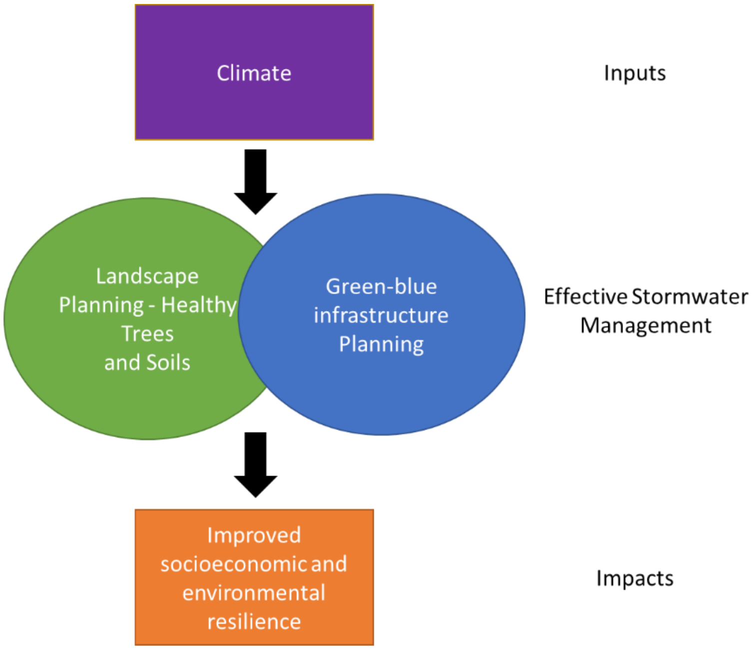

Figure 30 – Integrated Soil and Water Design Method

The effective integration of the two typically siloed disciplines 1) Arboriculture and 2) Environmental Engineering within the IWSRM has shown to be able to maximise 3BL benefits and climate adaptiveness of bespoke Living Infrastructure Solutions. Arboriculture is the industry tasked with individual tree management. It is primarily focused on risk mitigation and applies a subjective human interpretation in assessing the tree and referred to as Visual Tree Assessment (VTA). Environmental Engineering incorporates assessment of the water cycle to determine most practicable, fit for purpose management solutions primarily focused on risk mitigation to the environment and community.

10 Critical Review of Kingdom (2018)

Author: Matthew R, Daniel - GUF CEO, Arboriculture -Soil Specialist.

The Author is clear and confident in refusal to accept the conclusions of Kingdom (2018), as it fails to consider below ground aspects of critical tree health and function including soil, adequately enough for The Project to consider all accociated risk. Matthew Daniel has provided a critical response in relation to Arboriculture specialist# - Plant and Soil Health knowledge and experience and highlighted in yellow.

Method of Assessment [2018 update] by Advanced Treescape Consulting requested by Ecoline Pty Ltd prepared by Russell Kingdom.

An objective visual inspection *was made from the ground of the health and condition of the trees based* on the Levels of Visual Assessment method (Appendix 6a) – 'Level 2: Basic Assessment Process' *International Society of Arboriculture (ISA) (Dunster, et al., 2013) as well as the Visual Tree Assessment*

A visual Tree Inspection is Subjective, not objective in its assessment. No observable measures of any variable were obtained in the Report The Arborists Assessment is based on their perception, understanding, and interpretation of Tree and Environment.

(VTA) technique described by Mattheck and Breloer (Mattheck, et al., 1994), (Appendix 6b). The Tree Schedule (provided in Appendix 3) was based upon:

- Visual inspection of tree crowns by binoculars.
- Assessment of soil compaction by an 8mm x 400mm steel spike pushed by hand vertically into the ground.

This method is a misleading assessment of Soil Compaction. There is not a measurement provided, scale or method supplied. Even if they were, it is still an unreliable subjective assessment of a single Arboriculturists view. Questions must be asked: How effective is the Arborist at using a steel spike to determine their view on Soil Compaction? Are they of heavy Athletic build? Or light petite stature? This will vary due to the individual's stature, weight and assessment capability.

- All photographs that appear in this report are unaltered originals that were taken during site inspection (see Appendix 2).
- Estimation of tree heights by Silva Clinomaster/Heightmeter™ plus visual estimates of canopy spreads.
- Distances of trees, etc. are measured using a Leica Disto™ D2 Laser Distance Meter.
- Code Explanations (Appendix 4).
- Safe & Useful Life Expectancy (SULE) **Error! Reference source not found.**.

(SULE) is based on the UK developed subjective assessments of tree retention value included in these assessments.

This information has guided the conclusions in this report.

This assessment has been carried out by Russell Kingdom: Diploma in Arboriculture (AQF5), Graduate Diploma of Horticulture (AQF8) - Australian Qualification Framework (AQF) I (Department of Education and Training, Australian Government). Refer Attachment 1.

Site Inspection

The subject site was initially inspected in 19/02/2010 and then reinspected on 28/10/2013.

The map in Appendix 1a and 1b illustrates the location of all surveyed trees and reference numbers.

The site is located on natural and reclaimed land in the Yarra Flats. It has a naturally occurring slope from the south to the north.

The site is located within the Banyule Planning Scheme.

***Schedule 1 to the Environmental Significance Overlay (ESO)**, referred to as ESO 1 – Yarra River, Plenty River and Darebin Creek. Information required or ESO 1 will be addressed by the project ecologist.*

Required Information for ESO 4 is not listed in The Report.

***Schedule 4 to the ESO, referred to as ESO 4** – Significant Trees and Areas of Vegetation.*

Information required for ESO 4 are addressed in this report.

Required Information for ESO 4 is not listed in the Report.

***Schedule 1 to the Significant Landscape Overlay (SLO)**, referred to as SLO 1 – Yarra (Birrarung) River*

Corridor Environs. Information required for SLO 1 are addressed in this report.

Required Information for ESO 4 is not listed in the Report.

The site has been previously used for various purposes including mining, walking and mountain biking.

Currently the site appears to be bush.

Historic Agricultural Impact and current compounding impacts to Yarra Flats Park are not included as required information and is an essential factor to consider, investigate and include when considering amendments to Protection Overlays such as Environmental, Landscape and Tree Significance.

Site Assessment

- The microclimate of the site is excellent as all trees have been able to grow to their genetic potential.

This statement is misleading as Microclimate was not measured and it is the view of the Arborist. Microclimate science in relation to Urban Forestry is an emerging science. It requires sophisticated, instrumentation, methods, and analysis. It cannot be determined with subjective Visual Tree Assessment.

- There are no re-reflected heat load issues as the carpark is located to the south of the trees used in the Adventure Park.
- Sunlight levels on the site are not affected.

This statement is ambiguous. A more accurate assessment would be to measure individual trees use of sunlight to produce food via Photosynthesis. Then it could be Quantifiably determined if the tree is affected.

- There is currently no irrigation and there has previously been no irrigation on the site.
- The site is exposed to all winds. The area would be susceptible to wind damage. The most likely trees to be damaged by winds would be those located on the edge of the stand of trees. This is called edge effect.
- Some of the site becomes flooded by increases in Yarra River levels.
- There are noxious weeds growing around the trees identified for use within the TreeTop Adventure

Discussion of Site Assessment

The site conditions allow all vegetation to achieve its genetic potential.

This statement is misleading not based in fact.

Re-reflected heat load issues caused by the carpark would only affect trees located on the edge of the carpark. Established trees should have minimal impact from the re-reflected heat loads. Establishment of new plantings in this area would be more difficult than usual.

This statement is misleading. Re – reflected is not the correct term. A more accurate description of the impact to tree health is: The Material onsite (Road/carpark) causes Urban Heat Island Effect that releases radiant heat towards the trees day and night this negative impact to the trees Vapor Pressure Deficient (VPD) and can disrupt canopy function.

Noxious weeds will need to be removed from around the trees used in the course for access by staff to construct the course.

Soil Factors

The soil texture was sandy loam. Drainage characteristics are good due to the soil type.

This statement is inaccurate and misleading. The GUF Basic Plant and Soil Health Assessment of Tree # 1, determined drainage to be poor contributed by Soil Compaction, Historic, and current Land Use, and Climate Change.

Other Soil Considerations

There has been soil disturbance on some of the sites to the north as fill soils have been used.

This statement is inadequate and misleading. Soil disturbance has occurred throughout Yarra Flatts. The historic and current impacts are significant based on the GUF Basic Plant and Soil Health Assessment on Tree # 1.

There is no damage to any tree roots as the trees grew after fill soils deposited.

These methods of Tree Assessment are subjective and do not consider below ground aspects of tree growth and activity adequately. These industry-standard methods are entirely fair to apply in general Urban Forest Management to assess risk and retention of trees. They are not adequate when the whole plant analysis is required. For example, using trees as primary support

There are many weeds visible on-site e.g. Tradescantia fluminensis (Weeping Jew), Rubus fruticosus (Blackberry), Celtis sinensis (Japanese Hackberry), Acer negundo (Box Elder) and Onopordum acanthium (Scotch Thistle) and others.

This statement is misleading as damage to tree root was not qualified or quantified in [The Report].

There is no salt injury, soil erosion or evidence of soil contamination.

This statement is misleading. [The Report] does not contain a chemistry assessment to determine any form or level of salt or contamination in soils onsite. Soil erosion has occurred onsite in various forms historically.

There was no usage that would compact the soil in the site.

This statement is inaccurate. GEF investigation determined highly elevation soil compaction caused by current and historic impacts.

No compaction was detected.

This statement is inaccurate. GUF Investigations detected Compaction levels: 900 PSI @14 CM (Highly Elevated)

Tree Schedule

Appendix 3 summarises existing trees upon the site in terms of species, height and canopy spread,

structural condition, health, hazard rating and Safe and Useful Life Expectancy (SULE).

The trees contained within the Tree Schedule all have long SULEs. These trees also have low hazard. structures for human activities.

Existing Tree Problems

2.6 There are a few selected trees with minor problems visible.

This statement is inadequate, GUF Investigations of Tree # 1 identified Quantified Plant and Soil Health factors and visible problems such as Canker activity that can indicate pathogen infection.

There will be some minor branch removal required. All branches to be removed are less than 100mm in diameter.

The works will be minor pruning of vegetation to maintain or improve its health or appearance.

The required works would be covered as specified in '3.0 Permit requirement - To the pruning of vegetation to maintain or improve its health or appearance' in the Banyule Planning Scheme, Schedule 4 -To the Environmental Significance Overlay, referred to as ESO 4 - Significant Trees and Areas of Vegetation.

This statement is inadequate. There is no strategy to identify pathogens [The Report] and if anticipated issues such as pathogen activity is relied upon a visual Tree Assessment then this method can be deemed a failure of duty of care. Visual Symptoms of pathogen activity are the tip of the iceberg and not an accurate means of identifying soil borne plant pathogens.

Each tree that does have a small problem has been carefully inspected and is considered to pose an acceptable level of risk despite the visual defects.

This statement is contradictory and inadequate. GUF Quantified Assessment of Basic Plant and Soil Health determined measured site conditions to support Plant and Soil Health pose an unacceptable level of Risk regarding The Project without remediation.

Details of individual tree problems are listed in the comments section of the Tree Schedule (Appendix 3).

Future Problems with the Trees

With apparatus attached to trees, there is always the possibility of future problems with trees. To manage this issue, it is recommended that the trees are inspected annually and carefully detail the health and condition of the tree, and the area, where the apparatus was attached to the trunk of the tree.

This statement is inadequate and misleading. If future problems with trees are anticipated then protocols that assist in identifying, managing, and remediating these must be included. Additionally, this statement is inadequate in considering below ground aspects of tree health.

The assessment needs to detail if there is any-

- *cambial reaction wood growing,*
- *areas of dieback within the crown,*
- *any pathogen attacks,*
- *has the apparatus caused any conditions that have allowed for an insect attack?*
- *any other issues*

Once the inspection is completed and carefully photographed, the apparatus should be re-installed at a place that was pre-determined from the inspection. It may be necessary that every 3 years all apparatus' may need to be moved either up or down on the tree trunks. This would ensure that the point of contact (of apparatus) is not weakened and cause an increased level of risk of failure due to the apparatus.

These inspections need to be carried out regularly, well documented and at the end of every 3 years we then need to compile all the results. This works would be most useful for affixing various types of apparatus to trees I am very impressed with its *application and lack of impact on the trees compared to other methods which use shackles and bolts drilled through the centre of the tree.*

Extra inspections should also be carried out after severe weather events.

Remedial or Beneficial Work Recommended

The majority of beneficial work recommended is the removal of deadwood. These works need to be completed preferably before the opening of the Park to the public.

This Statement is inadequate and misleading. GUF Investigations Identified Poor Soil Health and indications of Poor Plant Health. The Site requires advanced Soil Remediation and management of below-ground aspects of tree growth. Remedial Regenerative works are essential with projects that elevate tree status.

3.1 Impacts on Tree Health & Stability Due to Construction of Apparatus

Impact on tree heath and stability will be addressed with the inspection and assessment of the trees. annually.

Due to the Tree Tops Adventure Park's commercial activities, there will be compaction on the footpath/trails through the site. This could be managed if there was some leaf mulch, woodchip mulch or gravels spread onto the ground surface.

This statement is contradictory to the [The Report], Inadequate and Misleading. GUF investigations have identified Tree Health impacts on site that require a more sophisticated management and quantified Plant and Soil assessment, which is far superior to the managing soil top dress materials hap hazard.

Path construction is to be guided by Parks Victoria's guidelines.

Guidelines for Design

Any new apparatus to be installed on trees should comply with existing methods (see Appendix 2:

Photographs).

Tree 1

This tree has an important role to play in the proposed Tree Tops course. It is used

in the blue, red and black courses as the starting tree. Due to the multiple course usage, having a

tree with a raised timber deck around it will be of great benefit to the tree because it will stop *compaction of the soil from the clients using each of these courses.*

This statement is inadequate and misleading as Soil Compaction has been identified at the current site. A raised deck will not stop the current compaction levels identified.

The proposed site office deck will be constructed on piers from Cyprus timber and will have gaps between boards.

3.3 *This method of construction will have an acceptable low inground impact on the subject tree as the excavation for the piers can be supervised by the project arborist and moved to accommodate any roots >50mm that may be located. The structure will allow water to flow between the decking boards onto the tree's root plate. It must be noted that there needs to be a gap of at least 100mm between the trunk of the tree and the Cyprus timber deck boards. These works will have an acceptable impact on this tree.*

This statement is inadequate and Misleading. Identifying the root habit and mapping it is essential in determining where structural footing could occur concerning root disturbance. As current soil conditions are poor and root habit and mapping not obtained the true impact of the construction is unknown concerning Tree # 1.

The deck for the office will be located over the TPZ of Tree 1 and within the TPZ of Tree 25. The project arborist is to be onsite during any inground works/excavation within the TPZ of Tree 1 and Tree 25.

Refer to Appendix 1a: Site Plan for Deck (Elevation View), Appendix 1b: Site Plan for Deck (Plan View) for deck details.

All of the climbing courses will have paths located in close proximity to the climbing apparatus. The paths are not yet constructed.

Tree Protection Zones

3.4 TPZs are not required.

This statement is inadequate and questionable. TPZ are an effective means of protecting trees on development sites. The Project is clearly a development site so TPZ would be required and assist in the optimized approach in the management of trees associated with The Project

END (Advanced Treescape Consulting) REPORT

11 Conclusion

11.1 Soil Health

The Banyule Planning Scheme Amendment C107 sets a dangerous precedent to future Urban Forest status and management for Banyule City Council. Amending Conservation Overlays based on inaccurate assessments of site biodiversity and Living Infrastructure health status, is problematic.

Living Infrastructure projects that elevate tree status must also in parallel, elevate the level of assessment.

Current International standards for Urban Forest tree assessments to identify Health Status, are based on subject assessments by professional Arborists.

Visual Tree Assessments are an essential part of managing trees in Urban Forests but are limited. When tree status is upgraded to Living Infrastructure, tree assessment must consider more advanced quantified methods to determine the whole organism health status.

This means an accurate assessment of the root system and Soil Health status must be sought.

Quantified Plant and Soil Health assessments are required for best practice management of trees as Living Infrastructure in Urban Forests.

Sophisticated levels of assessment lead to collaboration between disciplines. The Integrated Water & Soil Regenerative Method (IWSRM) allows specialist Arboriculturists and Environmental Engineers to communicate, measure, and provide evidence-based knowledge and assessment of specific site natural system function. Urban Water Cycle and Plant and Soil Health are interconnected, and it is at this point, Urban Forest management can be quantified. This legacy of information will inform and deliver, functional Living Infrastructure.

Amendment C107 must be abandoned, as it elevates tree status to Living Infrastructure but has not raised the level of tree assessment to include the below ground aspects of trees and a Quantified Health Status.

When Urban Forest management includes multiple stakeholders, and in this case, there are many, it is essential to elevate the tree status to protect the Living Infrastructure in perpetuity.

Banyule City Council has an opportunity to recognise how Urban Forest management must evolve and improve definitions of Urban Infrastructure standards and levels of assessment.

11.2 The Water Cycle

The advent of conventional agriculture and farming practices across the Yarra Flats landscape followed by urbanisation consisting of traditional engineering construction methods, conventional grey infrastructure and conveyance stormwater management systems has adversely impacted the native biodiversity of the Yarra Flats environment. The significant augmentation to the natural water cycle, soil and natural biodiverse environment has displaced rainfall and groundwater flow systems. This has in turn detrimentally affected soil health and the ability to sustain ongoing healthy vegetation and tree growth.

Regeneration of this environment must consider an integrated multidisciplinary design approach such as that presented in this document (Figure 30). This will ensure effective regeneration of the affected environment and the ability to reintroduce biodiversity, healthy soil and vegetation across the landscape.

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Appendices

Appendix A

Industry Standards for Visual Tree Assessments

Arboriculture internationally has many standards of assessing trees. The common ones used by professional Arborists are listed below. These assessments have a Visual Tree Assessment at the core. The outcomes of the assessments are primarily based on these subjective visual indicators. Below ground soil health assessment are not included as a fundamental standalone subject within these international standards. This identifies an area where Arboriculture can evolve to include Applied Science Soil Health Assessments in Urban Forestry.

Standard Reference - Determining the retention value of trees on development sites.

Reference - Treenet: https://treenet.org/resources/determining-the-retention-value-of-trees-on-development-sites/

1. BS 5837:1991

The British Standard (BS 5837:1991 – Guide for Trees in Relation to Construction) first published in 1980, provides guidance on preparing Pre-development Tree Surveys and establishing retention values for trees within development sites. BS 5837:1991 provides some basic categories and sub-categories that can be assigned to trees (refer Appendix 2). These categories were an attempt to sort-out trees in terms of their desirability or suitability for retention within the context of a development site in order to provide some guidance for planning purposes.

The short-coming of this method is that it is fairly conceptual and offers no criteria for assessment of these values or any detailed method to assign a tree to a particular category. In essence though, it promotes the idea that retention values should be based on an assessment of the amenity values of a tree as well as their overall health, condition and longevity (sustainability).

2. SULE

In 1993, the British Standard approach was superseded by a methodology known as Safe Useful Life Expectancy (SULE) developed by Jeremy Barrell, a British arboriculturist. SULE was based loosely on the British Standard but is more systematic and rigorous in its approach. SULE made an attempt to assimilate the health, condition and value of a tree, using remaining life expectancy (in consideration of safety issues) as a measure of its sustainability in the landscape. This system was promoted as best practice in pre-development tree surveys and has been widely used throughout Britain, the United States and Australia. The concept behind SULE is that of sustained amenity, the longer a tree can contribute to amenity in a sustainable way (in consideration of safety and the proposed development), the higher the retention value. The methodology is summarized in Appendix 3.

In spite of the objective of sustaining amenity though, there is little in this methodology that assists in determining the relative amenity value (or other value) of a tree or trees. The method focuses primarily on determining a tree's sustainability in the landscape (i.e. how long a tree can be retained in the landscape in consideration of its health & structural integrity (safety). However, other factors such as the size and appropriateness of retaining the tree in light of the proposed development (usefulness) are also considered.

3. Australian Standard 4970 – 2009 Protection of Trees on Development Sites

4. Tree Significance - Assessment Criteria and Tree Retention Value - Priority Matrix, are taken from the IACA Dictionary for Managing Trees in Urban Environments 2009 (Draper, et al., 2009).

5. Tree Risk Assessment Manual', published by International Society of Arboriculture (Dunster, et al., 2013).

6. 'The Body Language of Trees. A Handbook for Failure Analysis. Research for Amenity Trees' by Mattheck and Breloer (Mattheck, et al., 1994),

Appendix B

Quantifying Tree and Soil Health - Hume City Council, Global Urban Forest (GUF), Massachusetts Institute of Technology (MIT) - Australian Ground Truth Study 2019 - 2020

Quantifying Tree and Soil Health - January 2020

Hume City Council, Global Urban Forest GUF, Massachusetts Institute of Technology MIT

Quantifying Plant and Soil Health - Australian Ground Truth Study 2019 - 2020

Preliminary Results – Draft # 1

Sites 1 – 4, Anzac Park – Craigieburn – Victoria – Australia

By Matthew R Daniel

Highlights:

1. Canopy measurements taken with both the Our Sci Reflectometer and PhotosynQ MultispeQ tool were significantly correlated with tree health.
2. The Reflectometer canopy measurements were correlated with MultispeQ parameters and could be used to replace the MultispeQ. This would reduce the complexity of canopy measurement protocols and eliminate the need for more complex statistical pre-processing of data.
3. The Soil CO2 Respiration Kit and Reflectometer (measuring soil) were strongly related to soil organic matter content and the availability of key soil nutrients. These tests could be used to supplement laboratory analysis and reduce overall sampling costs for large scale Urban Forest Soil Health Assessments.

Site:

- ANZAC Park x 4 sites, Craigieburn, Victoria, Australia

Trees:

- 31 x Quercus – 5 years old

Measures:

1. Visual Tree Assessment (VTA) Industry standard
2. Vigour Condition Index (VCI) "what Matt recons"
3. Soil Biology - Agpath
4. Soil Chemistry - Total/Available/Exchangeable Nutrient - EAL

5. CO_2 Respiration – 24 hr. Burst method - GUF
6. Carbon Content (Spectrometry) - GUF
7. Soil Compaction (Penetrometer) - GUF
8. Soil Moisture - % / dry weight - GUF
9. Photosynthesis - (PhotosynQ MultispeQ Tool)
10. Photosynthesis - (OurSci Reflectometer)
11. Thermal Image x 31 trees @ 47°C (record breaking Heat Wave Victoria - December 2019)

note: Thermal Image data not included in correlation test, see GUF Study Final

Variables:

1. Poor soil health conditions
2. Soil Amendments (Compost/Mulch)
3. Good distribution of Poor, Fair, and Good- Visual Tree Assessment (VTA) Scores.

Soil Biology and Soil Chemistry:

Table B 1 Relationship between soil biology and chemistry. Pearson correlation coefficients, correlations in bold are significant at $p \leq 0.05$.

	Ca	Mg	K	Colwell P	Bray 2 P	nitrate	ammonium	sulfur	pH	EC	Total C	Total N	CN
Active Fungi	-0.205	-0.016	-0.197	-0.124	-0.130	-0.164	0.064	-0.164	-0.061	-0.216	-0.019	-0.116	**0.648**
Total Fungi	0.086	0.004	0.275	0.215	0.288	0.068	**0.389**	-0.098	0.193	-0.041	**0.431**	**0.410**	0.011
Active Bacteria	0.112	-0.149	0.235	**0.367**	0.306	**-0.409**	0.357	-0.021	0.240	-0.041	0.326	0.315	0.071
Total Bacteria	0.320	0.122	**0.365**	0.216	0.322	**0.486**	0.251	0.341	-0.065	**0.427**	**0.380**	**0.376**	-0.091
Actinobacteria	0.238	0.144	0.237	0.290	0.283	-0.120	0.350	-0.084	0.329	0.011	**0.385**	**0.358**	0.094
Flagellates	0.048	0.216	0.275	0.316	0.329	-0.030	-0.056	-0.069	-0.011	-0.051	0.303	0.280	0.075
Amoebae	0.090	0.131	0.238	0.330	0.340	0.049	-0.055	-0.054	0.001	-0.022	0.293	0.291	-0.013
Ciliates	0.215	0.024	0.290	0.336	**0.428**	0.063	-0.071	0.169	-0.069	0.219	**0.459**	**0.477**	-0.138
Nematodes	-0.206	-0.043	0.153	-0.106	-0.033	0.136	-0.228	-0.143	-0.160	-0.087	0.031	-0.025	0.269
Bacterial	-0.188	-0.055	0.173	-0.051	0.029	0.130	-0.183	-0.123	-0.170	-0.069	0.121	0.055	0.308
Fungal	-0.109	-0.002	0.032	-0.196	-0.165	0.155	-0.113	-0.021	-0.114	0.023	-0.167	-0.128	-0.207
Fungal/Root	0.052	0.069	0.300	-0.057	-0.016	-0.102	-0.063	-0.081	**0.412**	-0.018	-0.094	-0.091	-0.044
Root	-0.166	-0.023	-0.095	-0.260	-0.274	0.035	-0.288	-0.168	-0.060	-0.151	-0.266	-0.266	-0.009

Soil micro-organisms play a key role in mineralizing and solubilizing nutrients so that they're available to plants. Therefore, it is not surprising to see significant correlations between soil nitrate and bacteria, which mineralize organic N or between microbial communities and available P. Likewise, soil C and N provide food for micro-organisms, which explains the strong relationship between soil C and N and bacteria, fungi and ciliate populations. Lab analysis of these parameters is expensive, however, and would not be practical at a tree by tree level. Therefore, we evaluated two low-cost sensors, to see if their outputs would relate to soil biological or chemical properties. Both the Reflectometer and soil respiration kit showed strong relationships to important soil nutrients (N, P, K) and total C but not to biological parameters.

The reflectometer uses NIR/Vis spectroscopy to measure soil 'darkness', which is often correlated with soil organic matter, which impacts the availability of soil nutrients. The soil respiration kit measures the amount of soil CO2 evolved from a soil 24 hours after rewetting. This is a commonly used soil health test that measures the activity of soil microbes related to nutrient cycling.

Soil Health: Comparing samples of Laboratory Analysis: Soil Biology, Soil Chemistry with Reflectometry and CO2 Respiration sensors.

Table B 2 Relationship between Reflectometer and Soil Respiration kit measurements and soil biological and chemical properties. Pearson correlation coefficients, correlations in bold are significant at $p \leq 0.05$.

	soil365	soil385	soil450	soil500	soil530	soil587	soil632	soil850	soil880	soil940	ug C g soil
Active Fungi	0.062	0.109	0.103	0.139	0.128	0.181	0.166	-0.027	0.002	0.004	-0.240
Total Fungi	-0.314	-0.070	-0.056	-0.004	-0.060	-0.012	-0.061	-0.126	-0.126	-0.020	0.046
Active Bacteria	0.067	0.204	0.063	0.018	0.006	0.005	-0.014	-0.100	-0.132	-0.015	0.253
Total Bacteria	-0.267	-0.312	-0.286	-0.267	-0.296	-0.299	-0.326	-0.332	-0.284	-0.313	0.303
Actinobacteria	**-0.407**	-0.236	-0.152	-0.088	-0.148	-0.155	-0.143	-0.129	-0.137	-0.093	0.124
Flagellates	0.035	-0.074	-0.066	-0.146	-0.106	-0.165	-0.161	-0.185	-0.205	-0.152	0.215
Amoebae	-0.202	-0.267	-0.269	-0.333	-0.306	-0.318	-0.338	**-0.365**	-0.352	**-0.356**	0.314
Ciliates	-0.003	-0.268	**-0.427**	**-0.441**	**-0.450**	**-0.398**	**-0.446**	**-0.381**	**-0.387**	-0.351	0.207
Nematodes	0.315	0.293	0.116	0.081	0.125	0.157	0.106	-0.040	-0.017	0.018	-0.108
Bacterial	0.288	0.281	0.084	0.050	0.082	0.116	0.061	-0.107	-0.090	-0.031	-0.035
Fungal	-0.059	-0.117	-0.034	-0.129	-0.083	-0.056	-0.068	0.081	0.082	0.069	-0.061
Fungal/Root	-0.065	-0.013	-0.016	-0.083	-0.016	-0.015	-0.039	0.046	0.064	0.029	-0.014
Root	0.271	0.287	0.251	0.254	0.302	0.282	0.283	0.350	**0.392**	0.301	-0.274
Ca	-0.159	-0.346	**-0.401**	**-0.427**	**-0.420**	**-0.485**	**-0.486**	**-0.405**	**-0.414**	**-0.387**	**0.661**
Mg	0.215	-0.080	0.041	-0.021	0.024	0.002	0.009	-0.001	-0.065	-0.009	0.299
K	-0.187	-0.303	**-0.361**	**-0.465**	**-0.436**	**-0.481**	**-0.509**	**-0.435**	**-0.460**	**-0.371**	**0.769**
Colwell P	-0.164	**-0.403**	**-0.572**	**-0.603**	**-0.615**	**-0.635**	**-0.658**	**-0.629**	**-0.644**	**-0.553**	**0.773**
Bray 2 P	-0.182	**-0.426**	**-0.608**	**-0.642**	**-0.653**	**-0.669**	**-0.702**	**-0.672**	**-0.685**	**-0.588**	**0.761**
nitrate	-0.146	-0.124	-0.154	-0.160	-0.155	-0.181	-0.190	-0.107	-0.062	-0.135	0.170
ammonium	-0.212	0.035	0.054	0.069	0.032	-0.018	-0.012	0.056	0.042	0.073	0.197
sulfur	0.077	-0.146	-0.220	-0.257	-0.256	-0.301	-0.302	-0.199	-0.193	-0.172	0.322
pH	**-0.390**	-0.202	-0.098	-0.118	-0.108	-0.137	-0.131	-0.104	-0.127	-0.116	0.337
EC	0.002	-0.245	-0.323	**-0.370**	**-0.361**	**-0.413**	**-0.416**	-0.305	-0.301	-0.280	**0.491**
Total C	-0.133	-0.352	**-0.528**	**-0.538**	**-0.562**	**-0.566**	**-0.602**	**-0.623**	**-0.643**	**-0.516**	**0.718**
Total N	-0.174	**-0.401**	**-0.584**	**-0.599**	**-0.622**	**-0.630**	**-0.665**	**-0.651**	**-0.667**	**-0.554**	**0.747**
CN	0.315	0.310	0.341	**0.354**	**0.359**	**0.395**	**0.393**	0.195	0.174	0.249	-0.177

Photosynthesis sensors:

For the past few years, there have been attempts to use the MultispeQ photosynthesis meter as a tool for measuring tree health. While the MultispeQ is a sophisticated scientific instrument, it is very difficult to use under highly variable field conditions (i.e. outdoors). This is because the MultispeQ measures photosynthetic activity under ambient conditions, which change rapidly in the field. To overcome this constraint, users need to follow complicated protocols to measure the same plant multiple times per day and pre-process data using multiple linear regression to account for the effects of light intensity and time on outputs. In this experiment, we compared the MultispeQ to the same reflectometer as used in the previous section, only this time the reflectometer was used to measure tree leaves instead of soil. There were very strong correlations between the MultispeQ photosynthesis parameters and the Reflectometer (table 3). In general, the correlations were stronger between the 'spad 'values for each wavelength instead of the 'mean 'reflection values. This is most likely because the 'spad 'values are self-referencing, and therefore less likely to change based on small changes in LED intensity or detector efficiency.

Table B 3. Relationship between MultispeQ and Reflectometer measurements. Pearson correlation coefficients, correlations in bold are significant at p < 0.05.

	SPAD	Phi2	PhiNPQ	PhiNO	LTD	LEF
mean_365	0.226	0.079	-0.176	0.181	**-0.494**	-0.039
mean_385	0.334	0.128	-0.316	0.329	**-0.512**	0.106
mean_450	-0.153	-0.292	0.098	-0.020	-0.247	-0.208
mean_500	**-0.426**	**-0.550**	**0.400**	-0.291	-0.022	-0.476
mean_530	**-0.486**	**-0.561**	**0.366**	-0.248	-0.067	-0.510
mean_587	**-0.736**	**-0.722**	**0.608**	**-0.481**	0.187	-0.691
mean_632	**-0.702**	**-0.715**	**0.596**	**-0.468**	0.184	-0.660
mean_850	0.318	0.058	-0.318	0.354	**-0.375**	0.107
mean_880	0.309	0.045	-0.345	**0.390**	**-0.388**	0.125
mean_940	**0.456**	0.195	**-0.409**	**0.416**	**-0.435**	0.264
spad_365	0.144	0.085	-0.182	0.186	0.162	0.277
spad_385	0.088	0.034	-0.074	0.076	0.144	0.143
spad_450	0.336	0.228	-0.205	0.166	0.036	0.209
spad_500	**0.653**	**0.596**	**-0.622**	**0.537**	-0.240	**0.589**
spad_530	**0.660**	**0.579**	**-0.573**	**0.484**	-0.200	**0.592**

spad_587	**0.825**	**0.700**	**-0.730**	**0.629**	**-0.359**	**0.706**
spad_632	**0.786**	**0.702**	**-0.709**	**0.605**	-0.329	**0.688**
spad_850	0.144	0.214	-0.085	0.031	-0.017	0.294
spad_880	-0.065	0.196	0.017	-0.082	0.084	0.196
cvi	**0.426**	0.323	-0.227	0.162	-0.293	0.251
ndvi	**0.530**	**0.433**	**-0.458**	**0.397**	-0.165	**0.397**

The effectiveness of specific tools does not mean anything unless those tools relate to the health of the tree. We compared each of the soil and canopy measurements from the lab and other sensors to the health of each tree (using a 10-point scale with 10 being the healthiest and 1 the least healthy). Soil biological parameters did not correlate to tree health. However, the amount of organic matter (total C and N) and available P were significantly related to tree health. These results are not surprising as the primary function of the soil (in the context of tree health) is to deliver nutrients and water to the tree, which is primarily driven by soil organic matter. All of the MultispeQ measurements and most of the wavelengths measured by the Reflectometer were significantly related to tree health, suggesting that either the MultispeQ or Reflectometer can be useful tools measuring the tree canopy.

Soil Health and Photosynthesis:

Table B 4 Relationship between soil and canopy measurements and tree health. Pearson correlation coefficients, correlations in bold are significant at $p \leq 0.05$.

Soil measures			Canopy Measures
ActiveFungi	-0.144	**0.659**	SPAD
TotalFungi	0.074	**0.637**	Phi2
ActiveBacteria	-0.047	**-0.742**	PhiNPQ
TotalBacteria	0.162	**0.664**	PhiNO
Actinobacteria	-0.015	**-0.438**	LTD
Flagellates	**0.362**	**0.589**	LEF
Amoebae	0.237	0.314	mean_365
Ciliates	0.207	**0.456**	mean_385
Nematodes	0.093	-0.064	mean_450
Bacterial	0.086	-0.351	mean_500
Fungal	-0.002	**-0.406**	mean_530
FungalRoot	-0.074	**-0.603**	mean_587
Root	0.009	**-0.565**	mean_632
ugCgsoil	0.112	0.329	mean_850
Ca	0.256	0.326	mean_880
Mg	0.194	**0.489**	mean_940
K	0.267	0.053	spad_365
ColwellP	**0.413**	-0.048	spad_385
Bray2P	**0.459**	0.220	spad_450
nitrate	0.096	**0.615**	spad_500
ammonium	**-0.414**	**0.654**	spad_530
sulfur	**0.374**	**0.757**	spad_587
pH	-0.312	**0.702**	spad_632
EC	**0.364**	0.195	spad_850
TotalC	**0.473**	0.054	spad_880
TotalN	**0.456**	**0.443**	cvi
CN	0.010	**0.463**	ndvi

Appendix C

Innovative new Technology in Plant and Soil Health Analysis.

Matthew Daniel has assisted in the development of new leading environmental sensing technologies:

- **PhotosynQ** (MultispeQ)- Michigan State University - Kramer Labs - web-*based environmental sensing platform for Photosynthesis measure.*
- **CO2 Respiration Sensor** – OurSci - app-*based sensor for CO2 Respiration an indication of soil Microbiome*
- **Bionutrient Meter –** Our Sci/BFA **-** *App-Based spectrometer sensor developed with investment from BFA.*

These innovative technologies are well place to revolutionize environmental sensing and propelling the development of best practice natural asset management. There are opportunities in developing the participation of stakeholders in the industry and urban forest community sectors to assist in the larger future survey of the Urban Forest function.

Understanding the complexity of ecosystem function will require a diverse, detailed, and advanced approach to managing natural assets based on applied sciences and innovative technologies.

PhotosynQ

https://photosynq.org/

https://photosynq.org/users/matthew-daniel

PhotosynQ developed at Michigan State University in the Kramer Laboratory is by far the next global game-changer in environmental science. A device and platform that allows for intensive data collection to unlock nature's secrets and develop a greater understanding of how the natural world functions in its innumerable complexities.

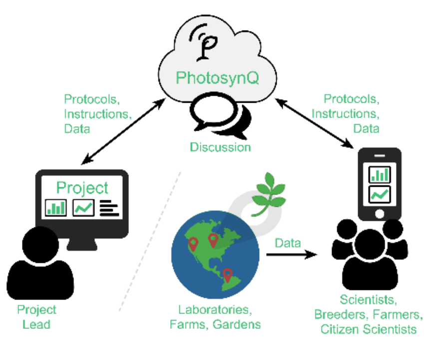

Figure C 1 PhotosynQ web-based environmental sensing platform

Using a multi-spectrometer device called a MultispeQ and the associated platform that facilitates the data accumulation PhotosynQ environmental data was obtained during the Hume Turf Trial to further understand the response of the turf to the fertilizer applications.

Figure C 2 PhotosynQ - MultispeQ spectrometer

PhotosynQ is a collaborative online plant research platform, which enables users to create, share and collaborate worldwide to analyze detailed sophisticated environmental scientific information.

Soil CO_2 Respiration "Sensing"

Soil respiration occurs when organisms respire oxygen and release carbon dioxide (CO_2). Soil respiration is defined as the combined production of CO_2 by all soil organisms and plant components. The rate of soil respiration reflects a soil's capacity to sustain flora and fauna and is highly indicative of microbial activity in the soil.

Soil respiration is measured using a Carbon Mineralization Sensor developed by Dr. Dan TerAvest of Our Sci, LLC, a start-up from Michigan, USA. This method adds water to an air-dry soil sample and measures the resulting "burst" of CO_2 after 24 hours by using a syringe to push air over a pass-through CO_2 sensor (Figure 4). This methodology is easy to conduct and can assist in the specification of input materials, such as composts and mulches. Most importantly, it can offer a proxy for soil microbial activity. The sensor is a good example of emerging sensing technology, as it is cloud-connected to the Our Sci mobile app, which offers data storage, and visualization.

cloud-connected to the Our Sci mobile app offers data storage, and visualization.

Figure C 3 The Our Sci Carbon Mineralization Sensor (left) connects to an Android-based app (right)

Figure C 4 CO_2 Method - a. Soil Samples prepared and numbered, b. Dry Soil Sample for 24 hrs., c. Measure 25g soil add to Mason Jar, d. Add 4ml Water to sample Mason Jar and close chamber for 24 hrs. to allow CO_2 burst from microbial activity.

Soil Carbon - OurSci LED Spectrum - Reflectometer

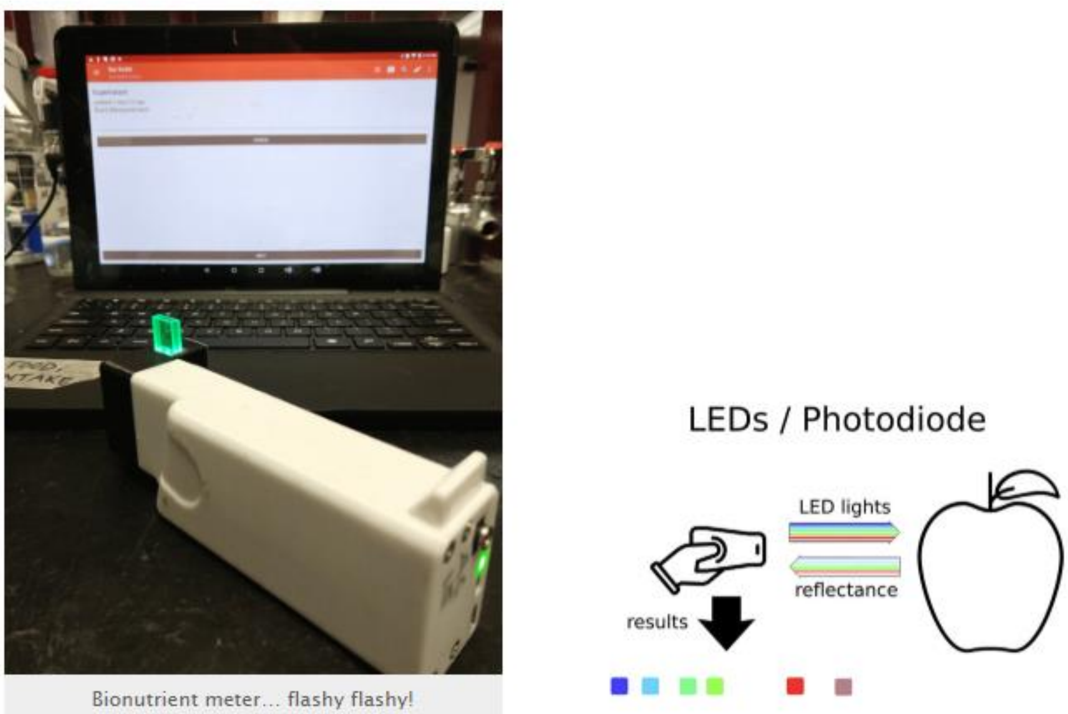

Figure C 5 OurSci – Reflectance Sensor that can be used to measure spectrum on various types of samples liquid and solid.

Appendix D

State of the Urban Forest Soil Microbiome 2018 – 2020 Analysis of GUF Soil Health Data

Data Analysis Reference – State of the Urban Forest Soil Microbiome 2018 – 2020 Analysis of GUF Soil Health Data

GUF CEO Matthew Daniel has been quantifying Urban Forest Plant and Soil Health for 12 years in capital cities throughout Australia. In this period a significant amount of data has been compiled. In 2020 a unique opportunity arose to analyses consecutive years in soil remediation data collection by Comparing all GUF Project Data in the 2017 – 2020 period where projects had before during and after. It shows when analysing Urban Forest Soil Health conditions are Poor and Regenerative methods can increase and sustain key areas such as the microbiome. Soil health data, Plant material type, soil moisture content, and temperature were all variable due to geography and not included. What the sites do have in common is poor Soil Health metrics at (Baseline - Pre-treatment. In further focus, the Soil Microbiome is consistently imbalance and fragmented when compared to healthy functional soils. Protozoa, Nematodes, and Mycorrhizae are outliers in this assessment as they are more complex and can't be compared as their units of measure are different, they too were not included.

Total and Available Bacteria and Fungi are the groups that are great indicators of the health and function of the Soil Microbiome. Based on these data the Author suggests Urban Forest Soils generally have poor Microbiome levels and this interferes with soil chemistry and physical structure. This means overall soil health at these sites is poor, meaning trees are susceptible to pathogens and decline sometimes from multiple abiotic vectors.

A majority of GUF projects involve diagnosis and remediation of declining trees and pathogens in Urban Forestry. In these situations, soil health and importantly Soil microbiomes are consistently poor and require remediation to improves consortia health and function and this must include disease suppression provided by Antagonists. The author recommends any Living Infrastructure project that elevates individual tree status, requires are a more sophisticated approach to the development design, short and long-term impact, construction, implementation, and management of the trees and this must include Quantified Plant and Soil Health throughout the workflow.

GUF Soil Microbiome Remediation Data, 2017 - 2020

Soil Microbiology (Direct Microscopy / SFI) data obtained during Urban Forest remediation project activities provided to Local Governments in Victoria, South Australia, and Queensland in 2018,2019,2020. Total and Active Bacteria µg/g and Fungi µg/g were used as a KPI. GUF Quantified Soil and Plant Health data show Urban Soil Health at a low base.

Table D1 Direct Microscopy Analysis of GUF Remediation focus on fungi and Bacteria to quantify Soil Microbiome.

Soil Health, Baseline - Pre-Treatment	n = 123
PHC Treatment fist year test after baseline	n =34
After PHC Treatments 2-3 years	n = 8
Mean	x
Sites: Melbourne, Brisbane, Adelaide	

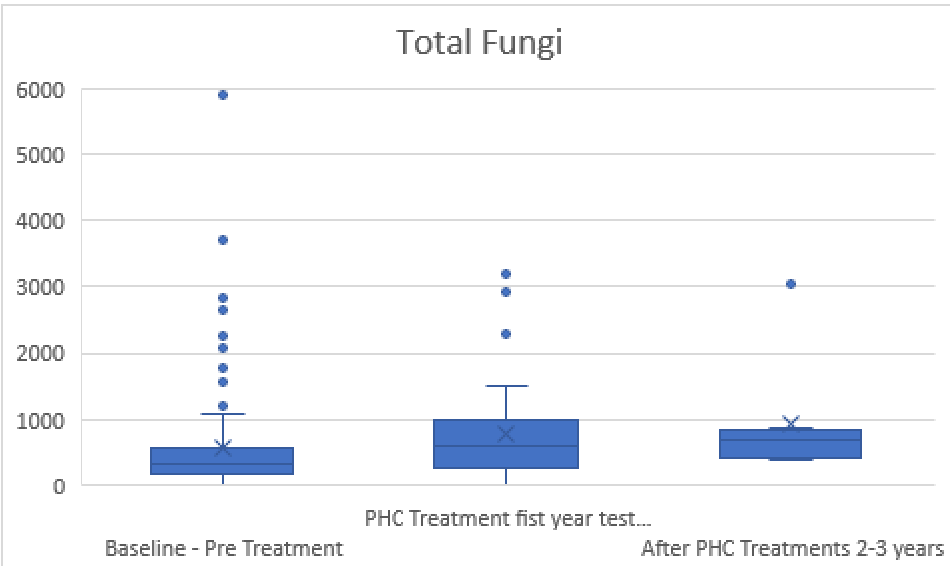

Figure D1 -Total Fungi increased over time in response to Remediation Activities.

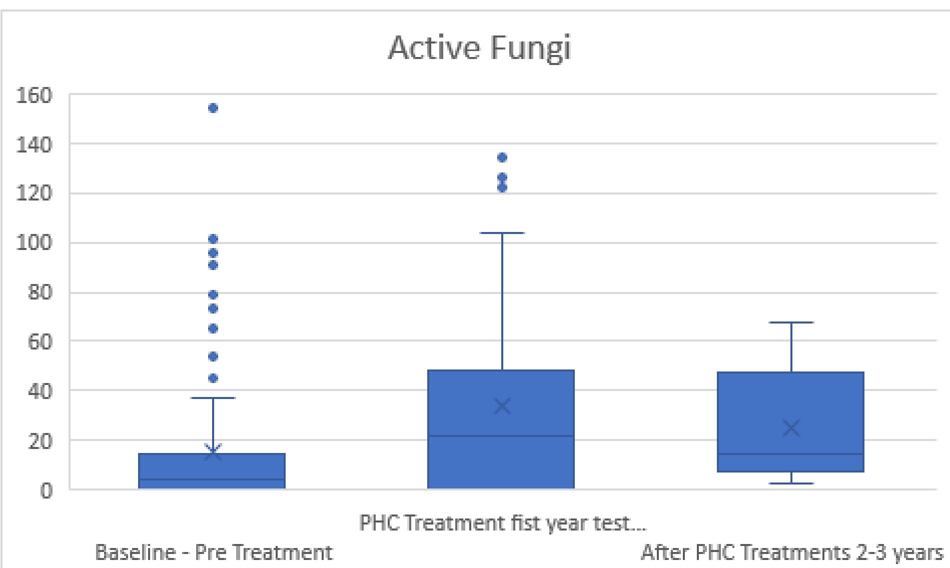

Figure D2 – Active Fungi increased over time in response to Remediation Activities.

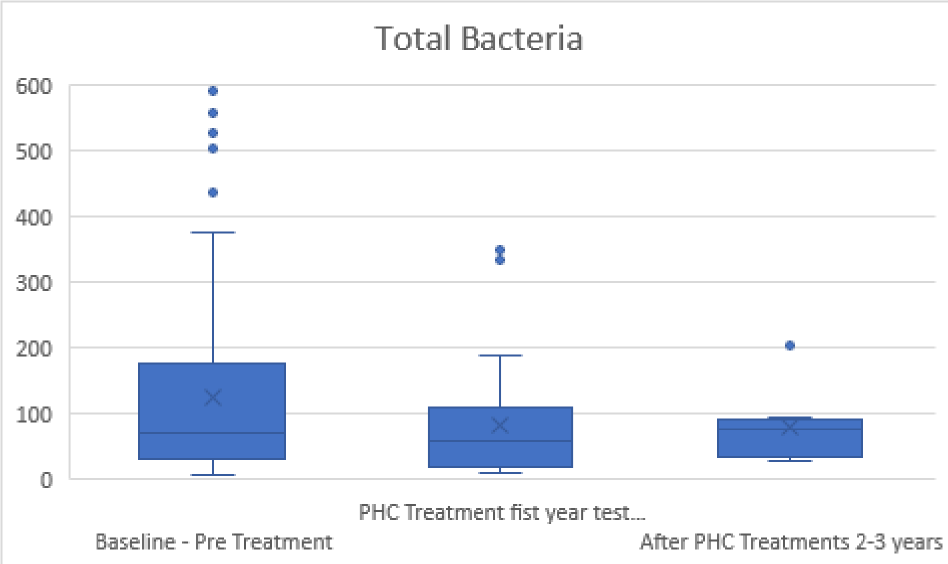

Figure D3 Total Bacteria reduced over time. The author cannot explain this data outcome as Active Bacteria increased see figure D5.

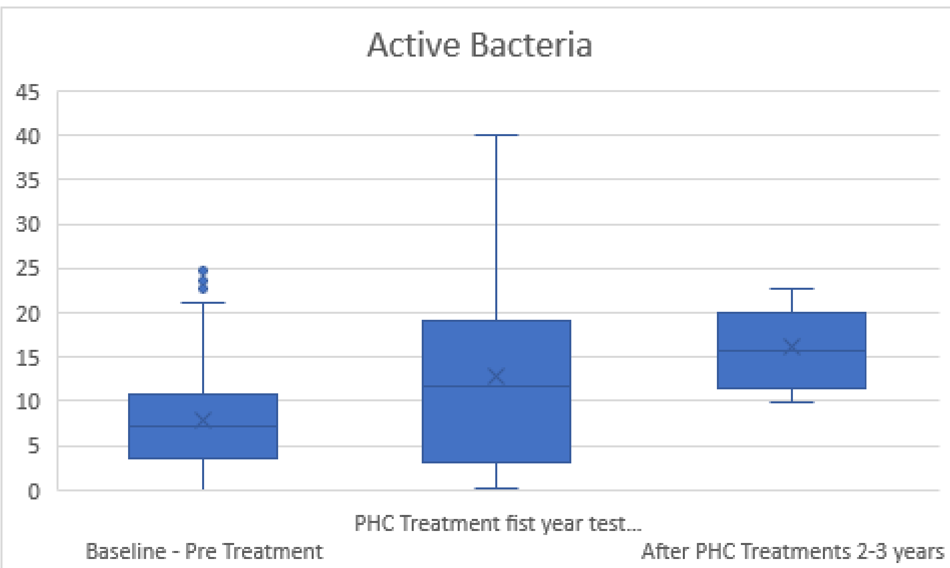

Figure D4 – Active Bacteria increased overtime in response to remediation activity.

Appendix E

Multidiscipline Collaboration (Engineers and Specialist Arborists working together) - Hume City Council – Living Infrastructure Workshop Proposal – March 2020 - Presenters: Matthew Daniel / Owen Richards

WHAT IS LIVING INFRASTRUCTURE?

***Living infrastructure** refers to all of the interconnected ecosystems within an urban catchment. **Living infrastructure** builds upon and combines the concepts of 'green **infrastructure**' (which focuses on vegetation) and 'blue **infrastructure**' (which focuses on water management)*

Source: urban landscapes. Jun 3, 2017

A major project in Australia using Living Infrastructure language: living infrastructure plan - Metro Tunnel

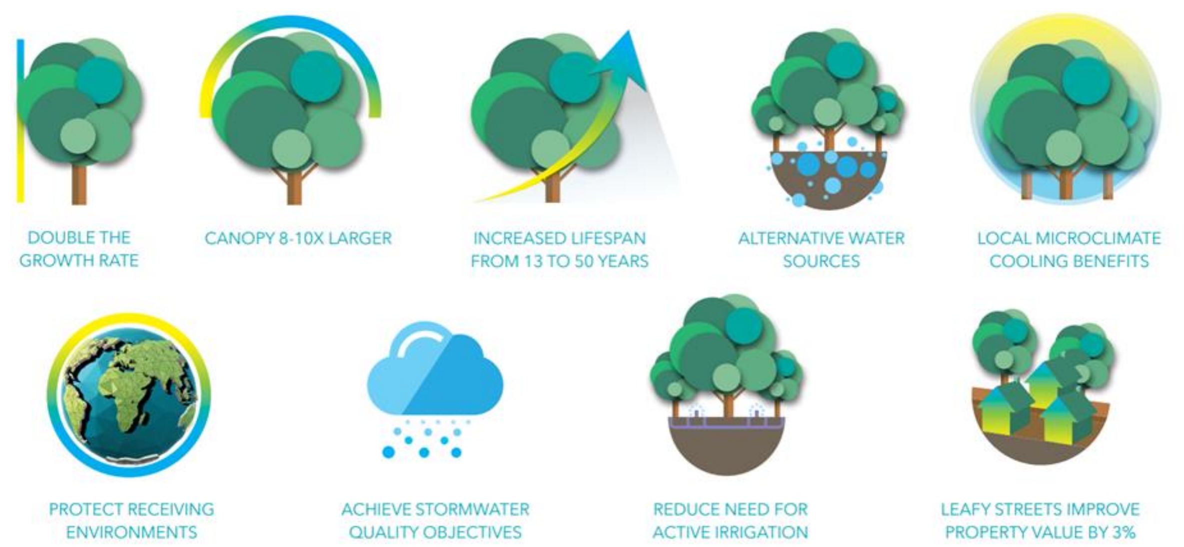

Figure E1 - Benefits of healthy soil, trees, and an integrated urban water cycle Source: Water by Design 2018

Natural systems and processes can be harnessed to protect communities against excessive heat or flooding. They can improve air, soil and water quality, as well as increase public amenity. When natural elements and features such as wetlands, the urban forest, and green refuges are incorporated into the design and operation of cities, this is called 'living infrastructure'. Living infrastructure requires a specific approach to design. The approach combines both natural and engineered elements to perform a range of functions that deliver combined environmental, social, and economic outcomes. This approach compels a strategic and holistic approach to the planning, design, construction, maintenance, and renewal of our communities.
Source: Canberra's living infrastructure information paper 2018

A Multidisciplinary Approach
When living infrastructure is developed for a functional purpose, such as WSUD implemented into Urban Forestry a unique specialist set of skills, metrics, design, and methodology are required. This is to ensure the success and sustainability of that living infrastructure and its asset status. The key aspect of this is Plant and Soil Health.
When Environmental Engineers and Plant and Soil Health Specialists work together in developing, remediating, and managing living infrastructure, a holistic and bespoke outcome can be achieved. Complexities in ecosystem function need to be embraced to optimize living infrastructure.
Quantifying Soil and Plant health is key, in measuring the ecosystem function that living infrastructure provides.
Soil Health can be defined "as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans"(**https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/**).

Soil Health can be defined in three essential components:

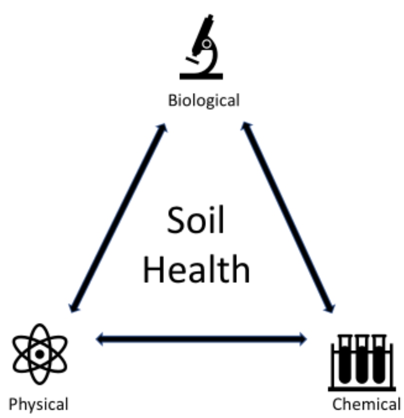

Figure 4- Soil health definition infographic – source Global Urban Forest Hume City Council – Living Infrastructure Workshop Proposal – March 2020

Chemical – *understand the total, available, and exchangeable nutrient pools in the soil concerning the requirements of supporting plant material.*
Physical – *measure and understand physical soil structure and water holding capacity.*
Biological – (Soil Microbiome)– *understand and measure the soil microbiome, a balanced set of functioning bacteria, fungi, protozoa, nematodes, and mycorrhizae that develop symbiotic relationships with plants.*

Soil and Tree Health Method

A key component within the core scope, assessing soil and tree health, to better understand and incorporate living infrastructure to the stormwater management strategy concept development.

A Soil Health management approach would involve the development of a baseline, management option to ensure optimization of natural assets with healthy trees and synergistic soil health, and effective stormwater management. This approach would quantify plant and soil health and function and develop holistic management of living infrastructure.

For example, we propose the 'GUF method' which strives to provide optimized conditions for living infrastructure to maximize Tree Health, Canopy Density, Ecosystem Function, and Microclimate Production. This is important to propose custom engineered solutions in stormwater management.

An assessment of Baseline Soil Health would be undertaken through:

1. Site soil sampling and Laboratory analysis
2. Site soil sampling using low-cost sensors.

Stormwater and Drainage

GHD's methodology for the development of concept design solutions and documentation includes:

1. Collaborating with GUF to identify the issues, design standards, drainage solutions criteria, and future works. GUF and GHD will work together to develop '*custom-engineered living infrastructure systems*' based on the application of the GUF Soil Health Method.

2. A complete design team that has experience in terms of civil design infrastructure, alternative drainage solutions, and geotechnical or stability issues.

3. Proven track record in developing practical and innovative stormwater design solutions in challenging environments.

A more sustainable Urban Water Cycle

The application of sustainable urban infrastructure and drainage solutions including improved soil and tree health will minimize extreme (episodic) rainfall-linked erosion and landslide events, thereby leading to a more sustainable and resilient urban water cycle (Richards 2019), as illustrated in Figure 5.

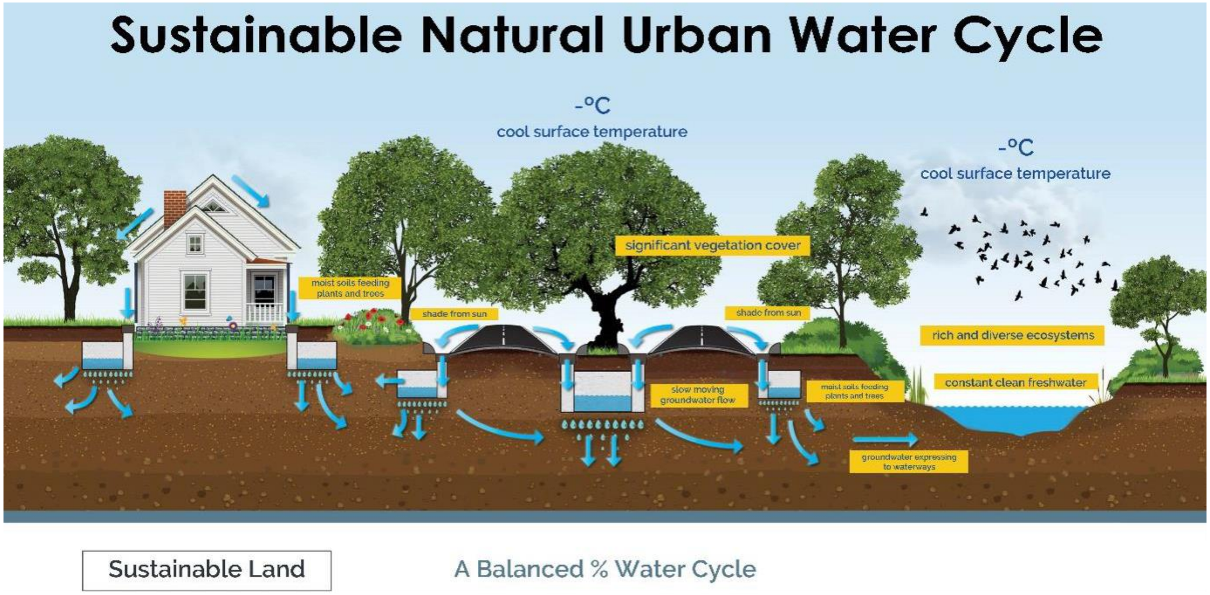

Figure 5 - Concept of a sustainable urban water cycle

Sustainable Urban Water Cycle through Source Control Stormwater Management

Recognition of adverse effects of urbanisation has led to a progression of evolving stormwater management strategies, each of which has attempted to minimise impacts of urban runoff on the flow regime of receiving watercourses. While these efforts have resulted in reduction of some impact, research has shown that the current state of practice with respect to stormwater management is often not sufficient to mitigate the hydraulic and environmental impacts of land use change and urban development on water receiving bodies.

Examination of the premise behind current management strategies clearly reveals the need for a paradigm shift in stormwater management practice. While end-of-pipe solutions have been effective to a degree in reducing flood flow and water quality impacts, current science points to the need for a water balance approach that promotes additional source and conveyance controls to minimize the increase in runoff generated from urban landscapes and reduce impacts to receiving watercourses and the aquatic habitats that they support.
Sustainable Urban Water Cycle through Source Control Stormwater Management Recognition of adverse effects of urbanisation has led to a progression of evolving stormwater management strategies, each of which has attempted to minimise impacts of urban runoff on the flow regime of receiving watercourses. While these efforts have resulted in reduction of some impact, research has shown that the current state of practice with respect to stormwater management is often not sufficient to mitigate the hydraulic and environmental impacts of land use change and urban development on water receiving bodies.

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Appendix F

Phytophthora Management Strategy- Source: GUF Tender Submission - Protecting Plant and Animal Biodiversity in the Otway Ranges, Bells Beach (Ironbark Basin) and Great ocean Road hinterland and from Phytophthora Dieback proposal 2020.

Project Description

A Multidisciplinary holistic approach to Phytophthora Management delivered by a compartmentalized group of specialists.

Utilizing advanced environmental health and function quantification methods, that identify interconnected causative environmental decline contributing factors, then develop from there site-specific remediation strategies that are underpinned with robust baseline data.

We are focused on Regenerative options for Phytophthora Management. Quantifying plant and soil health and land management impact on the water cycle alloys us to develop an accurate detailed understanding of the health status of the environment.

Our strength is in embracing complexity. Bespoke analysis of spatial Water Cycle, Plant and Soil Health data including high accuracy Whole of Genomic Sequence of Phytophthora species and Taxonomic Mycology, to provide an assessment of targeted soil biology crucial to remediation Activities.

Engaging community Stakeholders to better manage and monitor, plant and soil health and proactively contributing via the Internet of Nature (App-Based Sensors)

A holistic regenerative option, building communities that monitor and manage our environmental impact proactively.

A unique dataset informing considered, practical, and holistic Phytophthora Management outcomes that assist current a future management activity, to combat the environmental decline.

Combining a sampling strategy technique that Identifies the State of the Environment, Phytophthora activity, Current Soil Health Conditions, Endemic Water Cycle, and capacity of environmental health to deal with a Primary Pathogen such as *Phytophthora.*

Our Proposal provides a cross-project opportunity for community engagement projects, with baseline soil health data underpinning future remediation/management activities.

Project Methodology - Overview

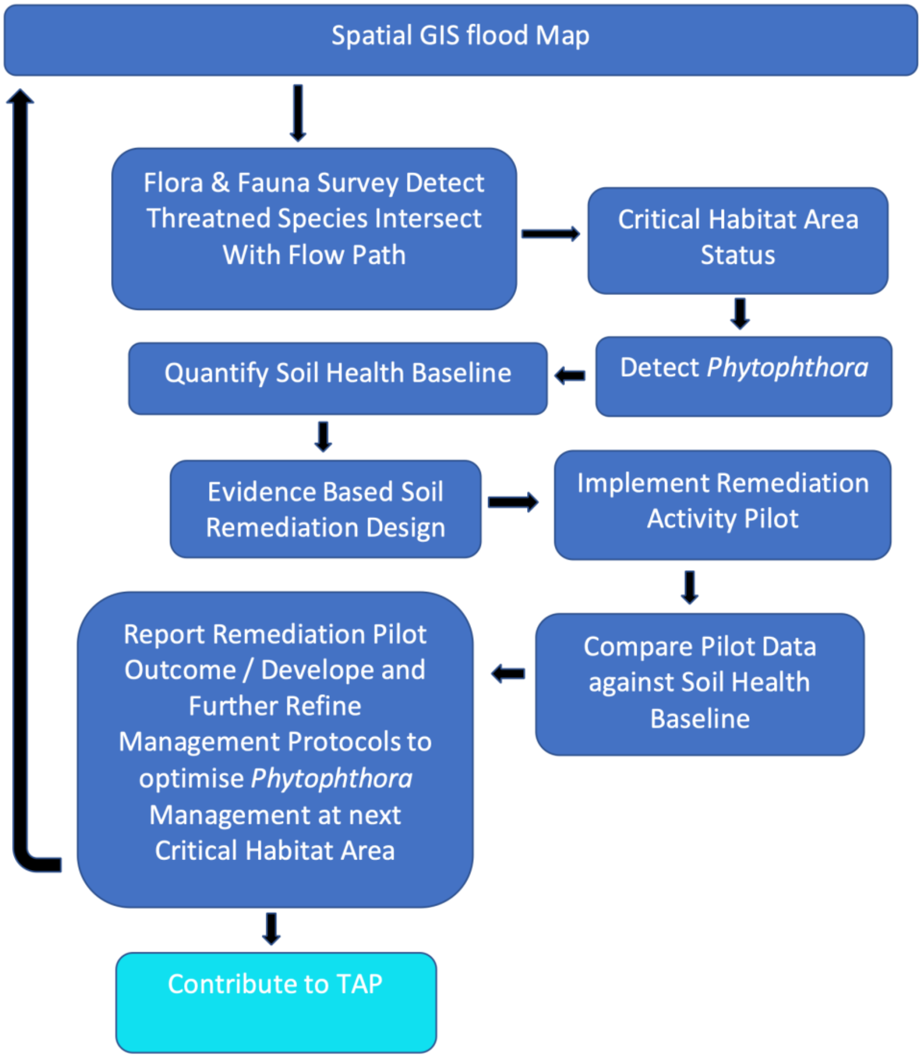

Figure F1 Option 1 - Phosphite Trial not included.

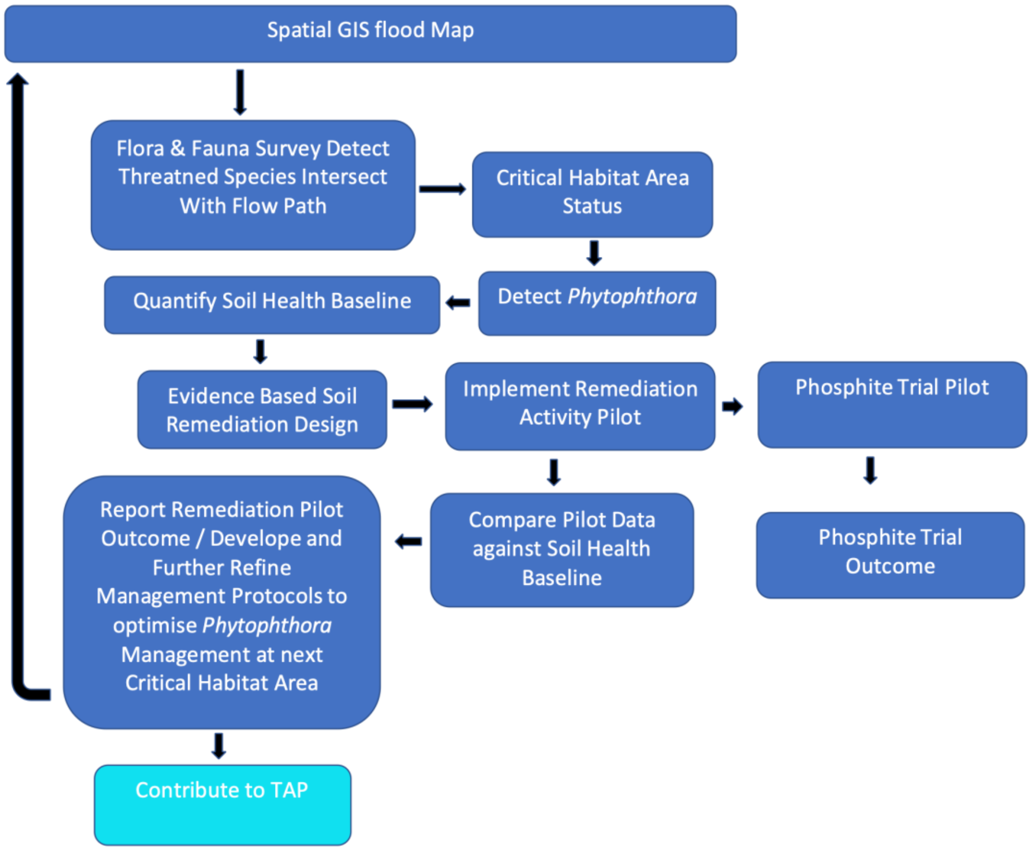

Figure F2 Option 2- Includes Phosphite Trial

Appendix G

City of Glen Eira - Phytophthora Remediation - Allnutt Park, Report 3 - (Canker Activity on diseased trees)

Stem Canker activity was first observed during the preliminary investigation in July 2018. Cankers can be found on most Eucalyptus sp throughout Allnutt Park, McKinnon, Vic in varying stages of growth and severity. In 2018 Matthew Daniel indicated that the canker growth throughout Allnutt Park trees was a symptom of highly elevated *Phytophthora* activity. Matthew Daniel has observed this Canker activity on investigations for the Mornington Peninsula Shire in relation to *Phytophthora* activity. It is not clear at this stage if the prevalence of canker in the park is a result of P*hytophthora* Activity or another independent pathogen such as a species of a newly described canker: *Caliciopsis pleomorpha.* With multiple known pathogens active in Allnutt Park, Soil Health conditions poor, and soil Microbiome levels low, have induced a reduction in disease suppression. It is fair to argue that the canker activity observed in Allnutt Park is a visual symptom of an ecosystem in decline.

http://fuse-journal.org/images/Issues/Vol2Art4.pdf

Figure G1- shows some examples of canker activity on Treatment trees., A. Tree # 29., B. Tree #22., C. Tree #22., D. Tree #7., E. Tree # 17 Cedrus. *requires monitoring for canker activity. Image Source Matthew Daniel GUF.*

Figure G2– Shows canker activity and canopy colour of Tree #7 – A. Significant canker formations located up the entire trunk stem., B. chlorotic canopy in February 2019. Similar visually to Mundulla Yellows Decline symptoms., C. Canopy chlorophyll production appears to have improved in July 2019. Image Source Matthew Daniel GUF.

Appendix H

Allnutt Park Phytophthora Remediation 2019

Soil CO2 Respiration –Results – (Feb, May, and July 2019) used as KPI in the Phytophthora Remediation Protocols developed by GUF. These data correlated against ground truthing Laboratory Direct Microscopy data to determine Soil Microbiome increase over time.

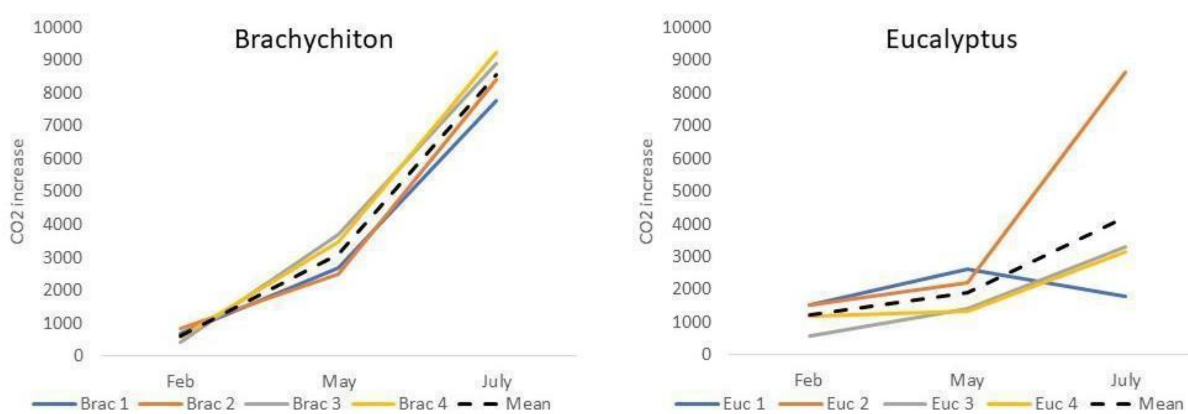

Figure H 1 - Soil CO2 Respiration by tree and Genus in February, May, and July 2019.

Remediation Project Outcomes– (Pathogen Activity)

Results of the Tree Decline Investigation – (Pathogen Sampling), before and after stage # 1 of the project 2018 - 2019.

Data includes previously reported figures-(July 2018, Report # 1). See report # 1 and September 2018 Report #2, and July 2019.

Data confirm Pathogen Activity in the form of *Phytophthora sp.*, and additional opportunistic pathogen species: *Fusarium sp* and *Pythium sp have been reduced by 75% after Stage # 1 remediation analysis.*

Appendix I

Expert Witness Information for Panel Hearing

Matthew R Daniel CEO Global Urban Forest Pty Ltd

Statement of expert's area of expertise to make the report:

Matthew R Daniel is a Specialist Arboriculturist in Quantified Plant and Soil Health. Applied Science methodologies to determine holistic tree health for best practice management of urban trees. His expertise is unique in the Arboriculture Industry with quantified Investigation of tree health status detail above current International & Australian Standards of Tree and Soil Assessment.

Brief of scope for the report:

This GUF report has been commissioned by Riverland Conservation Society of Heidelberg Inc. (Friends of Yarra Flats Park)

To provide a specialist Arboriculture opinion, conduct a desktop analysis of site history, Critical Analysis of the: *ARBORICULTURAL TREE HEALTH & HAZARD ASSESSMENT [2018 update] by Advanced Treescape Consulting requested by Ecoline Pty Ltd prepared by Russell Kingdom* [Kingdom, 2018] and completed an independent specialist Basic Site Soil Health Assessment and Soil Health Sampling Regime on Tree # 1.

The purpose was to identify unforseen risks and impact to individual trees and the wider environment from tree health issues accociated with engineered structures and historic impacts.

Discipline

Arboriculture / Urban Forestry / Soil Health

Expertise

Quantified Plant and Soil Health Investigation & Remediation, App – Based Environmental Sensing Technology and Application - Tools for the Internet of Nature (IoN , Photosynthetic Plant Science , Micro – climate Data and Quality Assessments, Pest and Disease / Biosecurity.

Arboriculture

Matthew has over 25 years' international experience in Urban Forest/ Arboriculture Industries and Regenerative Agriculture.

Technology Developer Plant and Soil Health Applied Science for the Urban Forest Industry. Quantifying Plant and Soil Health and function via Laboratory Analysis and App – Based Environmental sensors.

- OurSci PhotosynQ

Regenerative Agriculture Consultant / Trainer in Advanced Compost Production and Actively Aerated Compost Tea (AACT) and Waste Stream Analysis (Circular Economy)

- Weilong Grape Wine Company, Shandong Province, Eastern China.
- Queensland Government, Great Barrier Reef Recuse Soil Health Grant 2008, Monduran Citrus, Gin Gin, QLD.

Project Experience

- Scholarship Arborist with Launceston City Council led to overseas placement with Boston Tree Preservation on a H1 Residency Visa for 3 yrs.
- Dangerous Tree Management (Lead Climber) – Queensland Arboriculture Industry (QAA) - Boston Tree Preservation Massachusetts USA.
- Plant and Soil Health Science- Boston Tree Preservation Mass, USA.
- Powerline management (HV, LV – Feeder / Distribution Shutdown (Lead Climber). QLD
- Cyclone Storm Event Repair / Plant Health Care, Soil Health Rehabilitation – Laucala Island, Fiji
- Soil Health Industry Development
- Biohazard Identification and Management – Victorian, Giant Pine Scale Outbreak.
- Mornington Peninsula Shire - Phytophthora Cinnamomi and Tree Decline Investigation.
- Glen Eira City Council Phytophthora Remediation – Allnutt Park.
- Hume City Council – Quantified Plant and Soil Health study in collaboration with Massachusetts Institute of Technology.
- Swinburne University of Technology – Environmental Sensing Masterclass. Swinburne University of Technology - Environmental Sensing Masterclass
- Partner Collaborator - Mc Greggor Coxall – Climate Resilience, Bristol City, UK.
- Beta Tester / Expert Team - PhotosynQ Michigan State University – Urban Forest Photosynthesis.

Qualifications

- Arboriculture Cert 5 – 1997 – 1999 TAFE Tasmania
- Landscape Gardening Trade Certificate – 1997 – 1999 TAFE Tasmania
- Dangerous Tree Removal - Electrical Distribution Line Clearing certification Tas, QLD, NSW
- Soil Food Web International – Experts Program 2008-9 Southern Cross University

'I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.


Executed by Global Urban Forest Pty Ltd ACN 619 054 456 in accordance with Section 127(1) of the *Corporations Act 2001*:

Signature of Director

Matthew. K. Daniel
Print full name

Owen Richards

Associate Director | Global Environment Leader, McGregor Coxall

Qualifications:

- FIEAust
- Adjunct Associate Professor - Environmental Engineering Murdoch University (2018)
- Bachelor Environmental Engineering (Hons) Deakin University (1999)
- Graduate Certificate Management – Technology Management, APESMA, Deakin University, (2001)
- Certificate IV Fitness, Victorian Fitness Academy (2003)
- accredited IOWEU/Related Vision client coach (2013)

Discipline:

Environmental Engineering

Statement of expert's area of expertise to make the report:

Owen has over 25 years' extensive experience in both public and private sectors of environmental and civil engineering. Owen is an entrepreneur and inventor of two [2] patented stormwater management related systems. Owen's experience is extremely diverse and includes sea level rise, coastal vulnerability, storm surge assessments, subdivision design, hydrodynamic modelling, design of sewer and water infrastructure, water planning, integrated water cycle management (IWCM), water sensitive urban design (WSUD) and Asia Sponge City projects.

Inventor.

Invention name发明创造名称：Tree Nurturing System 一种植被养护系统 World Intellectual Property Organization (WIPO) Patent application number申请专利号：202010737882.5. Consisting of a continuous porous kerb rainwater inlet system, rainwater retention cells, soil structural cells and tree pit. Patent Pending.

Co-Inventor.

KerbiDrain™ continuous aggregate inlet drainage system. WIPO, International Bureau. Patent Cooperation Treaty (PCT). International Publication Number WO 2018/068095 A1 – PCT/AU2017/051108. Filing date 13.10.2017.

Awards.

Richards, O. (2003). *Stormwater Industry Association, AWA, Water Recycling Australia, Brisbane.* City of Greater Geelong/EarthTech Engineering with CSIRO – Indented Head First Flush Reuse Project.

Richards, O.; Tay, M.; Wallis, S. (2015) *Stormwater Association WA – Integrated Stormwater Design*, New Perth Stadium Railway Station – AECOM, DS Agencies.

Conferences/Published.

Anson, C.; Coombes, P.; Richards, O. (2006). A shift in paradigm curve of sustainable water use. A practical example: Mernda Villages, Victoria. Stormwater Industry Association. Conference, Launceston, Tasmania.

Anson, C.; Coombes, P.; Richards, O. (2008). A shift in paradigm curve of sustainable water use. A proposed fully integrated approach for the Gidgegannup Town Master Plan, Western Australia. Stormwater Industry Association. Conference, Perth, Western Australia.

Cummins, L.; Richards, O. (2013). Review and comparison of ERM and ILSAX hydrological models on drainage modelling for the Gateway WA Project, Perth, Western Australia. AECOM, Perth, WA.

Richards, O. (2013). Development of a High Early Discharge (HED) Stormwater Pit to halve detention volumes at the North Quay Rail Terminal (NQRT) Extension for Fremantle Ports. Infrastructure Project Innovation (nomination), AWA WA Annual Awards, Perth.

Richards, O. (2014). Practical application of Texas Tech University, Project 0-6549, Hydraulic Performance of Staggered Barrel Culverts for Stream Crossing for Rutilla Resources Central Pilbara Infrastructure Project, AusRAIL Conference & Exhibition, Perth, Western Australia.

Richards, O. (2015) Prof. John Argue, Engineers Australia, AR&R - Source Control for Stormwater Management. A practical example: New Perth Stadium Railway Station. Engineers Australia Education Course, Perth, Western Australia.

Richards, O. (2015). 4D Stormwater Asset Management & Failure Risk Forecasting System. OzWater, Perth.

Richards, O. (2016) Prof. John Argue, Engineers Australia, AR&R - Source Control for Stormwater Management. SOMe Source Control Stormwater Management: Application of continuous aggregate inlets. Engineers Australia Education Course, Perth, Western Australia.

Richards, O. (2016) IPWEA Training Week. Paper: Richards, O. SOMe Source Control – Stormwater Management, The most practicable approach in source control methodology.

Richards, O. (2017). SOMe Source Control Stormwater Management. IPWEA International Conference, Perth, Western Australia.

Richards, O (2017) Rich and Rare: Knowing and Caring for the Brixton Street Wetlands and Yule Brook. Paper: Richards, O. Wallis, S. SOMe Source Control – Stormwater Management, The most practicable approach in source control methodology.

Nayak, A.; Richards, O.; Wallis, S. (2017). SOMe Source Control – Stormwater Management, The most practicable approach in source control methodology. Future Drainage & Stormwater Networks Conference, Dubai.

Anda, M.; Dallas, S.; Richards, O. (2018). Performance assessment of an innovative 'at source' stormwater management system utilising permeable aggregate – the KerbiDrain™ system. IWA SWWS2018 Conference on 'Small Water & Wastewater Systems and Resources Oriented Sanitation', Perth, Western Australia.

Richards, O. (2018). SOMe Source Control – Stormwater management through biomimicry, reducing climate change impacts and building resilient urban centres. CRCWSC, DEDJTR, DELWP, Sichuan Sponge City Programme, Chengdu, China.

Richards, O. (2019). Book Chapter: Impacts of urbanisation and conventional drainage infrastructure on the natural water cycle of Yule Brook, Maddington Kenwick Strategic Employment Area (MKSEA), Perth, Western Australia. In: Lambers, H. ed. A Jewel in the Crown of a Global Biodiversity Hotspot. Perth: Kwongan Foundation and the Western Australian Naturalists' Club Inc.

'I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

Owen Emanuel Richards

Attachment 1

ARBORICULTURAL TREE HEALTH & HAZARD ASSESSMENT [2018 update] by Advanced Treescape Consulting requested by Ecoline Pty Ltd prepared by Russell Kingdom. [Kingdom 2018]