6 November 2020

Expert Witness Statement

Matters required by Planning Panels Victoria Guide to Expert evidence

Name: Dr Peter Sandercock

Address: 8 Philden Way, Spring Gully, Bendigo, Victoria 3550

I am a Senior Consultant, Geomorphologist working in Jacobs Water and Environment Business. I have a PhD in Fluvial Geomorphology (The University of Western Australia, 2004) and have completed post-doctoral studies on the use of vegetation to mitigate processes of erosion and desertification. I also completed an undergraduate degree of Bachelor of Science (Environmental Science) with 1st Class Honours in Geography (The University of Western Australia, 1999).

I have over 15 years' research and consulting experience, specialising in fluvial geomorphology investigations and studies that assess the impact of land use change and flow regulation on waterway management and rehabilitation. I have completed numerous urban growth area investigations and environmental flow studies for Melbourne Water in which I have developed and applied methodologies to assess the impact that urban induced hydrological changes have on the physical form of waterways, their geomorphological and ecological processes and values. I was lead author of a Technical Note and Fact Sheet that outlines the values of headwater streams (hydrological function, regulation of water quality, biodiversity and habitat values), how they can be protected through integrated urban and drainage design and the benefits of protecting them. I have also prepared a position paper on the issues and opportunities associated with the adoption of large-scale bioretention systems compared to constructed wetlands and completed a review of the design response to geomorphological issues associated with sodic soils and a future constructed waterway in the Merrifield area. I also recently completed a Sodic Soils Assessment for the Beveridge North West Precinct Area.

My Curriculum Vitae is attached to this statement. (Annexure A)

I have prepared this Expert Witness Statement with the assistance of Craig Clifton who has over 30 years' consulting and research experience in resilience, climate change and integrated natural resource management.

My letter of instructions from Harwood Andrews is attached to this statement (Annexure B).

In preparing this witness statement, I have relied on the 'Sodic Soils Assessment Shenstone Park Precinct Area' (version 6, Final, 6 November 2020)' (**Jacobs Report**). A copy of this report is attached to this statement (Annexure C).

I confirm that I adopt the assessment and any assumptions as outlined in the report. 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.

I was the lead author of the Jacobs Report, participated in the soil survey and led the project team that completed the assessment of the distribution of sodic soils, erosion risks and advice on treatment options.

I was assisted in preparing the Jacobs Report by the following:

- Craig Clifton - Global Technical Leader, Resilience and Climate Change, Project Director. As Project Director, Craig's role was to support the project team in delivering the project and provide a technical review of the report. He also developed Jacobs Vulnerability Assessment Approach that was used in this project.
- Christian Bannan – Christian is a Soil Scientist and director of South East Soil and Water. Christian has provided specialist advice on the characteristics of sodic and dispersive soils, the process for identifying erosion risks and management of these soils. Christian led the soil survey and analysis and provided input to the report on matters relating to the assessment of erosion risks and treatment options.
- Milos Pelikan - Milos is a senior analyst with 25 years' experience in applying spatial information and technologies in the Water and Natural Resource Management sectors. Milos developed the Spatial Logic Assessment Framework that was used in the delivery of this assessment. He was involved in workshops that developed landscape profile criteria for the assessment.
- Filomena Losi – Filomena is a spatial analyst. She assisted in the delivery of the Spatial Logic Framework, the Vulnerability Assessment, analysis and preparation of spatial outputs included in the report.
- Graeme Jardin – Global Technical Leader, Engineering Geology, Geotechnical Reviewer. Graeme has extensive experience with management of sodic and dispersive soils, particularly as they relate to stability of ground conditions for infrastructure assets. Graeme completed a technical review of the report.
- Adam Hall – Civil Engineer. Adam is experienced in waterway design in urban environments, engineering challenges associated with sodic soils, particularly in relation to the design of stable waterways and channel linings to prevent erosion of underlying materials. Adam completed a technical review of the report.

Discussion

I have reviewed the exhibited Amendment C241wsea to the Whittlesea Planning Scheme (Amendment) Shenstone Park Precinct Structure Plan (PSP) and background materials (as relevant), submissions (in particular submissions 19 and 25 which raise issues of soils) and the Victorian Planning Authority's (VPA) response to submissions. I understand that submissions have raised a number of concerns in relation to the soils in the Precinct area, the suitability of soils for development, management of erosion risks, implications for waterways, drainage and achievement of stormwater treatment.

Jacobs was engaged by VPA to map sodic soils and erosion risk and provide advice on treatment options in light of future planned development in four Precinct Areas located to the north of Melbourne: Beveridge North West, Wallan South, Wallan East and Shenstone Park. I am the Project

Manager for this project. The Sodic Soils Assessment for the Beveridge North West Precinct was completed in July 2020 and was presented as Expert Evidence to Planning Panels Victoria.

Jacobs has written the technical report "Sodic Soils Assessment Shenstone Park Precinct Area" dated 6 November 2020 to provide an assessment of the distribution of sodic soils and erosion risks that relate to the characteristics of these soils, their position in the landscape and the implications of this for future planned development within the Precinct Area. Advice is also provided on the range of treatment options that are available to manage identified sodic soils and erosion risks.

Relevant sections of this report are referred to in this statement.

The soils of the Shenstone Park Precinct Area assessed in this investigation are predominantly classified as Sodosols, with a clear or abrupt textural B horizon in which the major part of the upper B2 horizon is sodic and not strongly acid. Vertosols were also identified. These are clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth. Soils are predominantly sodic throughout the B horizons.

The technical report includes figures that map Topsoil Sodicity, Subsoil Sodicity and A horizon (Topsoil) depth across the Precinct Area (refer to Figure 4.2, Figure 4.3 and Figure 4.4 in report). The areas to the west of the quarry have topsoil with moderate to high Exchangeable Sodium Percentage (ESP) values (7-10%) and subsoils with very high to extreme ESP values (>15%). Areas east of the quarry generally have topsoils with low ESP values (<5%) and subsoils with moderate to very high ESP values (7 to <15%). A horizon topsoil depths vary across the Precinct, with measurements in the field ranging from 10-30 cm.

The concept of vulnerability was used to assess the implications of sodic soils for future planned urban development. This vulnerability assessment was completed for two scenarios, involving construction and the future developed land use. During construction, areas identified as particularly vulnerable to sodic soil erosion risks are the waterways (Retarding Basin/Water Quality Treatment Wetland and Waterway Corridors) and the area to the west of the Quarry that has soils with high to extreme sodicity values. Activities that expose these soils to rainfall and runoff need to be carefully managed to reduce erosion and the entrainment of fine sediment in water flows. For future developed land use, waterways, the land area to the west of the Quarry that has soils with high to extreme sodicity values and steeper slopes are areas identified with a high vulnerability to sodic soil erosion. Water balance changes resulting from future developed land use and associated impervious areas will generate high volumes of runoff, which will drain into the surrounding waterways, including an un-named Merri Creek tributary. The Merri Creek tributary is already in a degraded condition, further increases in flows would be expected to accelerate erosion of bed and bank materials and contribute to the turbidity of downstream waterways.

Recommended treatments for areas identified as having a high vulnerability to sodic soil erosion risks include:

- **Drainage depressions/seasonal wetlands** – Surface ground cover measures are critical for protecting the soils against dispersion and erosion. Ideally these areas should be identified and reserved as linear green spaces to maintain their important hydrological function in retaining and temporarily storing water in the landscape and regulating the flow of water and nutrients throughout a catchment.

- **Merri Creek tributary** – This waterway is in a degraded state and further increases in runoff may result in increased erosion. Significant engineering works are likely to be required to stabilise this waterway so that it is resilient to increased stormwater runoff that will accompany future land development.
- **Steeper slopes** – Cutting into these slopes will expose underlying subsoils, and erosion risk is increased with slope. Road batters must be designed with consideration to the erodibility of the soils. Stable linings that are resistant to rainfall and runoff will be required.

Erosion risks associated with sodic and dispersive soils can be managed by appropriate planning. The Jacobs report concurs with the planning requirements and guidelines documented in the Shenstone Park Precinct Structure Plan that relate to Integrated Water Management.

Drainage schemes for the waterways need to be designed with specific consideration of the erosion risks associated with sodic and dispersive soils. Engineering design is required to create waterway corridors that are stable and can withstand the volume of water that will be generated from the developed areas. It is expected that all of the waterways will need to have a constructed form, with appropriate channel linings and/or armouring to provide protection for dispersive subsoils. Where possible, it is recommended that the waterway corridor includes distributed wetland and swales, to assist with attenuation and treatment of stormwater runoff. This design concept has also been recommended for Merrifield Central Waterway, a tributary of Kalkallo Creek which is also experiencing sodic soil erosion issues.

Management of water flows over and through dispersive soils is a key tool in control of detrimental effects. Approaches may include: diversion of water away from these materials; minimising potential convergence and/or ponding of surface flows; compacting to minimise water movement through the material, and interception trenches. Soil chemical ameliorants are recommended for short-term stabilisation of soils on construction sites (i.e., Gypsum, Hydrated Lime and Agricultural Lime). Examples of soil physical ameliorants and options include: geotextile fabrics and mattings to provide sodic soil protection; organic matter used as protective shroud on topsoils; and seeding of fast growing species or application of instant turfs.

There are a number of technical manuals available that provide guidance on options for reducing the risk of soil erosion during construction from development works on dispersive soils. We have provided reference to these in Section 5.3 of our report. Management options start with the preservation and treatment of topsoil, with options variable depending on the level of disturbance.

It is recommended that consideration is also given to staging construction works, to manage erosion risks. In principle, it is better to work from top of catchment/higher areas in the landscape first and then progressively work downstream, but this may not be practical. Disturbances to high risk areas should be minimised, if not totally avoided, especially during the most erosive periods of the year (wetter months). The development sequence should allow the installation of temporary drainage and erosion control measures, and preferably, the permanent stormwater drainage system as soon as practicable. As waterways are a high risk area construction should commence on drainage schemes first. Runoff from construction sites should be managed by temporary drainage and sedimentation ponds, with the aim of preventing sediment-laden runoff from entering the waterway corridor until development is near completion. Appropriate hydrologic and hydraulic design is needed to size the drainage control measures for both the temporary and permanent drainage system.

It is recommended that detailed Site Environment Management Plans (SEMPs) and Erosion and Sediment Control Plans (ESCPs) are developed for managing sodic soil related erosion risks. These plans would be developed during the planning of building and construction projects within the Precinct Area. It is expected that further sampling of soils, as well as testing and analysis of their sodicity, dispersion and erosion potential will be required at a higher resolution to inform construction techniques and management of erosion risks.

The assessment completed for Shenstone Park and recommendations are similar to those outlined in the Beveridge North West Precinct Sodic Soil Assessment Report. This earlier assessment and its recommendations were supported by the conclusions of the Beveridge North West Panel Report.

It is understood that the following changes to the Amendment are proposed in response to submissions on the assumption that sodic/dispersive soils are identified:

- Insert a new Requirement to include the protection of sub soil layers.
- Insert new Guidelines regarding the management of subdivision, development, and stormwater to avoid or mitigate the potential risk of erosion.
- Amend the UGZ7 to:
  - include a permit trigger specific to earthworks where the land is identified as being subject to sodic or dispersive soils.
  - include an application requirement relating to the preparation of a sodic/dispersive soils management plan. The management plan will inform a subsequent site management plan required to be prepared as a condition on permit.
  - Include a mandatory permit condition requiring the preparation of a site management plan, to manage sodic/dispersive soils during subdivision and earthworks.

I consider these proposed amendments to be appropriate and provide a process for managing sodic soil erosion risks.

Yours sincerely

Peter Sandercock

Dr Peter Sandercock
Senior Consultant, Geomorphologist

6 November 2020

Dr Peter Sandercock

SENIOR CONSULTANT, GEOMORPHOLOGIST

EDUCATION/QUALIFICATIONS

PhD (Fluvial Geomorphology) 2004

B Sc (1st Cl Hons) (Env Sc) (Geography, Zoology) 1999

Peter is a Fluvial Geomorphologist working in Jacob's Water and Environment business. He has over 15 years' experience, specialising in fluvial geomorphology investigations and studies that assess the impact of land use change and flow regulation on waterway management and rehabilitation.

Peter has completed numerous urban growth area investigations and environmental flow studies for Melbourne Water in which he has developed and applied methodologies to assess the impact that urban induced hydrological changes have on the physical form of waterways, their geomorphological and ecological processes and values. Peter was lead author of a Technical Note and Fact Sheet that outlines the values of headwater streams (hydrological function, regulation of water quality, biodiversity and habitat values), how they can be protected through integrated urban and drainage design and the benefits of protecting them. He also prepared a position paper on the issues and opportunities associated with the adoption of large-scale bioretention systems compared to constructed wetlands and completed a review of the design response to geomorphological issues associated with sodic soils and a future constructed waterway in the Merrifield area. He recently completed a Sodic Soils Assessment for the Beveridge North West Precinct Area

Areas of Expertise

- Fluvial geomorphology
- Erosion prevention and mitigation
- Environmental flow assessments
- Channel responses to landuse change and flow regulation
- Design and implementation of monitoring programs
- Ecological risk assessment
- Environmental Impact Assessment
- Vegetation and large woody debris interactions with channel processes
- Flood impact investigations
- Dam decommissioning options assessment
- Sediment connectivity and construction of sediment budgets
- Use of prioritisation tools and development of catchment management programs

Relevant Project Experience

- **Sodic Soils Assessment Beveridge North West Precinct Area (Victorian Planning Authority):** Peter led this project that mapped the distribution of sodic soils. An assessment was made of erosion risks and treatment options in light of future planned development. Advice was also provided on changes to the planning ordinance to include the requirement for the development Sodic and Dispersive Soil Management Plan in applications to subdivide the lands or undertake bulk earthworks.
- **Wallan South and Wallan East PSP Geomorphology Assessment (Victorian Planning Authority):** Peter prepared a high level assessment of the geomorphology characteristics of these PSP areas and provided

advice on constraints as they relate to soil characteristics and erosion risks.

- **Independent Peer Review of Merrifield Central Waterway Geomorphology Report (Melbourne Water):** Peter led a peer review of a geomorphology report and design for a constructed waterway to replace an existing headwater stream. An alternative design concept was identified and recommended, a series of distributed seasonal wetlands and swales that provide some stormwater treatment and flow conveyance. This is considered to provide better outcomes for the local waterway because it more closely aligns with the characteristics and functioning of the existing waterway as a headwater stream.
- **Headwater Stream Fact Sheet and Technical Note (Melbourne Water):** Peter led the development of a Fact Sheet and Technical Note on the importance of protecting headwater streams. The communication products assist Melbourne Water in communicating to councils, developers, landowners, consultants and engineers why headwater streams are important and warrant protection. They provide a valuable contribution that has the potential to change people's perceptions of these streams value and function in the landscape.
- **Issues and Opportunities Review: Acceptance of large-scale bioretention systems (Melbourne Water)**: Peter managed this strategic review, which identified a range of issues that relate to the design, construction and maintenance of large-scale bioretention systems and more broad range of water treatment measures, including constructed wetlands. The outcomes from this project will assist Melbourne Water in adopting a policy position on the acceptance of these systems.
- **Werribee Junction Structure Plan Riparian Values Risk Assessment (Melbourne Water):** Peter was part of the multidisciplinary team that identified the geomorphic, flora and fauna values of Lollypop Creek, Cherry Creek and its tributary. Recommendations were made regarding priority areas for protection, these will inform the design of the Development Services Scheme.
- **Lollypop Creek FLOWS Study (Melbourne Water):** Peter managed an environmental flows assessment of Lollypop Creek, downstream from a proposed large scale stormwater harvesting scheme to Port Phillip Bay, with a focus on the flow dependant environmental values identified in the Western Treatment Plant. The outcomes of this study can be used to optimise the design and function of the stormwater harvesting scheme and provide a favourable flow regime for water-dependant values along the creek downstream.
- **Dandenong Creek Environmental Flows Study (Melbourne Water):** Peter managed this Flows Study which provides an understanding of the flow impacts of urbanisation and conventional storm drainage on streams in the Dandenong Creek catchment. The outcomes of this study help to identify the critical flow thresholds that need to be mitigated in already developed streams and those that should not be exceeded in new developments.
- **The Ivy, Doreen Geomorphology Assessment (Spiire):** Peter provided an assessment of the location of proposed stormwater outfall from an urban development project as there were concerns that the proposed location on an unstable gully could contribute to further erosion. Following an assessment of the site, an alternative location was selected closer to the Plenty River which was considered to be more stable.

- **Plenty Reserve Drainage Investigation (Spiire):** Peter completed an investigation of the potential impacts of urban development on the hydrology and geomorphology of several drainage lines. Recommendations were also made as to the design of works to mitigate erosion at proposed outfall locations.
- **Darebin, Findon and Edgars Creek Geomorphological Assessment, Wollert and Epping (Melbourne Water):** Peter completed a baseline geomorphological assessment of the creeks in an urban growth area and analysis of the sensitivity of the waterways to change in response to urbanisation. A risk based approach was developed to assess the potential hydrological impacts associated with urbanisation on the physical stream form. The project collated together information on thresholds of shear stress for different channel surfaces that if exceeded may result in significant geomorphological changes. High priority areas where erosion and channel changes are likely with urbanisation were identified and advice was provided on strategies to mitigate adverse impacts.
- **Coulstock Gully Geomorphology Investigation (Melbourne Water):** Peter completed a geomorphological assessment of a series of erosion problems along Coulstock Gully that developed following a large rainfall event. An assessment was also made of the threat that continued erosion at crossing location poses to a buried sewer pipe. A short report was produced that outlined the outcomes of the geomorphology investigation and provided recommendations to mitigate against further erosion. The report also included a description and costing for a rock chute structure to stabilise headcut and protect the sewage pipe.
- **Preliminary Geomorphic, Flora, Fauna and Socio-economic Assessment, Wyndham Vale and Truganina (Melbourne Water):** Peter completed a baseline assessment of geomorphic, flora, fauna and socio-economic values for the Wyndham Vale and Truganina growth area. The assessment focused on waterway values and the threat that urban induced hydrological changes pose to these values. A risk based approach was developed to assess the potential hydrological impacts associated with urbanisation on the waterway values. High priority areas where waterway values are threatened as a result of urban induced hydrological changes were identified and advice was provided on strategies to mitigate adverse impacts.
- **Plenty Estate Gully Investigation, Melbourne (Spiire):** Peter was engaged to undertake hydrological and geomorphological investigations of a confined upland channel leaving an urban development area and consider the impact that proposed development will have on the stability of the waterway. The stream network was found to be strongly influenced by surrounding geological controls. Development of the catchment area will result in increases in flow discharge, shear stresses, velocities and depths. However, the increases as modelled are not considered significant to impact on fluvial processes and the geomorphology of the stream.
- **Geomorphological Assessment of Melba Creek, Victoria (Melbourne Water):** Peter completed a geomorphological assessment of erosion issues and provided advice on engineering measures to mitigate against further erosion and potential failure of sewer pipes that cross the waterway. A risk assessment approach was used to assess the likelihood and consequences associated with continued erosion and develop recommendations to mitigate against identified risks.

Geomorphological assessment of Arundel Creek, Keilor (Melbourne Water): The Keilor archaeological site was among the first places to demonstrate the antiquity of Aboriginal occupation of Australia when a cranium, unearthed in 1940, was found to be nearly 15,000 years old. Subsequent investigations of Pleistocene alluvial terraces revealed hearths about 31,000 years BP, making Keilor one of the earliest sites of human habitation in Australia. A geomorphological assessment of the site was undertaken due to concerns that the creek was eroding its banks leading to the exposure and loss of culturally significant material. The nature of these erosion problems were investigated and working together with waterway engineers a series of channel stabilisation options were developed to protect the site.

HARWOOD ANDREWS

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23 September 2020

Peter Sandercock
Senior Consultant, Geomorphologist
Jacobs
Email: peter.sandercock@jacobs.com

Subject to legal professional privilege

Dear Peter,

Amendment C241wsea to the Whittlesea Planning Scheme (Amendment)
Shenstone Park Precinct Structure Plan (PSP)

We continue to act for Victorian Planning Authority (**VPA**) in relation to the upcoming panel hearing for the Amendment. The Amendment seeks to incorporate the PSP into the Whittlesea Planning Scheme (**Planning Scheme**).

Background

1. The PSP is located in the Northern Growth Corridor Plan area.

2. The PSP is adjoined to the north by the Donnybrook and Woodstock PSP area[1], the Melbourne-Sydney rail corridor to the west (and English Street[2], and Craigieburn North Employment Area[3] PSPs west of the rail corridor), the future Northern Quarries PSP area to the south, and the urban growth boundary to the east.

3. Land within the PSP has primarily been used for agricultural purposes, with the exception of the existing Woody Hill Quarry located in the central-western half of the PSP area.

4. The Amendment was exhibited in October and November 2019. The VPA received 32 submissions. In general terms, the key issues raised in submissions raised issues relate to:

   4.1. Protection of extractive resources, in particular the expansion of Woody Hill Quarry and future development of the Phillips Quarry, as well as access arrangements to Phillips Quarry.

   4.2. Land use compatibility and what development should be permitted within quarry buffers.

   4.3. Location of a potential Yarra Valley Water treatment facility.

   4.4. Location of the proposed school and local community centre in the north-central part of the PSP.

[1] The gazetted PSP is accessible here.
[2] The gazetted PSP is accessible here.
[3] The gazetted PSP is accessible here.

4.5. Heritage value of the homestead at 1030 Donnybrook road.

5. A planning panel (Nick Sarah Carlisle (Chair), Colin McIntosh, and Annabelle Paul) has been appointed to consider and hear submissions (**Panel**).

6. The Panel hearing will commence on Monday 16 November 2020 and continue until Wednesday 23 December 2020.

7. The hearing timetable schedules the VPA's case for Monday, Tuesday, Wednesday and Thursday 16 – 19 November 2020. We will confirm closer to the hearing which of these days you would be required to appear and provide evidence. Please let us know if you have any constraints 16 – 19 November 2020.

8. A copy of the Panel's primary directions are included in your brief. Items18-20 of the direction sets out requirements for the witness reports and includes a link to the Planning Panels guide to expert evidence which sets out further requirements for your witness statement.

9. Witness reports are required to be circulated by 4 pm on Wednesday 28 October 2020. We would appreciate a draft for review as soon as possible.

Instructions

We are now instructed to brief you to:

10. Review the exhibited amendment and background materials (as relevant);

11. Prepare an expert witness statement;

12. Appear at the panel hearing to provide expert evidence.

Your expert witness statement should, in addition to any other relevant matter, address the following issues:

13. Provide an expert report summarizing the sodic/dispersive soils investigations and results undertaken in relation to the PSP area.

14. Provide your expert opinion on whether or not the investigations necessitate a requirement for more detailed consideration of sodic/dispersive soils at the time of subdivision.

15. In the event conditions require specific controls, provide comment on the proposed VPA text and the application of those requirements across the PSP area.

Your fees

Our client will remain responsible for your fees in accordance with the procurement arrangements agreed between the VPA and yourself.

Legal professional privilege

We confirm that your professional opinion is sought in the context of us providing legal advice in relation to the Panel hearing for the Amendment.

Our advice, and your advice by virtue of your engagement by us, attracts legal professional privilege. Our client is therefore not required to disclose any advice provided by you to any other party unless that legal professional privilege is waived.

To ensure that legal professional privilege is maintained, we request that you do not advise anyone, other than our client or Harwood Andrews, that you have been requested to provide independent advice in relation to this matter.

We will notify you if legal professional privilege is waived in respect of your advice. We expect that this will not occur until just prior to the anticipated Panel hearing at the time when expert witness reports are due to be filed and served.

Contact

If you have any queries or require any further information, please contact Greg Tobin (gtobin@ha.legal or 5225 5252) or Aaron Shrimpton (ashrimpton@ha.legal; or 5225 5248).

Yours faithfully,

Harwood Andrews

HARWOOD ANDREWS

Encl.

Index to Brief

Exhibited Amendment	
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3.	PSP
4.	Background studies • Background Summary Report 2019 • Aboriginal Cultural Heritage Assessment - Biosis - October 2017 • Arboriculture Assessment - Treetec - February 2017 • Bushfire Development - Terramatrix - April 2019 • Community Infrastructure & Open Space Needs Assessment - City of Whittlesea & VPA - September 2019 • Economic Assessment - Ethos Urban - September 2019 • Geomorphology and Vegetation Values Assessment - Drainage - Alluvium - February 2018 • Hydrologic Regime - Drainage - Alluvium - February 2018 • Land Capability - Environmental Contamination Assessment - Meinhardt -March 2017 • Post Contact Heritage Assessment - Ecology and Heritage Partners Pty Ltd - May 2017 Quarry Impact Assessment - Addendum - GHD - September 2019 • Quarry Impact Assessment - GHD - December 2017 • Strategic Transport Modelling Assessment - GTA - September 2019 • Utility Services Infrastructure Assessment - Cardno - July 2017 • Visual Character Assessment - City of Whittlesea - November 2017
5.	Extractive resources background materials • Better Regulation Earth Resources 17 • Extractive resources strategy 18 • Growth Corridor Plan - Chapter 5 The North Corridor Plan - 2012 • Melbourne Supply Area – EIIA Review 2003 pt1 • Melbourne Supply Area – EIIA Review 2003 pt2 • Plan Melbourne 2017-2050 Strategy • Whole of Victorian Government Joint Ministerial-Statement Extractive Resource • Supply Demand of Extractive Resources report - PwC - May 2016
6.	PPV Guide to expert evidence.
Panel Documents	

7.	Direction and Timetable 4 September 2020.
Submissions	
8.	#1 – EPA Victoria
9.	#2 – APA Group
10.	#3 – Terrain Consulting Group (for owner 75 Langley Park Drive, Donnybrook)
11.	#4 – Mirvac
12.	#6 – Tract (for Golina Holdings Pty Ltd – owner of 570, 620 and 650 Summerhill Road, Wollert)
13.	#7 – Tract (for 910 Donnybrook Road Pty Ltd – owner of 910 Donnybrook Road, Donnybrook)
14.	#10 – Tract (for Retzos Group – prospective purchaser of 910 Donnybrook Road, Donnybrook)
15.	#12 – Tract (for Donnybrook Road Unit Trust– owner of 150 Donnybrook Road, Donnybrook)
16.	#13 – Tract (for Landream and Austral Brickworks– owner of land in Craigieburn East PSP)
17.	#15 – Sarah Davies (for owner of 825 and 795 Epping Road, Wollert)
18.	#16 – Insight Planning Consultants (for Lavender Rain Pty Ltd – owner of land in English Street PSP)
19.	#17 – DELWP
20.	#18 – Yarra Valley Water
21.	#19 – Melbourne Water
22.	#20 – Dominion Property Group (for 1100 Donnybrook Road Developments Pty Ltd – owner of 1100 Donnybrook Road, Donnybrook)
23.	#22 – Slattery Property Group (future developer of PSP property 13, being 1030 Donnybrook Road, Donnybrook)
24.	#23 – Donnybrook Joint Venture Pty Ltd (owner of 960 and 1030 Donnybrook Road, Donnybrook)
25.	#24 – Contour (on behalf of Barro Group Pty Ltd, owners and operator of the Woody Hill Quarry (870 Donnybrook Road, Donnybrook) and owner of the Phillips Quarry (430 Summerhill Road, Wollert)
26.	#25 – Merri Creek Management Committee
27.	#27 – Department of Jobs Precincts and Regions (DJPR) – Resources Branch
28.	#28 – Victorian School Building Authority
29.	#29 – CFA
30.	#30 – Department of Transport
31.	#32 – City of Whittlesea

Sodic Soils Assessment

Shenstone Park Precinct Area

6 | Final

6 November 2020

Victorian Planning Authority

Sodic Soils Assessment

Project No:	IA237500
Document Title:	Shenstone Park Precinct Area
Document No.:	6
Revision:	Final
Date:	6 November 2020
Client Name:	Victorian Planning Authority
Project Manager:	Dr Peter Sandercock
Author:	Peter Sandercock, Christian Bannan, Craig Clifton, Graeme Jardine, Adam Hall, Filomena Losi and Milos Pelikan
File Name:	06_SP_Sodic_Soils_Assessment 06112020.docx

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Document history and status

Revision	Date	Description	Author	Reviewed	Approved
01	21/10/2020	Draft	P. Sandercock,		
02	26/10/2020	Draft	P. Sandercock, C. Bannan		
03	29/10/2020	Draft	P. Sandercock, C. Bannan	C. Clifton, G. Jardine	
04	02/11/2020	Draft	P. Sandercock, C. Bannan	P. Sandercock, A. Hall	P. Sandercock
05	04/11/2020	Final	P. Sandercock, C. Bannan, C. Clifton, A. Hall	P. Sandercock	P. Sandercock
06	06/11/2020	Final	P. Sandercock, C. Bannan, C. Clifton, A. Hall	P. Sandercock	P. Sandercock

Contents

Executive Summary

Jacobs was engaged by the Victorian Planning Authority (VPA) to provide an assessment of the distribution of sodic and dispersive soils, erosion risks and consider their implications for future planned development in the Shenstone Park Precinct Area.

The soils of the Shenstone Park Precinct Area assessed in this investigation are predominantly classified as Sodosols, with a clear or abrupt textural B horizon in which the major part of the upper B2 horizon is sodic and not strongly acid. Vertosols were also identified, clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Areas to the west of Woody Hill Quarry have sodic topsoils with Exchangeable Sodium Percentage (ESP) values from 7 to 10%. Subsoils in this area exhibit higher to extreme sodicity with ESP values >15%. Areas east of the quarry have topsoils that are generally non-sodic with ESP values <5% and subsoils with moderate to very high sodicity, with ESP values ranging from 7 to 15%. A horizon topsoil depths vary across the Precinct, with measurements in the field ranging from 10-30 cm.

A vulnerability assessment approach was used to assess the implications of sodic soils for the construction phase and for the future developed land use.

Vulnerability (V) = Exposure (E) + Sensitivity (S)

Exposure (E): refers to attributes of soils that characterise their sodicity and exposure to erosion. Exposure criteria included sodicity of topsoil and subsoil, A horizon depth and slope.

Sensitivity (S) refers to attributes of the land or activities that influence the extent to which the land and urban developments may be disrupted or detrimentally affected by sodic soils. Sensitivity criteria included position relative to waterway, potential disturbance associated with construction activity for different land use types and water balance change expected for future land use.

During construction, areas identified as particularly vulnerable to sodic soil erosion are the waterways (Retarding Basin/WQT Wetland and Waterway Corridors) and the area to the west of the Quarry that has soils with high to extreme sodicity values. Activities that expose these soils to rainfall and associated runoff will present significant construction challenges and need to be managed carefully.

Water balance changes resulting from future developed land use and associated impervious areas will generate high volumes of runoff, which will drain into the surrounding waterways, including an un-named Merri Creek tributary. The Merri Creek tributary is already in a degraded condition, further increases in flows would be expected to accelerate erosion of bed and bank materials and contribute to the turbidity of downstream waterways.

Areas identified with a high vulnerability to sodic soils erosion risks and recommended treatments include:

- Drainage depressions/seasonal wetlands – Ideally these areas should be identified and reserved as linear green spaces to maintain their important hydrological function in retaining and temporarily storing water in the landscape and regulating the flow of water and nutrients throughout a catchment. Surface ground cover measures are critical for protecting the soils against dispersion and erosion.
- Merri Creek tributary – This waterway is in a degraded state and further increases in runoff may result in increased erosion. Significant engineering works are likely to be required to stabilise this waterway so that it is resilient to stormwater runoff from future land development.
- Steeper slopes – Cutting into these slopes will expose underlying subsoils, and erosion risk is increased with slope. Road batters must be designed with consideration to the erodibility of the soils. Stable linings that are resistant to rainfall and runoff will be required.

It is recommended that detailed plans are developed for managing sodic soil-related erosion risks in high vulnerability areas identified in this investigation.

Important note about your report

The purpose of this report and the associated services performed by Jacobs is to provide an assessment of the distribution of sodic soils and erosion risks that relate to the characteristics of these soils, their position in the landscape and the implications of this for future planned development within the Shenstone Park Precinct Area. Advice is also provided on the range of treatment options that are available to manage identified sodic soils and erosion risks. The work has been conducted in accordance with the scope of services set out in the contract between Jacobs (Australia) and Victorian Planning Authority.

In preparing this report, Jacobs has relied upon, and presumed accurate information provided by Victorian Planning Authority and/or other sources as referenced in the report. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, the observations and conclusions in this report may change.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession following applicable standards, guidelines, procedures and practices at the date of issue of this report. No other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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This report has been prepared on behalf of, and for the exclusive use of, Victorian Planning Authority subject to, and issued in accordance with, the provisions of the contract between Jacobs and Victorian Planning Authority.

1. Introduction

1.1 Background

Jacobs was engaged by the Victorian Planning Authority to map sodic soils and erosion risk and provide advice on treatment options in light of future planned development in four Precinct Areas located to the north of Melbourne: Beveridge North West, Shenstone Park, Wallan South and Wallan East.

1.2 Scope

This report provides an assessment of the distribution of sodic soils and erosion risks that relate to the characteristics of these soils, their position in the landscape and the implications of this for future planned development within the Shenstone Park Precinct Structure Plan (Figure 1.1).

The Precinct will include residential neighbourhoods with access to a local town centre within the precinct. Nationally significant conservation areas to the south-east and south-west will be protected. These provide habitat for nationally listed Grassy Eucalypt Woodland and Natural Temperate Grassland communities, as well as Growling Grass Frog. These areas will be retained, and habitat reinstated, while being incorporated into the design and layout of the precinct (Victorian Planning Authority 2019).

The Woody Hill Quarry was excluded from the investigation because it is currently zoned Special Use Zone (SUZ) and will not be developed for urban purposes.

A vulnerability assessment approach was used to assess the implications of sodic soils fur future planned urban development. This vulnerability assessment was completed for two scenarios, first the construction phase and second for the future developed land use. Advice is provided on the range of treatment options that are available to manage identified sodic soils and erosion risks.

1.3 Report structure

This report has been structured as follows:

- Section 2 provides a brief summary of sodic and dispersive soils definitions and terms used in this report, Victorian context regarding the distribution of sodic soils and their implications for urban development.
- Section 3 describes our approach to mapping sodic soils and erosion risks.
- Section 4 presents the results of the assessment.
- Section 5 provides discussion and recommendations on options to manage identified erosion risks, including potential planning control measures.
- Section 6 documents gaps in knowledge/requirements for further soil investigations and further work to validate the predictions of the distribution of sodic soils and erosion risks.

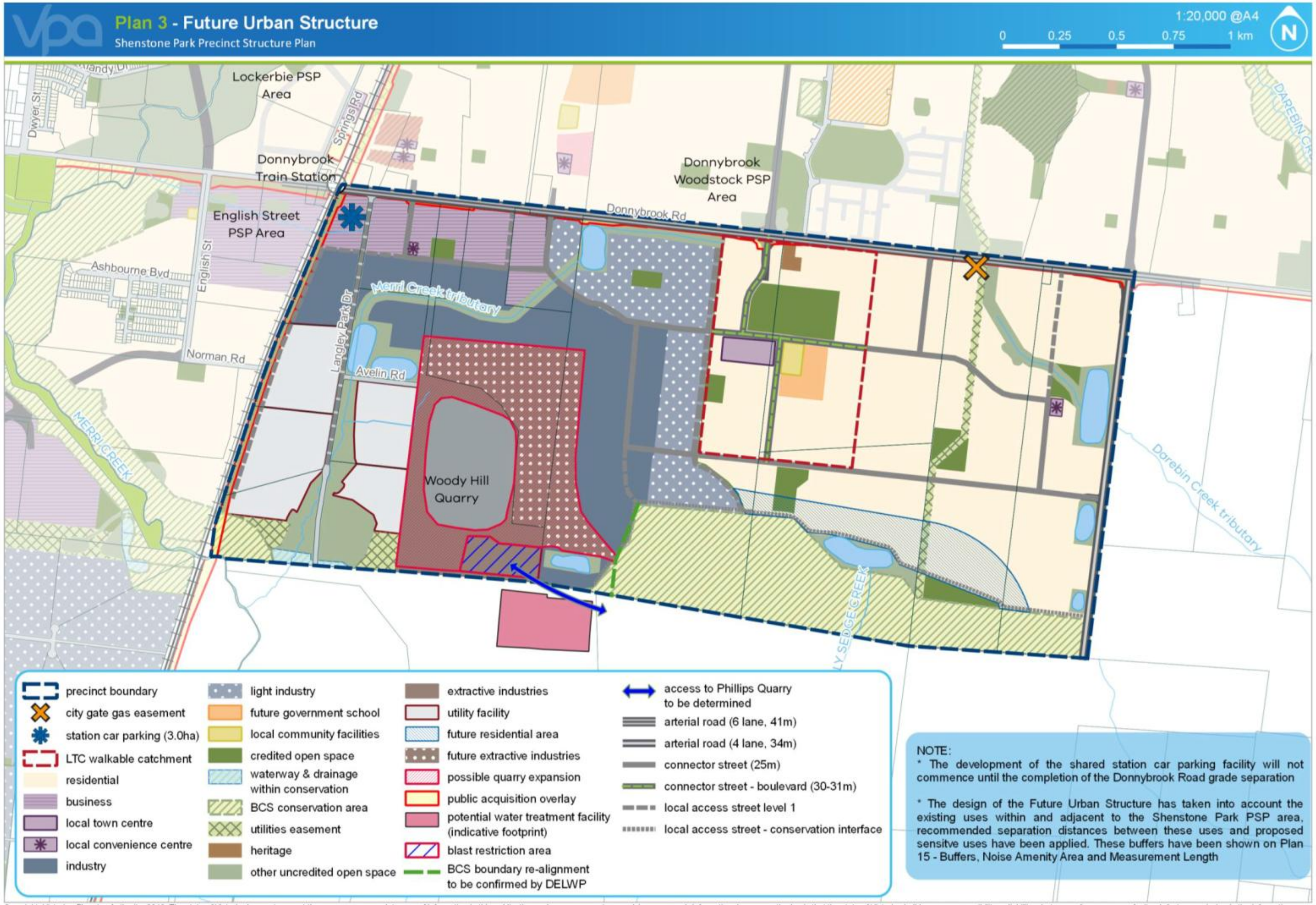

Figure 1.1: Shenstone Park Precinct – Site locality and context (Victorian Planning Authority 2019).

2. Sodic and dispersive soils

2.1.1 Sodic and dispersive soil definitions and terms used in this report

Sodic soils are defined in Australia as those with an exchangeable sodium percentage (ESP) of 6% or greater (Northcote & Skene 1972). An ESP of 6% is considered to be the threshold where the cation sodium in soil has an adverse impact on soil structure when in contact with fresh water, causing clay dispersion (Northcote & Skene 1972). Soils may also reveal dispersive behaviour under the influence of elevated exchangeable potassium (K) and magnesium (Mg) (Dang et al. 2018, Marchuk & Rengasamy 2012). These considerations are necessary in the evaluation of sodic and dispersive soils where dispersion is evident when ESP levels are below 6%.

Dispersive soils and criteria for their assessment were first recorded by Emerson (1967), with further research on the relationship between Emerson Score and hydraulic conductivity carried out by Loveday and Pyle (1973). Figure 2.1 provides examples of the Emerson Aggregate Test where varying levels of dispersion are recorded (Armstrong 2019).

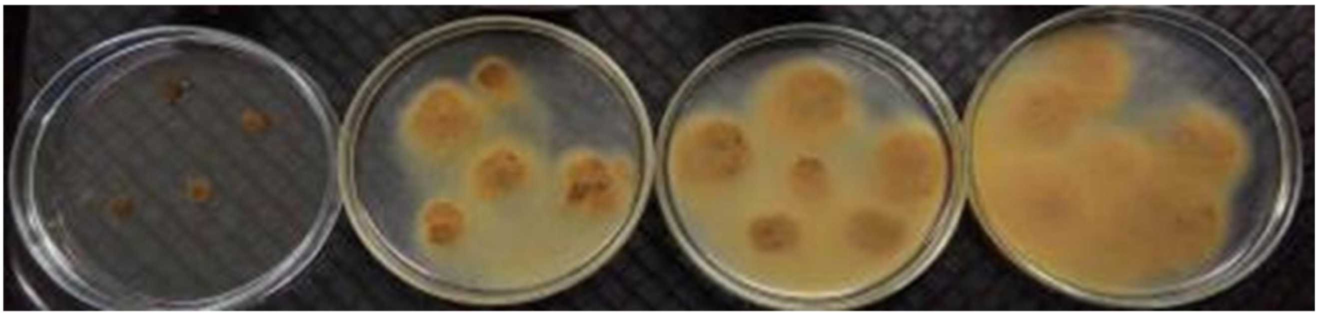

Figure 2.1: Examples of soil aggregates subject to the Emerson Aggregate Test, showing nil dispersion on the left with increasing levels of dispersion to the right (Armstrong 2019).

Impacts associated with wetting of sodic and dispersive soils potentially include soil structural decline, crusting, waterlogging, low rates of hydraulic conductivity, excessive runoff, erosion and poor agricultural performance. Types of erosion include sheet, rill, gully and tunnel erosion. These impacts are significant when sodic soils are disturbed or groundcover is removed or absent. Charman and Murphy (2007) provide further details of the impact of sodic and dispersive soils in an Australian context.

The Australian Soil Classification (Isbell & NCST 2016) outlines 14 soil orders, several of these contain soil materials that are sodic and dispersive. The soil order 'Sodosol' is a specific soil containing dispersive soil properties, defined with a 'strong texture contrast between the A horizon and sodic B horizons which are not strongly acid'. This report seeks to identify 'Sodosols' and other soil orders across the Shenstone Park Precinct. Soil orders other than Sodosols can be identified with sodic and dispersive properties. One of these includes 'Vertosols', which are 'clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates'.

2.1.2 Sodic soil distribution across Victoria.

The distribution of sodic soils across Victoria is well known and documented by Ford et al. (1993) with further mapping by others, including Agriculture Victoria (2020), as shown in Figure 2.2. Sodic soils are common across large expanses of land used for agricultural and urban development. Sodicity and dispersion characteristics vary depending on parent material, geomorphic processes, particle size distribution, rainfall and leaching. In most cases, soils with sodic horizons are texture contrast soils with a clear or abrupt A horizon topsoil layer overlying a finer textured, clay-dominant B horizon subsoil with lower permeability and a high propensity to adsorb cations including sodium.

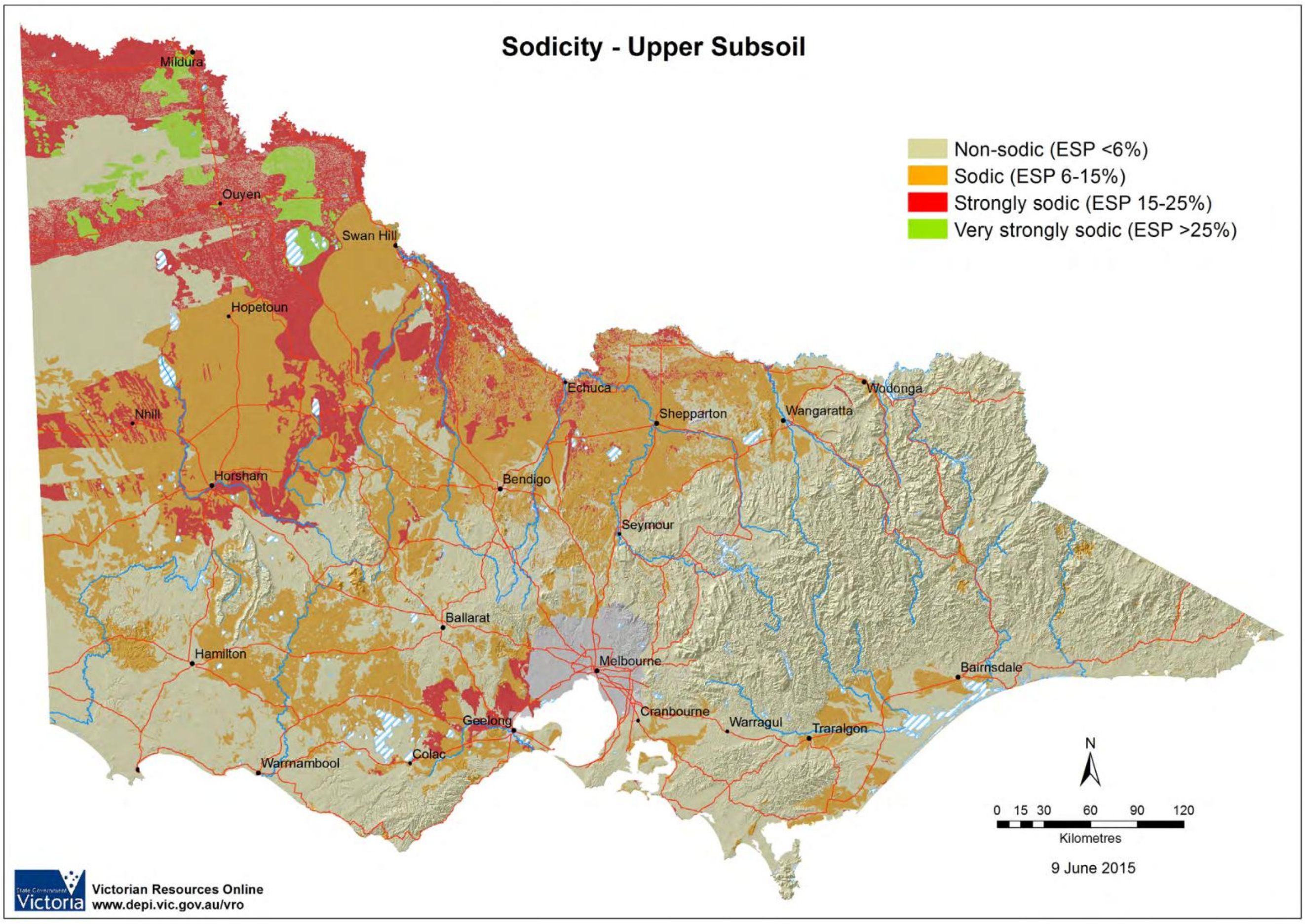

Figure 2.2: Mapping of Sodicity in Upper Subsoil, Victoria (Agriculture Victoria 2020).

2.1.3 Sodic soil implications for urban development

Urban development and site construction cause significant ground disturbance, impacting surface ground cover and exposing sodic soils to erosion. This has implications for both on and off-site development (SCA 1979).

On-site development impacts arising from sodic and dispersive soil conditions include:

- Dispersion of topsoil and subsoil.
- Loss of topsoil and subsoil with overland and subsurface flow (sheet, rill, tunnel and gully erosion).
- Poor infiltration and increased volumes of stormwater runoff.
- Water ponding in hollows, break of slope areas or depressions, increasing groundwater recharge.
- Poor ability to establish vegetation due to adverse soil chemical conditions.
- Lack of trafficability.

Other on-site or off-site development impacts arising from sodic and dispersive soil conditions include:

- Increased turbidity in waterways in response to runoff from development areas and a deterioration in water quality and degradation of aquatic flora and fauna habitat with effects on populations.
- Increased erosion potential in downstream waterways in response to larger volumes of stormwater runoff from developed areas.

3. Method

3.1 Spatial Logic Assessment Framework

Jacobs' Spatial Logic Assessment Framework was used in the delivery of this project (Figure 3.1). Spatial Logic is an approach that brings together source information, with the data used to represent criteria that reflect exposure or sensitivity. An assessment was made of potential sodic/dispersible soils' extent and their level of vulnerability to proposed future land uses.

Spatial Logic has 5 key stages (Figure 3.1):

- Define – Define the sodic soil/landscape profile relationships, scenarios for assessment and supporting data sources, including an assessment of data suitability.
- Collate and integrate – Collate source data and document for transparency, collate any accessible literature that supports soil studies in the area of interest that will inform or be the basis of the assessment. Integrate by converting source data into documented criteria.
- Assess – With reference to landscape profile criteria, undertake an assessment of potential sodic soil extent, severity and/or risk. The assessment indicates where sodic/dispersible soils may occur and their level of risk, based on available evidence.
- Communicate – Provide a report on the study area, the project evidence base, assessment of findings and the information package.

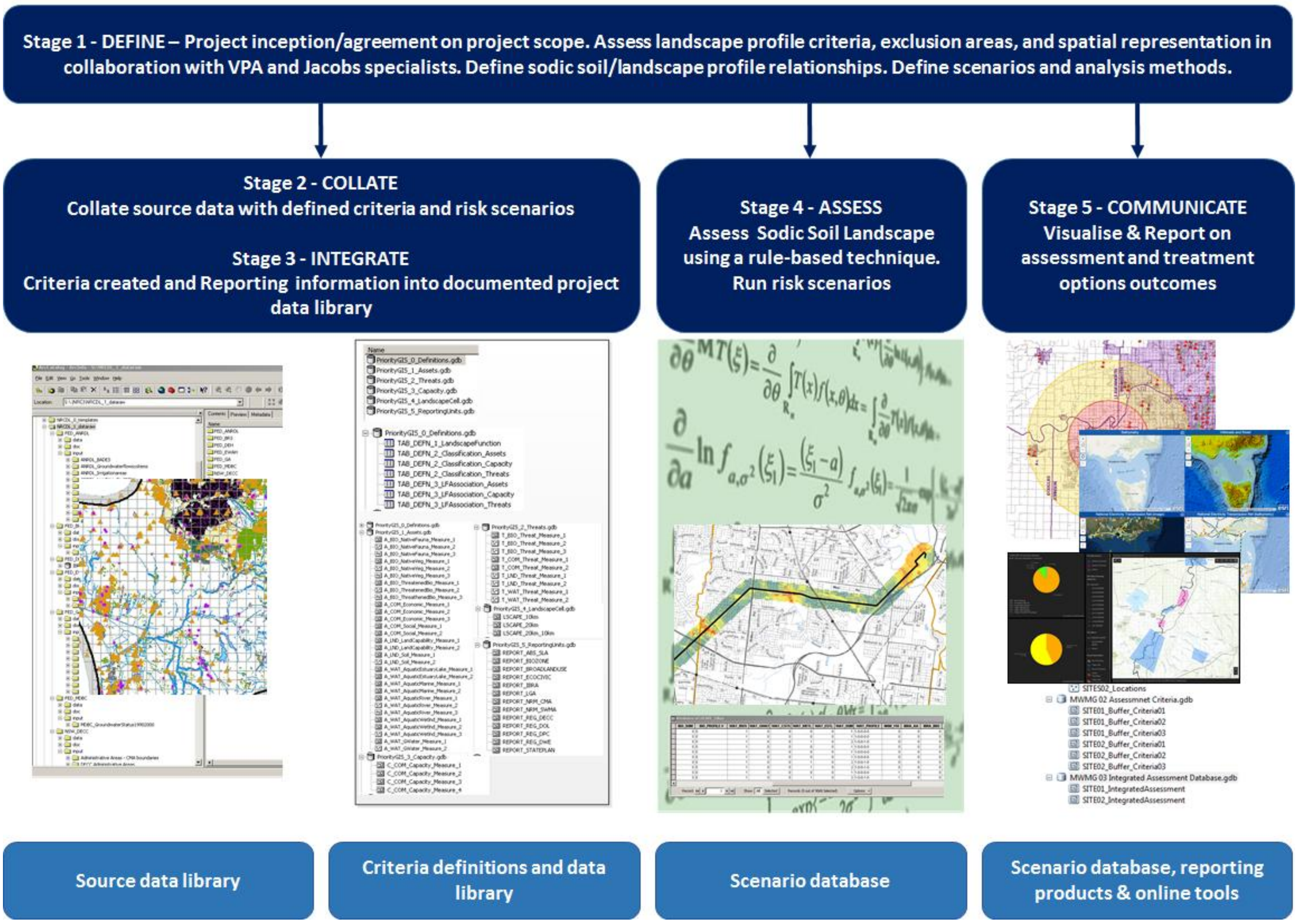

Figure 3.1: The Spatial Logic Assessment Framework.

3.2 Vulnerability Assessment

A specialist workshop was convened to define sodic soil/landscape profile relationships, risk scenarios and analysis methods. The principles of the Vulnerability Assessment approach and how they would be applied to this assessment were agreed upon in this workshop. Vulnerability is defined for the purposes of this assessment as:

Vulnerability (V) = Exposure (E) + Sensitivity (S)[1]

Where Exposure (E): Attributes of soils that characterise their sodicity and exposure to erosion
Sensitivity (S): Attributes of the land or activities that influence the extent to which the land and urban developments may be disrupted or detrimentally affected by sodic soils.

The specialist workshop identified that there was (at that time) insufficient information to adequately characterise soil sodicity levels across the precinct areas. This prompted further field sampling of soils and laboratory analysis (described in Appendix A).

3.2.1 Exposure criteria

Attributes of soils that were used to characterise their sodicity and exposure to erosion are:

- Sodicity of topsoil (0-10 cm) - Exchangeable Sodium Percentage (ESP) values. This soil layer is also referred to as A horizon topsoil throughout the report.
- Sodicity of subsoil (30-40 cm) – ESP. In most cases this layer is B horizon subsoil clay, but can include A2 horizon topsoil where topsoils were deeper than 40cm.
- A horizon depth – subsoil exposure/erosion risk decreases with depth.
- Slope – erosion risk increases with slope (which, for this assessment, was derived using 2017 LiDAR)

These attributes form the exposure criteria, with criteria values ranked according to the scoring system outlined in Table 3.1. Table 3.2 provides a description of the Exchangeable Sodium Percentage (ESP) values used to define the Sodicity exposure criteria.

3.2.2 Sensitivity criteria

Attributes of the land or activities that influence sensitivity to sodic soils are:

- Position relative to waterway – Based on mapped drainage extent in Future Urban Structure (FUS) Dataset.
- Construction activity – Potential disturbance of construction for future land use sub types mapped in FUS Dataset
- Water balance change – Potential for change in water balance due to future land use (based on FUS classes). This considers potential for increases in overland flow from impervious surfaces and stormwater pipes in proposed developments.

These attributes form the Sensitivity criteria, with criteria values ranked according to the scoring system outlined in Table 3.3. Table 3.4 and Table 3.5 provides a description of scorings used for Construction Activity and Water Balance Change criteria.

[1] Vulnerability is typically expressed as Exposure (E) + Sensitivity (S) – Adaptive Capacity (AC). In this case we have not included Adaptive capacity (AC) in the assessment. The Vulnerability assessment is essentially an assessment of potential impacts. Adaptive capacity is included in the discussion when considering aspects of urban development that can be managed to mitigate risks.

Table 3.1: Exposure criteria and scores. For further descriptions of ESP values/scores, refer to Table 3.2.

	Score				
Criteria	1	2	3	4	5
Sodicity of Topsoil (ESP)	<5%	5 to <7%	7 to <10%	10 to <15%	>15%
Sodicity of Subsoil (ESP)	<5%	5 to <7%	7 to <10%	10 to <15%	>15%
A horizon depth	>40cm	30-40cm	20-30cm	10-20cm	<10cm
Slope	0-1 %	1-5%	5 to 10%	10 to 20%	>20%

Table 3.2: Exchangeable Sodium Percentage (ESP) values used to define Sodicity exposure criteria.

Score	ESP Range	Description
1	<5%	Non-sodic, unlikely to reveal dispersion when in contact with fresh rainfall or runoff.
2	5 to <7%	Transition between non-sodic and sodic soil (sodic soil of 6%). Clay fraction within samples likely to evince dispersion when in contact with fresh rainfall or runoff.
3	7 to <10%	Moderate to high sodicity. Dispersion likely to occur when in exposed to fresh rainfall or runoff.
4	10 to <15%	High to very high sodicity. Dispersion likely. Significant erosion risk when exposed to fresh rainfall or runoff.
5	>15%	Very high to extreme sodicity. Significant erosion risk when exposed to fresh rainfall or runoff.

Table 3.3: Sensitivity criteria and scores. For further description of Construction Activity and Water Balance Change values/scores, refer to Table 3.4 and Table 3.5.

	Score				
Criteria	1	2	3	4	5
Waterway[1]	No	-	-	-	Yes
Construction activity	Minimal disturbance				High level of disturbance
Water balance change	Low (stay the same, infiltration)				High (generate runoff)

[1] Based on waterway extent as mapped as Drainage (LU_TYPE Attribute) in Future Urban Structure (FUS)

Table 3.4: Descriptions of scorings for Construction Activity ranked by level of disturbance expected for Land Use Sub Types (LU_SUBTYPE Attribute) mapped in the Future Urban Structure (FUS).

Score	Level of Disturbance	Land Use Sub Types (LU_SUBTYPE)
1	Minimal disturbance	Conservation, Local Park
2		(No land use subtypes fall in this category)
3		Local Sports Reserve, Post Contact (Heritage)
4		Business, Community Facilities, Electricity, Existing Road Reserve, Future Arterial Road, Gas/Oil, General Industrial, Government School, Local Convenience Centre, Local Town Centre, Medium Industrial, Public Acquisition Overlay (Arterial Road), Residential, Widening/Intersection Flaring
5	High level of disturbance	Retarding Basin/WQT Wetland, Waterways

Table 3.5: Description of scorings for Water Balance Change expected for Land Use Classes (LU_CLASS Attribute) mapped in the Future Urban Structure (FUS).

Score	Water Balance Change	Land Use Class (LU_CLASS)
1	Low (stay the same, infiltration)	Credited Open Space, Uncredited Open Space (Heritage, Conservation and Utility Easement/Corridor LU_TYPE), Other Non-Developable Land
2		(No land use classes fall in this category)
3		(No land use classes fall in this category)
4		Education/Community/Government, Developable Area – Residential, Developable Area - Employment
5	High (generate runoff)	Transport, Uncredited Open Space (Drainage LU_TYPE)

3.2.3 Risk scenarios

The distribution of erosion risk associated with sodic soils was modelled using the collated datasets. This assessment was undertaken using Jacobs' Vulnerability Assessment Engine (VAE) - a tool that assists in assembling and analysing spatial data sets.

The VAE was used to assess the risks associated with sodic soils for the following two scenarios:

- Construction phase, where the Vulnerability of land and urban development to sodic soil erosion risks during the construction phase is a function of the following Exposure and Sensitivity criteria:
  - Exposure (E) – Sodicity topsoil, Sodicity subsoil, A horizon Depth, Slope
  - Sensitivity (S) - Waterway, Construction Activity
- Future developed land use, where the Vulnerability of land and urban development to sodic soil erosion risks in the future land use is a function of the following Exposure and Sensitivity criteria:
  - Exposure (E) - Sodicity topsoil, Sodicity subsoil, A horizon Depth, Slope
  - Sensitivity (S) - Waterway, Water Balance Change

Exposure and Sensitivity criteria scores are summed to calculate Vulnerability. The decision was made to apply an equal weighting of scores to Exposure and Sensitivity criteria, they are all considered to be similarly important. The spatial distribution and range of Vulnerability scores informs an assessment of the potential impact of land and urban developments have on sodic soils erosion risks.

4. Results

4.1 Sodicity of soils and their exposure to erosion

The soils of the Shenstone Park Precinct sampled for this investigation are predominantly classified as Sodosols (91% of sampled points). The characteristics of these soils is consistent with definition of Sodosols (Isbell & NCST 2016), as 'soils with a clear or abrupt textural B horizon in which the major part of the upper B2 horizon is sodic and not strongly acid'. Vertosols were also identified at 9% of sampled points. Vertosols are 'clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates'. Vertosols also usually contain more than 35% clay throughout the profile. Soils are dominantly sodic throughout the B horizons.

The stability provided by organic matter including ground cover, plant growth and plant roots is vital for preventing erosion for both Sodosols and Vertosols with sodic and dispersive soil horizons. Disturbance to land such as clearing of vegetation, topsoil removal or construction of drainage channels impacts these sources of organic matter and exposes subsoil layers with negligible organic matter to fresh rainfall, increasing susceptibility to erosion. A good cover of grasses was present at the time of sampling. Stony rises appear sporadically across the precinct and shallow soils are also common. Basalt surface floaters and rock are found across most of the site, apart from where rock picking has occurred previously. Some photographs of the field area showing ground cover, stony rises, depressions, basalt outcrops and constructed incised drainage channel are presented in Figure 4.1.

Figure 4.1: Selected photographs of Shenstone Park Precinct: Stony rise (top left) saturated drainage depression / seasonal wetland (top right), basalt outcrops / floaters (bottom left) and a constructed incised drainage channel, tributary of upper Merri Creek (bottom right).

The sodicity of soils of the Shenstone Park Precinct are summarised with reference to exchangeable sodium percentage (ESP) values as follows:

§ 1-10cm (A1 horizon topsoil): Average ESP of 4.3%. Of the 46 samples collected, 37 samples (80%) were deemed non-sodic while 10 samples (20%) were deemed sodic. Sodic sites in this range mainly included the areas of SP37-SP46, located on the far western section of the precinct area. 0-10cm samples can be summarised as non-sodic across the areas east of the quarry and sodic to the west of the quarry (Figure 4.2).

§ 30-40cm (B horizon clay-dominant subsoil): Average ESP of 10.4%. Of the 41 samples collected from this depth, 27 samples were sodic (66%). All samples from SP36-42 on the western side of the precinct area were highly sodic, these recording an average ESP of 18.7%. Samples from 30-40cm on the eastern side are of moderate to high sodicity (Figure 4.3).

§ 40-120cm soil samples were also collected: A total of 14 deeper samples were collected. All samples were sodic, with an average ESP of 16.9%. Deeper subsoils are deemed highly sodic.

Detailed tables of soil test results are included in Appendix A.

An inverse distance weighted (IDW) interpolation was used to estimate values of soil sodicity (topsoil and subsoil) and A horizon depths at unsampled locations across the Precinct. IDW interpolation is a standard method that is used for spatial interpolation and development of soil maps (Mueller et al. 2004). It is expected that soil characteristics would generally vary in accordance with geology and topography. A spatial layer was developed that was a combination of geology, topography (LiDAR) and mapped boundaries of Stony Rises. The combined units provided the boundaries for soil mapping, the mean of interpolated values within each unit have been used to assign a score for each soil criteria.

Summary statistics for interpolated topsoil and subsoil sodicity across the precinct area and maps showing spatial distribution of scores applied to these two exposure criteria are presented on the following pages (Topsoil sodicity - Table 4.1 and Figure 4.2; Subsoil Sodicity - Table 4.2 and Figure 4.3). The areas to the west of the quarry with Newer Volcanic Group – basalt flows (Neo) units have topsoil with moderate to high ESP values (7-10%) and subsoils with very high to extreme ESP values (>15%). Areas east of the quarry with Newer Volcanic Group - stony rises basalt (Neo2) units generally have topsoils with low ESP values (<5%) and subsoils with moderate to very high ESP values (7 to <15%). Table 4.3 presents summary statistics for interpolated A horizon depth and Figure 4.4, a map showing distribution of scores across the precinct area. Mean values range from 10-20 cm to 20-30 cm.

The final exposure criteria used is slope, with classes shown in Figure 4.5. Figure 4.6 presents the sum of the four exposure criteria (Topsoil sodicity, Subsoil sodicity, A horizon depth and slope). Soils to the west of quarry have higher subsoil ESP values and greater erosion risk. Slope influences exposure to erosion, particularly in areas where gradients are higher than 10%.

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Table 4.1: Sodicity of topsoil – summary of Inverse Distance Weighted (IDW) interpolation of ESP values by geological units. Score and ESP Range assigned to unit presented in last two columns (based on mean IDW value).

Stratum (Unit)	ID	Area (Ha)	Summary of Soil Sodicity (ESP %)					Criteria	
			Min	Max	Range	Mean	STD	Score	ESP Range
Newer Volcanic Group – basalt flows (Neo)	8	0.1	7.8	10.9	3.1	9.8	1.4	3	7 to <10%
	9	6.4	6.2	12.0	5.8	9.6	1.9	3	7 to <10%
	10	1.6	3.7	9.3	5.5	7.0	2.1	3	7 to <10%
	11	91.1	5.0	12.0	7.0	7.5	1.3	3	7 to <10%
	12	6.5	4.7	9.8	5.1	7.6	1.3	3	7 to <10%
Stony Rises Area within Newer Volcanic Group – basalt flows (Neo)	19	0.2	3.8	4.6	0.8	4.2	0.3	1	<5%
	20	1.3	6.4	7.4	1.1	7.0	0.3	3	7 to <10%
	21	0.1	6.1	6.1	0.1	6.1	0.0	2	5 to <7%
Newer Volcanic Group - stony rises basalt (Neo2)	1	101.4	1.6	7.7	6.1	3.6	1.0	1	<5%
	2	1.1	2.2	4.0	1.8	3.1	0.4	1	<5%
	3	44.3	0.9	4.4	3.5	2.4	0.6	1	<5%
	4	0.3	1.2	2.7	1.5	1.8	0.4	1	<5%
	5	188.6	1.7	5.0	3.3	3.1	0.6	1	<5%
	6	1.8	3.7	6.3	2.6	5.8	0.8	2	5 to <7%
	7	38.6	2.0	6.1	4.1	3.7	1.2	1	<5%
Stony Rises Area within Newer Volcanic Group - stony rises basalt (Neo2)	13	39.8	1.7	4.8	3.1	3.0	0.5	1	<5%
	14	12.8	0.9	4.6	3.7	3.1	0.8	1	<5%
	15	1.6	1.2	3.7	2.5	1.9	0.7	1	<5%
	16	0.1	2.6	2.6	0.0	2.6	0.0	1	<5%
	17	20.5	1.6	4.9	3.3	3.3	0.5	1	<5%
	18	2.5	2.5	6.1	3.6	3.5	1.0	1	<5%

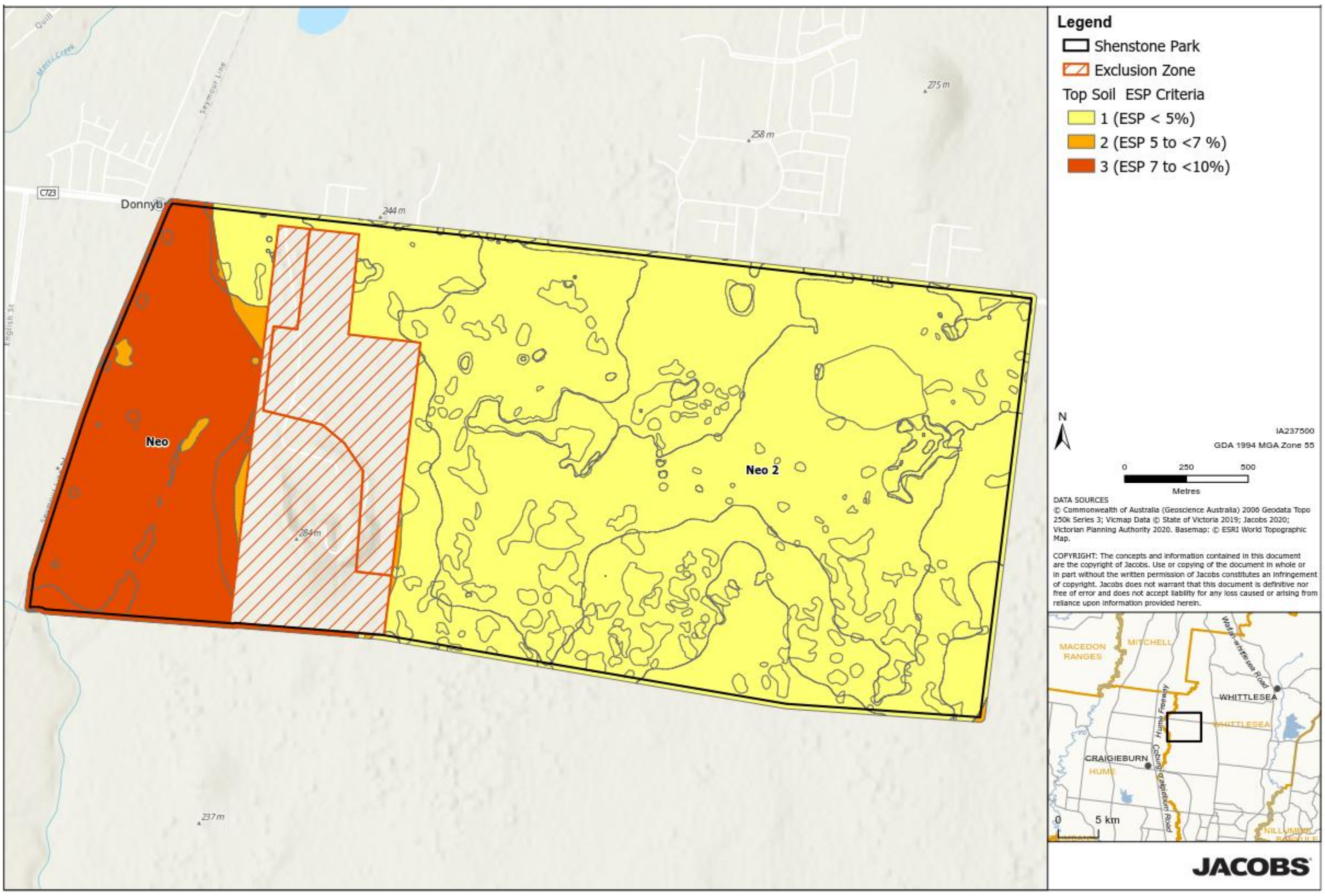

Figure 4.2: Sodicity of topsoil.

Table 4.2: Sodicity of subsoil - summary of Inverse Distance Weighted (IDW) interpolation of ESP values by geological units. Score and ESP Range assigned to unit presented in last two columns (based on mean IDW value).

			Summary of Soil Sodicity (ESP %)					Criteria	
Stratum (Unit)	ID	Area (Ha)	Min	Max	Range	Mean	STD	Score	ESP Range
Newer Volcanic Group – basalt flows (Neo)	8	0.1	20.0	20.1	0.2	20.1	0.1	5	>15%
	9	6.4	13.9	22.0	8.1	19.7	2.2	5	>15%
	10	1.6	7.4	24.6	17.2	17.5	6.7	5	>15%
	11	91.1	12.0	26.0	14.0	17.8	3.5	5	>15%
	12	6.5	12.1	25.9	13.8	20.5	3.7	5	>15%
Stony Rises Area within Newer Volcanic Group – basalt flows (Neo)	19	0.2	7.4	11.6	4.2	9.1	1.9	3	7 to <10%
	20	1.3	12.4	18.9	6.5	15.7	2.5	5	>15%
	21	0.1	14.3	14.4	0.1	14.4	0.0	4	10 to <15%
Newer Volcanic Group - stony rises basalt (Neo2)	1	101.4	3.2	18.9	15.8	8.7	2.7	3	7 to <10%
	2	1.1	4.2	11.6	7.4	7.8	1.5	3	7 to <10%
	3	44.3	2.0	11.3	9.2	4.8	1.4	1	<5%
	4	0.3	2.5	9.2	6.7	3.8	2.1	1	<5%
	5	188.6	2.9	16.5	13.6	7.3	1.9	3	7 to <10%
	6	1.8	8.2	14.4	6.2	13.4	1.9	4	10 to <15%
	7	38.6	5.9	14.5	8.5	9.1	2.8	3	7 to <10%
Stony Rises Area within Newer Volcanic Group - stony rises basalt (Neo2)	13	39.8	3.7	18.1	14.4	7.8	2.0	3	7 to <10%
	14	12.8	2.4	13.5	11.2	6.4	2.1	2	5 to <7%
	15	1.6	2.3	5.2	2.9	3.6	0.8	1	<5%
	16	0.1	6.4	6.5	0.1	6.5	0.0	2	5 to <7%
	17	20.5	2.9	18.5	15.6	7.9	2.3	3	7 to <10%
	18	2.5	6.8	14.4	7.6	8.7	2.3	3	7 to <10%

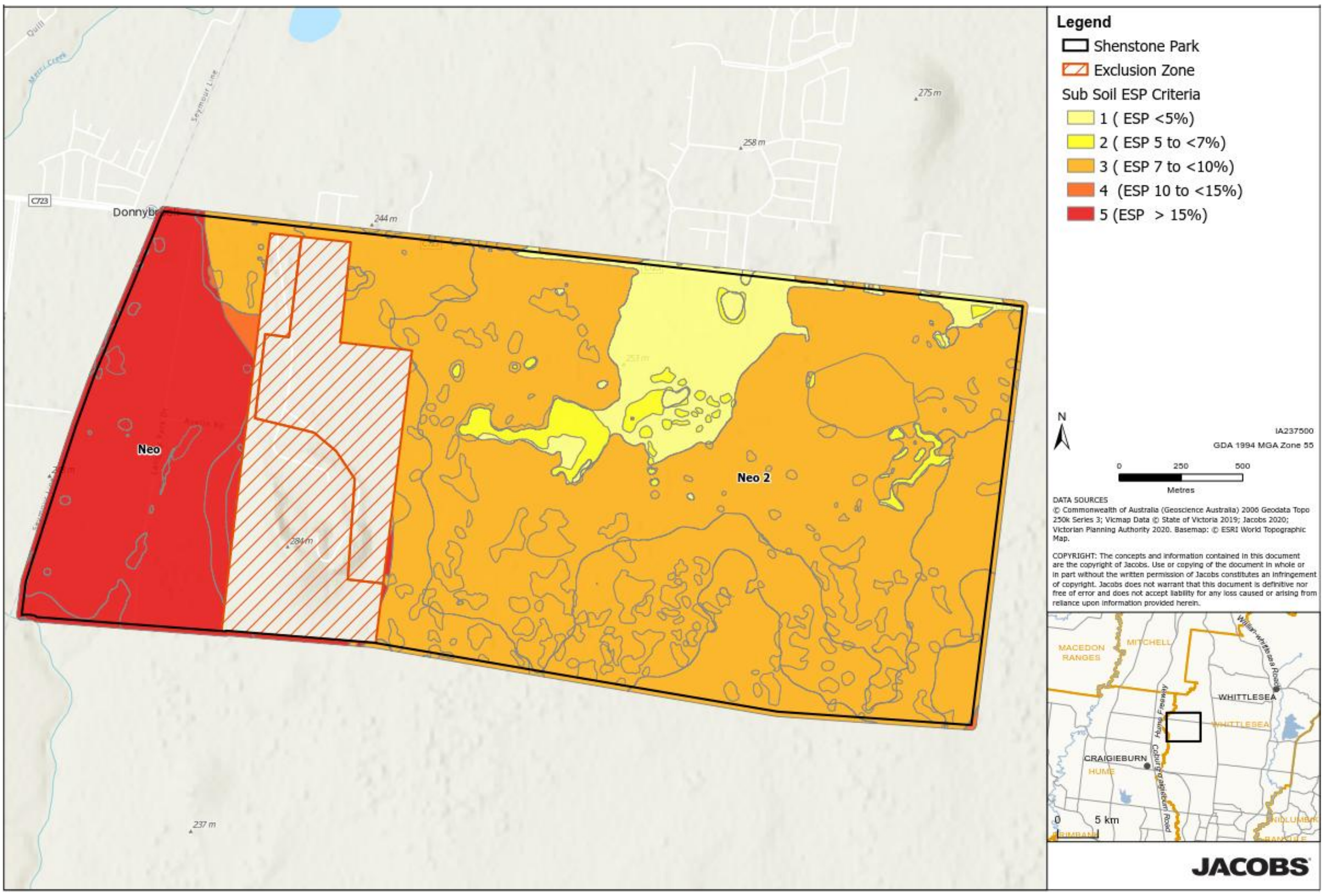

Figure 4.3: Sodicity of subsoil.

Table 4.3: A horizon depth – summary of Inverse Distance Weighted (IDW) interpolation by geological units. Score and depth range assigned to unit presented in last two columns (based on mean IDW value).

Stratum (Unit)	ID	Area (Ha)	Summary of A horizon depth (cm)					Criteria	
			Min	Max	Range	Mean	STD	Score	A horizon depth
Newer Volcanic Group – basalt flows (Neo)	8	0.1	19.3	20.9	1.5	19.9	0.7	4	10-20cm
	9	6.4	10.6	21.0	10.3	18.2	2.7	4	10-20cm
	10	1.6	16.0	23.3	7.3	20.2	2.3	3	20-30cm
	11	91.1	5.0	35.0	30.0	16.9	4.6	4	10-20cm
	12	6.5	15.4	31.8	16.4	21.7	3.3	3	20-30cm
Stony Rises Area within Newer Volcanic Group – basalt flows (Neo)	19	0.2	16.4	17.6	1.2	17.2	0.4	4	10-20cm
	20	1.3	13.2	19.8	6.6	16.2	2.5	4	10-20cm
	21	0.1	15.7	15.7	0.0	15.7	0.0	4	10-20cm
Newer Volcanic Group - stony rises basalt (Neo2)	1	101.4	5.0	22.5	17.5	13.0	2.8	4	10-20cm
	2	1.1	10.4	15.2	4.7	12.4	1.4	4	10-20cm
	3	44.3	5.0	28.5	23.5	11.4	2.8	4	10-20cm
	4	0.3	6.2	12.2	5.9	11.2	1.9	4	10-20cm
	5	188.6	5.0	34.6	29.6	12.8	3.8	4	10-20cm
	6	1.8	9.3	17.2	7.9	15.6	2.2	4	10-20cm
	7	38.6	8.2	21.9	13.7	13.3	3.2	4	10-20cm
Stony Rises Area within Newer Volcanic Group - stony rises basalt (Neo2)	13	39.8	5.6	27.0	21.3	13.2	3.7	4	10-20cm
	14	12.8	5.2	34.9	29.7	14.5	6.1	4	10-20cm
	15	1.6	6.4	32.8	26.4	12.2	6.4	4	10-20cm
	16	0.1	10.4	10.4	0.0	10.4	0.0	4	10-20cm
	17	20.5	5.5	20.1	14.7	12.7	2.4	4	10-20cm
	18	2.5	8.9	17.3	8.4	13.2	2.2	4	10-20cm

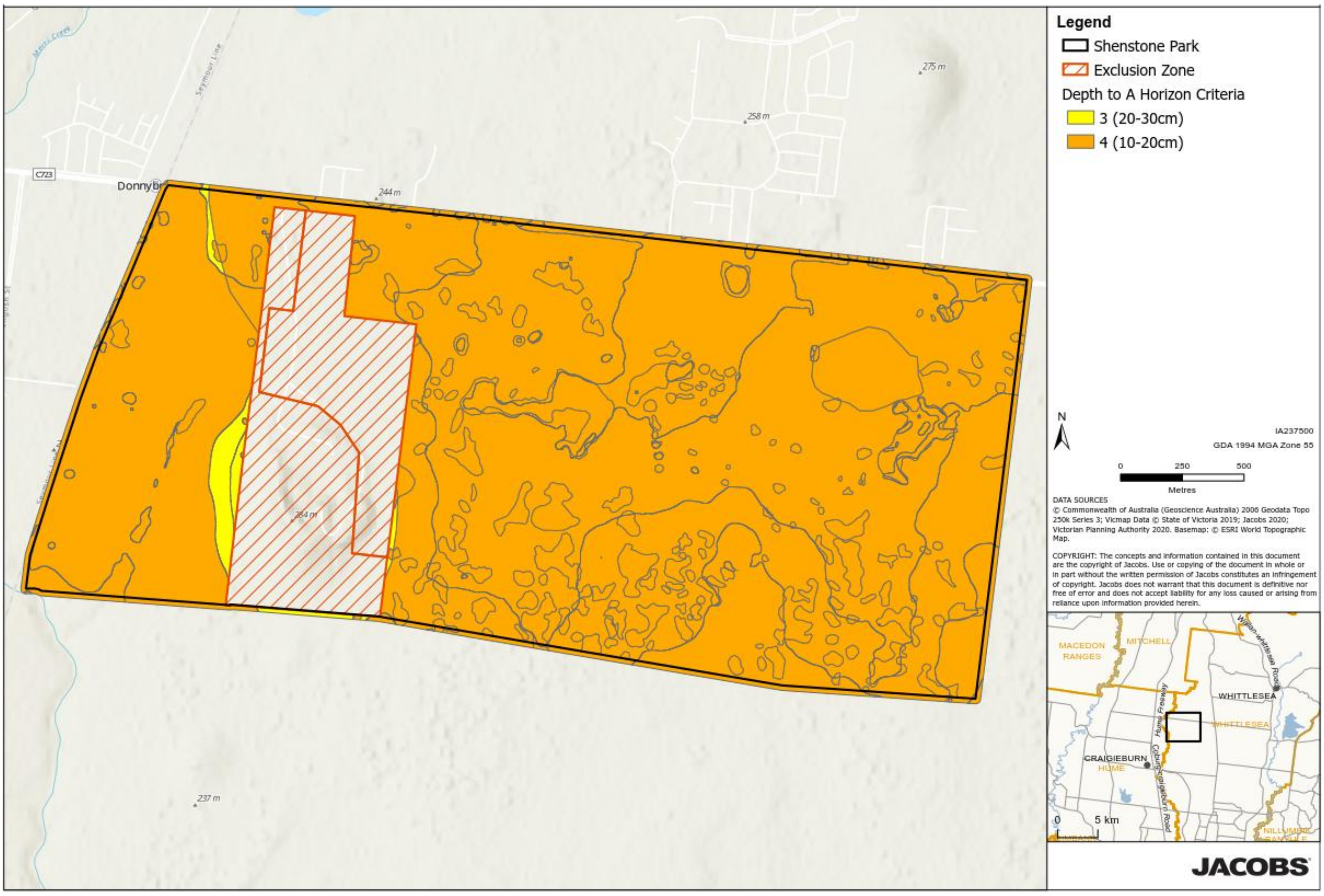

Figure 4.4: A horizon depth.

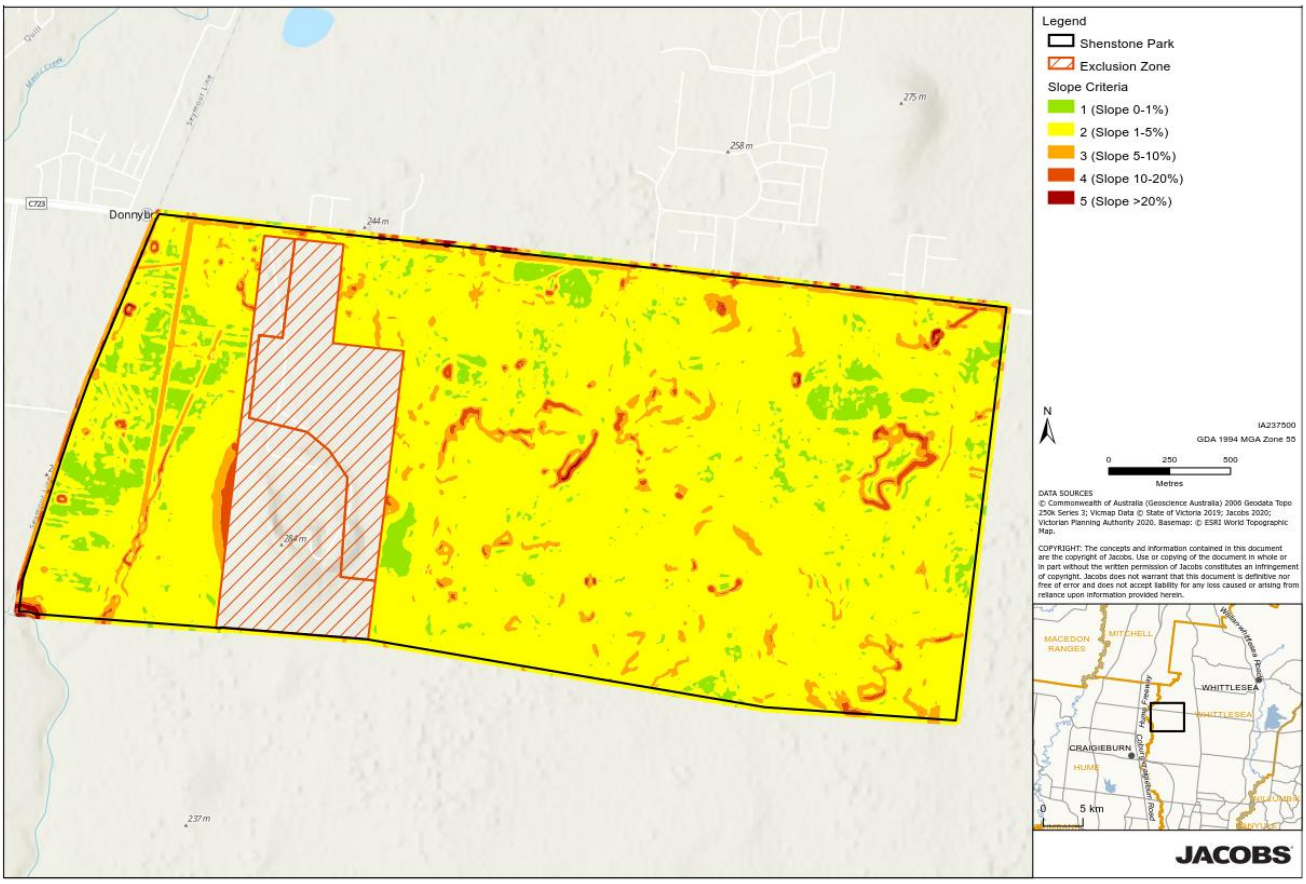

Figure 4.5: Slope.

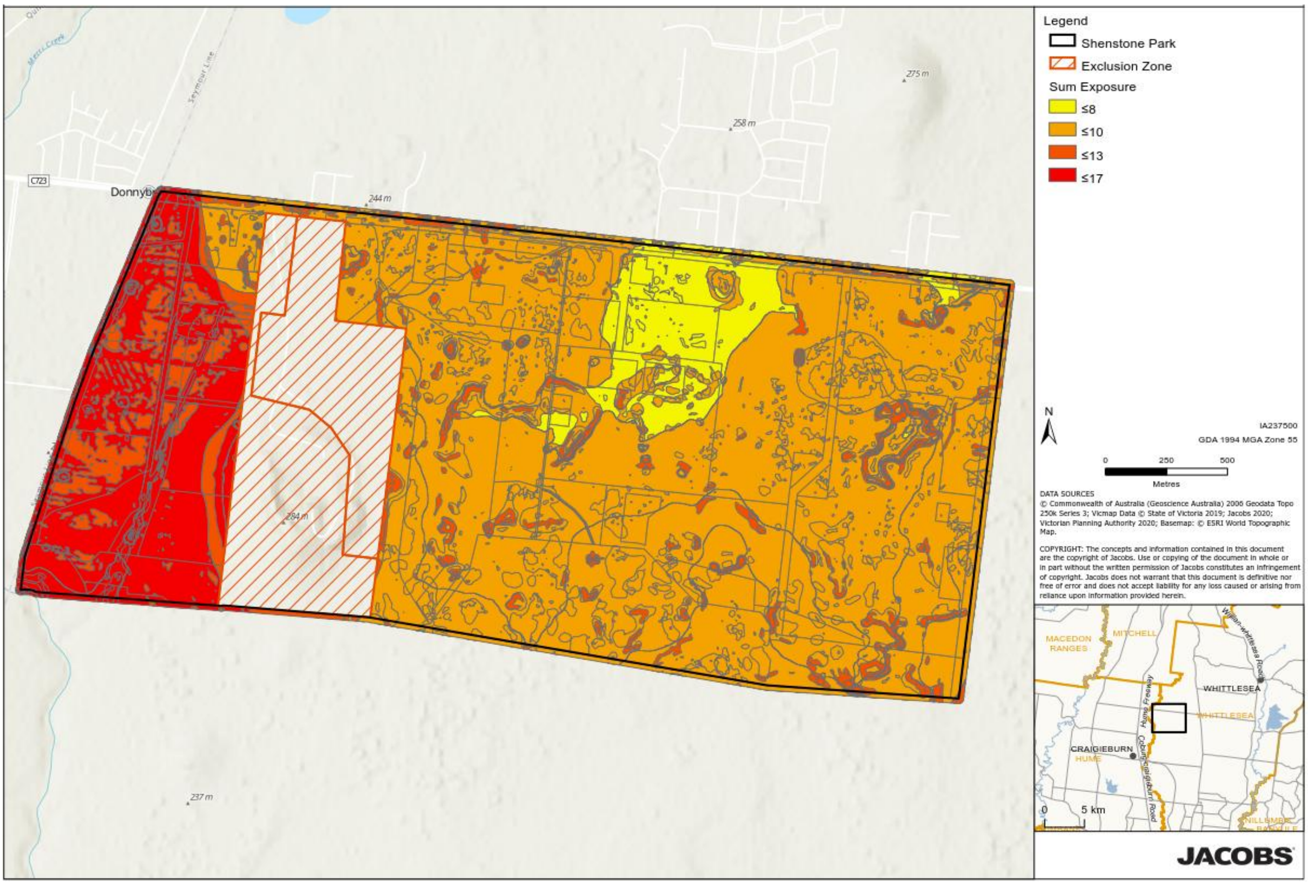

Figure 4.6: Sum of Exposure Criteria.

4.2 Sensitivity of land and urban development to sodic soils

The Future Urban Structure (FUS) dataset has been used as the basis for defining the sensitivity of land and urban development to sodic soils. Waterways are identified as areas that are particularly sensitive to disturbance of sodic soils. The waterway extent across the Precinct is mapped as Drainage in the FUS. This includes proposed corridors set aside for linear waterways as well as Retarding Basins/Water Quality Treatment (WQT) Wetlands. These areas score 5, whereas all other areas outside of the waterway extent score 1 (Figure 4.7).

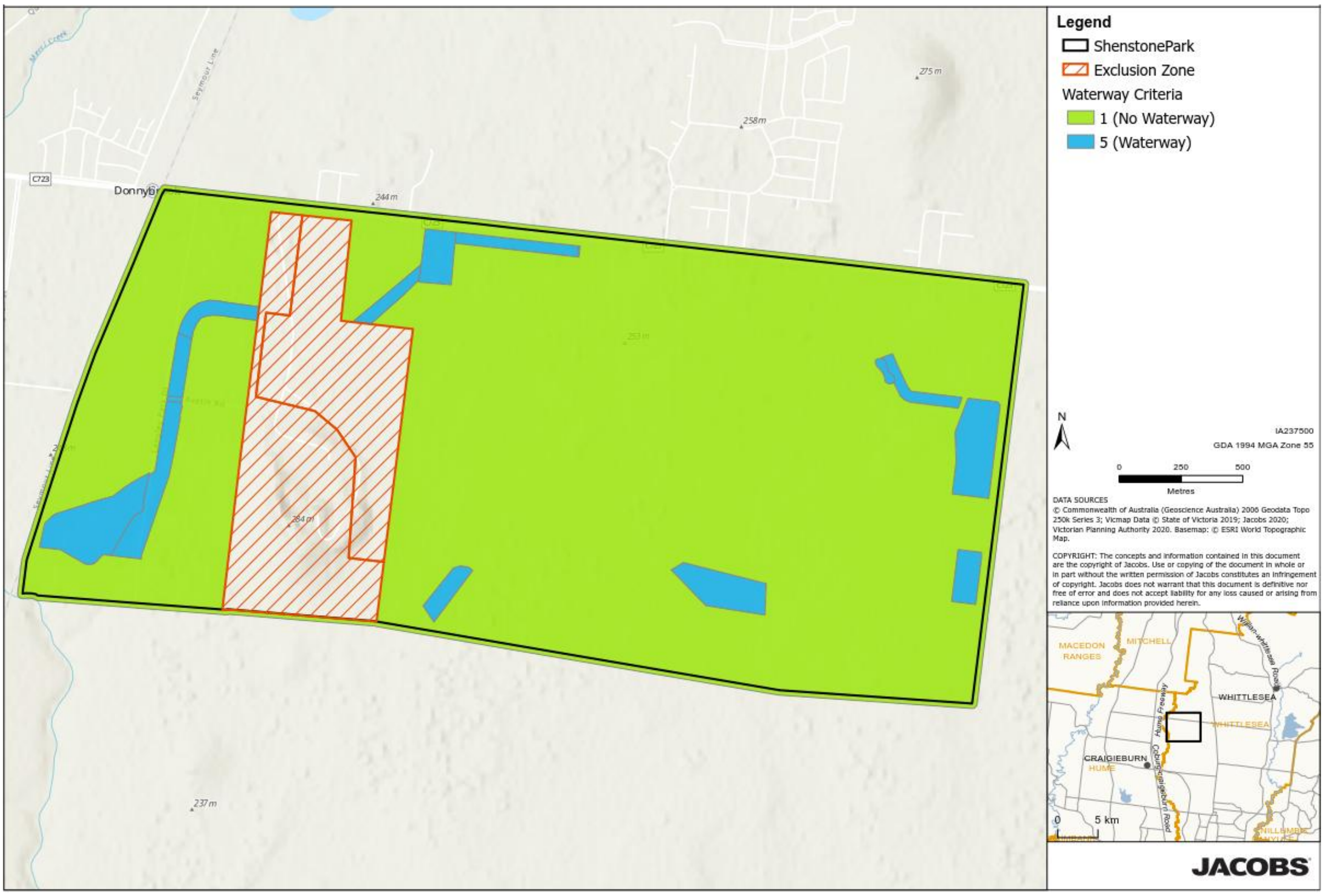

Figure 4.7: Waterway extent as mapped as Drainage in the Future Urban Structure (FUS) Dataset. This includes proposed corridors set aside for linear waterways as well as Retarding Basins/Water Quality Treatment (WQT) Wetlands.

Figure 4.8 and Figure 4.9 present the spatial distribution of sensitivity scores as applied to the FUS dataset for construction activity and water balance change. Construction activities in different land use types are ranked on a scale from minimal disturbance to high levels of disturbance. Areas that are set aside for conservation values / local park have low levels of development and are scored as minimal disturbance (1), with the level of disturbance increasing with the intensity of development. The majority of the land use sub types are given a score of 4, with Waterways (Retarding Basin/WQT Wetland and Waterway Corridors) experiencing the highest level of disturbance (5). Similarly, in scoring water balance change, open space areas, with the exception of areas with a Drainage LU_TYPE are expected to experience low levels of water balance change (1). Increasing development of land use, will result in development of impervious areas that generate runoff and therefore result in high levels of water balance change (5).

Figure 4.10 and Figure 4.11 present the combined sensitivity scores for the construction and future development scenarios. These show a similar pattern in that Waterways (Retarding Basin/WQT Wetland and Waterway Corridors) are identified as areas of highest sensitivity. Transport corridors are also identified as areas with high sensitivity in the future urban structure, due to the high water balance change and generation of runoff associated with impervious surfaces in these corridors.

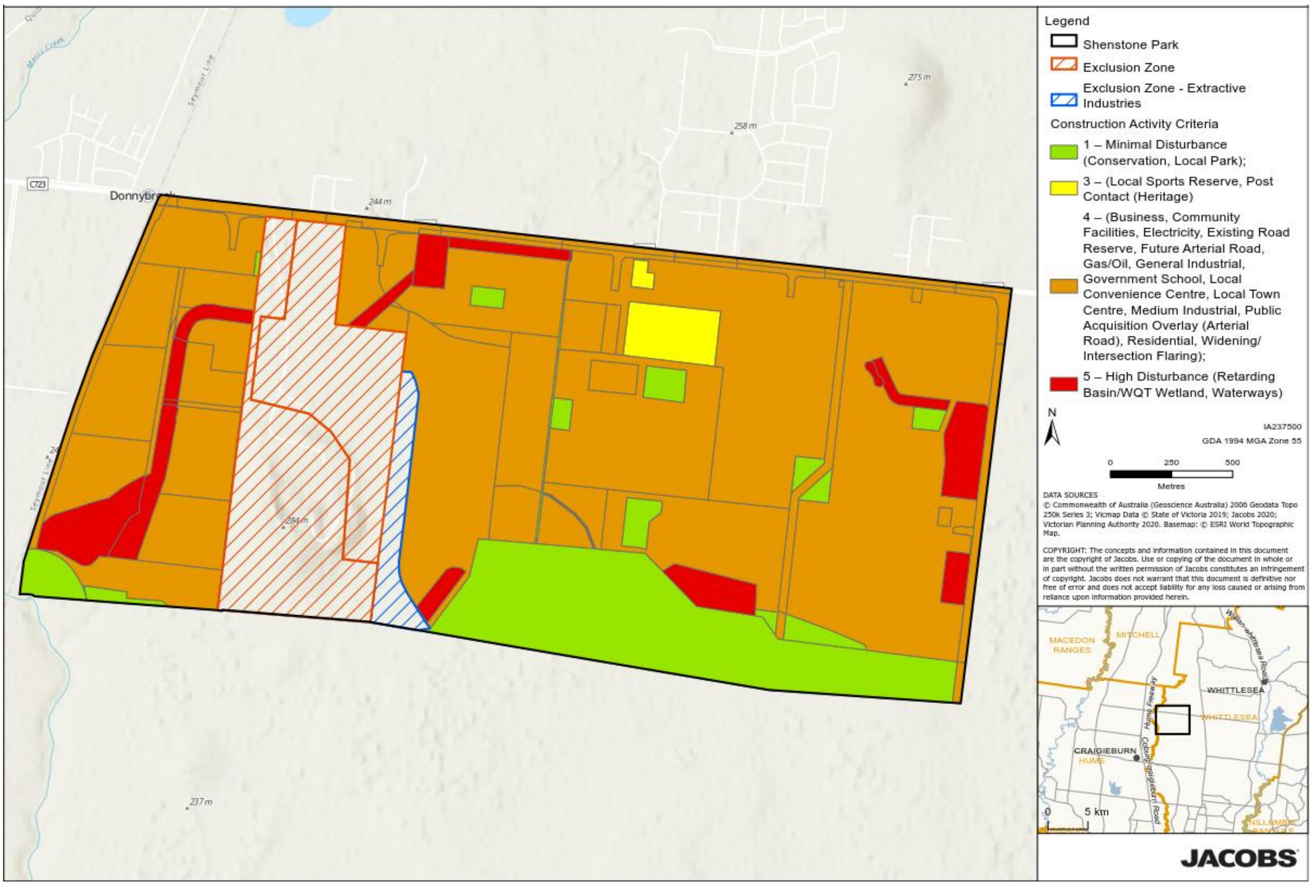

Figure 4.8: Construction activity.

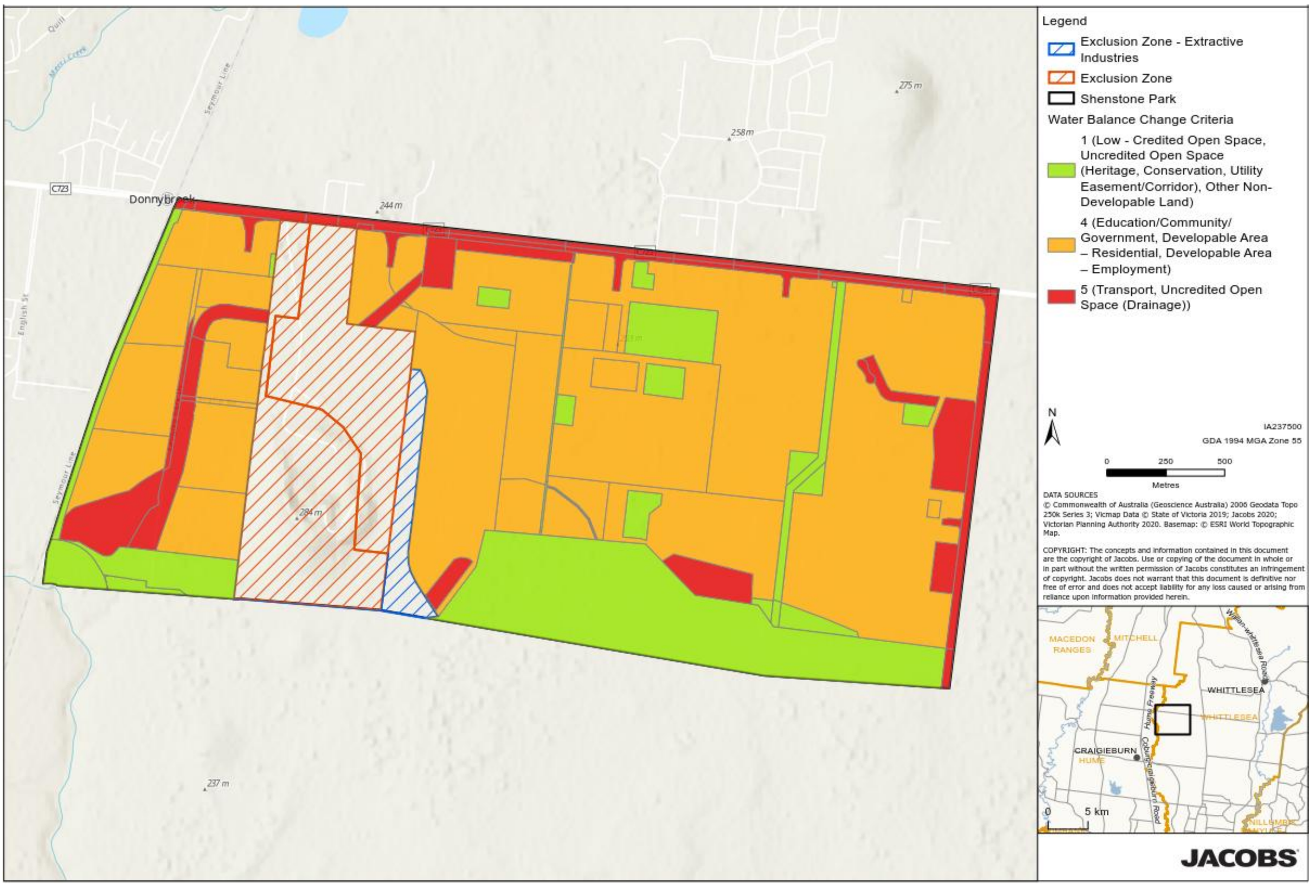

Figure 4.9: Water balance change.

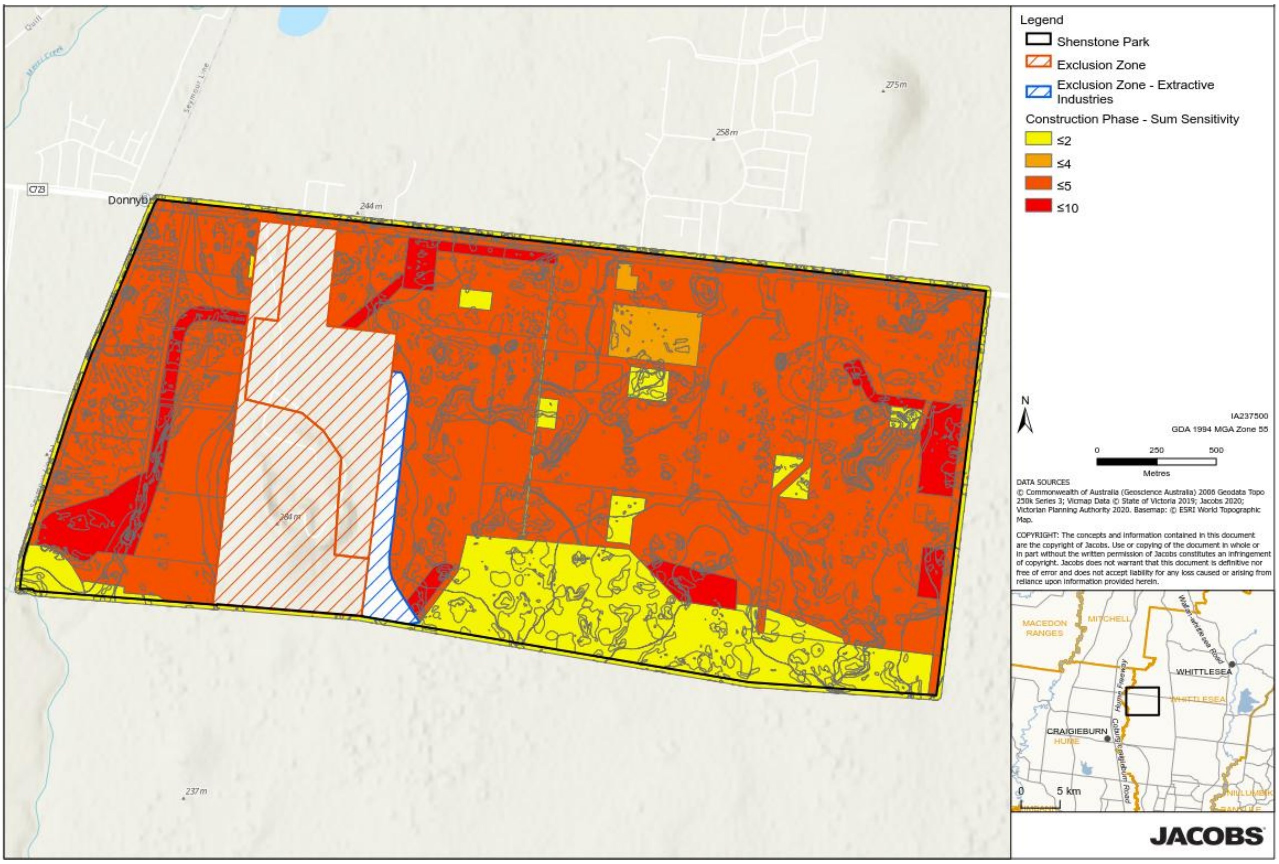

Figure 4.10: Sum of Sensitivity Criteria for Construction.

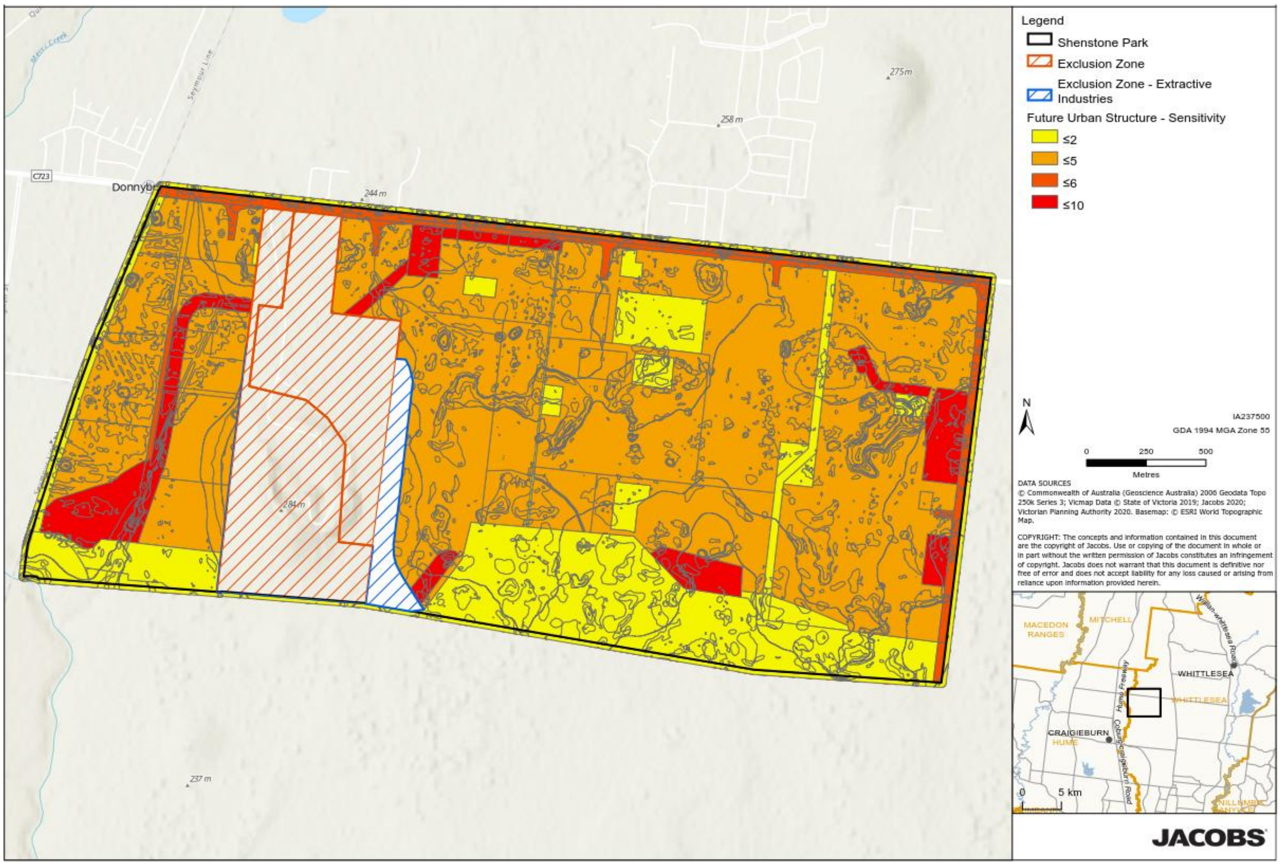

Figure 4.11: Sum of Sensitivity Criteria for Future Urban Structure.

4.3 Vulnerability assessment

The outcomes of the vulnerability assessment for the construction phase and future developed land use scenarios are presented in Figure 4.12 and Figure 4.13.

During construction, areas identified with a high vulnerability to sodic soil erosion are the waterways (Retarding Basin/WQT Wetland and Waterway Corridors). The area to the west of the Quarry that has soils with high to extreme sodicity values is also identified as a high vulnerability to sodic soil erosion risks (Figure 4.12). Activities that expose these soils to rainfall and associated runoff will present significant construction challenges and need to be managed carefully.

For future developed land use, waterways, the land area to the west of the Quarry that has soils with high to extreme sodicity values and steeper slopes are areas identified with a high vulnerability to sodic soil erosion (Figure 4.13). Water balance changes resulting from future developed land use and associated impervious areas will generate high volumes of runoff, which will drain into the surrounding waterways, including Merri Creek tributary. Merri Creek tributary is already in a degraded condition, further increases in flows would be expected to accelerate erosion of bed and bank materials.

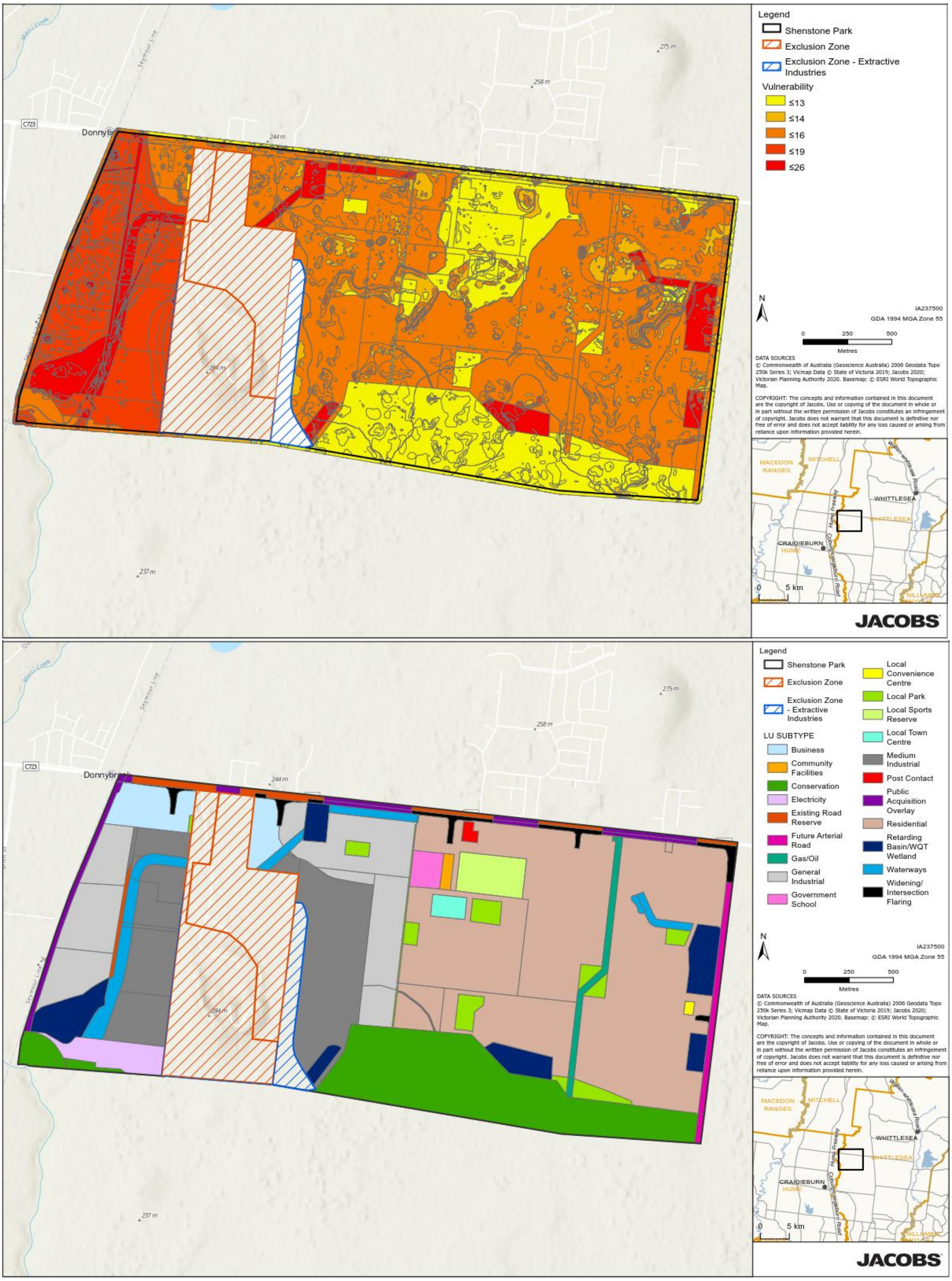

Figure 4.12: Vulnerability Construction Phase (upper). Yellow represents bottom 25% of data (low vulnerability) and red/brown top 25% of data (high vulnerability). Map of Future Land Use Sub Types (below).

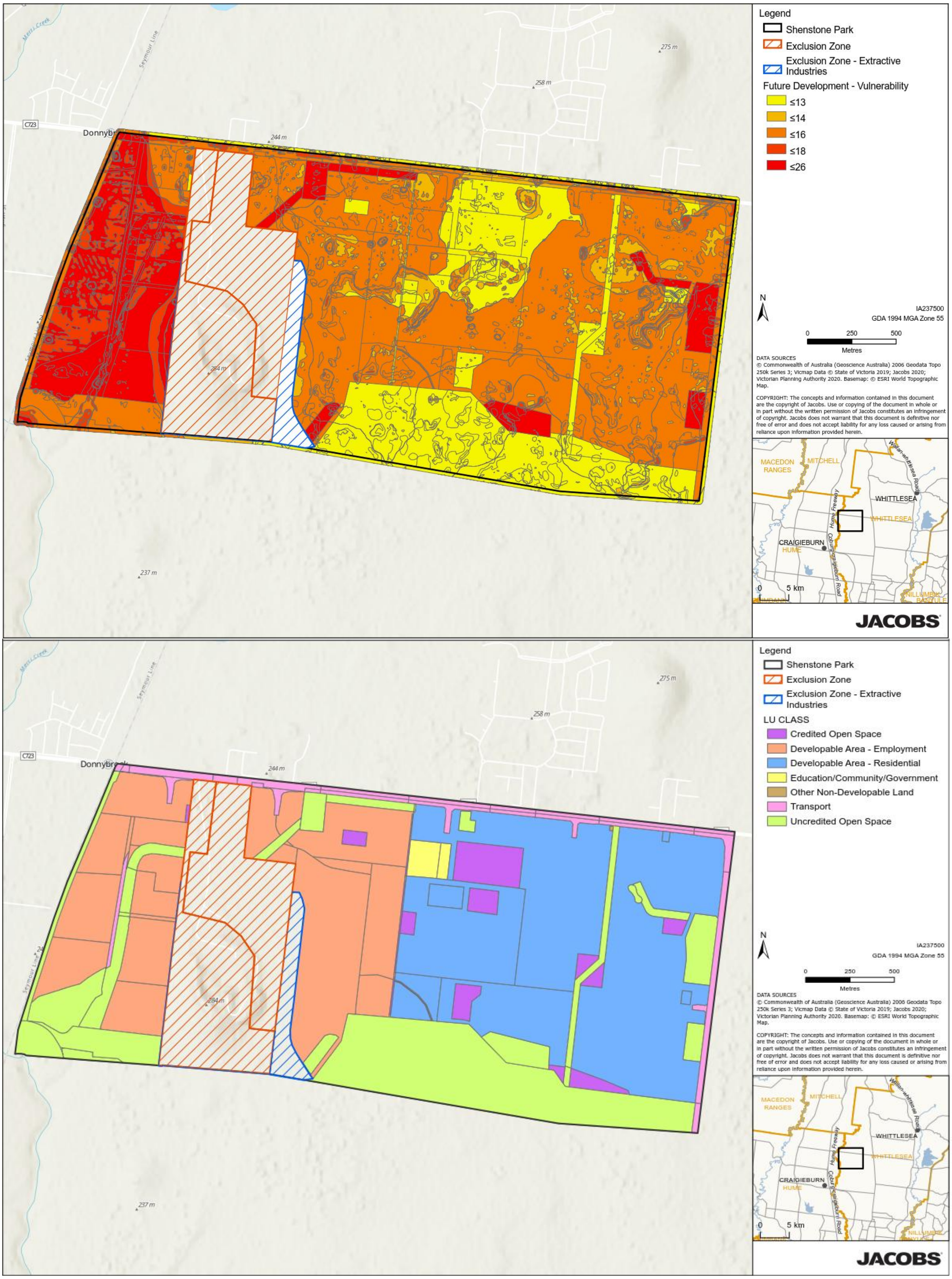

Figure 4.13: Vulnerability Future Developed Land Use (upper). Yellow represents bottom 25% of data (low vulnerability) and red/brown top 25% of data (high vulnerability). Map of Future Land Use Classes (below).

5. Discussion and recommendations

5.1 Erosion risks

Erosion risks are directly influenced by sodic soil exposure and changes in landscape hydrology. Examples of activities that may potentially expose sodic and dispersive soils include disturbance to vegetation and groundcover, removal of topsoil, subsoil excavations (cut and fill), supply of services by trenches and construction of roads and culverts. Changes to hydrology, such as the concentration of flow in culverts, runoff from impervious areas and ponding of rainfall can lead to concentrated, elevated velocity water flow and may also increase erosion risk.

Clay-loam and clay-dominant soil textures were recorded across all of the surveyed areas. Soils with these characteristics evince slow or poor infiltration and permeability. Consequently, when rainfall intensity exceeds the soils' capacity to infiltrate water, or when profiles are at field capacity, rainfall is rejected and becomes subject to accessions by overland flow. Overland flows will entrain sand, silt and clay particles when they are loose and disturbed, when velocity or shear stress of flows exceed thresholds for particle entrainment or where dispersive conditions lead to a deterioration in soil structure, breaking down aggregates and soil particles leaving them liable to erosion. Clay dispersion from fresh rainfall contact with sodic clay may induce sheet or rill erosion on exposed surfaces. This is the primary threat to the quality of stormwater, where turbidity will be high if soils on disturbed areas remain untreated. Turbid water will pond in localised depressions, or enter drainage lines and result in increased turbidity in connecting waterways off-site.

Erosion may also occur in areas of localised groundwater discharge, following recharge of rainfall upslope, seepage on top of clay or rock layers and a soak or discharge point appearing where clay or rock is close to the surface and/or there is break in slope. This increased erosion risk is typically associated with the break of slope below steeper slopes and was observed across several sample areas. Erosion issues are also expected to arise along drainage depressions and waterways and may be compounded by historical changes to the physical form of the waterway, such as the removal of vegetation from the landscape and the formation of artificial drains. Initiation of scour in drainage depressions arising from increased runoff, exposure of subsoils and the dispersive nature of these soils require specific management. Future urban development, with clearing and removal of topsoils, trenching and changes to drainage patterns increases the erosion risk. Sand and silt particles are heavy by comparison with suspended clay particles. All will migrate downslope with the flow of water, however sand and silt are likely to fall out of suspension in low-energy detention points, or where erosion control measures are installed. There are high prospects for the capture of sand and silt particles with erosion control measures proposed but not suspended clay particles.

The following areas are identified as areas of high erosion risk:

§ Drainage depressions/seasonal wetlands – These areas can be broadly classified as headwater streams – small flow lines (swales/wetlands), creeks and streams that are closely linked to adjacent slopes. They may only flow or have ponds of water periodically following rainfall events, however they do play an important role in retaining and temporarily storing water in the landscape (Jacobs 2016). This ability slows down the rate of flow over the land and assists in regulating flows and reducing downstream flood peaks. The infiltration of surface water in headwater streams into the local groundwater system also plays an important role contributing to groundwater levels and maintaining base flows in downstream waterways. In fact many headwater streams have their source of water as groundwater. If small headwater streams are destroyed because of urbanisation there is likely to be an increase in the number of high flows to downstream reaches. These high flow events can cause bed and bank erosion that significantly degrades community and environmental values (Bond & Cottingham 2008).

  Headwater streams make up a significant proportion of the stream network and collect the majority of the runoff and dissolved nutrients from a catchment. Nutrient cycling and retention in headwater streams can significantly reduce nutrient exports to downstream reaches, estuaries and bays. This is because headwater streams provide the ideal mix of shallow depths, high surface-to-volume ratios, water-sediment exchange and biotic communities required for nutrient cycling (Peterson et al. 2001). If the nutrient processing capacity of headwater streams is diminished (for example through changed flows or the clearing of riparian vegetation), or lost altogether (e.g. through drainage and urbanisation), then more nutrients are delivered to downstream reaches (Jacobs 2016). With urban development, many headwater streams are converted into stormwater drains and these modified drainage courses become a key driver in the degradation of downstream reaches (SKM 2013).

§ Merri Creek tributary – This waterway along large parts of its length has the form of an agricultural drain and is in a degraded state. Further increases in runoff could increase erosion.

§ Steeper slopes – The hillslopes in the precinct area vary in gradient. Cutting into steeper slopes will likely lead to the exposure of dispersive subsoils. Runoff from steep slopes will result in higher velocity flow with a greater risk of scour and erosion. Sediments eroded from these areas will be deposited on lower slopes or be carried into connecting waterways, adversely affecting water quality.

5.2 Planning measures

Erosion risks associated with sodic and dispersive soils can be managed by appropriate planning. This report concurs with the planning requirements and guidelines documented in the Shenstone Park Precinct Structure Plan that related to Integrated Water Management. These are reproduced in Table 5.1.

Table 5.1: Integrated Water Management Requirements and Guidelines (Victorian Planning Authority 2019).

Requirements	
R74	Stormwater runoff from the development must meet or exceed the performance objectives of the Best Practice Environmental Management Guidelines for Urban Stormwater Management (1999) prior to discharge to receiving waterways as outlined on Plan 12, unless otherwise approved by Melbourne Water and the responsible authority.
R75	Final design of constructed waterways (including widths), waterway corridors, stormwater quality treatment, retarding basins, wetlands, associated paths, boardwalks, bridges, and planting, must be to the satisfaction of Melbourne Water and the responsible authority.
R76	Development staging must provide for the delivery of ultimate waterway and drainage infrastructure, including stormwater quality treatment. Where this is not possible, development proposals must demonstrate how any interim solution adequately manages and treats stormwater generated from the development and how this will enable delivery of an ultimate drainage solution, to the satisfaction of Melbourne Water and the responsible authority.
R77	Subdivision applications must demonstrate how: § Waterways and integrated water management design enables land to be used for multiple recreation and environmental purposes; § Overland flow paths and piping within road reserves will be connected and integrated across property / parcel boundaries; and § Melbourne Water and the responsible authority's freeboard requirements for overland flow paths will be adequately contained within road reserves.
R78	Stormwater conveyance and treatment must be designed in accordance with the relevant Development Services Scheme to the satisfaction of Melbourne Water.
Guidelines	
G51	The design and layout of roads, road reserves and public open space should optimise water use efficiency and long-term viability of vegetation and public uses through the use of Water Sensitive Urban Design initiatives.
G52	Where practical, development should include integrated water management initiatives to reduce reliance on potable water and increase the utilisation of storm and waste water, contributing to a sustainable and green urban environment.
G53	Development should have regard to relevant policies and strategies being implemented by the responsible authority, Melbourne Water and Yarra Valley Water, including any approved Integrated Water Management Plan or local planning policy.
G54	Where practical, integrated water management systems should be designed to: § Maximise habitat values for local flora and fauna species; § Enable future harvesting and/or treatment and re-use of stormwater; and § Protect and manage for Matters of National Environment Significance (MNES) values, particularly within conservation areas, in relation to water quality and suitable hydrological regimes (both surface and groundwater).
G55	Where practical, and where primary waterway, conservation or recreation functions are not adversely affected, land required for integrated water management initiatives (such as stormwater harvesting, aquifer storage and recharge, sewer mining) should be incorporated within the precinct open space system as depicted on Plan 07 (Figure 5.1).

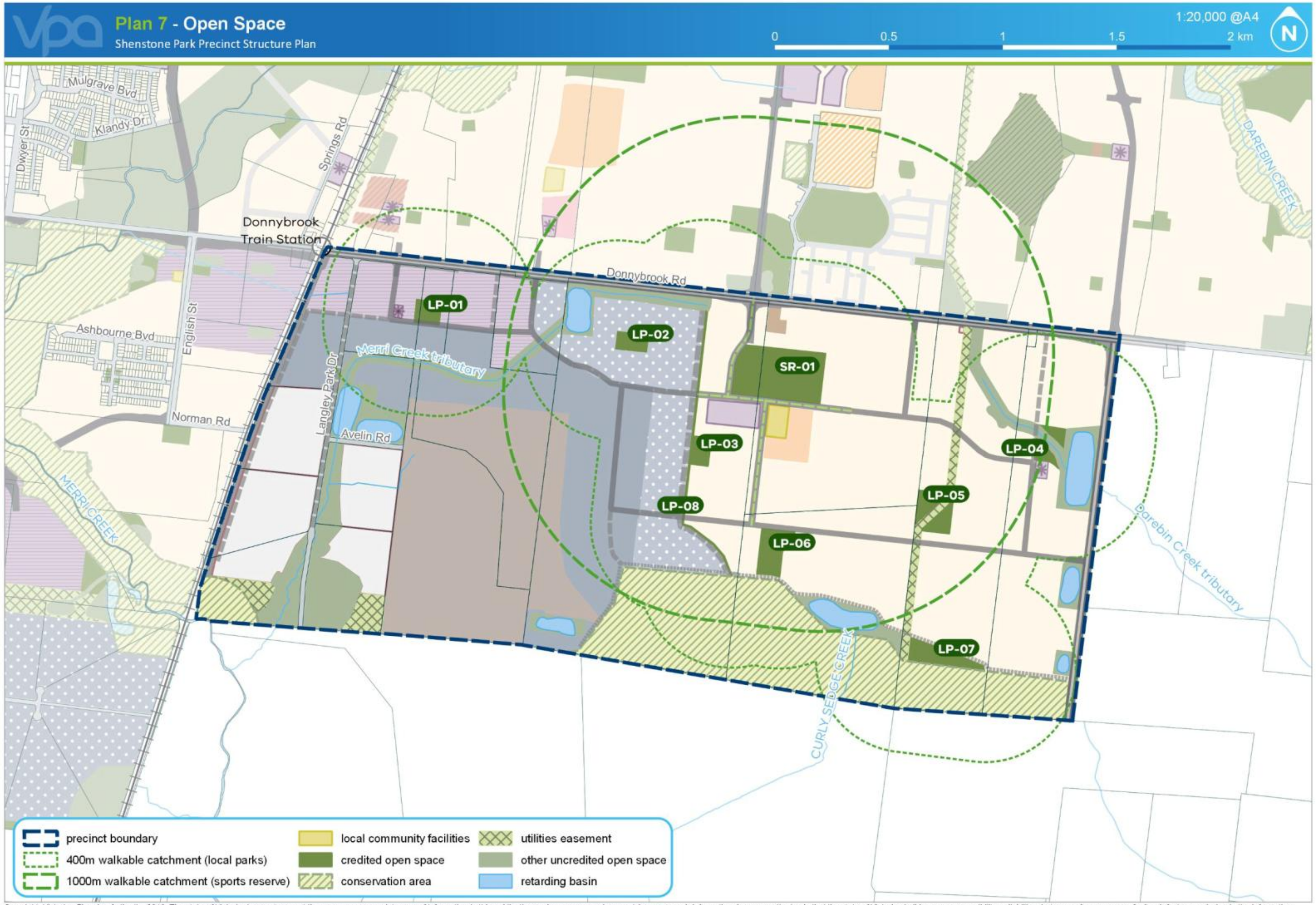

Figure 5.1: Shenstone Park Precinct Structure Plan – Open Space (Victorian Planning Authority 2019).

The Shenstone Park Precinct Area is located in one of the Stormwater Priority Areas identified in the 2018 Healthy Waterways Strategy (Melbourne Water 2018b, 2018c). One of the specific target objectives that have been set for this area is to constrain directly connected imperviousness (DCI)[2] levels to <2% and this will require undertaking significant harvesting and infiltration of stormwater. The current Lockerbie East Development Service Scheme (DSS) appears to include limited provision for stormwater harvesting or for protection of existing drainage depressions/wetlands and waterways in the Precinct (Figure 5.2). It is noted that there are several retardation basin/wetlands distributed throughout the precinct, however, it is not clear how they will function in the landscape or how effective they will be in treating stormwater. Stormwater control measures can only protect waterways downstream of where they are located.

It is acknowledged that Melbourne Water are in the process of completing a range of investigations that are exploring alternative options for the location of wetland/regarding basins which may result in a different layout to that outlined in the August 2018 Lockerbie East DSS (Figure 5.2). This includes a retarding basin/wetland in the southwest corner of the Shenstone Park Precinct Area to manage increased flows expected along tributary of Merri Creek. An investigation has also been completed to assess options to minimise the hydrologic impacts of urban development on Curly Sedge Creek.

It is recommended that further work is undertaken to align the DSS with Best Practice as summarised by the following references:

§ *Urban Water: Best Practice Environmental Management Guidelines* (CSIRO 1999) states that stormwater management should be based on the principles of preservation, source and structural controls:

  - Preservation: preserve existing valuable elements of the stormwater system, such as natural channels, wetlands and stream-side vegetation;
  - Source control: limit changes to the quantity and quality of stormwater at or near the source; and
  - Structural control: use structural measures, such as treatment techniques or detention basins, to improve water quality and control streamflow discharges.

  These principles should be applied as part of an ordered framework to achieve environmental objectives as described in Figure 5.3.

§ *"Best practice planning for urban development requires that the catchment's hydrologic response is maintained as close as practicable to pre-development conditions. Appropriately conceived and designed water management infrastructure can achieve this outcome"* (Melbourne Water 2009).

§ Following on from this, it is now understood that maintaining ecologically and geomorphically important flow metrics close to their natural values requires preventing almost all the additional surface runoff generated by urbanisation from entering waterways (Duncan et al. 2016).

It is recommended that Melbourne Water undertake further work on the Lockerbie East DSS in light of the planned development in Shenstone Park PSP. This should consider the existing form of the waterways and how these may be protected or modified in future land developments. One design concept that Jacobs (2019) recommended for the Merrifield Central Waterway, a tributary of Kalkallo Creek which is also experiencing sodic soil erosion issues, is that of distributed seasonal wetlands and swales that provides some stormwater treatment and flow conveyance. Further details of this design concept are provided here:

§ Configuration - A series of seasonal wetlands positioned along and across the width of the waterway corridor, which are connected by a low-flow channel or series of low-flow channels (rocky/grassed swales).

§ Hydraulic behaviour – Seasonal wetland and channel features extend across the width of the waterway corridor. Widening of features within the corridor and reduction of overall gradient will assist in lowering boundary shear stresses. Low-flow channel(s) convey and spill water into wetland areas.

§ How surface treatments may vary – Treatment of sodic soils with chemical and physical ameliorants will be required throughout, but it is expected that treatments will vary. For example, within the body and margins

[2] The proportion of impervious area within a catchment that is directly connected to a stream via the stormwater drainage system

of a wetland, gypsum treatment, geotextile barrier, minimal topsoil and revegetation may be sufficient. More extensive rock treatment may be required in areas of high boundary shear stress (along low-flow channels and where water spills into wetland). Less rock treatment may be required within the body and margins of wetland where water ponds and boundary shear stresses are lower.

Figure 5.4 is a schematic to help illustrate the design concept and show how the wetland and swale/low-flow channel would be distributed and connect along the waterway corridor. Further detail in relation to the sizing and configuration of wetlands and low-flow channel(s) in the waterway corridor and how surface treatments (chemical amelioration, physical armouring/protecting) may vary would need to be worked through as part of the design process. It is expected that the hydraulic aspects of the design will require a number of iterations, varying the longitudinal grade and cross-sectional grades so as to distribute flow within the system of low-flow channels and seasonal wetlands, minimising bed shear stresses whilst also providing the required conveyance along the waterway corridor.

Careful design and construction of swale and wetland features, with particular attention to the formation of a protective layer on top of sodic soils will be required to provide a stable waterway corridor. In the case of Merrifield Central Waterway, this concept is considered to provide better outcomes as it more closely aligns with the characteristics and functioning of the existing waterway as a headwater stream, which is a broad depression/seasonal wetland that periodically holds water following rainfall events. Similar design concepts may also be applicable to the waterway corridors in the Shenstone Park Precinct Area.

Within the catchment areas that drain to these waterways, where ever construction is proposed it is critical that on site management includes measures that provide for protection and treatment of sodic and dispersive soils so as to limit the potential for erosion and generation of turbid water. Turbid water from construction areas also needs to be treated on site, as once clays are in suspension and turbid water runs off into waterways, it is very difficult to remove this from the water. Vegetated swales and wetlands along waterways will assist with stormwater treatment and entrapment of silt and sand fractions , but are unlikely to be effective in removing dispersed clay from suspension. Treatment of water collected in sedimentation basins within the construction site may be required to remove suspended clays from water, prior to discharge of water into waterways. Water collected in sedimentation basins may be treated with a flocculant to improve water quality, prior to entering waterways.

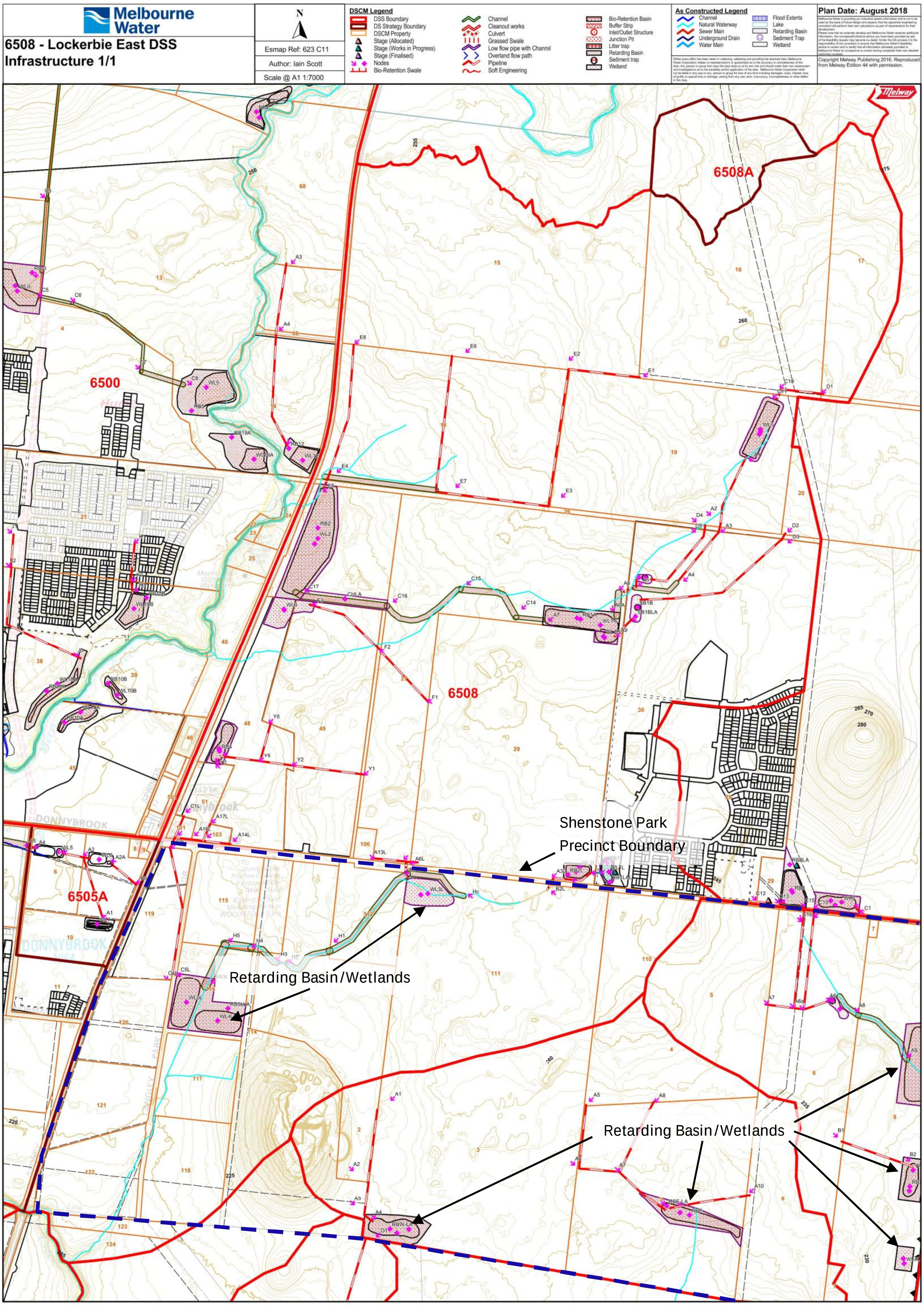

Figure 5.2: Lockerbie East DSS Infrastructure (Melbourne Water 2018a).

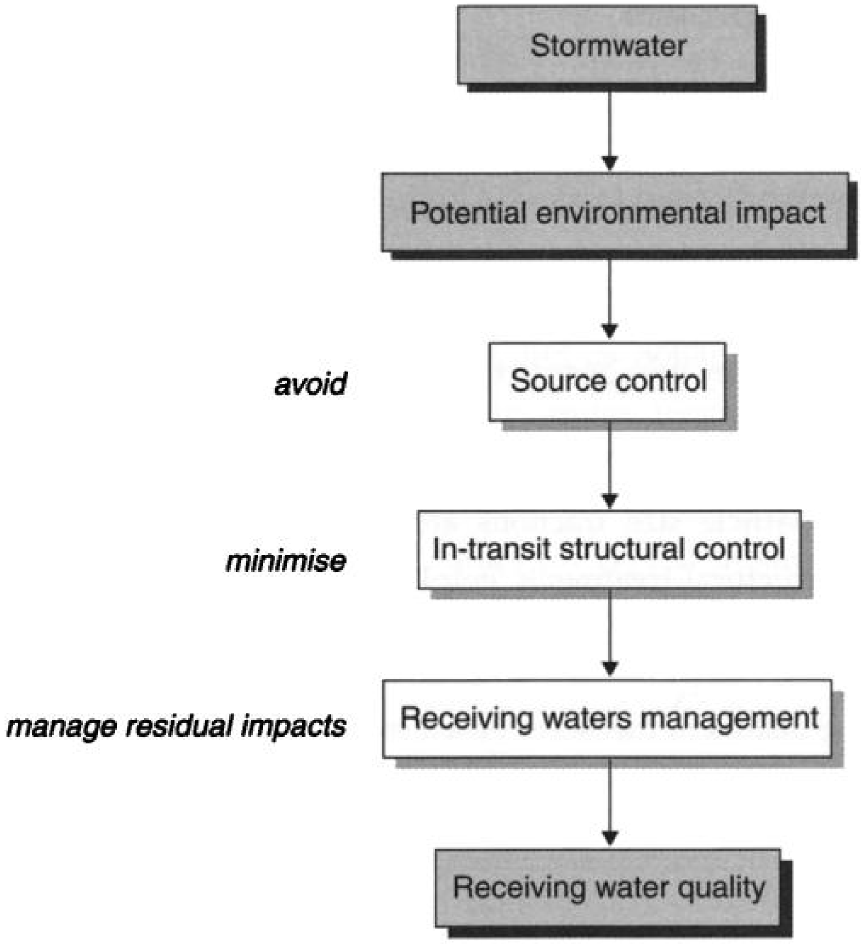

Figure 5.3: Stormwater management framework (CSIRO 1999).

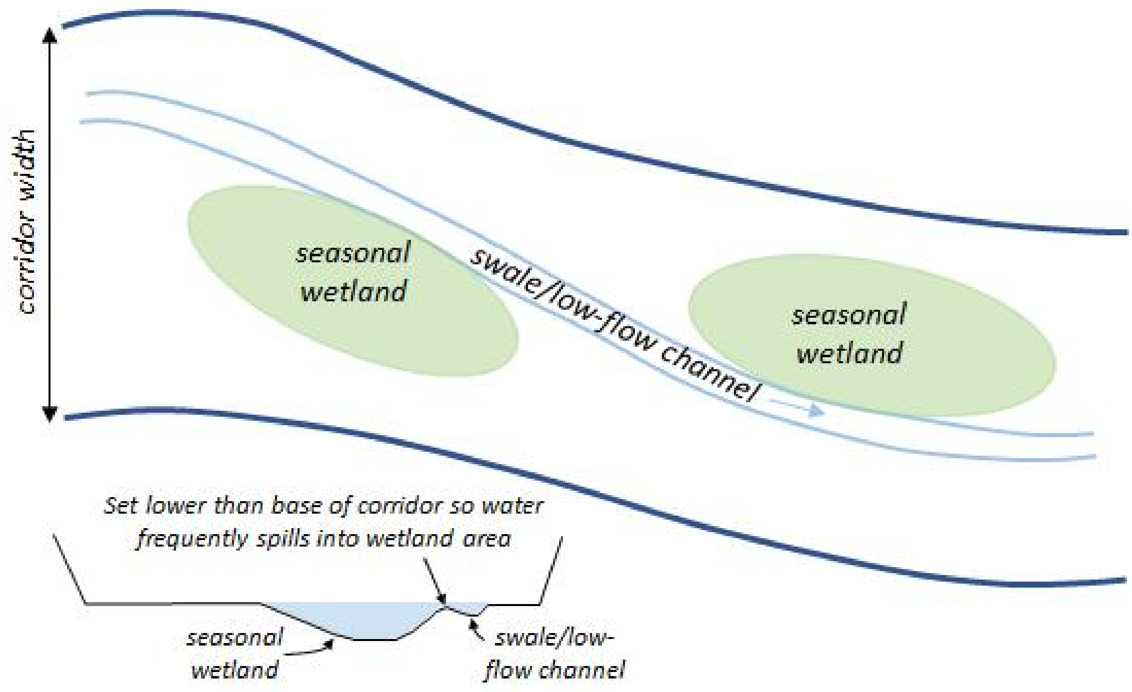

Figure 5.4: Schematic of distributed seasonal wetlands and swale/low flow channel (Jacobs 2019).

5.3 Treatment options

For areas identified with a high vulnerability to sodic soil erosion risks, treatment options include:

- Drainage depressions/seasonal wetlands – Ideally these areas should be identified and reserved as linear green spaces to maintain their important hydrological function in retaining and temporarily storing water in the landscape and regulating the flow of water and nutrients throughout a catchment (Jacobs 2016, Walsh et al. 2016). Surface ground cover measures are critical for protecting the soils against dispersion and erosion.
- Merri Creek tributary – This waterway along large parts of its length has the form of an agricultural drain and is in a degraded state. Further increases in runoff could increase erosion. Significant engineering works are likely to be required to stabilise this waterway so that is resilient to stormwater runoff from future land development (treatment of sodic and dispersive soils, construction of grade-control structures, geosynthetic clay liners / rock treatment of low-flow channels and where water spills into wetlands).
- Steeper slopes – Cutting into these slopes exposes underlying subsoils, and erosion risk is increased with slope. Road batters must be designed with consideration to the erodibility of the soils. Stable linings that are resistant to rainfall and runoff will be required.

The management of water flows over and through dispersive soils is a key tool in control of detrimental effects. Approaches may include:

- Diversion of water flows away from these materials. This is not always possible due to the extensive distribution of these dispersive soils.
- Minimising potential convergence and/or ponding of surface flows, particularly on disturbed soils;
- Compacting to reduce pore spaces and minimise water movement through the material. This will reduce the potential for soil dispersion and piping developing, however it may promote overland flow. For road formation levels and any other areas stripped or in shallow excavations (culverts, utility ducts) consideration should be given to running plant over the surface a number of times or placing engineered fill. In the case of utility trenches, backfill material should be at least the same density as the material surrounding to minimise ponding, infiltration, leaching within the trench and around the ducting/piping;
- The use of concave batter slopes without benching or contour banks has been shown to reduce the potential for convergence of water flows and to minimise flow velocities leading to gullying. However, it should be borne in mind that building extensive bank systems on dispersive soils can be problematic in themselves due to their surface erosion and tunnelling/piping potential; and
- Reducing the potential for undercut and piping failures for proposed road formations could be achieved by excavating interception trenches below and parallel with both sides of the formations. If these trenches are to carry large flows, then the use of agricultural pipes with appropriate granular backfill would be appropriate, and where low flows are anticipated then the use of use appropriate granular porous backfill to the trench may be relevant. It may also be appropriate to line the trenches with impervious materials.

Soil chemical ameliorants are recommended for short-term stabilisation of dispersive soils on construction sites. Three primary soil chemical ameliorants and their uses for stabilising dispersive soils on construction sites are:

- Gypsum ($CaSO_4$), primarily for stabilising dispersive topsoil or subsoil not intended for construction or geotechnical use. Gypsum flocculates soil and increases soil permeability, rendering materials less favourable for compaction and geotechnical use. Gypsum significantly reduces dispersion of clay and turbidity of runoff.
- Hydrated Lime ($Ca(OH)_2$). When slaked in water, hydrated lime stabilises soil cations by supply of calcium (reducing or eliminating dispersion and sodicity) and increases soil strength. Hydrated lime is the favoured soil chemical ameliorant for stabilisation of soils in civil and geotechnical works such as around pipes, structures, roads, trenches and any works requiring compaction upon reinstatement.
- Agricultural Lime ($CaCO_3$). Standard agricultural lime will provide minor soil stability however the solubility is low and immediate response is poor. Given that topsoils are acidic (pH water average 5.77) agricultural

lime could be used to support improving plant growing conditions by adjustment of soil pH, however the effect on soil stability is expected to be low or negligible in the short term by comparison with gypsum, but it cannot be discounted. Agricultural lime will be a critical ameliorant in the reuse of topsoil across recreational and environmental areas upon completion of works, given that soils are acidic and an improvement in soil health and plant growth is expected with the application of agricultural lime.

- Use of polyacrylamides or other polymers to help sodic soils absorb water rather than show spontaneous rejection (Georgees et al. 2017). This option will not necessarily reduce sodicity and dispersion.

Soil physical ameliorants are recommended for long-term structural stability of soils. Their effectiveness varies, depending on the nature of the ameliorant and how effective it is for protecting dispersive soils from direct contact with fresh water and erosion, or slowing down water flow. Examples of soil physical ameliorants and options include:

- Geotextile fabrics and mattings that provide sodic soil protection, shrouding and assist with plant establishment.
- Organic matter. Used as a protective shroud on topsoils, improving soil physical structure and biological condition. Hydro-mulching is a form of stabilisation using organic matter. Organic matter is not suitable for stabilisation of soils for civil or geotechnical works unless it is a final layer of protection used for shrouding.
- Direct seeding of sites to fast-growing species, or application of instant turfs by seed drills, spreader trucks or aerial seeding. This option will not necessarily reduce sodicity and dispersion.

DPIW (2008), Witheridge (2012), ICC (2016), SCA (1979) and others provide advice on options for reducing the risk of soil erosion during construction arising from development works on dispersive soils. Management options start with preservation and treatment of topsoil, with options variable depending on the level of disturbance (Table 5.2).

The stormwater drainage requirements of a site to be developed within the Precinct Area also needs to be appropriately incorporated into all stages of construction. This will require the development of temporary drainage control measures, separate to the sites' permanent drainage system. This will need to recognise the requirements and provide an appropriate drainage design for the diversion of up-slope "clean" water as opposed to the delivery of sediment-laden water generated within the construction site to sedimentation ponds. Appropriate hydrologic and hydraulic design is needed to size the drainage control measures for both the temporary and permanent drainage system (IECA 2008).

Table 5.2: Management options for reducing risk of erosion during construction for sodic and dispersive soils.

Management options	
Preservation and treatment of topsoil	§ Preservation of A-horizon topsoil should be used to shroud sodic and dispersive subsoil in all areas across the precinct. § Topsoils with clay-loam textures have a greater resilience to erosion by comparison with finer textured clay-dominant subsoils. Topsoils are also easier to stabilise from dispersion and erosion. § Gypsum treatment of all topsoils to minimise dispersion of any clay within topsoil or subsoil. Gypsum treatment of topsoil is a simple, fast and cost-effective solution that can be applied without use of specialised equipment.
Undisturbed sites	§ Maintenance of topsoil across undisturbed land, preferably with grasses to provide surface soil stability and root anchorage. § Maintenance of tree cover where trees exist. § Groundcover including a mix of perennial grasses and larger shrubs and overstory vegetation is critical for slowing down overland flow and providing root anchorage of soil.
Disturbed sites – large scale surface disturbance	§ Minimise the amount of time land is exposed (e.g. by staging development). § Apply gypsum to all topsoils for improved stability. § Avoiding removal or disturbance to topsoil or vegetation until absolutely necessary. § Covering dispersive subsoils with a shroud of stabilised topsoil (100-150mm), should works cease for any period of time or prolonged rainfall is forecast.

Management options	
	§ Consider using appropriately specified geotextile barriers and other engineering measures to protect disturbed areas particularly where there is minimal topsoil, or where steep slopes occur. § Re-vegetate exposed areas immediately after completion of earthworks, with specific emphasis on steep slopes. § Avoid construction techniques that result in exposure of dispersive subsoils. § Use alternatives to 'cut and fill' construction such as pier and pile foundations. § Use of interception trenches stabilised with topsoil to catch runoff in a controlled fashion and divert flow to sedimentation ponds to capture sediments. § Use of organic materials on finished surfaces to soften the impact of rainfall, filter runoff and aid the generation of seed or turf. § Use of agricultural fertilisers at sound agronomic rates to expedite the process of vegetation establishment.
Disturbed sites – Trenching, culverts and drains	§ Where possible avoid the use of trenches for the construction of services i.e. water & power. § If trenches must be used, ensure that repacked spoil is properly compacted, treat with hydrated lime (subsurface treatment) and gypsum treat topsoils to limit dispersion and erosion. § Consider alternative trenching techniques that do not expose dispersive subsoils. i.e. use of trenchless technology installations of utilities/services such as horizontal directional drilling § Ensure runoff from hardstand areas is not discharged into areas with dispersive soils. § If necessary create safe areas for discharge of runoff. § If possible do not excavate culverts and drains in dispersive soils. § Following engineered design, consider placement of non-sodic soil to create appropriate road surfaces and drains without the need for excavation. § Ensure that culverts and drains excavated into dispersive subsoils are capped with non-dispersive topsoil, gypsum stabilised and vegetated.

Where strongly duplex soils exist, management and amelioration of lighter-textured topsoil is normally favoured because it provides a source of cover and protection of dispersive subsoil. Lighter textured topsoils are also easier to ameliorate by comparison with clay loams and clays. For the Shenstone Park precinct, soils are not strongly duplex and topsoil depth averages 14cm. As organic matter plays a significant role in maintaining soil structure and providing some resilience to dispersion and erosion, careful management of any available topsoil is imperative. Staging of earthworks to minimise disturbance of soils and immediate gypsum treatment is recommended to reduce potential dispersion of clay with rainfall and runoff events.

Table 5.3 provides calculated rates of gypsum to minimise or eliminate dispersion based on the analysis of soils across the precinct. These rates are a guide only and should be further refined with the development of sodic soil management plans at an individual subdivision level.

Table 5.3: Calculated rates of gypsum to minimise or eliminate dispersion for soils in the Shenstone Park Precinct.

Gypsum treatment	Topsoil (0-10cm)	Subsoil (30-40cm)	Deeper subsoil (>40cm)
Full gypsum rate to displace exc. Na, Mg and K to optimum levels (t/Ha/100mm).	8.4 0.84% w/v.	18.8 1.88% w/v.	30.16 3.02%w/v.
Gypsum rate to displace exc. Na to below 5% (t/Ha/100mm).	0.13	2.11	7.61
Gypsum rate to displace exc. Mg to below 15%.	7.97	16.70	22.55
Gypsum rate to displace exc. K to below 5% (t/Ha/100mm).	0.11	0.00	0.00

The drainage schemes for the waterways, in particular Merri Creek tributary need to be designed with specific consideration to the erosion risks associated with sodic and dispersive soils. A high level of engineering will be required to create waterway corridors that are stable and can withstand the volume of water that will be generated from the developed areas. It is expected that all of the waterways will need to have a constructed form, with appropriate channel linings and/or armouring to provide protection for dispersive subsoils. Where possible, it is recommended that the waterway corridor includes distributed wetland and swales, to assist with attenuation and treatment of stormwater runoff.

It is recommended that further consideration is given to staging construction works, to manage erosion risks. In principle, it is better to work from top of catchment/higher areas in the landscape first and then progressively work downstream, but this may not be practical. Disturbances to high risk areas should be minimised, if not totally avoided, especially during the most erosive periods of the year (wetter months). The development sequence should allow the installation of temporary drainage and erosion control measures, and preferably permanent stormwater drainage system as soon as practicable. As waterways are a high risk, if possible, it makes sense to start on these first and construct the drainage schemes and get the waterway corridors ready for the future developed land use.

Runoff from construction sites should be managed by temporary drainage and sedimentation ponds, with the aim that it does not enter the waterway corridor until development is near completion. Harvesting of stormwater in appropriately designed sedimentation ponds within each development area, then dosing these with flocculants to drop out clay and improve water clarity before releasing downstream is recommended. Runoff dams can be designed and managed to capture runoff events, with immediate dosing and release in the days following collection.

6. Knowledge gaps and recommendations for further investigations

6.1 Knowledge gaps

The spatial assessment undertaken in this investigation broadly considers surface erosion potential, however subsurface seepage and tunnel erosion impacts are difficult to relate with the data currently available. Processes of recharge and discharge are not well understood across the precinct area and are not represented in the spatial assessment.

This assessment has focused on sodic and dispersive characteristic of soils as they relate to erosion risks. Some of the soils assessed in the field (9% of sample sites) were classified as Vertosols. These have vertic properties, experience significant shrinking and swelling, resulting from drying and wetting. This often results in the development of features such as surface cracking and gilgai formation. Evidence of vertic properties includes the presence of slickensides and/or lenticular peds in the subsoil. The amount of swelling is dependant on the type of clay present. These features are of significant importance for engineering purposes and controls against the adverse impacts of these soils character will be important if there is to be proposed development (pavement, shallow foundations, subsurface utilities etc). The controls to manage the effects of reactive/vertic soils may differ to those applicable to sodic, erosive soils.

6.2 Recommendations for further investigations

It is recommended that detailed Site Environment Management Plans (SEMPs) and Erosion and Sediment Control Plans (ESCPs) are developed for managing sodic soil related erosion risks. These plans would be developed during the planning of building and construction projects within the Precinct Area. It is expected that further sampling of soils, testing and analysis of the sodicity of soils, dispersion and erosion potential will be required at a higher resolution to inform construction techniques and management of erosion risks.

It is recommended at a minimum that sodic soil management plans are a requirement at a subdivision / zone level, and at the individual block level. The subdivision level needs to be a detailed investigation with a report that covers all aspects of the subdivision, works to occur and management techniques to manage sodic and dispersive soil and erosion. The individual block level could simply be a set of requirements set by local council that ensure good soil management practices are mandated and sodic soil exposure and disturbances are minimised, with disturbed areas treated or shrouded where possible.

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Appendix A. Soil Sampling and Analysis

A.1 Project scope

Jacobs and project partners South East Soil and Water (SESW) were engaged by Victorian Planning Authority to complete additional soil sampling and analysis so as to obtain additional data on the sodicity of soils in the Shenstone Park Precinct. The soil sampling and analysis methodology is similar to that which was undertaken for the Sodic Soils Assessment of the Beveridge North West Precinct (Jacobs 2020).

Fieldwork was carried out by Peter Sandercock of Jacobs and Christian Bannan of South East Soil and Water on the 5th and 6th of October 2020. Samples were collected using a gridded sampling program, with approximately one sampling site per 10-hectares of land available for sampling. The extent of samples collected allow for a suitable representation of the range of geological conditions for use in interpolating data and providing an indication of variability of soil characteristics across the Precinct.

The total number of sites inspected was 46 with the total number of samples collected recorded at 101. Figure 7-1 provides an overview of the sampling sites. A Garmin 76CX handheld GPS was used to locate sites in the field. The breakdown of samples comprised of:

- 0-10cm samples: 46
- 30-40cm samples: 41
- Deeper samples from 60-130cm: 14

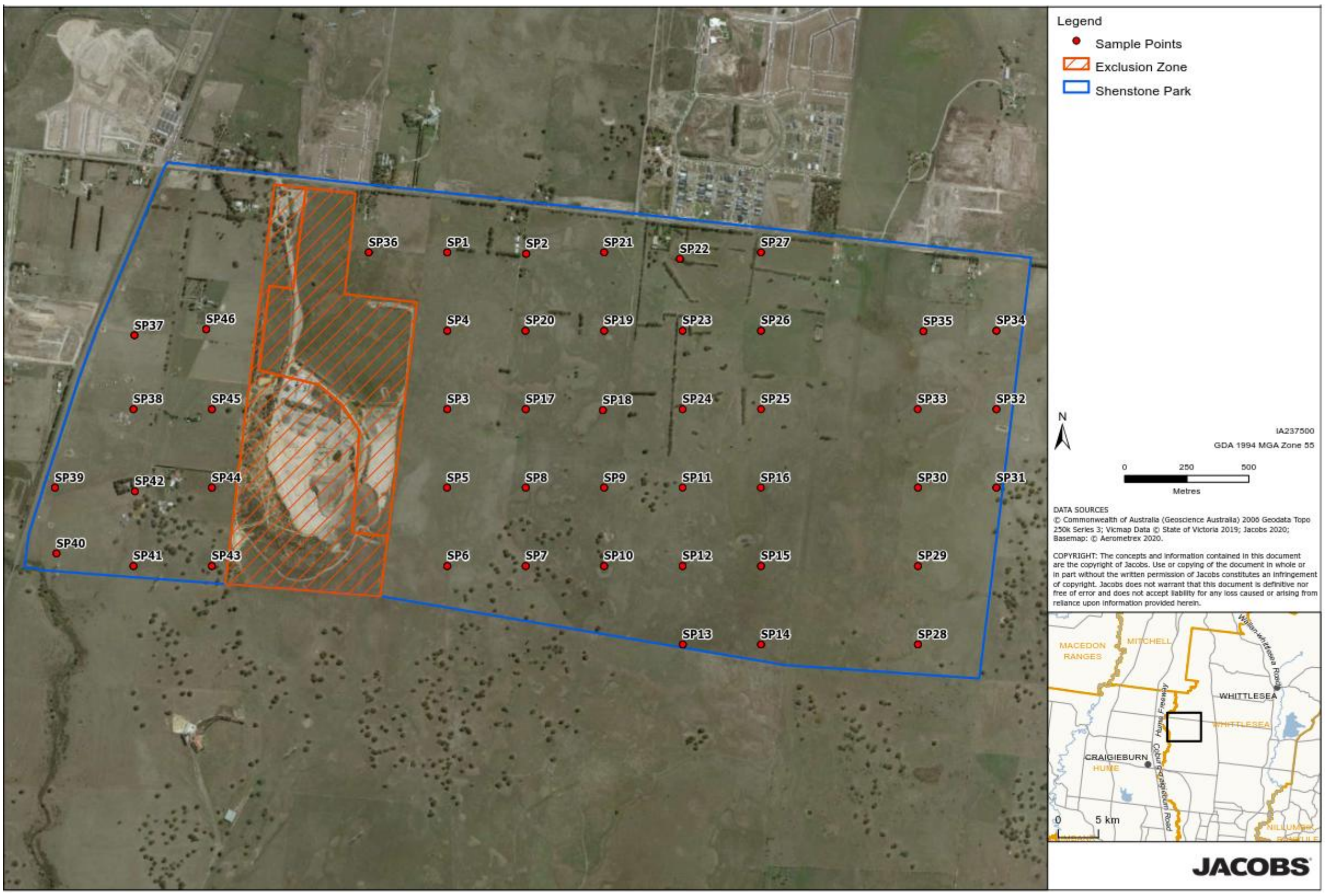

Figure 7-1: Shenstone Park Sample Points October 2020.

Access and sampling was not possible for a number of properties for a range of different reasons. As discussed with the Victorian Planning Authority it was agreed that Woody Hilly Quarry (80 Donnybrook Road) would be excluded from the assessment. A number of smaller properties were also not accessed (40 Langley Park Road, 840 Donnybrook Road and 1100 Donnybrook Road). Soil conditions for these areas have been interpolated from data collected at adjacent properties.

For accessible sites, soil cores were collected from proposed sample points at 0-10cm and 30-40cm, limited by the depth to rock. There were 14 randomly selected sites where samples were collected from depths greater than 40cm to gain general information on deeper sodicity and textural characteristics. Examples of soil cores from sites SP4, SP14, SP21, SP37 and SP46 are shown in Figure 7-2 to Figure 7-6.

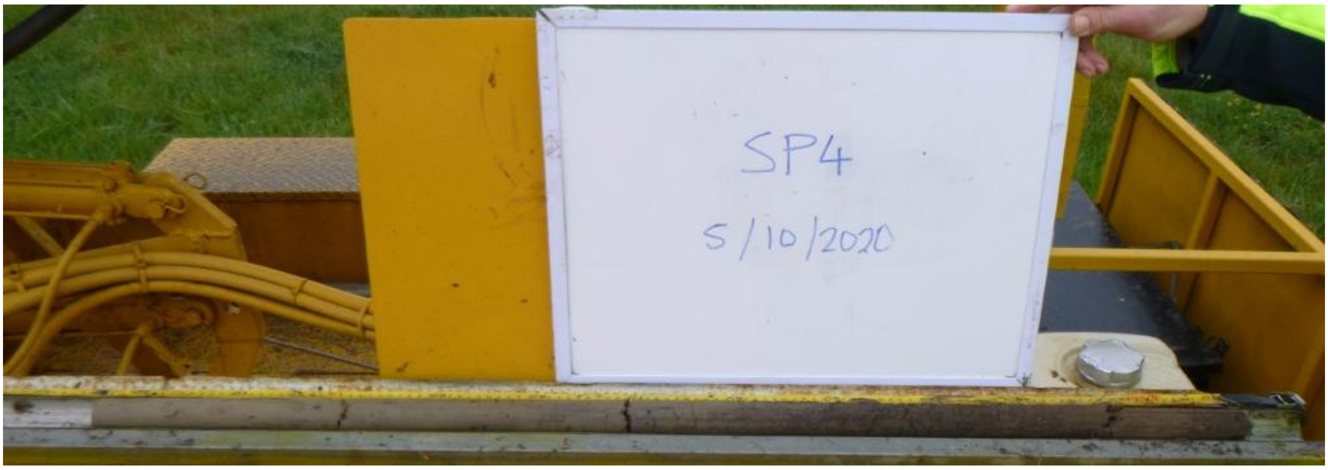

Figure 7-2: Soil core from sample site SP4.

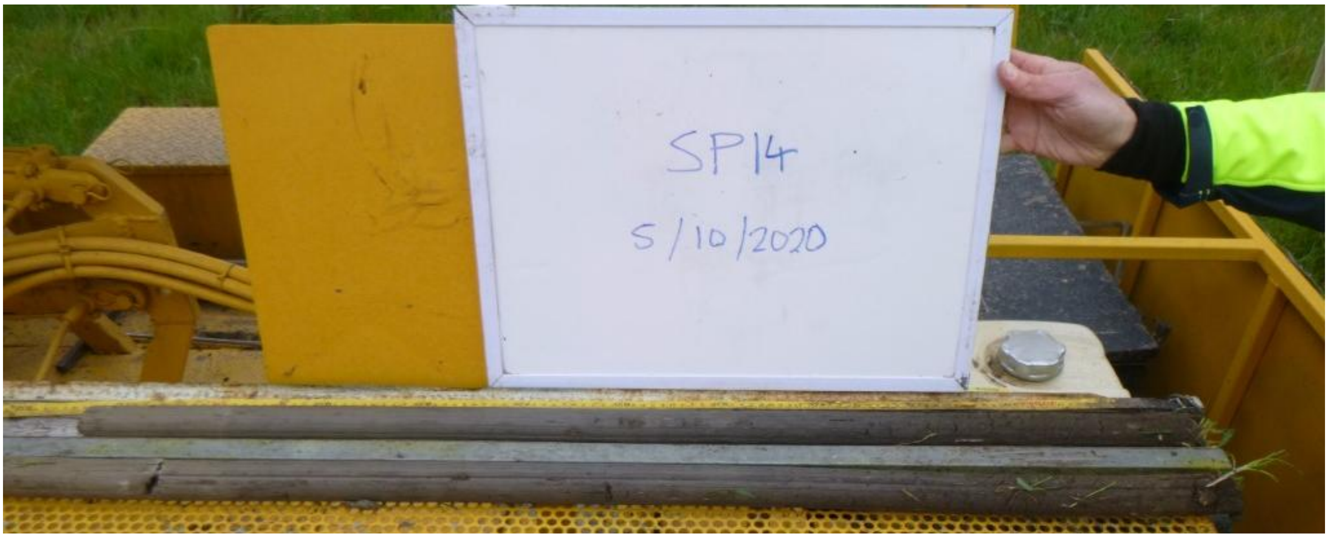

Figure 7-3: Soil cores from sample site SP14.

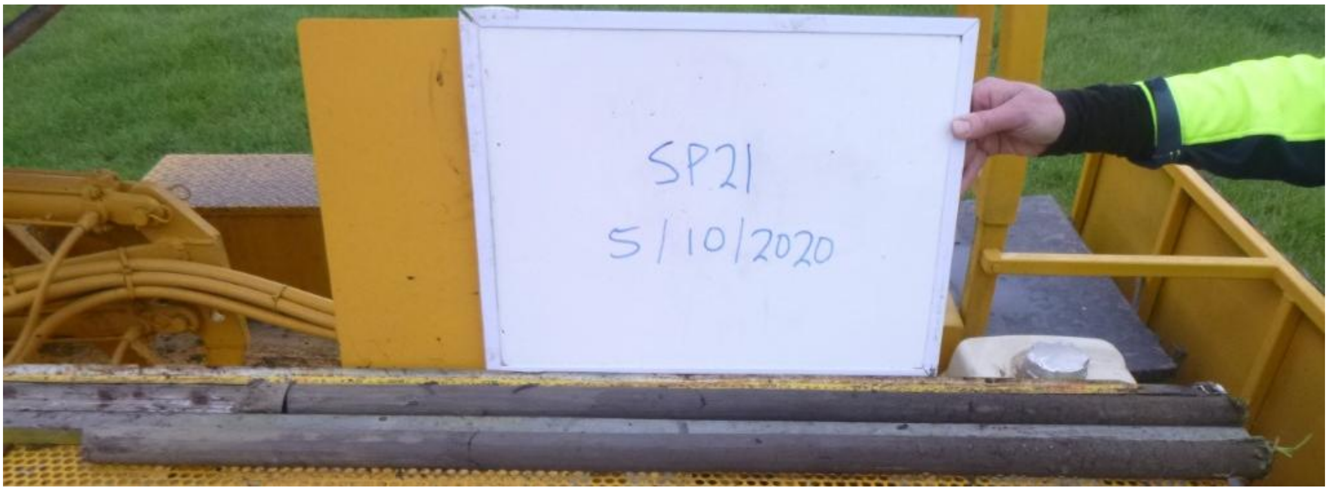

Figure 7-4: Soil cores from sample site SP21.

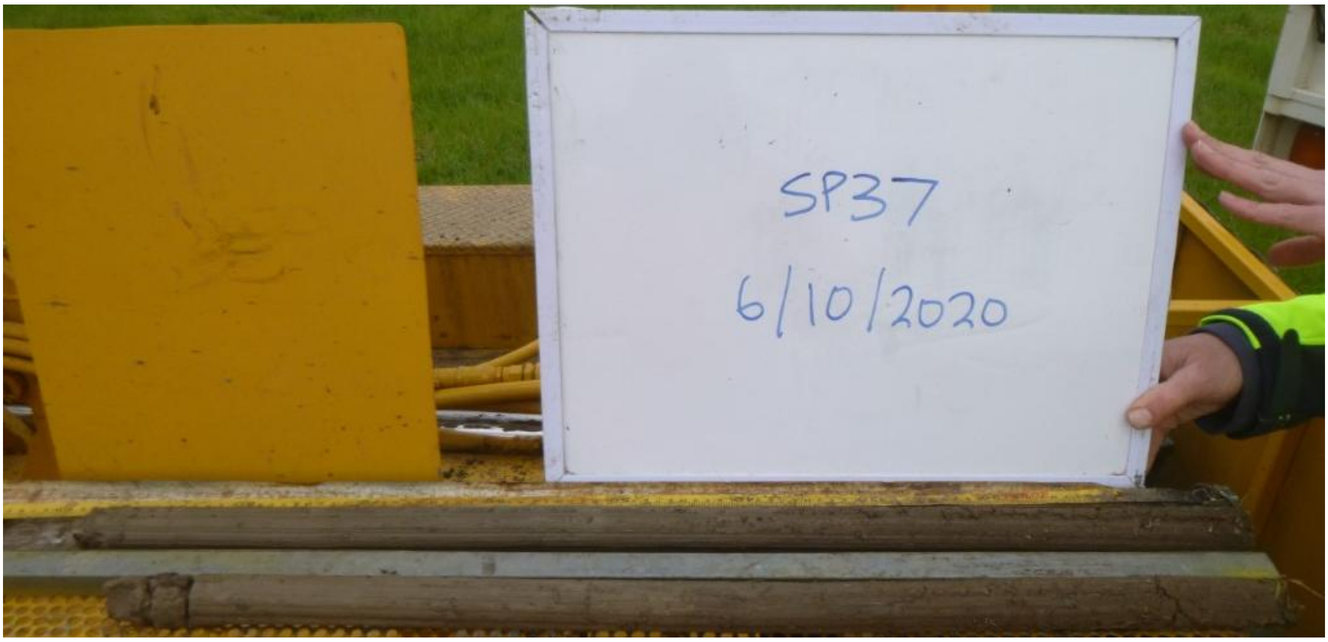

Figure 7-5: Soil cores from sample site SP37.

Figure 7-6: Soil cores from sample site SP46.

A.2 Soil sampling and laboratory analysis

At each location, a soil core was collected to sample specific soil depths and carry out a basic visual and textural classification of the profile. The following parameters were recorded:

- depth of A horizon topsoil.
- hand texture of the A and B horizons
- visual colour and Munsell colour of the A and B horizons
- other notes on soil physical characteristics defined by the assessor
- photograph of the core or sample collected.

Samples were collected from two depths, A horizon topsoil (0-10cm) and B horizon subsoil (30-40cm). Additional samples were also collected at greater depths at some locations (ranging from 40-130cm) sporadically across the sample areas.

Soil samples were dispatched to Nutrient Advantage (NA) Laboratories, Werribee, Victoria on the 7th of October with results received on 15th of October. NA are an ASPAC and NATA accredited laboratory. The following laboratory analysis were undertaken of the soil samples:

- Soil pH (water)
- Soil pH (CaCl2)
- Electrical Conductivity (1:5 soil water) (uS/cm and dS/m)
- Exchangeable Cations, including calcium, magnesium, potassium, sodium and aluminium (cmol/kg and base saturation percentage)
- Emerson Dispersion Class
- Loveday & Pyle Dispersion Score
- Calculated ESP and exchangeable cation levels.

In addition to receival of laboratory results, calculations were carried out on all samples to calculate cation levels in mg/kg. Indicative gypsum calculations were carried out by SESW and results are provided in this report as a guide to gypsum requirements for minimising soil dispersion.

A.3 Summary

Across the Shenstone Park Precinct, a total of 42 out of the 46 sampling sites or 91% of sampled points are classified as Sodosols, with a clear or abrupt textural B horizon in which the major part of the upper B2 horizon is sodic and not strongly acid (Isbell & NCST 2016). Sodosols range from shallow with less than 50cm of topsoil overlying rock, to deep with more than 1.0 metre of clay-dominant soil overlying rock. These soils are particularly sensitive to erosion when disturbed.

Vertosols are also identified at 4 of the 46 sample sites or 9% of sampled points, identified where texture in the surface soil is recorded as light clay or medium clay overlying medium clay subsoil. Vertosols are clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Vertosols also usually contain more than 35% clay throughout the profile. Soils are dominantly sodic throughout the B horizons. Erosion risks are notable in Vertosols where sodic or dispersive conditions exist throughout any exposed soil horizon.

In the evaluation of soils and understanding relationships with geology units, soils across the precinct area can be divided into three groups, listed according to local soil descriptions below:

1) Volcanic soils on basalt - deep. These soils are gradational or uniform soils, greater than 1.0 metre of depth and identified as clay-loam or clay topsoil overlying deeper medium or heavy clay. These soils are known as mostly Sodosols, with some recorded as Vertosols. These soils were widespread across the survey area, found on mid-slope, lower-slope, break-of-slope and flat areas away from rock outcrops (except for the quarry site).
2) Volcanic soils on basalt – shallow. These soils are gradational or uniform soils which record less than 50cm of clay-loam or clay topsoil, overlying rock. In some cases a thin layer of clay exists between topsoil and rock. These soils were found in all areas where basalt rock outcrops exist and on upper-slope margins fringing these sites (except for the quarry site). In most cases these soils are also classified as Sodosols, based on their duplex characteristics with sodic clay subsoil.
3) Dermosol soils, as mapped in Victorian Soil type mapping dataset (DJPR 2018). According to this dataset, the quarry site contains soils of this order. These soils were not assessed as part of this investigation.

Soils across the precinct area closely relate to geology and geomorphology. Deep volcanic clays with sodic properties were most common. Stony rises appearing sporadically across the precinct area with shallow soils are also common. Basalt surface floaters and rock are found almost entirely across the site, apart from where rock picking has occurred previously. This pattern is consistent with other catchments to the north and west of Melbourne. This is a normal occurrence across Victorian soils with many areas of urban development located on Sodosol and Vertosol soil types (Agriculture Victoria 2020, Ford et al. 1993).

Soils were weakly duplex, gradational or uniform. Extensively bleached subsurface conditions were not common.

A number of tests were undertaken to identify sodic and dispersive soils, however in developing exposure criteria (refer to 3.2.1) we have chosen to base this on Exchangeable Sodium Percent (ESP), or ‘sodicity’ value (Ford et al. 1993, Isbell & NCST 2016). Exchangeable Sodium Percent (ESP) is the most common analytical technique used to identify sodic or potentially dispersive soils (DPIW 2008).

Of the 46 inspection sites accessed, sodicity results measured in terms of exchangeable sodium percentage (ESP) are summarised as follows:

§ 1-10cm (A1 horizon topsoil): Average ESP of 4.3%. Of the 46 samples collected, 37 samples (80%) were deemed non-sodic while 10 samples (20%) were deemed sodic. Sodic sites in this range mainly included the areas of SP37-SP46, located on the far western section of the precinct area. 0-10cm samples can be summarised as non-sodic across the areas east of the quarry and sodic to the west of the quarry.

§ 30-40cm (B horizon clay-dominant subsoil): Average ESP of 10.4%. Of the 41 samples collected from this depth, 27 samples were sodic (66%). All samples from SP36-42 on the western side of the precinct area were highly sodic, these recording an average ESP of 18.7%. Samples from 30-40cm on the eastern side are of moderate to high sodicity.

- 40-120cm soil samples were also collected: A total of 14 deeper samples were collected. All samples were sodic, with an average ESP of 16.9%. Deeper subsoils are deemed highly sodic.

In addition to the results for ESP, the following observations are made from the data set:

- 0-10cm samples: Several that are non-sodic, but evince dispersion while many are sodic and do not record dispersion. The pattern is not perfectly clear and indicates that the influence of high exchangeable potassium, elevated salinity or thick surface organic matter and plant roots may be influencing the results obtained.
- 30-40cm samples: All except for 3 samples were dispersive, however 14 of these samples were non-sodic. Similar to the 0-10cm samples, the pattern is not perfectly clear with elevated salinity and high exchangeable K likely to be influencing the results.
- Samples below 40cm: All samples were sodic with an average ESP 16.9%, yet several were non-dispersive. It appears that the correlation between nil dispersion and elevated salinity is likely in this data set.

Soils across the precinct area soils are dominated by Sodosols, with some Vertosols. All sites contain topsoils of varying sodicity and dispersion, overlying sodic and generally dispersive subsoil. Areas of the precinct west of the quarry evince higher levels of sodicity by comparison to the east of the quarry. The correlation between sodic soil conditions and Emerson dispersion class is strongly correlated in samples from 30-40cm. Sodicity and dispersive soil risks across this precinct area are high and increase proportional to the depth of exposure or excavation. We maintain that the measure of sodicity with reference to ESP values has been effective for inferring dispersive soil risks to erosion across the precinct.

The results confirm that gypsum responses are likely to be observed. Table A.1 provides calculated rates of gypsum to minimise or eliminate dispersion. Calculations adopt the following criteria:

- Reduce ESP to below 5%
- Reduce exchangeable magnesium to below 15%
- Reduce exchangeable potassium to below 5%.

Table A.1: Calculated rates of gypsum to minimise or eliminate dispersion.

Gypsum treatment	Topsoil (0-10cm)	Subsoil (30-40cm)	Deeper subsoil (>40cm)
Full gypsum rate to displace exc. Na, Mg and K to optimum levels (t/Ha/100mm).	8.4 0.84% w/v.	18.8 1.88% w/v.	30.16 3.02%w/v.
Gypsum rate to displace exc. Na to below 5% (t/Ha/100mm).	0.13	2.11	7.61
Gypsum rate to displace exc. Mg to below 15%.	7.97	16.70	22.55
Gypsum rate to displace exc. K to below 5% (t/Ha/100mm).	0.11	0.00	0.00

A.4 Analytical results

Results from the laboratory were collated with additional information collected in the field. Results from the field and laboratory analysis of soils are also documented here in the following pages.

Table A.2: Shenstone Park Field Sheet.

				Topsoil 0-10cm Sample						Subsoil 30-40cm Sample				
New Site Name	Photo Collect	Easting	Northing	Lab Barcode	0-10cm Sample Collected	Depth of A Horizon (cm)	0-10cm Sample Texture	0-10cm Sample Visual Colour	0-10cm Sample Munsell Colour	Lab Barcode	30-40cm Samp Collected.	30-40cm Sample Texture	30-40cm Sample Visual Colour	30-40cm Sample Munsell Colour
SP1	Y	321800	5842635	22354934	Y	10	Clay Loam	Dark Grey Brown	10YR 3/2	22354933	Y	Medium Clay (Silty)	Yellow Grey Brown	10YR 3/1
SP2	Y	322118	5842629	22354932	Y	5	Clay Loam	Dark Grey Brown	10YR 3/2	22354931	Y	Heavy Clay (Silty)	Dark Grey	10YR 3/1
SP3	Y	321800	5842003	22354930	Y	5	Light Clay (Silty)	Dark Grey Brown	10YR 4/1	22354929	Y	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/1
SP4	Y	321800	5842319	22354927	Y	25	Sandy Clay Loam	Grey Brown	7.5YR 4/2	22354894	Y	Medium Heavy Clay (Silty)	Dark Grey Brown	10YR 4/1
SP5	Y	321799	5841687	22354925	Y	22	Light Sandy Clay Loam	Grey Brown	10YR 4/3	22354924	Y	Medium Heavy Clay (Silty)	Dark Grey Brown	10YR 5/2
SP6	Y	321800	5841371	22354923	Y	12	Clay Loam	Dark Grey	10YR 4/1	22354922	Y	Heavy Clay (Silty)	Yellow Grey Brown	10YR 5/1
SP7	Y	322116	5841371	22354921	Y	7	Sandy Clay Loam	Dark Grey	10YR 4/1	22354920	Y	Heavy Clay (Silty)	Yellow Grey	2.5Y 4/2
SP8	Y	322116	5841687	22354918	Y	27	Clay Loam	Dark Brown	7.5YR 3/3	22354917	Y	Light Medium Clay	Yellow Grey Brown	10YR 4/3
SP9	Y	322432	5841687	22354916	Y	8	Light Medium Clay (Silty)	Dark Grey	2.5Y 3/1	22354915	Y	Heavy Clay	Dark Grey	2.5Y 2.5/1
SP10	Y	322432	5841371	22354914	Y	12	Clay Loam	Dark Grey Brown	10YR 4/2	22354913	Y	Heavy Clay (Silty)	Dark Grey Brown	10YR 4/1
SP11	Y	322748	5841687	22354911	Y	15	Clay Loam (Silty)	Dark Grey Brown	10YR 4/1					
SP12	Y	322748	5841371	22354910	Y	13	Clay Loam (Silty)	Dark Grey	10YR 4/2	22354909	Y	Medium Heavy Clay	Yellow Grey	2.5Y 4/2
SP13	Y	322749	5841055	22354906	Y	9	Clay Loam (Silty)	Dark Grey Brown	10YR 4/2	22354907	Y	Heavy Clay (Silty)	Yellow Grey Brown	10YR 4/1
SP14	Y	323064	5841055	22354904	Y	12	Clay Loam (Silty)	Grey Brown	10YR 4/2	22354903	Y	Heavy Clay (Silty)	Yellow Grey Brown	10YR 5/2
SP15	Y	323064	5841371	22354897	Y	22	Sandy Clay Loam	Grey Brown	10YR 4/2	22354896	Y	Medium Heavy Clay (Silty)	Dark Grey Brown	10YR 4/2
SP16	Y	323063	5841687	22354895	Y	11	Clay Loam (Silty)	Dark Grey	10YR 3/1					
SP17	Y	322116	5842003	22354893	Y	5	Medium Clay (Silty)	Grey Brown	10YR 4/3	22354901	Y	Heavy Clay	Yellow Grey	2.5Y 4/2
SP18	Y	322427	5841999	22354900	Y	35	Clay Loam (Silty)	Grey Brown	7.5YR 3/2	22354899	Y	Clay Loam (Silty)	Dark Brown	7.5YR 3/3
SP19	Y	322432	5842319	22354898	Y	13	Clay Loam (Silty)	Grey Brown	10YR 3/2	22340789	Y	Heavy Clay	Grey Brown	10YR 4/3
SP20	Y	322115	5842319	22352487		14	Sandy Clay Loam	Grey Brown	10YR 4/3	22340788	Y	Heavy Clay	Dark Grey Brown	10YR 3/2
SP21	Y	322432	5842635	22352498	Y	17	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352497	Y	Heavy Clay	Dark Grey	10YR 3/1
SP22	Y	322737	5842609	22352500	Y	12	Clay Loam (Silty)	Grey Brown	10YR 3/2	22352499	Y	Heavy Clay	Dark Grey	2.5Y 3/1
SP23	Y	322748	5842319	22352501	Y	5	Clay Loam (Silty, Gravelly)	Grey Brown	10YR 3/2					
SP24	Y	322748	5842003	22352502	Y	5	Light Clay (Silty)	Dark Grey Brown	10YR 4/2	22352503	Y	Medium Heavy Clay	Dark Grey	10YR 3/1
SP25	Y	323064	5842003	22352504	Y	10	Loam (Silty)	Dark Grey Brown	7.5YR 3/2					
SP26	Y	323064	5842319	22352506	Y	8	Clay Loam (Silty)	Grey Brown	10YR 3/2	22352505	Y	Medium Heavy Clay (Silty)	Grey Brown	10YR 4/2
SP27	Y	323064	5842635	22352508	Y	12	Light Clay (Silty)	Dark Grey	10YR 3/1	22352509	Y	Heavy Clay (Silty)	Dark Grey	2.5Y 3/1
SP28	Y	323696	5841055	22352485	Y	8	Clay Loam (Silty)	Dark Grey Brown	10YR 3/2	22352490	Y	Medium Heavy Clay (Silty)	Dark Grey	2.5Y 3/1
SP29	Y	323696	5841371	22352488	Y	5	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352486	Y	Heavy Clay (Silty)	Dark Grey	10YR 4/1
SP30	Y	323696	5841687	22352511	Y	12	Clay Loam (Silty)	Dark Grey Brown	10YR 4/2	22352510	Y	Heavy Clay	Yellow Grey	2.5Y 5/3
SP31	Y	324012	5841687	22352513	Y	13	Loam (Silty)	Grey Brown	10YR 4/2	22352512	Y	Medium Clay (Silty)	Yellow Grey	2.5Y 4/2
SP32	Y	324012	5842003	22352517	Y	15	Clay Loam (Silty)	Dark Grey Brown	10YR 4/2	22352516	Y	Medium Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2
SP33	Y	323695	5842003	22352519	Y	10	Clay Loam (Silty)	Dark Grey Brown	10YR 3/1					
SP34	Y	324012	5842319	22352522	Y	7	Clay Loam (Silty)	Dark Grey Brown	10YR 3/2	22352521	Y	Medium Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2
SP35	Y	323718	5842317	22352524	Y	22	Clay Loam (Silty)	Dark Grey Brown	10YR 4/2	22352523	Y	Medium Heavy Clay (Silty)	Dark Grey	10YR 3/2
SP36	Y	321484	5842635	22352526	Y	20	Loam (Silty)	Grey Brown	10YR 4/2	22352525	Y	Heavy Clay (Silty)	Yellow Brown	2.5Y 4/2
SP37	Y	320540	5842301	22352527	Y	13	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352528	Y	Heavy Clay (Silty)	Dark Grey	2.5Y 4/2
SP38	Y	320536	5842003	22352518	Y	5	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352530	Y	Heavy Clay (Silty)	Dark Grey	10YR 4/1
SP39	Y	320220	5841687	22352532	Y	17	Clay Loam (Silty)	Grey Brown	10YR 4/3	22352531	Y	Medium Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2
SP40	Y	320226	5841422	22352520	Y	20	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352534	Y	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2
SP41	Y	320536	5841371	22352808	Y	21	Clay Loam (Silty)	Grey Brown	10YR 4/2	22352805	Y	Heavy Clay (Silty)	Dark Grey	10YR 4/1
SP42	Y	320542	5841672	22352785	Y	12	Clay Loam (Silty)	Grey Brown	10YR 4/3	22352809	Y	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2
SP43	Y	320852	5841371	22352807	Y	35	Loam (Silty)	Grey Brown	10YR 4/3	22352806	Y	Light Clay (Silty)	Dark Grey Brown	10YR 3/2
SP44	Y	320852	5841687	22352803	Y	24	Loam (Silty)	Grey Brown	10YR 4/3	22352804	Y	Heavy Clay (Silty)	Dark Grey Brown	10YR 4/2
SP45	Y	320852	5842003	22352802	Y	23	Loam (Silty)	Grey Brown	10YR 4/3	22352801	Y	Light Clay (Silty)	Dark Grey Brown	10YR 4/2
SP46	Y	320829	5842325	22352799	Y	17	Clay Loam (Silty)	Grey Brown	10YR 4/3	22352798	Y	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/2

Table A.1: Shenstone Park Field Sheet (Continued).

New Site Name	Lab Barcode	Deep Sample Collected	Deep Sample Depth	Deep Sample Texture	Deep Sample Visual Colour	Deep Sample Munsell Colour	Notes
SP1							Shallow soil ovelying rock. Refusal with core at 40cm. Basalt floaters at surface.
SP2							Shallow soil ovelying rock. Refusal with core at 55cm. Basalt floaters at surface.
SP3	22354928	Y	80-90	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/1	Shelf at break of slope of stony rise, see south facing photo, poor drainage and rushes apparent. Photos may be anticlockwise 90 degrees.
SP4	22354926	Y	100-120	Heavy Clay (Silty)	Yellow Grey	2.5Y 5/3	Shelf at break of slope of stony rise.
SP5							Shallow soil overlying rock at 40cm. Duplex soil with a very slight bleached A2 horizon from 10-25cm. Site flattens to the west towards the quarry.
SP6							Shallow soil over rock at 35cm. Basalt floaters.
SP7	22354919	Y	110-130	Heavy Clay	Yellow Grey	2.5Y 6/2	Site may be headwater stream, check contours, see if continuous
SP8							Shallow soil over rock at 45cm. Site positioned on edge of rock outcrop/stony rise.
SP9							Shallow Clay Loamay, refusal at 40cm. Clay is very dark grey to gley, signs of high OM and poor drainage.
SP10	22354912	Y	90-100	Heavy Clay (Silty)	Yellow Grey	2.5Y 5/2	Between rock outcrop and drainage line. Basalt floaters, deep clay.
SP11							Shallow topsoil over rock. A2 horizon above rock is bleached.
SP12	22354908	Y	110-120	Heavy Clay	Yellow Grey	2.5Y 6/3	Between stony rise and low area. Calcium carbonate at 1m.
SP13	22354905	Y	70-80	Heavy Clay	Yellow Grey	2.5Y 5/2	Site on slope between stony rise and flat land, basalt floaters.
SP14	22354902	Y	100-110	Heavy Clay	Yellow Grey	2.5Y 5/2	Deep clay with basalt floaters, close to rock outcrop on east side.
SP15		N	120	Heavy Clay	Yellow Grey	2.5Y 5/3	Uniform long slope between east boundary and dam. Some basalt floaters. Clay greater than 1.2m depth.
SP16							Basalt rock at 12cm, basalt floaters/basalt rise.
SP17		N	110	Heavy Clay	Yellow Grey	2.5Y 5/3	Cored to 1.2m
SP18							Shallow clay loam over basalt rock at 35cm.
SP19							Core refusal at 35cm on rock, basalt floaters, site located 10m from farm dam.
SP20							Core refusal at 45cm.
SP21	22352389	Y	110-120	Heavy Clay	Yellow Grey	2.5Y 5/3	Core to 1.3m. Calcium carbonate at 1.0m.
SP22							Core retrieved to 75cm, core pushed into 1m. Heavy clay may be at depth. Some basalt floaters.
SP23							Site located on basalt rise, gravelly and stony topsoil.
SP24							Core refusal at 45cm on rock or stone, basalt floaters.
SP25							Very stony and rocky.
SP26	22352507	Y	60-70	Heavy Clay (Silty)	Yellow Grey	2.5Y 4/2	Core refusal at 80cm on stone.
SP27							Site located on midslope close to rock outcrop on west side.
SP28	22352491	Y	70-80	Heavy Clay (Silty)	Yellow Grey	2.5Y 4/2	Undulating with rock outcrops and then flatter steps between outcrops and lowland.
SP29							Basalt floaters, gently undulating slope.
SP30							Gently undulating to flat area. Surface is rough and gilgaed. Rushes on surface a sign of poor drainage.
SP31	22352515	Y	60-70	Heavy Clay	Yellow Brown	2.5Y 6/3	Poorly drained area with small ponds, rushes. Bleaching in A2 horizon from 5-12cm.
SP32		N	70-80	Heavy Clay (Silty)	Yellow Brown	2.5Y 5/3	
SP33							Site on basalt rise.
SP34		N	60-70	Heavy Clay	Yellow Brown	2.5Y 5/2	Core refusal at 80cm from rock.
SP35		N	70-80	Heavy Clay (Silty)	Dark Grey	2.5Y 4/1	Deep clay, core to 1m retrieval to 80cm, bleached A2 horizon from 15-22cm. Flat to low lying area collecting drainage, poorly drained.
SP36							Low lying,poorly drained, lot of rushes and weeds. Bleached A2 horizon from 10-20cm.
SP37	22352529	Y	80-90	Heavy Clay (Silty)	Yellow Grey	2.5Y 5/2	Core hit stone at 90cm, paddocks are rough from cracking clay soils. Bleaching in A2 horizon.
SP38							Flat and poorly drained area.
SP39	22352533	Y	70-80	Heavy Clay (Silty)	Yellow Brown	2.5Y 5/3	Flat and poorly drained area. Very rough from crab holes.
SP40		N	60-70	Heavy Clay (Silty)	Yellow Brown	2.5Y 5/3	Bleached A2 horizon from 10-20cm. Site is sloping towards Merri Creek.
SP41							Slight bleach in A2 horizon from 10-21 cm, some basalt floaters (most have been picked up).
SP42							Could not extract core below 50cm, slightly bleached A2 horizon from 5-12cm.
SP43		N	50-60	Medium Heavy Clay (silty, Gravelly)	Dark Grey	2.5Y 4/1	Minor sandstone fragments up to 30mm in diameter to 60cm, bleached A2 horizon from 20-35cm. Uniform slope, basalt floaters.
SP44		N	50-60	Heavy Clay (Silty)	Dark Grey Brown	10YR 4/2	Site on slope, still signs of poor drainage.
SP45	22352800	Y	90-100	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 5/2	Zone from 20-50cm above heavy clay is saturated.
SP46		N	70-80	Heavy Clay (Silty)	Yellow Grey Brown	2.5Y 4/3	Site on flat ground on break of slope, poorly drained.

Table A.3: Shenstone Park 0-10cm Sample Analytical Results.

Sample ID	Site	Sample Name	Sample Start Depth	Sample End Depth	Zone	GPS Easting	GPS Northing	**Texture**	pH (1:5 Water)	pH (1:5 CaCl2)
			cm	cm				**SESW Field Classification**		
22354934	SP1	SP1. 0-10	0	10	55H	321800	5842635	Clay Loam	5.5	4.7
22354932	SP2	SP2. 0-10	0	10	55H	322118	5842629	Clay Loam	5.8	5.0
22354930	SP3	SP3. 0-10	0	10	55H	321800	5842003	Light Clay (Silty)	6.1	5.3
22354927	SP4	SP4. 0-10	0	10	55H	321800	5842319	Sandy Clay Loam	5.7	4.7
22354925	SP5	SP5. 0-10	0	10	55H	321799	5841687	Light Sandy Clay Loam	5.5	4.7
22354923	SP6	SP6. 0-10	0	10	55H	321800	5841371	Clay Loam	6.1	5.1
22354921	SP7	SP7. 0-10	0	10	55H	322116	5841371	Sandy Clay Loam	6.5	5.7
22354918	SP8	SP8. 0-10	0	10	55H	322116	5841687	Clay Loam	5.7	4.7
22354916	SP9	SP9. 0-10	0	10	55H	322432	5841687	Light Medium Clay (Silty)	5.7	4.7
22354914	SP10	SP10. 0-10	0	10	55H	322432	5841371	Clay Loam	5.7	4.7
22354911	SP11	SP11. 0-10	0	10	55H	322748	5841687	Clay Loam (Silty)	5.7	4.8
22354910	SP12	SP12. 0-10	0	10	55H	322748	5841371	Clay Loam (Silty)	5.9	4.9
22354906	SP13	SP13. 0-10	0	10	55H	322749	5841055	Clay Loam (Silty)	5.9	5.0
22354904	SP14	SP14. 0-10	0	10	55H	323064	5841055	Clay Loam (Silty)	5.9	4.9
22354897	SP15	SP15. 0-10	0	10	55H	323064	5841371	Sandy Clay Loam	5.6	4.7
22354895	SP16	SP16. 0-10	0	10	55H	323063	5841687	Clay Loam (Silty)	5.8	4.9
22354893	SP17	SP17. 0-10	0	10	55H	322116	5842003	Medium Clay (Silty)	5.8	4.8
22354900	SP18	SP18. 0-10	0	10	55H	322427	5841999	Clay Loam (Silty)	6.1	5.1
22354898	SP19	SP19. 0-10	0	10	55H	322432	5842319	Clay Loam (Silty)	5.8	4.8
22352487	SP20	SP20. 0-10	0	10	55H	322115	5842319	Sandy Clay Loam	5.5	4.5
22352498	SP21	SP21. 0-10	0	10	55H	322432	5842635	Clay Loam (Silty)	5.8	4.9
22352500	SP22	SP22. 0-10	0	10	55H	322737	5842609	Clay Loam (Silty)	5.9	5.0
22352501	SP23	SP23. 0-10	0	10	55H	322748	5842319	Clay Loam (Silty, Gravelly)	6.6	5.9
22352502	SP24	SP24. 0-10	0	10	55H	322748	5842003	Light Clay (Silty)	5.9	5.1
22352504	SP25	SP25. 0-10	0	10	55H	323064	5842003	Loam (Silty)	5.4	4.6
22352506	SP26	SP26. 0-10	0	10	55H	323064	5842319	Clay Loam (Silty)	5.8	4.8
22352508	SP27	SP27. 0-10	0	10	55H	323064	5842635	Light Clay (Silty)	5.8	4.9
22352485	SP28	SP28. 0-10	0	10	55H	323696	5841055	Clay Loam (Silty)	5.8	5.0
22352488	SP29	SP29. 0-10	0	10	55H	323696	5841371	Clay Loam (Silty)	5.6	4.7
22352511	SP30	SP30. 0-10	0	10	55H	323696	5841687	Clay Loam (Silty)	5.6	4.7
22352513	SP31	SP31. 0-10	0	10	55H	324012	5841687	Loam (Silty)	5.5	4.6
22352517	SP32	SP32. 0-10	0	10	55H	324012	5842003	Clay Loam (Silty)	5.6	4.6
22352519	SP33	SP33. 0-10	0	10	55H	323695	5842003	Clay Loam (Silty)	5.5	4.6
22352522	SP34	SP34. 0-10	0	10	55H	324012	5842319	Clay Loam (Silty)	5.7	4.7
22352524	SP35	SP35. 0-10	0	10	55H	323718	5842317	Clay Loam (Silty)	5.6	4.7
22352526	SP36	SP36. 0-10	0	10	55H	321484	5842635	Loam (Silty)	5.7	4.7
22352527	SP37	SP37. 0-10	0	10	55H	320540	5842301	Clay Loam (Silty)	5.6	4.5
22352518	SP38	SP38. 0-10	0	10	55H	320536	5842003	Clay Loam (Silty)	5.8	4.7
22352532	SP39	SP39. 0-10	0	10	55H	320220	5841687	Clay Loam (Silty)	5.7	4.5
22352520	SP40	SP40. 0-10	0	10	55H	320226	5841422	Clay Loam (Silty)	6.2	5.2
22352808	SP41	SP41. 0-10	0	10	55H	320536	5841371	Clay Loam (Silty)	5.8	4.6
22352785	SP42	SP42. 0-10	0	10	55H	320542	5841672	Clay Loam (Silty)	5.9	4.8
22352807	SP43	SP43. 0-10	0	10	55H	320852	5841371	Loam (Silty)	5.7	4.6
22352803	SP44	SP44. 0-10	0	10	55H	320852	5841687	Loam (Silty)	5.6	4.5
22352802	SP45	SP45. 0-10	0	10	55H	320852	5842003	Loam (Silty)	5.5	4.6
22352799	SP46	SP46. 0-10	0	10	55H	320829	5842325	Clay Loam (Silty)	5.7	4.7

Table A.2: Shenstone Park 0-10cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Electrical Conductivity (1:5 water)	Exchangeable Sodium Percentage	Emerson Class	Disp. Index, Loveday/Pyle	Slaking 2Hrs
			dS/m	%			
22354934	SP1	SP1. 0-10	0.10	2.1	7	4	Water Stable
22354932	SP2	SP2. 0-10	0.15	3.5	8	5	Partial
22354930	SP3	SP3. 0-10	0.12	2.4	7	1	Water Stable
22354927	SP4	SP4. 0-10	0.08	4.9	7	1	Water Stable
22354925	SP5	SP5. 0-10	0.12	4.4	7	1	Water Stable
22354923	SP6	SP6. 0-10	0.09	2.9	8	3	Water Stable
22354921	SP7	SP7. 0-10	0.12	3.2	2	4	Partial
22354918	SP8	SP8. 0-10	0.06	1.7	3	1	Partial
22354916	SP9	SP9. 0-10	0.09	2.3	8	3	Partial
22354914	SP10	SP10. 0-10	0.09	3.6	7	1	Water Stable
22354911	SP11	SP11. 0-10	0.07	1.9	3	2	Partial
22354910	SP12	SP12. 0-10	0.10	4.7	2	6	Water Stable
22354906	SP13	SP13. 0-10	0.09	2.7	8	3	Water Stable
22354904	SP14	SP14. 0-10	0.09	3.1	7	1	Water Stable
22354897	SP15	SP15. 0-10	0.06	2.1	2	3	Partial
22354895	SP16	SP16. 0-10	0.08	1.6	3	1	Partial
22354893	SP17	SP17. 0-10	0.12	4.7	8	7	Partial
22354900	SP18	SP18. 0-10	0.08	3.8	3	2	Partial
22354898	SP19	SP19. 0-10	0.06	3.9	7	3	Water Stable
22352487	SP20	SP20. 0-10	0.08	4	7	3	Water Stable
22352498	SP21	SP21. 0-10	0.10	4.4	8	5	Partial
22352500	SP22	SP22. 0-10	0.09	1.5	8	2	Water Stable
22352501	SP23	SP23. 0-10	0.09	0.86	8	2	Water Stable
22352502	SP24	SP24. 0-10	0.11	2.3	8	2	Water Stable
22352504	SP25	SP25. 0-10	0.06	2.8	7	0	Water Stable
22352506	SP26	SP26. 0-10	0.08	3.1	2	6	Partial
22352508	SP27	SP27. 0-10	0.08	1.6	7	1	Water Stable
22352485	SP28	SP28. 0-10	0.15	3.7	7	3	Water Stable
22352488	SP29	SP29. 0-10	0.09	2.9	8	4	Partial
22352511	SP30	SP30. 0-10	0.09	5	8	7	Partial
22352513	SP31	SP31. 0-10	0.14	7.7	8	8	Water Stable
22352517	SP32	SP32. 0-10	0.09	4.3	7	4	Water Stable
22352519	SP33	SP33. 0-10	0.07	2	2	5	Partial
22352522	SP34	SP34. 0-10	0.07	2.1	7	3	Water Stable
22352524	SP35	SP35. 0-10	0.09	3	7	3	Water Stable
22352526	SP36	SP36. 0-10	0.08	4.5	8	6	Water Stable
22352527	SP37	SP37. 0-10	0.08	6.5	8	8	Partial
22352518	SP38	SP38. 0-10	0.09	6.5	8	9	Water Stable
22352532	SP39	SP39. 0-10	0.08	9.9	2	10	Partial
22352520	SP40	SP40. 0-10	0.18	12	2	11	Partial
22352808	SP41	SP41. 0-10	0.11	11	2	12	Partial
22352785	SP42	SP42. 0-10	0.13	6.2	8	6	Partial
22352807	SP43	SP43. 0-10	0.07	5	8	7	Partial
22352803	SP44	SP44. 0-10	0.08	9.9	7	6	Water Stable
22352802	SP45	SP45. 0-10	0.09	7.6	7	3	Water Stable
22352799	SP46	SP46. 0-10	0.10	6.6	2	5	Partial

Exchangeable Sodium Percentage (ESP) Interpretation

Colour	ESP Range	Interpretation
(green)	<6%.	Non-sodic.
(orange)	6.1-10%.	Moderately Sodic
(red)	10.1-15.0%	Strongly Sodic
(dark red)	>15.1%	Very Strongly Sodic

Emerson Dispersion Class Interpretation.

Colour	Emerson Class	Interpretation
(green)	4, 5, 6, 7, 8	Non-dispersive.
(orange)	3	Partial Dispersion after remoulding
(red)	2	Partial Dispersion
(dark red)	1	Complete Dispersion

Loveday & Pyle (L&P) Score Interpretation.

Colour	L&P Score	Interpretation
(green)	0, 1, 2, 3, 4	Low to moderate. Nil to slight gypsum resonse expected where dispersive.
(orange)	5, 6, 7, 8	Moderate to high. Gypsum response expected to control dispersion.
(red)	9, 10, 11, 12	High. Gypsum response expected to control dispersion. High rates required.
(dark red)	13, 14, 15, 16	Very high. Very high rates required to control dispersion.

Slaking Class Interpretation.

Colour	Slaking Class	Interpretation
(green)	Water Stable	Aggregate stable when wetted, nil or minimal breakdown in structure.
(orange)	Partial	Low aggregate stability. Partial breakdown in structure when wetted.
(red)	Considerable	Unstable. High or significant loss of structure when wetted.

Table A.2: Shenstone Park 0-10cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Calcium (Amm-acet.) mg/kg	Magnesium (Amm-acet.) mg/kg	Available Potassium mg/kg	Sodium (Amm-acet.) mg/kg	Aluminium (KCl) mg/kg	Calcium (Amm-acet.) cmol(+)/kg	Magnesium (Amm-acet.) cmol(+)/kg	Potassium (Amm-acet.) cmol(+)/kg	Sodium (Amm-acet.) cmol(+)/kg	Aluminium (KCl) cmol(+)/kg	Cation Exch. Cap. cmol(+)/kg	Calcium (Amm-acet.) %	Magnesium (Amm-acet.) %	Potassium (Amm-acet.) %	Aluminium Saturation %
22354934	SP1	SP1. 0-10	1160	678	469	64	33	5.8	5.6	1.20	0.28	0.4	13.1	44	42	8.9	2.8
22354932	SP2	SP2. 0-10	2200	1331	430	193	<9.0	11.0	11.0	1.10	0.84	<0.1	23.8	45	47	4.6	<1.0
22354930	SP3	SP3. 0-10	2200	1452	230	129	<9.0	11.0	12.0	0.59	0.56	<0.1	23.5	46	49	2.5	<1.0
22354927	SP4	SP4. 0-10	900	424	100	99	16	4.5	3.5	0.26	0.43	0.2	8.8	51	39	2.9	2.1
22354925	SP5	SP5. 0-10	960	678	62	115	32	4.8	5.6	0.16	0.50	0.4	11.4	42	49	1.4	3.1
22354923	SP6	SP6. 0-10	1320	1331	290	129	9.1	6.6	11.0	0.74	0.56	0.1	19.1	35	58	3.9	0.5
22354921	SP7	SP7. 0-10	2800	1210	260	184	<9.0	14.0	10.0	0.65	0.80	<0.1	25.1	54	40	2.6	<1.0
22354918	SP8	SP8. 0-10	1080	411	450	41	44	5.4	3.4	1.10	0.18	0.5	10.6	51	32	11.0	4.6
22354916	SP9	SP9. 0-10	2200	1331	240	124	12	11.0	11.0	0.61	0.54	0.1	23.5	47	48	2.6	0.6
22354914	SP10	SP10. 0-10	1340	774	110	115	<9.0	6.7	6.4	0.28	0.50	<0.1	13.8	49	46	2.0	<1.0
22354911	SP11	SP11. 0-10	1300	399	140	46	<9.0	6.5	3.3	0.35	0.20	<0.1	10.4	63	32	3.4	<1.0
22354910	SP12	SP12. 0-10	1160	702	310	143	<9.0	5.8	5.8	0.78	0.62	<0.1	13.0	44	45	6.0	<1.0
22354906	SP13	SP13. 0-10	1880	1210	180	127	<9.0	9.4	10.0	0.45	0.55	<0.1	20.4	46	49	2.2	<1.0
22354904	SP14	SP14. 0-10	1300	653	310	94	<9.0	6.5	5.4	0.80	0.41	<0.1	13.1	49	41	6.1	<1.0
22354897	SP15	SP15. 0-10	960	460	230	46	<9.0	4.8	3.8	0.58	0.20	<0.1	9.5	51	41	6.2	<1.0
22354895	SP16	SP16. 0-10	1760	617	320	55	<9.0	8.8	5.1	0.82	0.24	<0.1	14.9	59	34	5.5	<1.0
22354893	SP17	SP17. 0-10	1740	1452	420	253	20	8.7	12.0	1.10	1.10	0.2	23.4	37	53	4.6	0.9
22354900	SP18	SP18. 0-10	1700	520	69	117	<9.0	8.5	4.3	0.18	0.51	<0.1	13.5	63	32	1.3	<1.0
22354898	SP19	SP19. 0-10	900	581	90	90	<9.0	4.5	4.8	0.23	0.39	<0.1	9.9	45	48	2.3	<1.0
22352487	SP20	SP20. 0-10	1000	666	120	108	45	5.0	5.5	0.30	0.47	0.5	11.8	43	47	2.5	4.3
22352498	SP21	SP21. 0-10	1340	774	200	143	<9.0	6.7	6.4	0.50	0.62	<0.1	14.2	48	45	3.5	<1.0
22352500	SP22	SP22. 0-10	1640	581	400	48	<9.0	8.2	4.8	1.00	0.21	<0.1	14.3	57	34	7.1	<1.0
22352501	SP23	SP23. 0-10	1980	738	450	35	<9.0	9.9	6.1	1.10	0.15	<0.1	17.3	57	35	6.6	<1.0
22352502	SP24	SP24. 0-10	1500	1004	280	90	<9.0	7.5	8.3	0.72	0.39	<0.1	16.9	44	49	4.3	<1.0
22352504	SP25	SP25. 0-10	1100	387	59	67	97	5.5	3.2	0.15	0.29	1.1	10.2	54	31	1.5	11.0
22352506	SP26	SP26. 0-10	1380	714	140	99	16	6.9	5.9	0.36	0.43	0.2	13.8	50	43	2.6	1.3
22352508	SP27	SP27. 0-10	2800	1452	120	97	<9.0	14.0	12.0	0.32	0.42	<0.1	26.3	53	44	1.2	<1.0
22352485	SP28	SP28. 0-10	1680	1004	440	159	<9.0	8.4	8.3	1.10	0.69	<0.1	18.6	45	45	6.1	<1.0
22352488	SP29	SP29. 0-10	1520	992	160	113	19	7.6	8.2	0.40	0.49	0.2	16.9	45	49	2.4	1.3
22352511	SP30	SP30. 0-10	960	835	130	150	25	4.8	6.9	0.33	0.65	0.3	13.0	37	53	2.5	2.2
22352513	SP31	SP31. 0-10	740	557	170	170	19	3.7	4.6	0.44	0.74	0.2	9.6	38	47	4.5	2.2
22352517	SP32	SP32. 0-10	1120	774	170	131	19	5.6	6.4	0.43	0.57	0.2	13.2	42	48	3.3	1.6
22352519	SP33	SP33. 0-10	1320	787	220	67	32	6.6	6.5	0.57	0.29	0.4	14.4	46	45	4.0	2.5
22352522	SP34	SP34. 0-10	1500	1041	100	83	10	7.5	8.6	0.26	0.36	0.1	16.8	44	51	1.6	0.7
22352524	SP35	SP35. 0-10	1680	920	87	115	9.5	8.4	7.6	0.22	0.50	0.1	16.8	50	45	1.3	0.6
22352526	SP36	SP36. 0-10	880	436	110	90	12	4.4	3.6	0.28	0.39	0.1	8.8	50	41	3.2	1.5
22352527	SP37	SP37. 0-10	820	617	140	159	29	4.1	5.1	0.36	0.69	0.3	10.5	39	49	3.5	3.1
22352518	SP38	SP38. 0-10	1080	823	150	207	26	5.4	6.8	0.38	0.90	0.3	13.9	39	49	2.8	2.1
22352532	SP39	SP39. 0-10	740	496	79	216	42	3.7	4.1	0.20	0.94	0.5	9.4	39	44	2.1	5.0
22352520	SP40	SP40. 0-10	780	799	91	345	<9.0	3.9	6.6	0.23	1.50	<0.1	12.2	32	54	1.9	<1.0
22352808	SP41	SP41. 0-10	740	617	95	253	23	3.7	5.1	0.24	1.10	0.3	10.4	35	49	2.3	2.5
22352785	SP42	SP42. 0-10	960	726	510	186	15	4.8	6.0	1.30	0.81	0.2	13.1	37	46	9.9	1.3
22352807	SP43	SP43. 0-10	800	750	180	133	32	4.0	6.2	0.46	0.58	0.4	11.6	35	54	4.0	3.1
22352803	SP44	SP44. 0-10	620	303	67	156	42	3.1	2.5	0.17	0.68	0.5	6.9	45	36	2.5	6.8
22352802	SP45	SP45. 0-10	1000	436	92	177	41	5.0	3.6	0.24	0.77	0.5	10.1	50	35	2.3	4.5
22352799	SP46	SP46. 0-10	860	557	120	152	19	4.3	4.6	0.30	0.66	0.2	10.0	43	46	3.0	2.2

Table A.2: Shenstone Park 0-10cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Calcium/Magnesium Ratio	ESP% + EPP% Calculation
				SESW Calculation
22354934	SP1	SP1. 0-10	1.0	11.0
22354932	SP2	SP2. 0-10	1.0	8.1
22354930	SP3	SP3. 0-10	0.9	4.9
22354927	SP4	SP4. 0-10	1.3	7.8
22354925	SP5	SP5. 0-10	0.9	5.8
22354923	SP6	SP6. 0-10	0.6	6.8
22354921	SP7	SP7. 0-10	1.4	5.8
22354918	SP8	SP8. 0-10	1.6	12.7
22354916	SP9	SP9. 0-10	1.0	4.9
22354914	SP10	SP10. 0-10	1.0	5.6
22354911	SP11	SP11. 0-10	2.0	5.3
22354910	SP12	SP12. 0-10	1.0	10.7
22354906	SP13	SP13. 0-10	0.9	4.9
22354904	SP14	SP14. 0-10	1.2	9.2
22354897	SP15	SP15. 0-10	1.3	8.3
22354895	SP16	SP16. 0-10	1.7	7.1
22354893	SP17	SP17. 0-10	0.7	9.3
22354900	SP18	SP18. 0-10	2.0	5.1
22354898	SP19	SP19. 0-10	0.9	6.2
22352487	SP20	SP20. 0-10	0.9	6.5
22352498	SP21	SP21. 0-10	1.0	7.9
22352500	SP22	SP22. 0-10	1.7	8.6
22352501	SP23	SP23. 0-10	1.6	7.5
22352502	SP24	SP24. 0-10	0.9	6.6
22352504	SP25	SP25. 0-10	1.7	4.3
22352506	SP26	SP26. 0-10	1.2	5.7
22352508	SP27	SP27. 0-10	1.2	2.8
22352485	SP28	SP28. 0-10	1.0	9.8
22352488	SP29	SP29. 0-10	0.9	5.3
22352511	SP30	SP30. 0-10	0.7	7.5
22352513	SP31	SP31. 0-10	0.8	12.2
22352517	SP32	SP32. 0-10	0.9	7.6
22352519	SP33	SP33. 0-10	1.0	6.0
22352522	SP34	SP34. 0-10	0.9	3.7
22352524	SP35	SP35. 0-10	1.1	4.3
22352526	SP36	SP36. 0-10	1.2	7.7
22352527	SP37	SP37. 0-10	0.8	10.0
22352518	SP38	SP38. 0-10	0.8	9.3
22352532	SP39	SP39. 0-10	0.9	12.0
22352520	SP40	SP40. 0-10	0.6	13.9
22352808	SP41	SP41. 0-10	0.7	13.3
22352785	SP42	SP42. 0-10	0.8	16.1
22352807	SP43	SP43. 0-10	0.7	9.0
22352803	SP44	SP44. 0-10	1.2	12.4
22352802	SP45	SP45. 0-10	1.4	9.9
22352799	SP46	SP46. 0-10	0.9	9.6

Table A.4: Shenstone Park 30-40cm Sample Analytical Results.

Sample ID	Site	Sample Name	Sample Start Depth	Sample End Depth	Zone	GPS Easting	GPS Northing	**Texture**	pH (1:5 Water)	pH (1:5 CaCl2)
			cm	cm				**SESW Field Classification**		
22354933	SP1	SP1. 30-40	30	40	55H	321800	5842635	Medium Clay (Silty)	6.1	5.0
22354931	SP2	SP2. 30-40	30	40	55H	322118	5842629	Heavy Clay (Silty)	7.8	7.1
22354929	SP3	SP3. 30-40	30	40	55H	321800	5842003	Heavy Clay (Silty)	7.4	6.2
22354894	SP4	SP4. 30-40	30	40	55H	321800	5842319	Medium Heavy Clay (Silty)	6.8	5.3
22354924	SP5	SP5. 30-40	30	40	55H	321799	5841687	Medium Heavy Clay (Silty)	6.2	5.1
22354922	SP6	SP6. 30-40	30	40	55H	321800	5841371	Heavy Clay (Silty)	6.6	5.3
22354920	SP7	SP7. 30-40	30	40	55H	322116	5841371	Heavy Clay (Silty)	8.1	7.0
22354917	SP8	SP8. 30-40	30	40	55H	322116	5841687	Light Medium Clay	6.6	5.5
22354915	SP9	SP9. 30-40	30	40	55H	322432	5841687	Heavy Clay	6.6	5.5
22354913	SP10	SP10. 30-40	30	40	55H	322432	5841371	Heavy Clay (Silty)	7.1	6.0
22354909	SP12	SP12. 30-40	30	40	55H	322748	5841371	Medium Heavy Clay	6.9	5.7
22354907	SP13	SP13. 30-40	30	40	55H	322749	5841055	Heavy Clay (Silty)	7.4	6.1
22354903	SP14	SP14. 30-40	30	40	55H	323064	5841055	Heavy Clay (Silty)	7.0	5.8
22354896	SP15	SP15. 30-40	30	40	55H	323064	5841371	Medium Heavy Clay (Silty)	6.5	5.1
22354901	SP17	SP17. 30-40	30	40	55H	322116	5842003	Heavy Clay	7.6	6.4
22354899	SP18	SP18. 30-40	30	40	55H	322427	5841999	Clay Loam (Silty)	6.8	5.6
22340789	SP19	SP19. 30-40	30	40	55H	322432	5842319	Heavy Clay	6.4	5.2
22340788	SP20	SP20. 30-40	30	40	55H	322115	5842319	Heavy Clay	6.8	5.5
22352497	SP21	SP21. 30-40	30	40	55H	322432	5842635	Heavy Clay	6.5	5.2
22352499	SP22	SP22. 30-40	30	40	55H	322737	5842609	Heavy Clay	6.9	5.8
22352503	SP24	SP24. 30-40	30	40	55H	322748	5842319	Medium Heavy Clay	6.8	5.7
22352505	SP26	SP26. 30-40	30	40	55H	323064	5842319	Medium Heavy Clay (Silty)	6.8	5.4
22352509	SP27	SP27. 30-40	30	40	55H	323064	5842635	Heavy Clay (Silty)	7.1	6.2
22352490	SP28	SP28. 30-40	30	40	55H	323696	5841055	Medium Heavy Clay (Silty)	6.9	5.8
22352486	SP29	SP29. 30-40	30	40	55H	323696	5841371	Heavy Clay (Silty)	8.2	7.0
22352510	SP30	SP30. 30-40	30	40	55H	323696	5841687	Heavy Clay	8.1	7.0
22352512	SP31	SP31. 30-40	30	40	55H	324012	5841687	Medium Clay (Silty)	7.5	6.6
22352516	SP32	SP32. 30-40	30	40	55H	324012	5842003	Medium Heavy Clay (Silty)	6.8	5.7
22352521	SP34	SP34. 30-40	30	40	55H	324012	5842319	Medium Heavy Clay (Silty)	7.2	5.9
22352523	SP35	SP35. 30-40	30	40	55H	323718	5842317	Medium Heavy Clay (Silty)	6.7	5.9
22352525	SP36	SP36. 30-40	30	40	55H	321484	5842635	Heavy Clay (Silty)	8.3	7.5
22352528	SP37	SP37. 30-40	30	40	55H	320540	5842301	Heavy Clay (Silty)	6.9	5.6
22352530	SP38	SP38. 30-40	30	40	55H	320536	5842003	Heavy Clay (Silty)	6.2	4.9
22352531	SP39	SP39. 30-40	30	40	55H	320220	5841687	Medium Heavy Clay (Silty)	7.0	5.8
22352534	SP40	SP40. 30-40	30	40	55H	320226	5841422	Heavy Clay (Silty)	6.1	5.1
22352805	SP41	SP41. 30-40	30	40	55H	320536	5841371	Heavy Clay (Silty)	7.1	6.3
22352809	SP42	SP42. 30-40	30	40	55H	320542	5841672	Heavy Clay (Silty)	7.0	6.1
22352806	SP43	SP43. 30-40	30	40	55H	320852	5841371	Light Clay (Silty)	6.2	5.0
22352804	SP44	SP44. 30-40	30	40	55H	320852	5841687	Heavy Clay (Silty)	7.2	5.9
22352801	SP45	SP45. 30-40	30	40	55H	320852	5842003	Light Clay (Silty)	6.4	4.9
22352798	SP46	SP46. 30-40	30	40	55H	320829	5842325	Heavy Clay (Silty)	7.0	5.7

Table A.3: Shenstone Park 30-40cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Electrical Conductivity (1:5 water)	Exchangeable Sodium Percentage	Emerson Class	Disp. Index, Loveday/Pyle	Slaking 2Hrs
			dS/m	%			
22354933	SP1	SP1. 30-40	0.05	2.8	8	3	Partial
22354931	SP2	SP2. 30-40	0.42	9.1	2	9	Partial
22354929	SP3	SP3. 30-40	0.08	4	8	3	Partial
22354894	SP4	SP4. 30-40	0.11	15	1	16	Considerable
22354924	SP5	SP5. 30-40	0.09	5.4	8	4	Partial
22354922	SP6	SP6. 30-40	0.07	4.5	2	10	Partial
22354920	SP7	SP7. 30-40	0.14	8.8	2	13	Partial
22354917	SP8	SP8. 30-40	0.06	4.2	3	6	Partial
22354915	SP9	SP9. 30-40	0.08	3.7	2	10	Partial
22354913	SP10	SP10. 30-40	0.19	8.8	1	15	Considerable
22354909	SP12	SP12. 30-40	0.12	9.8	1	16	Partial
22354907	SP13	SP13. 30-40	0.09	6.3	2	12	Partial
22354903	SP14	SP14. 30-40	0.11	8	2	13	Partial
22354896	SP15	SP15. 30-40	0.06	5.9	1	16	Partial
22354901	SP17	SP17. 30-40	0.14	11	1	15	Considerable
22354899	SP18	SP18. 30-40	0.05	3.3	3	6	Partial
22340789	SP19	SP19. 30-40	0.08	5.7	2	10	Partial
22340788	SP20	SP20. 30-40	0.07	5.7	1	12	Considerable
22352497	SP21	SP21. 30-40	0.08	7.3	1	16	Considerable
22352499	SP22	SP22. 30-40	0.08	3	2	8	Partial
22352503	SP24	SP24. 30-40	0.09	4.1	2	2	Water Stable
22352505	SP26	SP26. 30-40	0.09	6.6	1	10	Considerable
22352509	SP27	SP27. 30-40	0.09	2	7	0	Water Stable
22352490	SP28	SP28. 30-40	0.15	7.1	2	11	Partial
22352486	SP29	SP29. 30-40	0.14	8.2	2	10	Partial
22352510	SP30	SP30. 30-40	0.21	12	2	12	Considerable
22352512	SP31	SP31. 30-40	0.35	14	2	12	Partial
22352516	SP32	SP32. 30-40	0.15	9.4	1	15	Considerable
22352521	SP34	SP34. 30-40	0.07	4.6	2	10	Partial
22352523	SP35	SP35. 30-40	0.34	11	1	11	Considerable
22352525	SP36	SP36. 30-40	0.48	19	1	14	Partial
22352528	SP37	SP37. 30-40	0.12	12	1	16	Partial
22352530	SP38	SP38. 30-40	0.14	16	1	16	Considerable
22352531	SP39	SP39. 30-40	0.19	21	1	16	Considerable
22352534	SP40	SP40. 30-40	0.35	20	1	14	Partial
22352805	SP41	SP41. 30-40	0.45	22	1	14	Partial
22352809	SP42	SP42. 30-40	0.39	21	1	15	Partial
22352806	SP43	SP43. 30-40	0.27	25	2	11	Partial
22352804	SP44	SP44. 30-40	0.15	26	1	15	Partial
22352801	SP45	SP45. 30-40	0.10	20	1	15	Considerable
22352798	SP46	SP46. 30-40	0.12	12	1	16	Partial

Exchangeable Sodium Percentage (ESP) Interpretation

Colour	ESP Range	Interpretation
Green	<6%.	Non-sodic.
Amber	6.1-10%.	Moderately Sodic
Red	10.1-15.0%	Strongly Sodic
Dark red	>15.1%	Very Strongly Sodic

Emerson Dispersion Class Interpretation.

Colour	Emerson Class	Interpretation
Green	4, 5, 6, 7, 8	Non-dispersive.
Amber	3	Partial Dispersion after remoulding
Red	2	Partial Dispersion
Dark red	1	Complete Dispersion

Loveday & Pyle (L&P) Score Interpretation.

Colour	L&P Score	Interpretation
Green	0, 1, 2, 3, 4	Low to moderate. Nil to slight gypsum resonse expected where dispersive.
Amber	5, 6, 7, 8	Moderate to high. Gypsum response expected to control dispersion.
Red	9, 10, 11, 12	High. Gypsum response expected to control dispersion. High rates required.
Dark red	13, 14, 15, 16	Very high. Very high rates required to control dispersion.

Slaking Class Interpretation.

Colour	Slaking Class	Interpretation
Green	Water Stable	Aggregate stable when wetted, nil or minimal breakdown in structure.
Amber	Partial	Low aggregate stability. Partial breakdown in structure when wetted.
Red	Considerable	Unstable. High or significant loss of structure when wetted.

Table A.3: Shenstone Park 30-40cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Calcium (Amm-acet.) mg/kg	Magnesium (Amm-acet.) mg/kg	Available Potassium mg/kg	Sodium (Amm-acet.) mg/kg	Aluminium (KCl) mg/kg	Calcium (Amm-acet.) cmol(+)/kg	Magnesium (Amm-acet.) cmol(+)/kg	Potassium (Amm-acet.) cmol(+)/kg	Sodium (Amm-acet.) cmol(+)/kg	Aluminium (KCl) cmol(+)/kg	Cation Exch. Cap. cmol(+)/kg	Calcium (Amm-acet.) %	Magnesium (Amm-acet.) %	Potassium (Amm-acet.) %	Aluminium Saturation %
22354933	SP1	SP1. 30-40	1480	1113	145	113	<9.0	7.4	9.2	0.4	0.5	<0.1	17.5	43	53	2.1	<1.0
22354931	SP2	SP2. 30-40	2800	2178	190	736	<9.0	14.0	18.0	0.5	3.2	<0.1	35.0	40	50	1.4	<1.0
22354929	SP3	SP3. 30-40	2400	1936	160	276	<9.0	12.0	16.0	0.4	1.2	<0.1	29.3	41	53	1.4	<1.0
22354894	SP4	SP4. 30-40	720	908	86	437	<9.0	3.6	7.5	0.2	1.9	<0.1	13.3	27	56	1.7	<1.0
22354924	SP5	SP5. 30-40	1220	1452	80	230	13	6.1	12.0	0.2	1.0	0.2	19.5	31	61	1.0	0.8
22354922	SP6	SP6. 30-40	1620	1936	170	253	<9.0	8.1	16.0	0.4	1.1	<0.1	25.2	32	62	1.7	<1.0
22354920	SP7	SP7. 30-40	2400	2057	230	644	<9.0	12.0	17.0	0.6	2.8	<0.1	32.2	37	52	1.9	<1.0
22354917	SP8	SP8. 30-40	1060	871	98	129	<9.0	5.3	7.2	0.3	0.6	<0.1	13.4	40	54	1.9	<1.0
22354915	SP9	SP9. 30-40	2800	2057	170	276	<9.0	14.0	17.0	0.4	1.2	<0.1	32.1	43	52	1.4	<1.0
22354913	SP10	SP10. 30-40	1980	2057	170	621	<9.0	9.9	17.0	0.4	2.7	<0.1	30.5	33	57	1.4	<1.0
22354909	SP12	SP12. 30-40	1720	1815	200	598	<9.0	8.6	15.0	0.5	2.6	<0.1	26.7	32	56	2.0	<1.0
22354907	SP13	SP13. 30-40	2000	2057	150	437	<9.0	10.0	17.0	0.4	1.9	<0.1	29.3	36	56	1.3	<1.0
22354903	SP14	SP14. 30-40	1780	1815	120	483	<9.0	8.9	15.0	0.3	2.1	<0.1	26.7	33	57	1.1	<1.0
22354896	SP15	SP15. 30-40	980	992	78	193	<9.0	4.9	8.2	0.2	0.8	<0.1	14.1	35	58	1.4	<1.0
22354901	SP17	SP17. 30-40	2000	1936	150	759	<9.0	10.0	16.0	0.4	3.3	<0.1	30.1	34	53	1.2	<1.0
22354899	SP18	SP18. 30-40	1320	714	41	99	<9.0	6.6	5.9	0.1	0.4	<0.1	13.0	51	45	0.8	<1.0
22340789	SP19	SP19. 30-40	1260	1452	99	253	9.8	6.3	12.0	0.3	1.1	0.1	19.7	32	61	1.3	0.6
22340788	SP20	SP20. 30-40	1320	1331	100	253	<9.0	6.6	11.0	0.3	1.1	<0.1	19.4	34	59	1.3	<1.0
22352497	SP21	SP21. 30-40	1800	1331	110	368	<9.0	9.0	11.0	0.3	1.6	<0.1	21.4	42	49	1.3	<1.0
22352499	SP22	SP22. 30-40	1800	1573	240	161	<9.0	9.0	13.0	0.6	0.7	<0.1	23.0	39	55	2.6	<1.0
22352503	SP24	SP24. 30-40	2000	2178	140	276	<9.0	10.0	18.0	0.4	1.2	<0.1	30.0	35	60	1.2	<1.0
22352505	SP26	SP26. 30-40	1700	1815	140	391	<9.0	8.5	15.0	0.4	1.7	<0.1	25.8	33	59	1.4	<1.0
22352509	SP27	SP27. 30-40	3200	2299	160	168	<9.0	16.0	19.0	0.4	0.7	<0.1	36.1	45	52	1.1	<1.0
22352490	SP28	SP28. 30-40	2200	1815	170	460	9.1	11.0	15.0	0.5	2.0	0.1	28.6	38	53	1.6	0.4
22352486	SP29	SP29. 30-40	2200	1936	140	552	<9.0	11.0	16.0	0.4	2.4	<0.1	29.5	36	55	1.2	<1.0
22352510	SP30	SP30. 30-40	1600	2178	130	828	<9.0	8.0	18.0	0.3	3.6	<0.1	30.1	27	61	1.1	<1.0
22352512	SP31	SP31. 30-40	1380	2299	160	966	<9.0	6.9	19.0	0.4	4.2	<0.1	30.5	23	62	1.4	<1.0
22352516	SP32	SP32. 30-40	1680	1936	160	598	<9.0	8.4	16.0	0.4	2.6	<0.1	27.4	31	58	1.5	<1.0
22352521	SP34	SP34. 30-40	2000	1936	120	299	<9.0	10.0	16.0	0.3	1.3	<0.1	27.9	37	57	1.1	<1.0
22352523	SP35	SP35. 30-40	2000	1815	120	736	<9.0	10.0	15.0	0.3	3.2	<0.1	29.4	35	53	1.1	<1.0
22352525	SP36	SP36. 30-40	1560	2057	120	1334	<9.0	7.8	17.0	0.3	5.8	<0.1	30.6	26	54	1.0	<1.0
22352528	SP37	SP37. 30-40	1680	1694	130	736	<9.0	8.4	14.0	0.3	3.2	<0.1	26.3	32	55	1.3	<1.0
22352530	SP38	SP38. 30-40	1120	1089	94	644	12	5.6	9.0	0.2	2.8	0.1	17.8	31	50	1.3	0.8
22352531	SP39	SP39. 30-40	1080	1331	100	1012	<9.0	5.4	11.0	0.3	4.4	<0.1	21.1	25	53	1.2	<1.0
22352534	SP40	SP40. 30-40	820	1053	82	759	<9.0	4.1	8.7	0.2	3.3	<0.1	16.2	25	54	1.3	<1.0
22352805	SP41	SP41. 30-40	1180	1573	110	1242	<9.0	5.9	13.0	0.3	5.4	<0.1	24.1	25	52	1.2	<1.0
22352809	SP42	SP42. 30-40	1320	1452	120	1127	<9.0	6.6	12.0	0.3	4.9	<0.1	23.9	27	51	1.3	<1.0
22352806	SP43	SP43. 30-40	500	726	51	644	12	2.5	6.0	0.1	2.8	0.1	11.5	21	52	1.1	1.1
22352804	SP44	SP44. 30-40	780	908	110	966	<9.0	3.9	7.5	0.3	4.2	<0.1	15.8	25	47	1.8	<1.0
22352801	SP45	SP45. 30-40	560	460	62	414	<9.0	2.8	3.8	0.2	1.8	<0.1	8.6	33	45	1.9	<1.0
22352798	SP46	SP46. 30-40	1460	1573	140	644	<9.0	7.3	13.0	0.4	2.8	<0.1	23.6	31	56	1.5	<1.0

Table A.3: Shenstone Park 30-40cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Calcium/Magnesium Ratio	ESP% + EPP% Calculation
				SESW Calculation
22354933	SP1	SP1. 30-40	0.8	4.9
22354931	SP2	SP2. 30-40	0.8	10.5
22354929	SP3	SP3. 30-40	0.8	5.4
22354894	SP4	SP4. 30-40	0.5	16.7
22354924	SP5	SP5. 30-40	0.5	6.4
22354922	SP6	SP6. 30-40	0.5	6.2
22354920	SP7	SP7. 30-40	0.7	10.7
22354917	SP8	SP8. 30-40	0.7	6.1
22354915	SP9	SP9. 30-40	0.8	5.1
22354913	SP10	SP10. 30-40	0.6	10.2
22354909	SP12	SP12. 30-40	0.6	11.8
22354907	SP13	SP13. 30-40	0.6	7.6
22354903	SP14	SP14. 30-40	0.6	9.1
22354896	SP15	SP15. 30-40	0.6	7.3
22354901	SP17	SP17. 30-40	0.6	12.2
22354899	SP18	SP18. 30-40	1.1	4.1
22340789	SP19	SP19. 30-40	0.5	7.0
22340788	SP20	SP20. 30-40	0.6	7.0
22352497	SP21	SP21. 30-40	0.8	8.6
22352499	SP22	SP22. 30-40	0.7	5.6
22352503	SP24	SP24. 30-40	0.6	5.3
22352505	SP26	SP26. 30-40	0.6	8.0
22352509	SP27	SP27. 30-40	0.8	3.1
22352490	SP28	SP28. 30-40	0.7	8.7
22352486	SP29	SP29. 30-40	0.7	9.4
22352510	SP30	SP30. 30-40	0.4	13.1
22352512	SP31	SP31. 30-40	0.4	15.4
22352516	SP32	SP32. 30-40	0.5	10.9
22352521	SP34	SP34. 30-40	0.6	5.7
22352523	SP35	SP35. 30-40	0.7	12.1
22352525	SP36	SP36. 30-40	0.5	20.0
22352528	SP37	SP37. 30-40	0.6	13.3
22352530	SP38	SP38. 30-40	0.6	17.3
22352531	SP39	SP39. 30-40	0.5	22.2
22352534	SP40	SP40. 30-40	0.5	21.3
22352805	SP41	SP41. 30-40	0.5	23.2
22352809	SP42	SP42. 30-40	0.6	22.3
22352806	SP43	SP43. 30-40	0.4	26.1
22352804	SP44	SP44. 30-40	0.5	27.8
22352801	SP45	SP45. 30-40	0.7	21.9
22352798	SP46	SP46. 30-40	0.6	13.5

Table A.5: Shenstone Park >40cm Sample Analytical Results.

Sample ID	Site	Sample Name	Sample Start Depth	Sample End Depth	Zone	GPS Easting	GPS Northing	Texture	pH (1:5 Water)	pH (1:5 CaCl2)	Electrical Conductivity (1:5 water)	Exchangeable Sodium Percentage	Emerson Class	Disp. Index, Loveday/Pyle	Slaking 2Hrs
			cm	cm				SESW Field Classification			dS/m	%			
22354928	SP3	SP3. 80-90	80	90	55H	321800	5842003	Heavy Clay (Silty)	8.4	7.5	0.21	6.5	7	0	Water Stable
22354926	SP4	SP4. 100-120	100	120	55H	321800	5842319	Heavy Clay (Silty)	8.8	8.2	0.84	26	2	8	Considerable
22354919	SP7	SP7. 110-130	110	130	55H	322116	5841371	Heavy Clay	9.1	8.3	0.62	21	2	8	Considerable
22354912	SP10	SP10. 90-100	90	100	55H	322432	5841371	Heavy Clay (Silty)	8.8	8.3	0.75	11	7	0	Water Stable
22354908	SP12	SP12. 110-120	110	120	55H	322748	5841371	Heavy Clay	9.0	8.4	0.88	16	6	0	Partial
22354905	SP13	SP13. 70-80	70	80	55H	322749	5841055	Heavy Clay	8.8	8.2	0.56	9.4	7	0	Water Stable
22354902	SP14	SP14. 100-110	100	110	55H	323064	5841055	Heavy Clay	8.9	8.4	0.86	12	6	0	Partial
22352489	SP21	SP21. 110-120	110	120	55H	322432	5842635	Heavy Clay	8.4	8.1	1.71	17	6	0	Partial
22352507	SP26	SP26. 60-70	60	70	55H	323064	5842319	Heavy Clay (Silty)	8.3	7.5	0.33	10	2	4	Partial
22352491	SP28	SP28. 70-80	70	80	55H	323696	5841055	Heavy Clay (Silty)	8.2	7.6	0.64	13	3	2	Partial
22352515	SP31	SP31.60-70	60	70	55H	324012	5841687	Heavy Clay	8.6	8.2	1.12	18	7	0	Water Stable
22352529	SP37	SP37. 80-90	80	90	55H	320540	5842301	Heavy Clay (Silty)	8.0	7.4	0.84	18	2	11	Considerable
22352533	SP39	SP39. 70-80	70	80	55H	320220	5841687	Heavy Clay (Silty)	8.4	7.2	0.32	27	1	14	Considerable
22352800	SP45	SP45. 90-100	90	100	55H	320852	5842003	Heavy Clay (Silty)	8.1	7.3	0.44	31	1	16	Considerable

Exchangeable Sodium Percentage (ESP) Interpretation

Colour	ESP Range	Interpretation
Green	<6%.	Non-sodic.
Amber	6-10%.	Moderately Sodic
Red	10.1-15.0%	Strongly Sodic
Dark red	>15.1%	Very Strongly Sodic

Emerson Dispersion Class Interpretation.

Colour	Emerson Class	Interpretation
Green	4, 5, 6, 7, 8	Non-dispersive.
Amber	3	Partial Dispersion after remoulding
Red	2	Partial Dispersion
Dark red	1	Complete Dispersion

Loveday & Pyle (L&P) Score Interpretation.

Colour	L&P Score	Interpretation
Green	1, 2, 3, 4	Low to moderate. Nil to slight gypsum resonse expected where dispersive.
Amber	5, 6, 7, 8	Moderate to high. Gypsum response expected to control dispersion.
Red	9, 10, 11, 12	High. Gypsum response expected to control dispersion. High rates required.
Dark red	13, 14, 15, 16	Very high. Very high rates required to control dispersion.

Slaking Class Interpretation.

Colour	Slaking Class	Interpretation
Green	Water Stable	Aggregate stable when wetted, nil or minimal breakdown in structure.
Amber	Partial	Low aggregate stability. Partial breakdown in structure when wetted.
Red	Considerable	Unstable. High or significant loss of structure when wetted.

Table A.4: Shenstone Park >40cm Sample Analytical Results (Continued).

Sample ID	Site	Sample Name	Calcium (Amm-acet.)	Magnesium (Amm-acet.)	Available Potassium	Sodium (Amm-acet.)	Aluminium (KCl)	Calcium (Amm-acet.)	Magnesium (Amm-acet.)	Potassium (Amm-acet.)	Sodium (Amm-acet.)	Aluminium (KCl)	Cation Exch. Cap.	Calcium (Amm-acet.)	Magnesium (Amm-acet.)	Potassium (Amm-acet.)	Aluminium Saturation
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	cmol(+)/kg	%	%	%	%
22354928	SP3	SP3. 80-90	2400	2057	130	483	<9.0	12.0	17.0	0.3	2.1	<0.1	31.9	39	54	1.00	<1.0
22354926	SP4	SP4. 100-120	1360	2057	150	2001	<9.0	6.8	17.0	0.4	8.7	<0.1	33.2	21	52	1.10	<1.0
22354919	SP7	SP7. 110-130	1620	1936	120	1518	<9.0	8.1	16.0	0.3	6.6	<0.1	31.0	26	51	0.98	<1.0
22354912	SP10	SP10. 90-100	3600	2420	150	1150	<9.0	18.0	20.0	0.4	5.0	<0.1	43.9	41	46	0.87	<1.0
22354908	SP12	SP12. 110-120	3600	2541	110	1771	<9.0	18.0	21.0	0.3	7.7	<0.1	47.0	38	45	0.59	<1.0
22354905	SP13	SP13. 70-80	3400	2057	110	805	<9.0	17.0	17.0	0.3	3.5	<0.1	37.3	45	45	0.79	<1.0
22354902	SP14	SP14. 100-110	4200	2057	120	1150	<9.0	21.0	17.0	0.3	5.0	<0.1	43.3	48	40	0.69	<1.0
22352489	SP21	SP21. 110-120	4400	2783	170	2116	<9.0	22.0	23.0	0.4	9.2	<0.1	54.8	40	42	0.81	<1.0
22352507	SP26	SP26. 60-70	1960	2178	150	759	<9.0	9.8	18.0	0.4	3.3	<0.1	31.9	31	58	1.20	<1.0
22352491	SP28	SP28. 70-80	2400	2783	180	1219	<9.0	12.0	23.0	0.5	5.3	<0.1	40.0	29	56	1.10	<1.0
22352515	SP31	SP31.60-70	2200	2541	130	1587	<9.0	11.0	21.0	0.3	6.9	<0.1	39.2	28	54	0.85	<1.0
22352529	SP37	SP37. 80-90	2000	2299	160	1518	<9.0	10.0	19.0	0.4	6.6	<0.1	36.2	28	52	1.10	<1.0
22352533	SP39	SP39. 70-80	1400	1936	140	1978	<9.0	7.0	16.0	0.4	8.6	<0.1	32.4	22	51	1.10	<1.0
22352800	SP45	SP45. 90-100	1160	1331	140	1748	<9.0	5.8	11.0	0.4	7.6	<0.1	24.4	24	44	1.50	<1.0

Sample ID	Site	Sample Name	Calcium/Magnesium Ratio	ESP% + EPP% Calculation
				SESW Calculation
22354928	SP3	SP3. 80-90	0.7	7.5
22354926	SP4	SP4. 100-120	0.4	27.1
22354919	SP7	SP7. 110-130	0.5	22.0
22354912	SP10	SP10. 90-100	0.9	11.9
22354908	SP12	SP12. 110-120	0.9	16.6
22354905	SP13	SP13. 70-80	1.0	10.2
22354902	SP14	SP14. 100-110	1.2	12.7
22352489	SP21	SP21. 110-120	1.0	17.8
22352507	SP26	SP26. 60-70	0.5	11.2
22352491	SP28	SP28. 70-80	0.5	14.1
22352515	SP31	SP31.60-70	0.5	18.9
22352529	SP37	SP37. 80-90	0.5	19.1
22352533	SP39	SP39. 70-80	0.4	28.1
22352800	SP45	SP45. 90-100	0.5	32.5