DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Urban salinity management in the Western Sydney Aerotropolis area

Derived from Western Sydney Hydrogeological Landscapes (2011)

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Cover photo: Confluence of South Creek and Thompsons Creek, Rossmore, Western Sydney. Carl Tippler/CTENVIRONMENTAL

Publication of this report was funded by the NSW Government under the Marine Estate Management Strategy 2018–2028. The 10-year strategy was developed by the NSW Marine Estate Management Authority to coordinate the management of the marine estate.

Published by:

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ISBN 978-1-922672-66-7
EES 2021/0342
August 2021

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Contents

List of tables

List of figures

1. Background

This report was prepared to support planning processes for delivery of Stage 1 of the Western Sydney Aerotropolis. It focuses on management of urban salinity in the Western Sydney hydrogeological landscapes (HGLs), where there is a high risk of salinity hazard impacts on both the built form (such as buildings and roads), and water dependent ecosystems that make up the blue-green grid. The management of rural salinity is not discussed in this report. Information about rural salinity management is available in Wooldridge et al. (2015).

The report summarises key considerations for urban salinity management and water dependent ecosystems from the Western Sydney Hydrogeological Landscapes: May 2011 (First Edition) data package (DECCW, 2011), which is available from SEED – the portal for Sharing and Enabling Environmental Data in NSW.

There has been no reassessment of (mapping) linework or applicability of the original management options. Some management descriptions have been revised to be more urban-specific and consider impacts on waterways and water dependent ecosystems.

1.1 Western Sydney hydrogeological landscapes (2011)

In recognition of the high salinity risk to increasing urban development in Western Sydney, Hawkesbury-Nepean Catchment Management Authority engaged Department of Environment, Climate Change and Water (DECCW) in 2010 to carry out an HGL classification of the Western Sydney area at 1:100,000 scale, to better understand how salinity manifests across the landscape and guide how salinity may be best managed.

Funding for this work was made available by the Salinity Strategy Enhancement Program.

For Western Sydney, HGL classification primarily focuses on salinity; however, the full HGL unit descriptions provided in DECCW (2011) make reference to soil and land degradation issues as outlined in *Soil Landscapes of the Penrith 1:100,000 sheet* (Bannerman & Hazelton 1990) and *Soil and Land Resources of the Hawkesbury-Nepean Catchment* (DECC 2008).

1.2 Limitations

Scale of mapping for the Western Sydney HGL is 1:100,000. This scale is semi-detailed; however, the product can be applied at a finer scale by using the conceptual cross-sections to identify management areas when doing field investigations to assist in targeting the appropriate management actions to the correct landscape positions.

Some datasets used to define the HGL boundaries are now outdated. Any future revisions to the Western Sydney HGL would incorporate current geological and soil landscape mapping, which may result in changes to HGL boundaries and distribution.

The scale of the spatial HGL linework as supplied in the Western Sydney HGL data package lacks the positional accuracy required for precinct or finer scale land use planning. Using it for these purposes without more detailed investigation and refinement at a local scale may lead to negative outcomes for infrastructure, development and environment if the salinity condition is exacerbated.

2. About hydrogeological landscapes

HGLs enable an understanding of how differences in salinity are expressed across the landscape and provide a tool to target a specific combination of land use activities where they will provide the best salinity management outcomes.

Each HGL unit spatially differentiates areas having similar salt stores and pathways for salt mobilisation. The term ‘hydrogeological’ highlights the important components of water, geology and regolith, whereas ‘landscape’ represents the significant influence of landforms, regolith and soils on the hydrological regime.

HGL unit descriptions integrate information from sources such as soil landscape and geology maps, site characterisation, salinity occurrence maps, hydrogeological data, surface water and groundwater data.

HGL unit descriptions give a framework to spatially define salinity management areas and recommend how best to manage and prioritise these landscapes. These management areas encompass a unique combination of landscape factors, such as soil, groundwater, geology and slope. The salinity response and salinity management options applied will usually differ between HGL units.

For Western Sydney, HGL unit descriptions are provided in the *Western_Sydney_HGL_Descriptions* folder of the *Western Sydney Hydrogeological Landscapes: May 2011 (First Edition)* data package (DECCW 2011).

The Western Sydney HGLs that cover the Aerotropolis area are:

- Shale Plains HGL
- Upper South Creek HGL
- Mt Vernon HGL
- Mulgoa HGL
- Greendale HGL.

Salinity hazard and urban salinity management information specific to each of these HGLs has been extracted from the original HGL unit descriptions and provided in **Appendix A**. Groundwater dependent ecosystem (GDE) considerations have been incorporated.

2.1 Using HGLs for salinity management

Because HGL boundaries and management area definitions are based on geology, soils, landforms and hydrologic systems, by incorporating additional data, the tool can be modified to aid understanding and management of other landscape themes such as soil degradation and wetlands.

When used for salinity management, HGLs describe the landscape impacts and hazards of salinity in an HGL unit. They consider risks associated with **land salinity**, in-stream **salt load**, and in-stream **electrical conductivity (EC)**, as well as the **overall salinity hazard** posed by the HGL unit.

2.1.1 Land salinity

Land salinity results from high water tables and concentration of salt due to evaporation at the soil surface. This impacts on land assets by damaging infrastructure, ecosystems, vegetation, soil health and agricultural production.

2.1.2 Salt load

Salt load is a measure of the dissolved load of salt in a stream and is expressed as a mass per unit time (e.g. tonnes per day). High salt loads can result from low volumes of water with high concentrations of salt, or high volumes of water with low concentrations of salt. Salt loads vary because of salt distribution and redistribution in the landscape. Streams and rivers move diffuse salt sources in upland and slope areas to areas further downstream in catchments. Extraction of water from rivers and streams for irrigation redistributes some of this salt load into the soil. Salt loads are also redistributed across wetlands and flood plains during floods, particularly in non-regulated streams. Floods also flush the near-surface soil layers, leaching salts further into the regolith.

2.1.3 Stream EC (water quality)

Stream salinity is a primary water quality indicator. In a salinity context, water quality primarily relates to the concentration of dissolved salts in the water, measured in terms of its EC, which is a function of the total concentration of dissolved salts. High salinity levels in water systems can harm the ecological function of riverine environments and wetland systems. They also limit domestic, recreational, industrial and agricultural water use.

2.1.4 Overall salinity hazard

The overall salinity hazard and resultant priority for action can be inferred from the interaction of land/load/EC factors. Salinity assessment of a landscape is made by determining salinity hazard using a standard risk format, with the overall salinity hazard being determined by the ‘likelihood of occurrence’ and ‘potential impact’ of salinity for each HGL.

2.1.5 Targeting management using conceptual cross-sections

Each HGL is characterised by a conceptual cross-section that explores the way water moves through the HGL, where salt might be stored in the HGL and how the geology, soils, geomorphology and vegetation interact to influence land and water salinisation. These conceptual cross-sections help explain why we see salt and other hazards manifesting in the landscape in certain patterns and allow us to design strategic management solutions to address a given problem. For managing salinity, the conceptual cross-sections are divided into **management areas**.

2.1.6 Management areas

Management areas are defined as areas of land within an HGL that can be uniformly managed. They enable the link between landscape and targeted management and are based on landform facets (crest, upper slopes, lower slopes, floodplains, etc.) (NCST 2009). For ease of comparison, HGL management areas have been standardised (Table 1). Not all management areas will be defined in an HGL unit.

Management areas allow a complex suite of **management actions** to be directed to the appropriate part of each landscape.

For the Western Sydney HGLs, **the management areas are only defined in the conceptual cross-sections**. They have not been spatially mapped in the GIS product. The cross-sections for each HGL are provided in the descriptions in **Appendix A**.

Table 1 HGL management areas

Management area	Description
MA1	Crest or ridge
MA2	Upper slope – erosional
MA3	Upper slope – colluvial
MA4	Mid slope
MA5	Lower slope – colluvial
MA6	Rises
MA7	Saline site
MA8	Structurally controlled saline sites
MA9	Alluvial plains
MA10	Alluvial channels

2.2 Management actions

Management actions deliver management outcomes. Detailed and specific management actions are assigned to appropriate management areas, ensuring the management outcomes are optimal.

The **applicability of a management action may vary – sometimes the action is very suitable for delivering one strategy, but unsuitable for a different strategy**. A management action that is suitable for salinity management in one landscape may be unsuitable or ineffective in another. Combinations of management actions are tailored in accordance with management strategy objectives. **Landscape and targeted management strategies for urban salinity are described in general in Appendix B**.

Impacts on water dependent ecosystems ('blue-grid')

Water dependent ecosystems are ecosystems in which the composition of species and natural ecological processes are determined by the permanent or temporary presence of flowing or standing surface water or groundwater (Richardson et al. 2011). For Western Sydney they include in-stream areas of rivers, riparian vegetation, wetlands, floodplain and groundwater dependent terrestrial vegetation (some of which are protected under the NSW *Biodiversity Conservation Act 2016*, and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*).

Changing land use will alter the hydrology and/or the hydrogeology that supports a water dependent ecosystem. The subsequent changes in water availability or quality (such as salinity) will influence the composition, structure and function of these ecosystems (Eamus et al. 2006).

Some management actions for mitigating risk of impacts of salinity on the built form will impact water dependent ecosystems. For example, lining water sensitive urban design (WSUD) measures such as detention basins will reduce infiltration and recharge to groundwater. Over-irrigation can cause the transport of salt to the surface resulting in the development of shallow saline groundwater. This in turn can cause salinisation of the plant root zone and subsequent collapse of the ecosystem.

Further information on the impacts of management actions on the structure and function of water dependent ecosystems is provided in **Appendix C**.

2.3 High hazard land use

High hazard land uses are considered for their impact and their priority for salinity management. An action that may result in immediate and severe salinity impacts in one landscape may be less damaging in another. Similarly, a management action that is suitable in one location may have negative outcomes if applied somewhere else.

High hazard land use and management actions appropriate for each HGL in the Aerotropolis area are outlined in Appendix A.

3. Overview of Western Sydney Aerotropolis urban salinity management

This section provides a summary of salinity information for the Western Sydney Aerotropolis area as described by the Western Sydney HGLs developed in 2011.

HGL distribution and overall salinity hazard are shown in Figures 1 and 2 respectively. A summary of salinity conditions, management constraints and opportunities is given in Table 2.

General information about urban salinity management strategies and actions can be found in **Appendix B**.

Management information for each Aerotropolis HGL, including where to target specific management actions, is provided in Appendix A.

3.1 Overarching principles for urban salinity management

Where salinity is likely to occur in areas of urban development, the following overarching principles should apply:

- Land managers should clearly demonstrate what measures will be employed to ensure the salinity hazard does not increase (both on site and on adjoining land) as a result of a development.
- Identify and manage sensitive soils (e.g. sodic soils, reactive soils, type of salts, salt loads).
- Consider the impacts that changing recharge and water quality regimes will have on groundwater and other water dependent ecosystems (see Appendix C).
- New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity (including the establishment of good drainage prior to construction).
- Drainage pits and some WSUD actions are not appropriate for high salt store or sensitive landscape positions.
- Leaky pipes in older delivery and stormwater systems will impact on the water balance and salt movement within a catchment and must be considered as part of the overall salinity management strategy.
- Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns, and limit the application of extra salt through water recycling programs or irrigation of saline groundwater.
- Implement a monitoring program (where deemed necessary) including a clear identification of responsibilities.

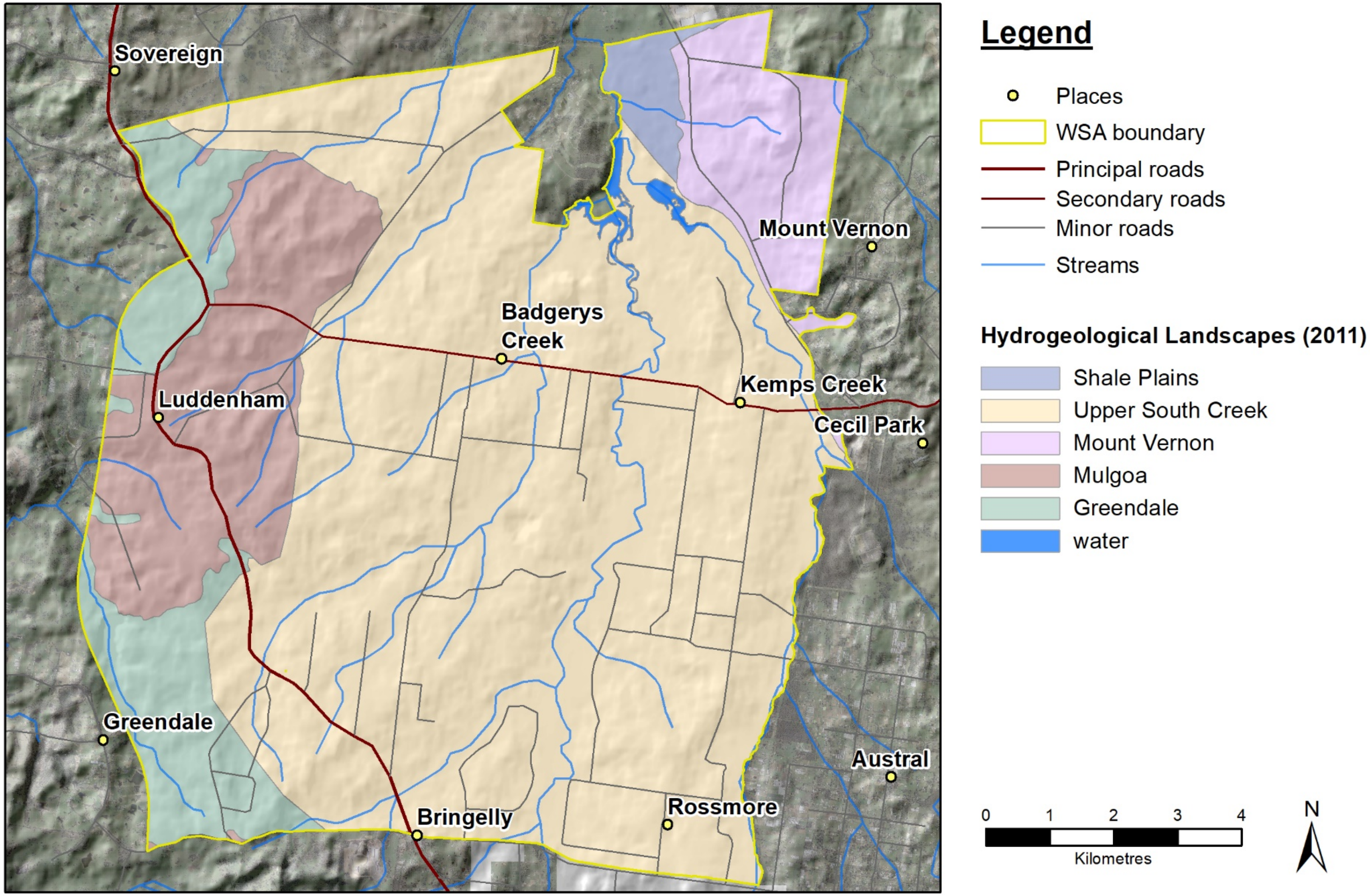

Figure 1 **Western Sydney HGL (2011) distribution in the Western Sydney Aerotropolis area**
(Image: ADS40 / Department of Finance, Services and Innovation)

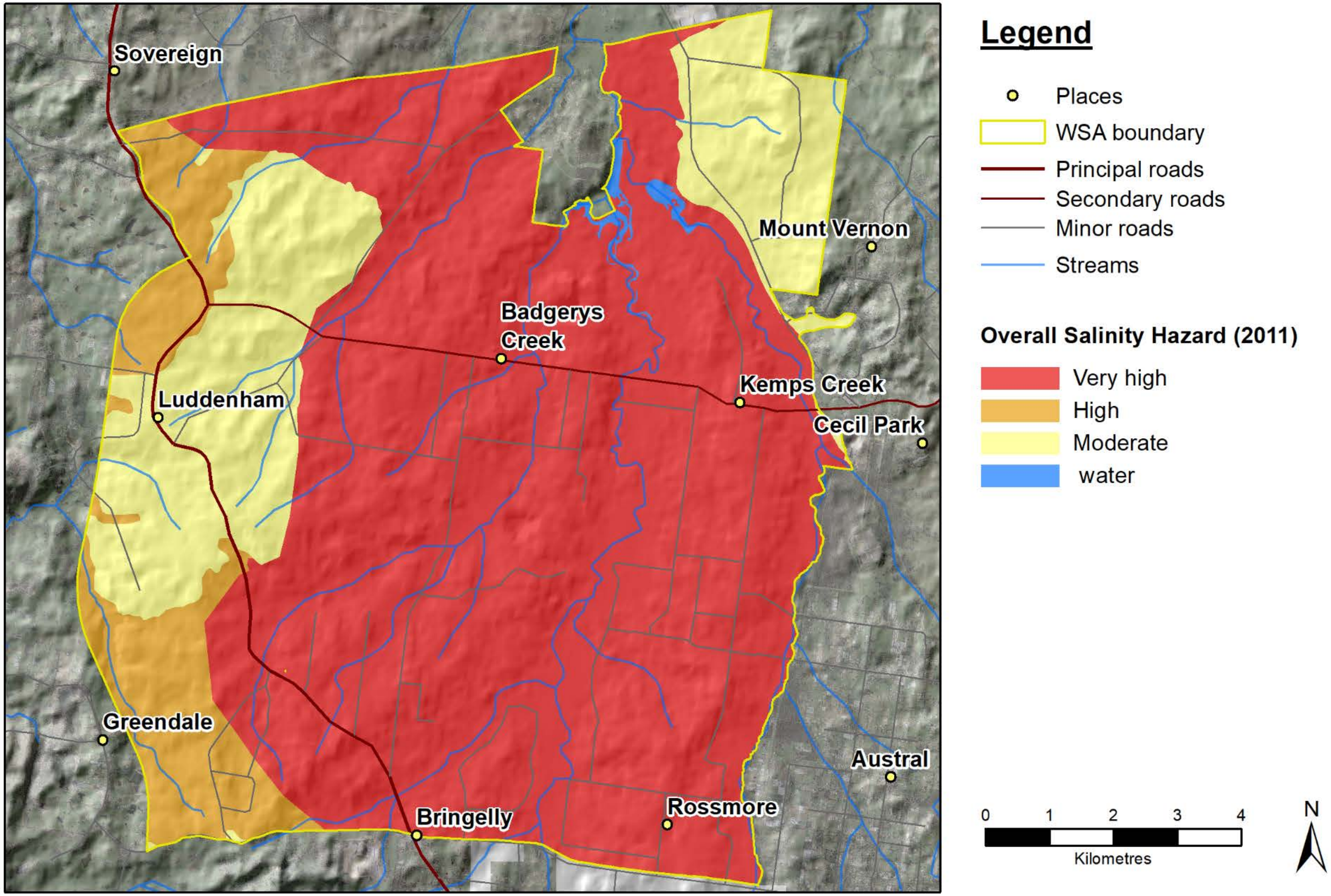

Figure 2 **Overall salinity hazard (2011) for HGLs in the Western Sydney Aerotropolis area**
(Image: ADS40 / Department of Finance, Services and Innovation)

Table 2 **Summary of urban salinity hazard, management constraints and opportunities for HGLs in the Aerotropolis area**

HGL name	Land salinity impacts	Salt load export impacts	Water EC impacts	Overall hazard	Urban landscape management strategies	Targeted urban management strategies	Management constraints	Management opportunities
Shale Plains	High	High	High	Very High	2,4,1,6 (refer to Appendix B)	UI, UP, UC, UM, UV, RM (refer to Appendix B)	• Urban development may increase the rate of accumulation of salt in upland depressions and on lower colluvial slopes, potentially exacerbating land salinity impact in low lying areas. • Seasonal waterlogging. • The flat constricted alluvial plain area is highly sensitive. Disturbance of the area is likely to significantly increase erosion and increase recharge, which will mobilise salt to the adjacent stream. • Plant species selection will require waterlogging tolerance.	• Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available. • Deep-rooted trees and shrubs to intercept shallow groundwater will provide salinity control at seasonal salt sites as well as points of constriction.

HGL name	Land salinity impacts	Salt load export impacts	Water EC impacts	Overall hazard	Urban landscape management strategies	Targeted urban management strategies	Management constraints	Management opportunities
Upper South Creek	High	High	High	Very High	2,4,1,6 (refer to Appendix B)	UP, UI, UC, UV, UM, RM (refer to Appendix B)	• Urban development activities may increase the rate of accumulation of salt in upland depressions and on lower colluvial slopes, potentially exacerbating land salinity impact in low lying areas. • Seasonal waterlogging. • The flat constricted alluvial plain area is highly sensitive. Disturbance of the area is likely to significantly increase erosion and increase recharge, which will mobilise salt to the adjacent stream. • Plant species selection will require waterlogging tolerance.	• Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available. • Deep-rooted trees and shrubs to intercept shallow groundwater will provide salinity control at seasonal salt sites as well as points of constriction.

HGL name	Land salinity impacts	Salt load export impacts	Water EC impacts	Overall hazard	Urban landscape management strategies	Targeted urban management strategies	Management constraints	Management opportunities
Mount Vernon	Moderate	Moderate	High	Moderate	1,3,4,6 (refer to Appendix B)	UI, UP, UM, UC, UV, RM (refer to Appendix B)	• Steep slopes may affect construction activities such as cut-and-fill and building of foundations. • In unsewered areas, onsite wastewater disposal leakages may interact with landscape salt stores to increase salinity hazard. • Urban development activities may increase waterlogging and the rate of accumulation of salt on mid and lower slopes where salinity is already an issue.	• Local scale hydrological systems allow specific targeting of recharge with direct impact on discharge. Pre-planning at the local scale will reduce the impact on the built environment. • Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available in the lower landscape. • Discharge management – integrated use of urban salinity management practices (salt resistant/resilient materials, water management) consistent with building codes would enable protection of infrastructure and dwellings in the lower landscape.

HGL name	Land salinity impacts	Salt load export impacts	Water EC impacts	Overall hazard	Urban landscape management strategies	Targeted urban management strategies	Management constraints	Management opportunities
Mulgoa	Moderate	Moderate	Moderate	Moderate	1,4,5,6 (refer to Appendix B)	UP, UV, UI, UM, RM, UC (refer to Appendix B) (Specific urban management actions have not been specified for Mulgoa HGL)	• In unsewered areas, onsite wastewater disposal leakages may interact with landscape salt stores to increase salinity hazard. • Steep slopes may affect construction activities such as cut-and-fill, building of foundations and retaining walls. Creation of barriers can increase localised accumulation of salt.	• Salt sites are small and easily remedied. • Remnant vegetation – trees and shrubs will assist controlling waterlogging and will assist salinity control at small salt sites in upper drainage lines.

HGL name	Land salinity impacts	Salt load export impacts	Water EC impacts	Overall hazard	Urban landscape management strategies	Targeted urban management strategies	Management constraints	Management opportunities
Greendale	Moderate	Low	Moderate	High	1,2,4,6 (refer to Appendix B)	UP, UI, UC, UM, UV, RM (refer to Appendix B)	• Urban development activities may increase waterlogging and the rate of accumulation of salt on elevated upper and lower slopes where salinity is already an issue. • In unsewered areas, onsite wastewater disposal leakages may interact with landscape salt stores to increase salinity hazard. • Seasonal waterlogging is an issue in upper landscape elements. • Urbanisation of areas currently under peri-urban land use will increase the recharge potential.	• Isolated salt sites in the upper landscape are of manageable size. • Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available. • Discharge management – integrated use of urban salinity management practices (salt resistant/resilient materials, water management) consistent with building codes would enable protection of infrastructure and dwellings in the lower landscape.

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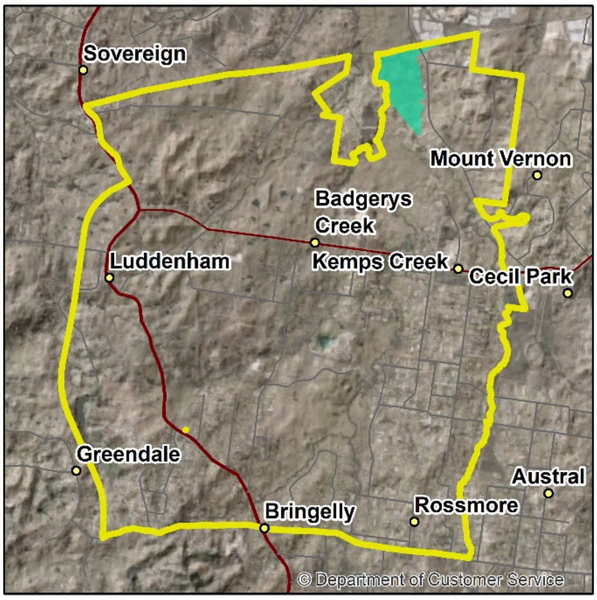
Appendix A: HGL-specific management

Shale Plains HGL

Overall hazard	Very High
Likelihood	High
Overall impact	Severe
Urban landscape management strategies	2,4,1,6
Targeted urban management strategies	UI, UP, UC, UM, UV, RM



Salinity expression

Land salinity	Land salinity is high. Frequent small to moderate (0.1–1 ha) cyclic salt sites occur in this landscape within urban structures (e.g. sporting fields, developed parks, stormwater detention basins). Some larger sites also occur along drainage lines and colluvial slopes. There appears to be a combination of localised salt cycling and deeper groundwater rise contributing to the total salt affected land. The land surface salinity impact of this HGL is high.
Salt load (export)	Salt load is high, driven by salt wash off and groundwater discharge. Small to moderate but frequent widely distributed salt sites contribute high load during rain events whilst salty groundwater discharge maintains significant load in dry times.
Water EC (water quality)	Water EC high. Generally brackish water (1.6–4.8 dS/m). The water quality impact of this HGL is high.

Specific land management constraints

- Urban development may increase the rate of accumulation of salt in upland depressions and on lower colluvial slopes, potentially exacerbating land salinity impact in low lying areas.
- Seasonal waterlogging.
- The flat constricted alluvial plain area is highly sensitive. Disturbance of the area is likely to significantly increase erosion and increase recharge, which will mobilise salt to the adjacent stream.
- Plant species selection will require waterlogging tolerance.

Specific land management opportunities

- Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available.
- Deep-rooted trees and shrubs to intercept shallow groundwater will provide salinity control at seasonal salt sites as well as points of constriction.

Strategies for urban salinity management (refer to Appendix B)

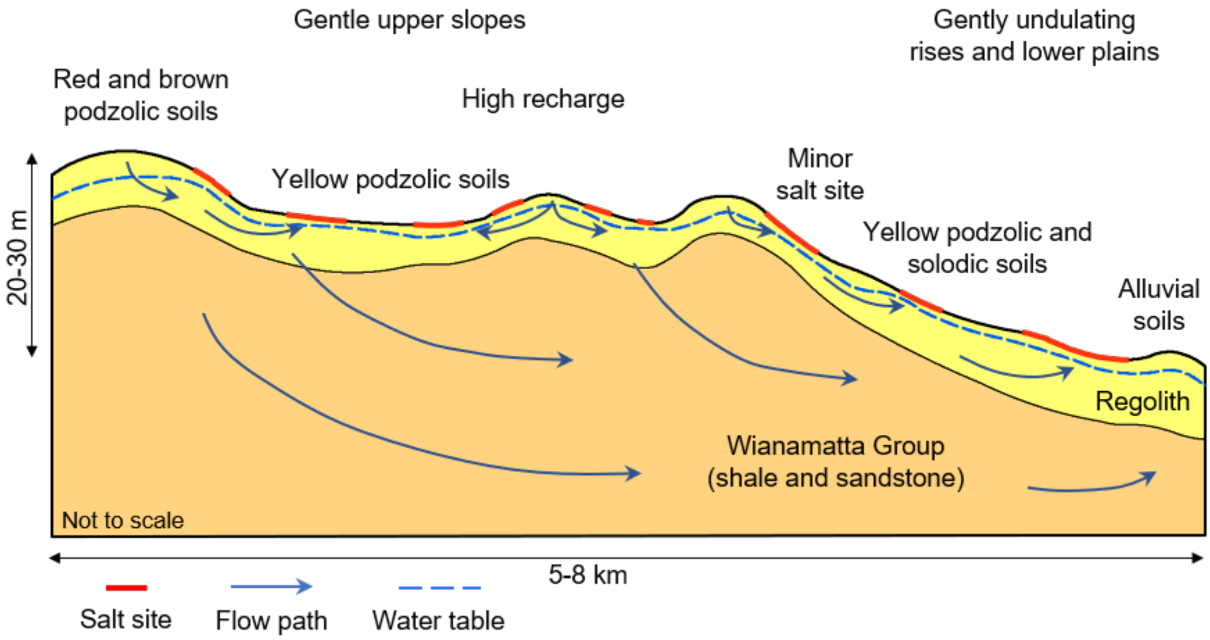
Urban landscape management strategies

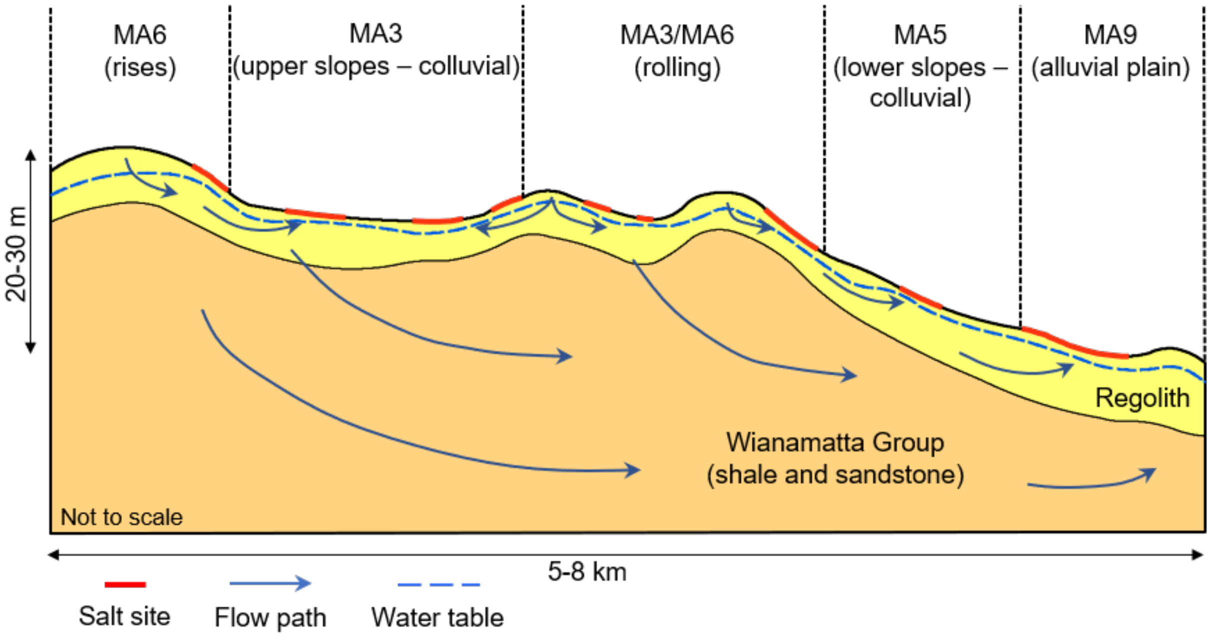
- **Intercept the lateral flow and shallow groundwater (2):** This HGL can target shallow water tables that exist at the contact between underlying geology and around colluvial elements. Rows of deep-rooted trees (8–30 rows) and shrubs can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater. Where tree rows are not an option, depending on local factors, 200 metre belts of actively growing deep-rooted shrubs and grassland may provide similar benefits.
- **Discharge rehabilitation (4):** The saline sites are numerous and vary in size. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Buffer the salt store (1):** There are discrete stores of salt in upper colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy and comprise a significant percentage of this HGL.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Targeted urban management strategies (in priority order)

- **Urban investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. There are areas of sensitive sodic soils, particularly in drainage lines, that need to be identified.
- **Urban planning (UP):** Planning of subdivision layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.
- **Urban construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The typical slope gradient of this HGL requires careful consideration of depth of cut and location of roads on hillslopes; and all infrastructure, including underground utilities.
- **Urban management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water, requires careful management.
- **Urban vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Riparian management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.

Conceptual cross-section and management areas





High hazard land use

There are some activities that should be discouraged in this HGL as they will have negative impacts on salinity.

At risk management areas	Action
MA3, MA5, MA6	• Avoid deep cut and exposure of susceptible soils during development when establishing infrastructure and dwellings
MA3, MA5, MA6, MA9	• Avoid obstruction to surface and sub-surface drainage that will cause wet areas creating waterlogging and salt mobilisation

Management actions

Urban salinity management actions to consider for specific management areas in this landscape are as follows:

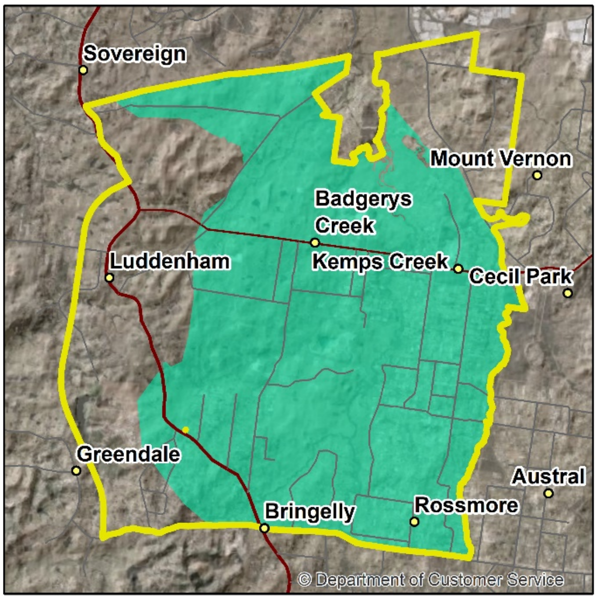
Management areas	Action
MA6 (Rises)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) **Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawn (UM2) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge site (UV1) • Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas (UV5)
MA3 (Upper slopes – colluvial)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) • Identify and manage sodic soils (UI3) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby groundwater dependent ecosystems (GDEs) (UP2) • In areas where nearby GDEs are not reliant on recharge, maximise the size of impervious surfaces to prevent recharge of (perched) groundwater tables. Constructed pervious surfaces may need to be lined and drained to stormwater outlets. Consideration will need to be given to the offsite ecological impacts of diverting runoff (UP4) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban construction** • In areas where nearby GDEs are not reliant on recharge, deep drainage should be minimised by maximising surface water runoff (UC2) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Establish good drainage prior to construction in shrink/swell soils (UC4) • Ensure road construction is suitable for conditions (UC5)

Management areas	Action
	• New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options (UC6) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas (UV3) • Establish new vegetation using salt tolerant species (UV4)
MA3/MA6 (Rolling)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) • Identify and manage sodic soils (UI3) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • In areas where nearby GDEs are not reliant on recharge, maximise the size of impervious surfaces to prevent recharge of (perched) groundwater tables. Constructed pervious surfaces may need to be lined and drained to stormwater outlets. Consideration will need to be given to the offsite ecological impacts of diverting runoff (UP4) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban construction** • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Establish good drainage prior to construction in shrink/swell soils (UC4) • Ensure road construction is suitable for conditions (UC5) • New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options (UC6) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) **Urban vegetation** • Establish new vegetation using salt tolerant species (UV4)

Management areas	Action
MA5 (Lower slopes – colluvial)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) • Use geophysical techniques to define geological contact (EM survey) (UI2) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban construction** • Establish good drainage prior to construction in shrink/swell soils (UC4) • Ensure road construction is suitable for conditions (UC5) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas (UV3) • Establish new vegetation using salt tolerant species (UV4)
MA9 (Alluvial plain)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) **Urban construction** • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban management** • Minimise leakage of standing waterbodies, pools, lakes, and service pipes (UM1) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge site (UV1) • Establish new vegetation using salt tolerant species (UV4) **Riparian management** • Retain or re-establish areas of effectively vegetated riparian buffer zones to manage discharge areas (preferably salt tolerant indigenous vegetation) (RM1) • Maintain/re-establish effective vegetated riparian buffer zones (RM2)

Upper South Creek HGL

Overall hazard	Very High
Likelihood	High
Overall impact	Severe
Urban landscape management strategies	2,4,1,6
Targeted urban management strategies	UP, UI, UC, UV, UM, RM



Salinity expression

Land salinity	Land salinity is high. Some moderate to large (1–10 ha) salt sites occur in this landscape. These sites mostly occur on footslopes at the contact between Second Ponds Creek Soil Landscape and South Creek Soil Landscape. The salt sites are on the colluvial footslopes (often associated with irrigation) and in the upper colluvial areas (Blacktown Soil Landscape).
Salt load (export)	Salt export is high. High export driven by salt wash off and lateral throughflow and groundwater discharge into streams. Moderate to large salt sites contribute significant load.
Water EC (water quality)	Water EC is high. Ranges from 0.5–1.54 dS/m. Base flow EC generally brackish (1.6–4.8 dS/m).

Specific land management constraints

- Urban development activities may increase the rate of accumulation of salt in upland depressions and on lower colluvial slopes, potentially exacerbating land salinity impact in low lying areas.
- Seasonal waterlogging.
- The flat constricted alluvial plain area is highly sensitive. Disturbance of the area is likely to significantly increase erosion and increase recharge, which will mobilise salt to the adjacent stream.
- Plant species selection will require waterlogging tolerance.

Specific land management opportunities

- Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available.
- Deep-rooted trees and shrubs to intercept shallow groundwater will provide salinity control at seasonal salt sites as well as points of constriction.

Strategies for urban salinity management (refer to Appendix B)

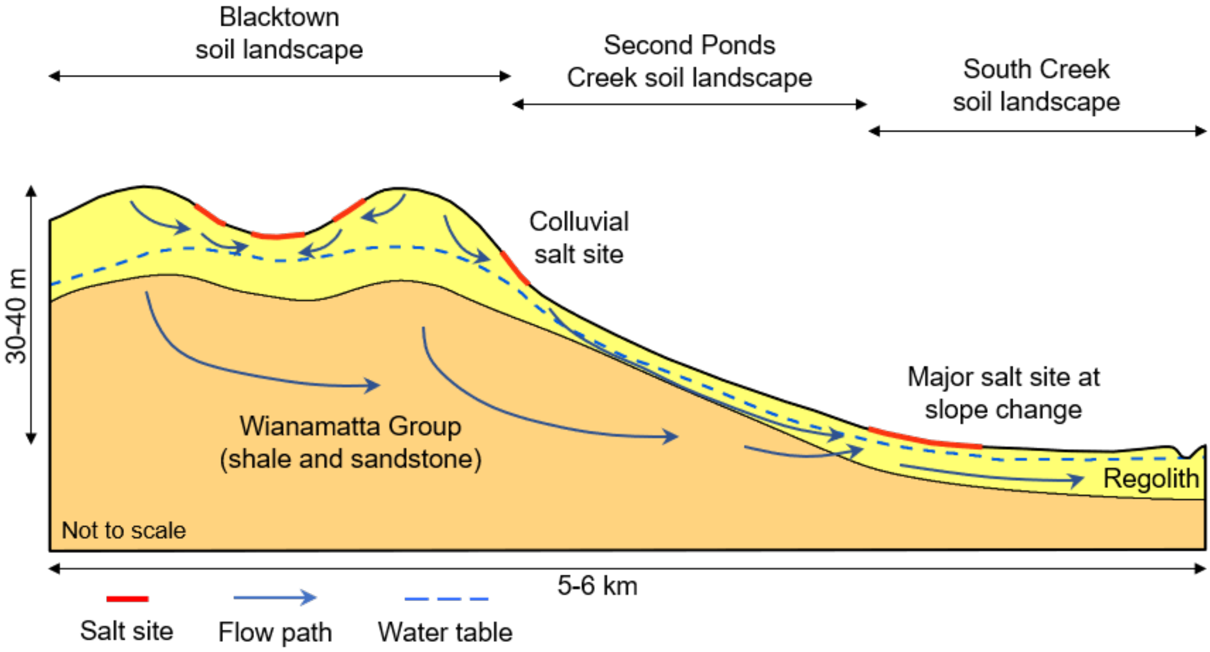
Urban landscape management strategies

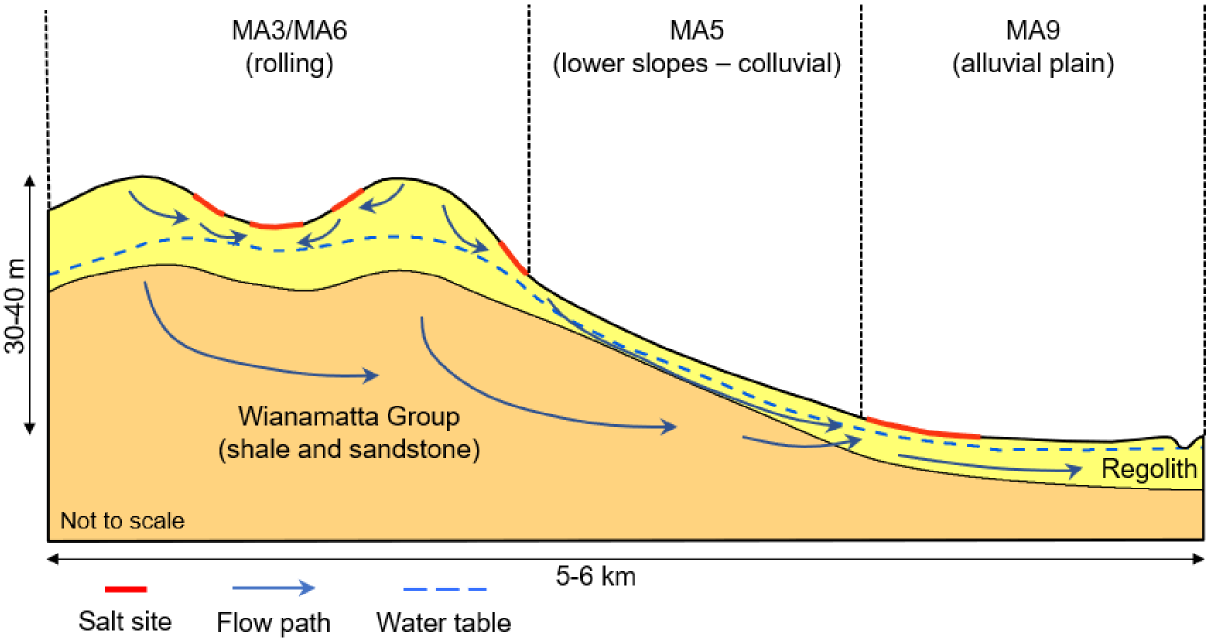
- **Intercept the lateral flow and shallow groundwater (2):** This HGL can target shallow water tables that exist at the contact between underlying geology and colluvial slopes. Rows of deep-rooted trees (8–30 rows) and shrubs can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater. Where tree rows are not an option, depending on local factors, 200 metre belts of actively growing deep-rooted shrubs and grassland may provide similar benefits.
- **Discharge rehabilitation (4):** The saline sites are numerous and variable in size. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Buffer the salt store (1):** There are stores of salt in discrete upper and lower colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy and comprise a significant percentage of this HGL.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Targeted urban management strategies (in priority order)

- **Urban planning (UP):** Planning of subdivision layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.
- **Urban investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. There are areas of sensitive sodic soils, particularly in drainage lines, that need to be identified.
- **Urban construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The typical slope gradient of this HGL requires careful consideration of depth of cut and location of roads on hillslopes; and all infrastructure, including underground utilities.
- **Urban vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Urban management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water requires careful management.
- **Riparian management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.

Conceptual cross-section and management areas





High hazard land use

There are some activities that should be discouraged in this HGL as they will have negative impacts on salinity.

At risk management areas	Action
MA5, MA3/MA6	• Avoid deep cut and exposure of susceptible soils during development when establishing infrastructure and dwellings
MA5, MA3/MA6, MA9	• Avoid obstruction to surface and sub-surface drainage that will cause wet areas creating waterlogging and salt mobilisation • Avoid activities that will increase recharge • Natural and induced salinity risk area – extensive investigations and planning are required

Management actions

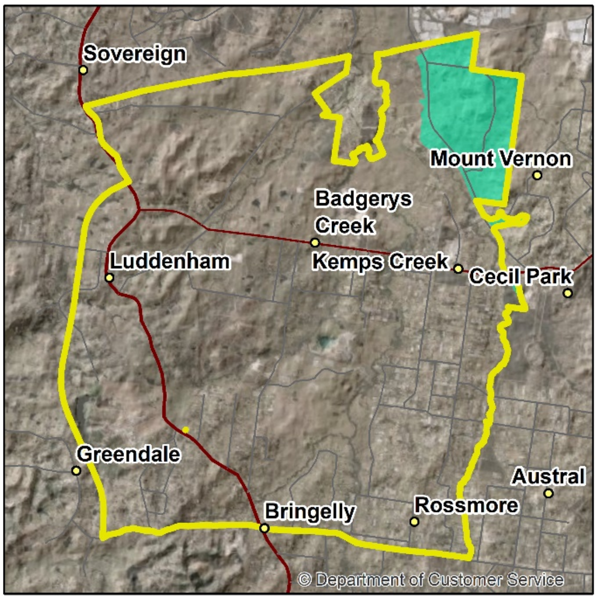
Urban salinity management actions to consider for specific management areas in this landscape are as follows:

Management areas	Action
MA3/MA6 (Rolling)	**Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • In areas where nearby GDEs are not reliant on recharge, maximise the size of impervious surfaces to prevent recharge of (perched) groundwater tables. Constructed pervious surfaces may need to be lined and drained to stormwater outlets. Consideration will need to be given to the offsite ecological impacts of diverting runoff (UP4) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) • Identify and manage sodic soils (UI3) **Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Establish good drainage prior to construction in shrink/swell soils (UC4) • Ensure road construction is suitable for conditions (UC5) • New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options (UC6) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant vegetation to manage recharge or discharge site (UV1) • Establish new vegetation using salt tolerant species (UV4) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawn (UM2)
MA5 (Lower slopes – colluvial)	**Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2)

Management areas	Action
	• Implementation of WSUD techniques consider the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) • Use geophysical techniques to define geological contact (EM survey) (UI2) **Urban construction** • Establish good drainage prior to construction in shrink/swell soils (UC4) • Ensure road construction is suitable for conditions (UC5) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas (UV3) • Establish new vegetation using salt tolerant species (UV4) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2)
MA9 (Alluvial plain)	**Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2) **Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban construction** • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge site (UV1) • Establish new vegetation using salt tolerant species (UV4) **Urban management** • Minimise leakage of standing waterbodies, pools, lakes and service pipes (UM1) **Riparian management** • Retain or re-establish areas of effectively vegetated riparian buffer zones to manage discharge areas (preferably salt tolerant indigenous vegetation) (RM1) • Maintain/re-establish effective vegetated riparian buffer zones (RM2)

Mount Vernon HGL

Overall hazard	Moderate
Likelihood	Moderate
Overall impact	Significant
Urban landscape management strategies	1,3,4,6
Targeted urban management strategies	UI, UP, UM, UC, UV, RM



Salinity expression

Land salinity	Land salinity is moderate. Numerous small salt outbreaks can occur in low lying lower slope and upper slope positions.
Salt load (export)	Salt load is moderate. Salty groundwater discharges into streams from relatively small catchment area and flow volume. The salt export impact of this HGL is moderate.
Water EC (water quality)	Water EC is high. Low quality and generally brackish water ranging from 1.9–3.9 dS/m.

Specific land management constraints

- Steep slopes may affect construction activities such as cut-and-fill and building of foundations.
- In unsewered areas, onsite wastewater disposal leakages may interact with landscape salt store to increase salinity hazard.
- Urban development activities may increase waterlogging and the rate of accumulation of salt on mid and lower slopes where salinity is already an issue.

Specific land management opportunities

- Local scale hydrological systems allow specific targeting of recharge with direct result on discharge. Pre-planning at the local scale will reduce the impact on the built environment.
- Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available in the lower landscape.
- Discharge management – integrated use of urban salinity management practices (salt resistant/resilient materials, water management) consistent with building codes would enable protection of infrastructure and dwellings in the lower landscape.

Strategies for urban salinity management (refer to Appendix B)

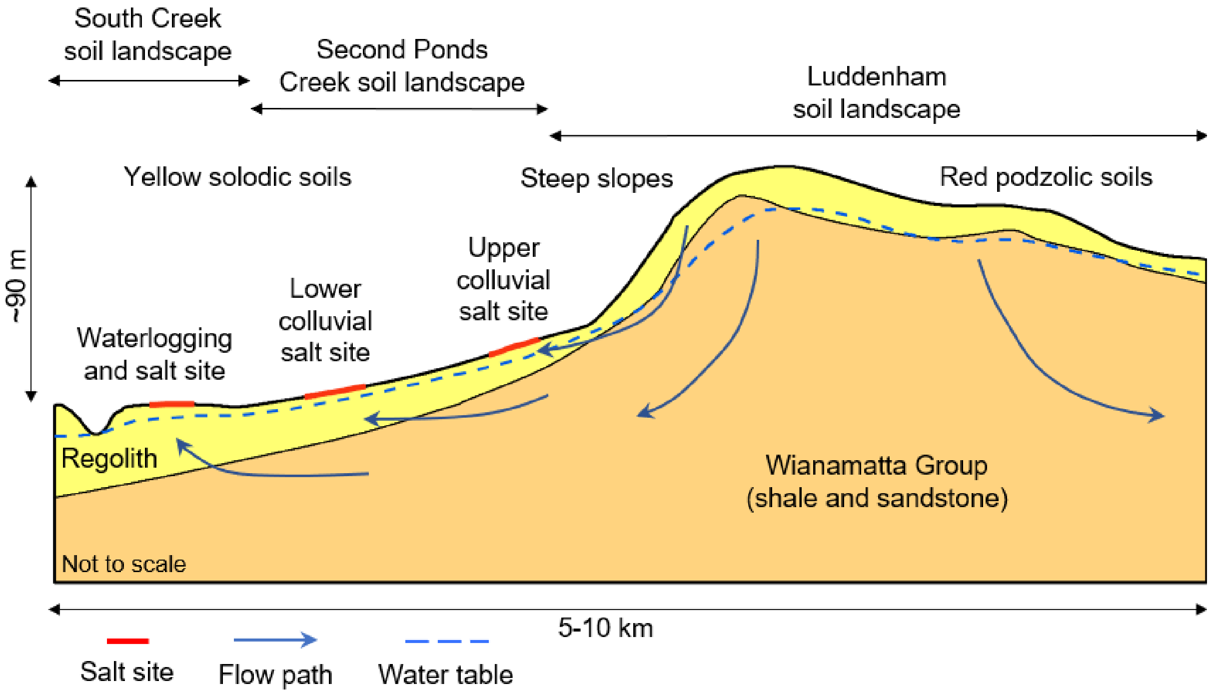
Urban landscape management strategies

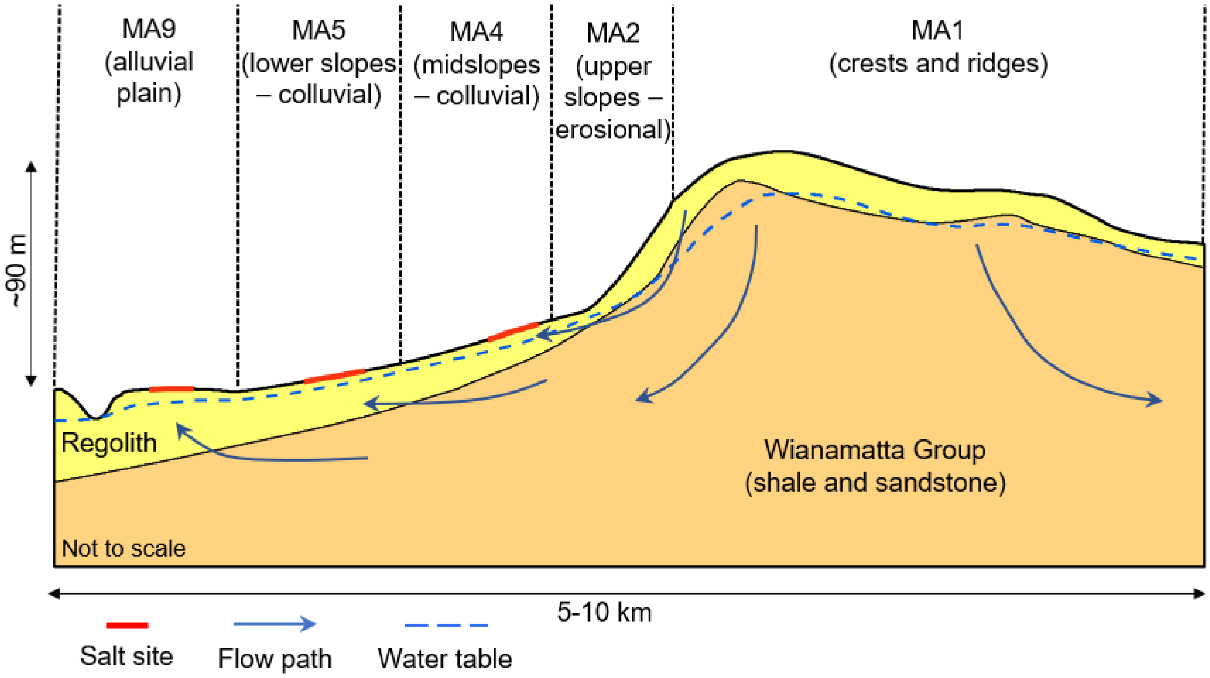
- **Buffer the salt store (1):** There are stores of salt in discrete upper and lower colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy and comprise a significant percentage of this HGL.
- **Stop discrete landscape recharge (3):** There are discrete elements of this landscape where specific recharge occurs.
- **Discharge rehabilitation (4):** The saline sites are small and numerous. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Targeted urban management strategies (in priority order)

- **Urban investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. There are areas of sensitive sodic soils, particularly in drainage lines, that need to be identified.
- **Urban planning (UP):** Planning of subdivision layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.
- **Urban management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water requires careful management.
- **Urban construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The typical slope gradient of this HGL requires careful consideration of depth of cut and location of roads on hillslopes; and all infrastructure, including underground utilities.
- **Urban vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Riparian management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.

Conceptual cross-section and management areas





High hazard land use

There are some activities that should be discouraged in this HGL as they will have negative impacts on salinity.

At risk management areas	Action
MA4, MA5, MA9	• Correct selection of vegetation species is required to effectively reduce amount of shallow groundwater salinity reaching the surface

At risk management areas	Action
MA5, MA9	• Avoid recharge through over-irrigation and onsite wastewater disposal leakages • Use salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) • Avoid obstruction to surface and sub-surface drainage that will cause wet areas creating waterlogging and salt mobilisation

Management actions

Urban salinity management actions to consider for specific management areas in this landscape are as follows:

Management areas	Action
MA1 (Ridges)	**Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) • In areas where nearby GDEs are not reliant on recharge, deep drainage should be minimised by maximising surface water runoff (UC2) • Establish good drainage prior to construction in shrink/swell soils (UC4) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage (UV3)
MA2 (Upper slopes – erosional)	**Urban planning** • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) **Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Ensure road construction is suitable for conditions (UC5) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2)
MA4 (Midslopes – colluvial)	**Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1)

<table>
<tr><th>Management areas</th><th>Action</th></tr>
<tr><td></td><td>

Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2)
Identification of discharge sites should influence the size of the area to be developed (UP3)
Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5)

Urban management

Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2)

Urban construction

Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1)
Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3)
Ensure road construction is suitable for conditions (UC5)
New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options (UC6)
Minimise the alteration of natural drainage patterns when constructing houses, roads, railways, channels, etc. (UC8)

Urban vegetation

Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge sites (UV1)
Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2)
Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage (UV3)

</td></tr>
<tr><td>MA5
(Lower slopes – colluvial)</td><td>
Urban investigations

Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1)

Urban planning

Prior to commencement of earthworks sodic/saline soils should be identified (UP1)
Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2)
Identification of discharge sites should influence the size of the area to be developed (UP3)
Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5)

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<table>
<tr><th>Management areas</th><th>Action</th></tr>
<tr><td></td><td>Urban management
Minimise leakage of standing waterbodies, pools, lakes and service pipes (UM1)
Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2)
Urban construction
In areas where nearby GDEs are not reliant on recharge, deep drainage should be minimised by maximising surface water runoff (UC2)
Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3)
Ensure road construction is suitable for conditions (UC5)
New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options (UC6)
Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7)
Minimise the alteration of natural drainage patterns when constructing houses, roads, railways, channels, etc. (UC8)
Urban vegetation
Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge sites (UV1)
Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2)
Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage (UV3)</td></tr>
<tr><td>MA9
(Alluvial plain)</td><td>Urban construction
Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7)
Urban vegetation
Establish new vegetation using salt tolerant species (UV4)
Riparian management
Retain or re-establish areas of effectively vegetated riparian buffer zones to manage discharge areas (preferably salt tolerant indigenous vegetation) (RM1)
Maintain/re-establish effective vegetated riparian buffer zones (RM2)</td></tr>
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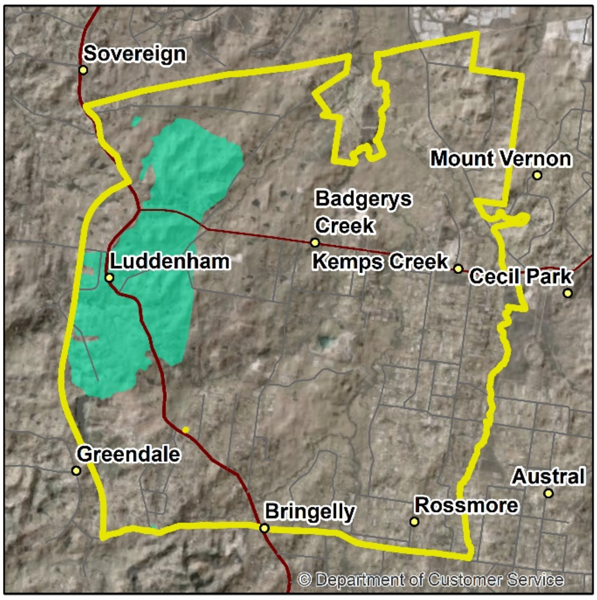
Mulgoa HGL

Overall hazard	Moderate
Likelihood	Moderate
Overall impact	Significant
Urban landscape management strategies	1,4,5,6
Targeted urban management strategies	UP, UV, UI, UM, RM, UC



Salinity expression

Land salinity	Land salinity is moderate. Frequent small salt sites in upper drainage lines. Minor salt sites do occur in the low lying low slope areas.
Salt load (export)	Salt export is moderate. Lateral throughflow and groundwater discharge into the Nepean River will contribute load, however the Nepean River will significantly dilute salt discharge emanating from this HGL.
Water EC (water quality)	Water EC is moderate. The internal drainage lines have moderate EC.

Specific land management constraints

- In unsewered areas, onsite wastewater disposal leakages may interact with landscape to increase salinity hazard.
- Steep slopes may affect construction activities such as cut-and-fill, building of foundations and retaining walls. Creation of barriers can increase localised accumulation of salt.

Specific land management opportunities

- Salt sites are small and easily remedied.
- Remnant vegetation – trees and shrubs will assist controlling waterlogging and will assist salinity control at small salt sites in upper drainage lines.

Strategies for urban salinity management (refer to Appendix B)

Urban landscape management strategies

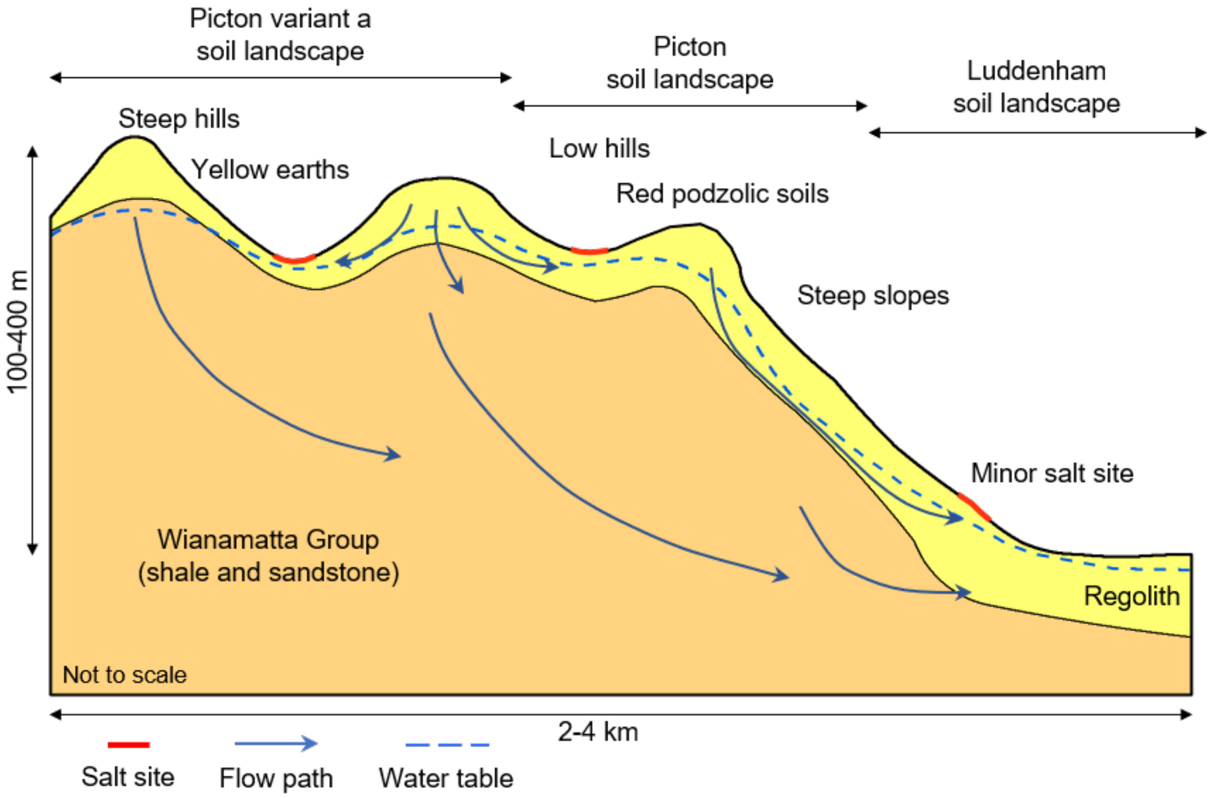
- **Buffer the salt store (1):** There are stores of salt in discrete upper and lower colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper erosional elements of the landscape associated with specific stratigraphy and comprise a significant percentage of this HGL.

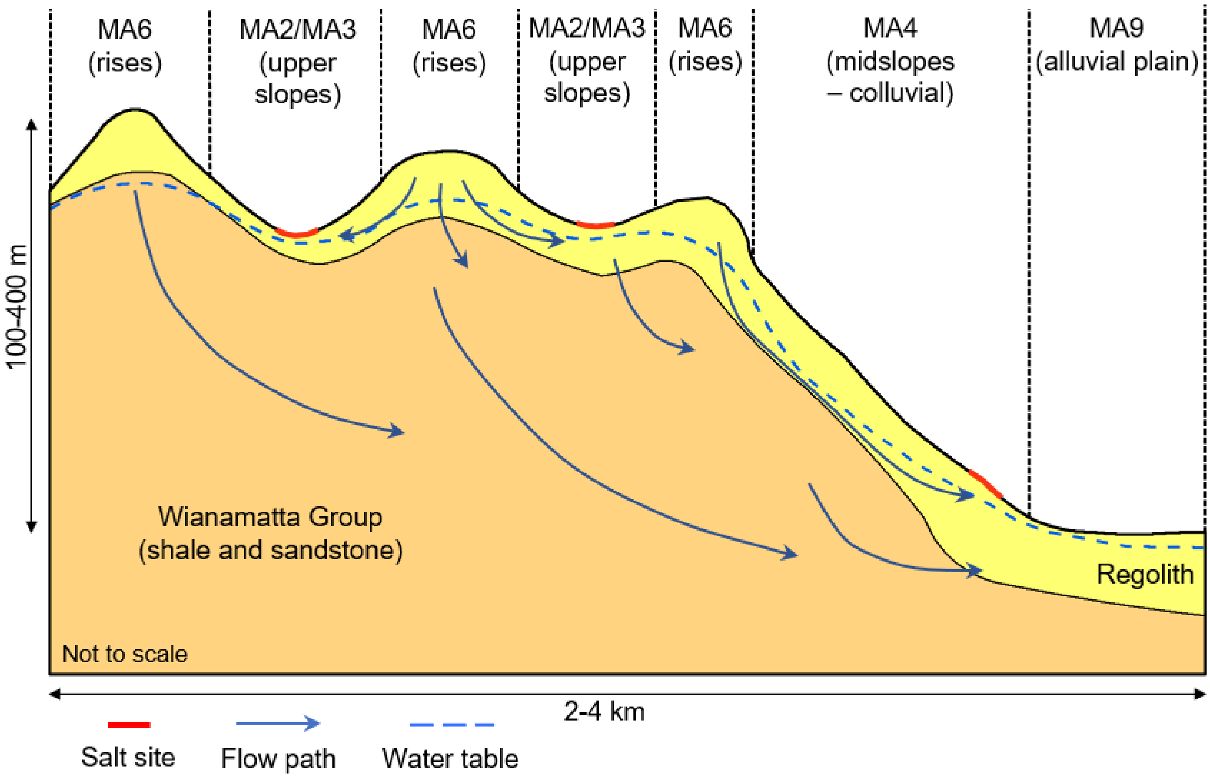
- **Discharge rehabilitation (4):** The saline sites are small in size and numerous. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Increase agricultural production to dry out the landscape and reduce recharge (5):** The area is currently mostly in agricultural or horticultural usage. There are significant native and introduced pastures in the area.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Targeted urban management strategies (in priority order)

- **Urban planning (UP):** Planning of subdivision layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.
- **Urban vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Urban investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. There are areas of sensitive sodic soils, particularly in drainage lines, that need to be identified.
- **Urban management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water requires careful management.
- **Riparian management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.
- **Urban construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The typical slope gradient of this HGL requires careful consideration of depth of cut and location of roads on hillslopes; and all infrastructure, including underground utilities.

Conceptual cross-section and management areas





High hazard land use

There are some management actions that should be discouraged in this HGL as they will have negative impacts on salinity.

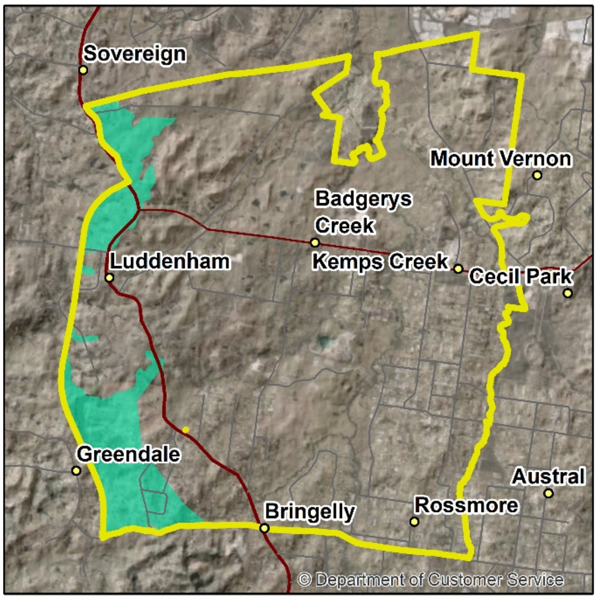
At risk management areas	Action
MA4, MA9	• Avoid obstruction to surface and sub-surface drainage that will cause wet areas creating waterlogging and salt mobilisation • Avoid recharge through over-irrigation and onsite wastewater disposal leakages

Management actions

Urbanisation was minimal in this HGL when the original Western Sydney HGL classification was undertaken. Hence specific urban salinity management actions were not derived for the HGL.

Greendale HGL

Overall hazard	High
Likelihood	High
Overall impact	Significant
Urban landscape management strategies	1,2,4,6
Targeted urban management strategies	UP, UI, UC, UM, UV, RM



Salinity expression

Land salinity	Land salinity is moderate. Frequent small seasonal salt sites may occur on the elevated low rises and on ponded areas.
Salt load (export)	Salt export is low. The lack of free-flowing drainage lines and associated higher recharge areas restricts salt export via surface water flows.
Water EC (water quality)	Water EC is moderate. Base flow and ponded water EC generally marginal (0.2–1.8 dS/m). Increased EC in ponds may occur during dry periods. The impact of salt on water quality is moderate (localised).

Specific land management constraints

- Urban development activities may increase waterlogging and the rate of accumulation of salt on elevated upper and lower slopes where salinity is already an issue.
- In unsewered areas, onsite wastewater disposal leakages may interact with landscape salt stores to increase salinity hazard.
- Seasonal waterlogging is an issue in upper landscape elements.
- Urbanisation of areas currently under peri-urban land use will increase the recharge potential.

Specific land management opportunities

- Isolated salt sites in the upper landscape are of manageable size.
- Discharge management – deep-rooted trees and shrubs are likely to be effective in this landscape if correct species are selected based on salinity tolerance. There is an abundance of shallow groundwater available.
- Discharge management – integrated use of urban salinity management practices (salt resistant/resilient materials, water management) consistent with building codes would enable protection of infrastructure and dwellings in the lower landscape.

Strategies for urban salinity management (refer to Appendix B)

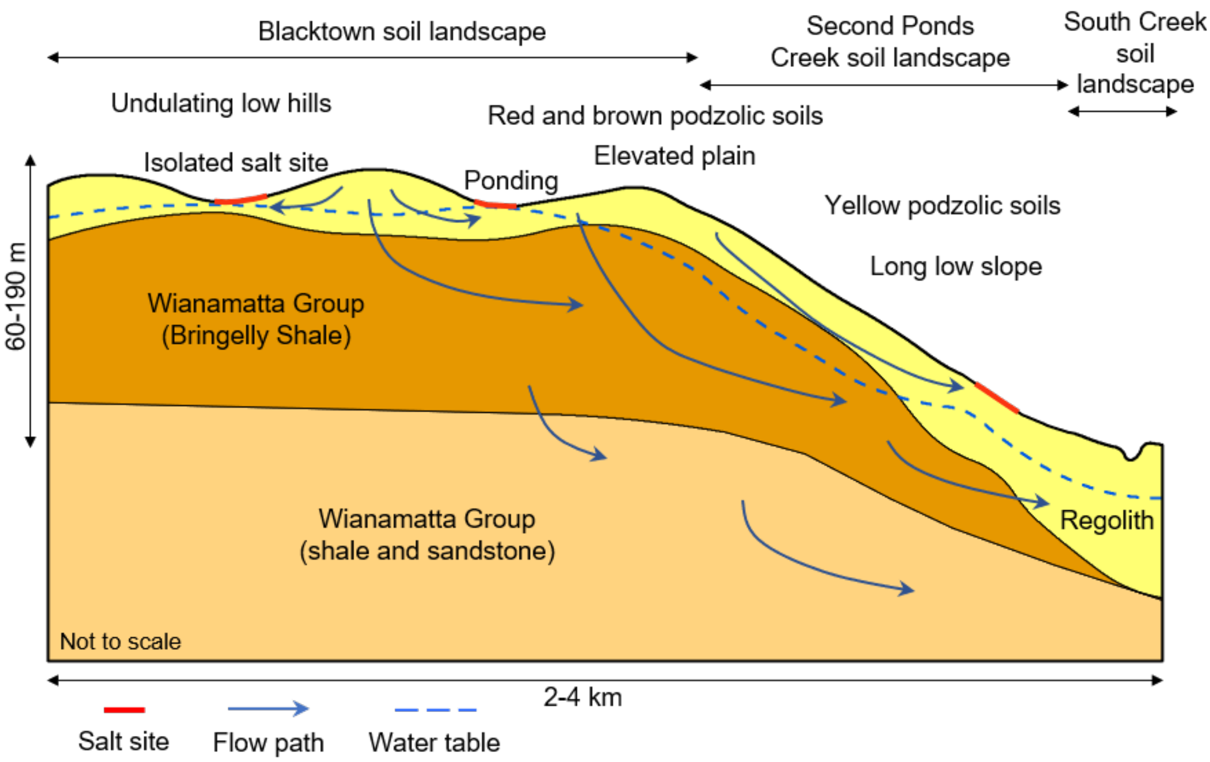
Urban landscape management strategies

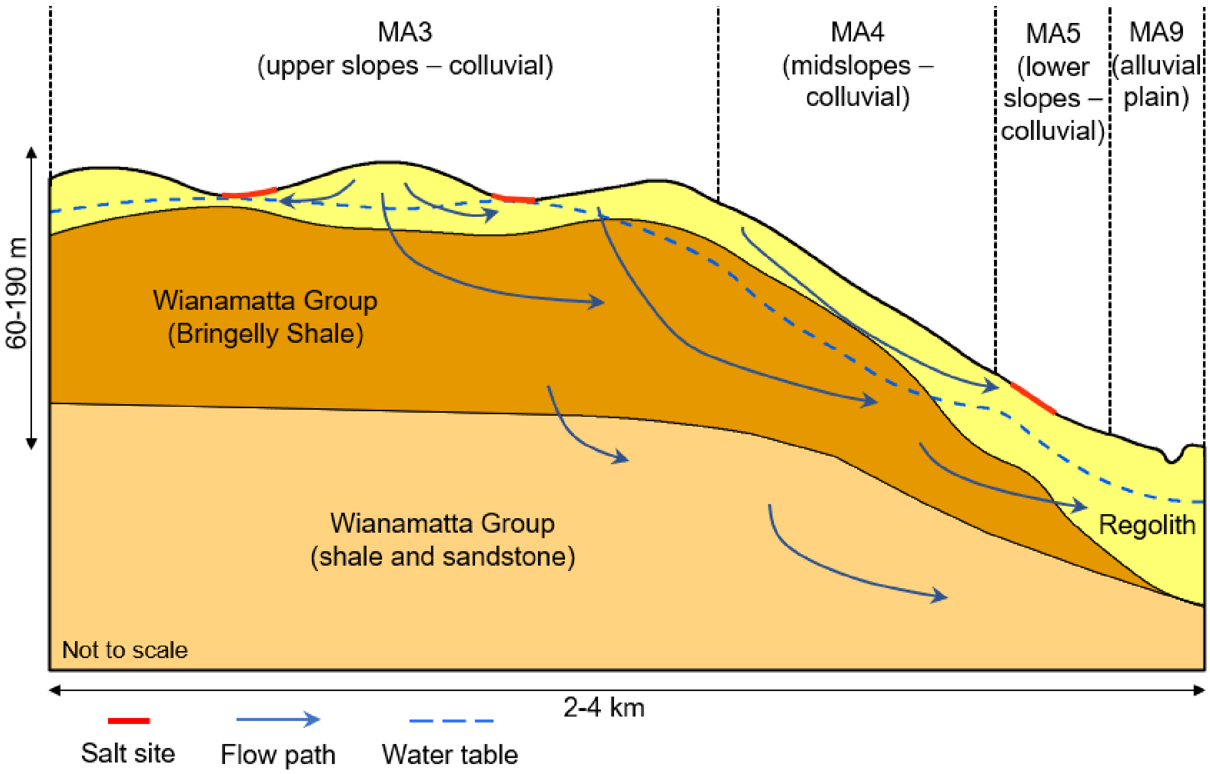
- **Buffer the salt store (1):** There are stores of salt in discrete upper and lower colluvial areas, which vegetation can buffer, limiting the salinity impact. They are generally in the upper elements of the landscape controlled by regolith depth.
- **Intercept the lateral flow and shallow groundwater (2):** This HGL can target shallow water tables that exist at the upper and lower colluvial slope elements and where the regolith is shallow. Rows of deep-rooted trees (8–30 rows) and shrubs can be effective in interception of lateral flow. Rooting depth will intercept shallow groundwater in the upper part of the landscape. Where tree rows are not an option, depending on local factors, 200 metre belts of actively growing deep-rooted shrubs and grassland may provide similar benefits.
- **Discharge rehabilitation (4):** The saline sites are small and numerous. Discharge management will reduce salt discharge to streams when species' salt tolerances are matched to salt site intensity.
- **Dry out the landscape with diffuse actions over most of the landscape (6):** Maximise plant growth and water use to use excess soil moisture and shallow groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

Targeted urban management strategies (in priority order)

- **Urban planning (UP):** Planning of subdivision layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.
- **Urban investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. There are areas of sensitive sodic soils, particularly in drainage lines, that need to be identified.
- **Urban construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The typical slope gradient of this HGL requires careful consideration of depth of cut and location of roads on hillslopes; and all infrastructure, including underground utilities.
- **Urban management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water requires careful management.
- **Urban vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Riparian management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.

Conceptual cross-section and management areas





High hazard land use

There are some activities that should be discouraged in this HGL as they will have negative impacts on salinity.

At risk management areas	Action
MA3, MA4, MA5, MA9	• Avoid recharge that leads to waterlogging through over-irrigation and onsite wastewater disposal leakages • Correct selection of vegetation species is required to effectively reduce amount of shallow groundwater salinity reaching the surface
MA5, MA9	• Avoid recharge through over-irrigation and onsite wastewater disposal leakages • Avoid obstruction to surface and sub-surface drainage that will cause wet areas creating waterlogging and salt mobilisation

Management actions

Urban salinity management actions to consider for specific management areas in this landscape are as follows:

Management areas	Action
MA3 (Upper slopes – colluvial)	**Urban planning** • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2) • Identification of discharge sites should influence the size of the area to be developed (UP3) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Ensure road construction is suitable for conditions (UC5) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawn (UM2) **Urban vegetation** • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2)
MA4 (Midslopes – colluvial)	**Urban planning** • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2) • Identification of discharge sites should influence the size of the area to be developed (UP3)

Management areas	Action
	• Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban construction** • Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline (UC1) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) **Urban management** • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge sites (UV1) • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage (UV3)
MA5 (Lower slopes – colluvial)	**Urban planning** • Prior to commencement of earthworks sodic/saline soils should be identified (UP1) • Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs (UP2) • Identification of discharge sites should influence the size of the area to be developed (UP3) • Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue (UP5) **Urban investigations** • Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard (UI1) **Urban construction** • In areas where nearby GDEs are not reliant on recharge, deep drainage should be minimised by maximising surface water runoff (UC2) • Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging (UC3) • Ensure road construction is suitable for conditions (UC5) • Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services) (UC7) • Minimise the alteration of natural drainage patterns when constructing houses, roads, railways, channels, etc. (UC8)

Management areas	Action
	Urban management • Minimise leakage of standing waterbodies, pools, lakes and service pipes (UM1) • Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns (UM2) • Manage plant growth to maximise water usage (UM3) **Urban vegetation** • Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge sites (UV1) • Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas (UV2) • Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage (UV3)
MA9 (Alluvial plain)	**Urban vegetation** • Establish new vegetation using salt tolerant species (UV4) **Riparian management** • Retain or re-establish areas of effectively vegetated riparian buffer zones to manage discharge areas (preferably salt tolerant indigenous vegetation) (RM1) • Maintain/re-establish effective vegetated riparian buffer zones (RM2)

Appendix B: Urban salinity management

In an urban environment, the appropriate management strategy and priority for an action should be applied at a local spatial scale.

The following sequence is used in each HGL unit:

urban landscape management strategy > targeted urban management strategy > management area > urban management action

Urban landscape management strategies

Urban salinity management is guided by the broad landscape management strategies as described in Wooldridge et al. (2015), adjusted to be more appropriate for specific urban situations (Table 3). This table presents all the management strategies available. Not all will be suitable for HGLs in the Aerotropolis area. A strategy that delivers positive outcomes for one HGL may have negative impacts when used in a different HGL.

Each HGL will have a different combination of strategies that are suitable. **The appropriate urban landscape management strategies for each HGL in the Aerotropolis area are indicated in Table 2 and in Appendix A**.

Table 3 Urban landscape management strategies

Strategy	Description
1	Buffer the salt store – keep it dry and immobile
2	Intercept shallow lateral flow and shallow groundwater
3	Stop discrete landscape recharge
4	Rehabilitate and manage discharge
5	Increase agricultural production to dry out the landscape and reduce recharge
6	Dry out the landscape with diffuse actions over most of the landscape
7	Access and use groundwater to change the water balance
8	Maximise recharge to dilute water tables with engineering actions
9	Minimise recharge with engineering actions
10	Maintain or maximise runoff
11	Manage and avoid acid sulfate hazards

Targeted urban management strategies

These strategies are used to target activities in each HGL. They recognise the need for diffuse and specific activities within the landscape that are required to impact on salinity issues.

Targeted urban management strategies are grouped into six areas of activity:

- **Urban investigations (UI)**: The landscape contains significant salinity, and geological situations that predispose it to salinity development. Assessment of the location, intensity and scale of salinity is needed. Identification of extreme salinity is needed.
- **Urban planning (UP)**: Planning of subdivision layout and design is required to manage salinity consequences. Development should not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and WSUD.

- **Urban construction (UC)**: Construction on saline land will require salt resistant/resilient materials. The salinities encountered in this HGL require careful consideration of construction method, depth of cut and location of roads, and all infrastructure including underground utilities.
- **Urban management (UM)**: The input of water into the landscape (from lawns, gardens, sporting fields), including the management of recycled water, requires careful management.
- **Urban vegetation (UV)**: Maintain and enhance vegetation (including remnant vegetation) for the management of recharge and as a buffer to excess water input. Waterwise gardening should be encouraged in residential areas.
- **Riparian management (RM)**: Vegetation management in riparian areas will assist in minimising salt export to streams.

Urban management action priorities will vary in importance between HGLs in the Aerotropolis area as indicated in Table 4.

Table 4 Targeted urban management strategy group priorities for Western Sydney HGLs in the Aerotropolis area

Urban HGLs	Targeted urban management strategy group (in priority order)
Shale Plains HGL	UI, UP, UC, UM, UV, RM
Upper South Creek HGL	UP, UI, UC, UV, UM, RM
Mt Vernon HGL	UI, UP, UM, UC, UV, RM
Mulgoa HGL	UP, UV, UI, UM, RM, UC
Greendale HGL	UP, UI, UC, UM, UV, RM

Urban management actions

Specific urban management actions are assigned to appropriate management areas, ensuring that salinity management options used give optimal outcomes across the urban landscape.

The applicability of a management action may vary. Sometimes the action is very suitable for delivering one strategy but unsuited to delivering a different strategy. Similarly, a management action that is suitable for salinity management in one landscape may be unsuitable or ineffective in another. Combinations of urban management actions are tailored in accordance with the urban management strategy objectives.

The **key to urban salinity management using the HGL framework is to match the specific actions to the appropriate management area.** As an example, a key urban management action priority for slope areas and the alluvial plain of the Upper South Creek HGL is **urban planning (UP)**, specifically **UP1**. In this case, sodic/saline soils should be identified prior to starting earthworks.

The urban management actions of each targeted urban management strategy group are described in Table 5. This table presents all the management actions available; not all will be suitable for every HGL in the Aerotropolis area.

The appropriate urban management actions to apply to specific management areas in each HGL in the Aerotropolis area are described in Appendix A.

Table 5 Targeted urban management strategy groups and associated actions for Western Sydney HGLs in the Aerotropolis area

Targeted urban management strategy group	Code	Management action
Urban planning	UP1	Prior to starting earthworks, sodic/saline soils should be identified
	UP2	Minimise use of infiltration and detention of stormwater in hazard areas; consider lining of detention systems to prevent infiltration. Reconsider WSUD implications in relation to salinity management and potential impact on nearby GDEs
	UP3	Identification of discharge sites should influence the size of the area to be developed
	UP4	In areas where nearby GDEs are not reliant on recharge, maximise the size of impervious surfaces to prevent recharge of (perched) groundwater tables. Constructed pervious surfaces may need to be lined and drained to stormwater outlets. Consideration will need to be given to the offsite ecological impacts of diverting runoff
	UP5	Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity effects are an issue
Urban investigations	UI1	Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard
	UI2	Use geophysical techniques to define geological contacts (EM survey)
	UI3	Identify and manage sodic soils
Urban vegetation	UV1	Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge site
	UV2	Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas
	UV3	Develop native landscaping and waterwise gardens to reduce over-irrigation and water usage
	UV4	Establish new vegetation using salt tolerant species
	UV5	Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas
Urban construction	UC1	Minimise depth of cut and exposure in susceptible soils during development. Ensure fill material interface is not saline
	UC2	In areas where nearby GDEs are not reliant on recharge, deep drainage should be minimised by maximising surface water runoff
	UC3	Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid waterlogging

Targeted urban management strategy group	Code	Management action
	UC4	Establish good drainage prior to construction in shrink/swell soils
	UC5	Ensure road construction is suitable for conditions
	UC6	New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or incorporating open space options
	UC7	Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services)
	UC8	Minimise the alteration of natural drainage patterns when constructing houses, roads, railways, channels, etc.
Urban management	UM1	Minimise leakage of standing waterbodies, pools, lakes and service pipes
	UM2	Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns
	UM3	Manage plant growth to maximise water usage
Riparian management	RM1	Retain or re-establish effectively vegetated riparian buffer zones to manage discharge areas (preferably with salt tolerant indigenous vegetation)
	RM2	Maintain/re-establish effective vegetated riparian buffer zones

High hazard land use

High hazard land uses have a range of impacts that have a negative outcome in the landscape. Salinity processes will intensify, and salt mobilisation will be increased due to:

- lowered evapotranspiration/plant water use
- rising and high water tables
- changed water balance and surface water management requirements.

High hazard land uses range in their importance across different landscapes and across different management areas. They can have the following negative outcomes:

- lower plant water use leading to more recharge
- increased hydraulic head
- lower surface water runoff leading to less dilution flow in streams
- limited conditions for soil water storage
- limited conditions for plant water use
- damage to infrastructure
- adding salt to soil profile.

Appendix C: Determining the potential impact of land use changes and management actions on water dependent ecosystems

Altering the hydrology and/or the hydrogeology that supports a water dependent ecosystem will affect its long-term survival. A rapid decline in water table levels can result in an immediate and complete collapse of particularly sensitive ecosystems such as wetlands (Le Maitre et al. 1999). For other ecosystems, a community's response to water level declines can be more subtle. For example, a decline in water tables can prevent seedling recruitment and alter vegetation dynamics with little obvious impact in the short term, but can completely change the vegetation community composition in the long term (Le Maitre et al. 1999).

Similarly, a change to the quality of water (e.g. increase in salt loads) could dramatically affect ecosystem functioning, persistence and resilience. Changes to species composition could occur, and potentially any fauna that might be especially dependent on the current environmental conditions. **If groundwater becomes too salty it is likely plants will not use that water. Water dependent ecosystems within the Western Sydney Aerotropolis area largely depend on fresh water or in some areas, moderately saline water**.

The ecosystems at most risk from saline discharge are those that occur in the lowest topographic positions in the landscape such as riparian zones, floodplains, and wetlands, both fresh and naturally saline. For continued survival, wetland vegetation often relies on the regular flushing of salt from the root zone. A change in hydrology that leads to the constant presence of a shallow saline water table could reduce the leaching of salt from the root zone and cause a decline in vegetation health (Cramer & Hobbs 2002). Wetlands that form terminal systems (those that hold water after flood flows have receded) are potentially at greater risk than flow-through systems as evaporation from terminal systems will result in high salt concentrations in the remaining body of water and in the surrounding soil (Smith et al. 2006)

The raising of groundwater levels by over-irrigation can cause the transport of salt to the surface resulting in the development of shallow saline groundwater. This in turn can cause salinisation of the plant root zone and subsequent collapse of the ecosystem.

The discharge and disposal of saline groundwater into streams and other water dependent ecosystems as a result of elevated groundwater levels can contribute to increased salt concentrations within these ecosystems. Saline groundwater discharge into streams can result in the formation of saline pools (haloclines) in the floor of streams, i.e. salty water lying under a freshwater layer. These pools, once fed by relatively fresh groundwater, turn anoxic (oxygen depleted) and can no longer act as refuges for aquatic fauna during periods of low or no flow. Flushing of these pools during high flow events may also send a pulse of highly saline de-oxygenated water along the stream which may affect sensitive aquatic species (SKM 2001).

In areas with high salinity, water movement needs to be managed across the whole landscape. Recharge should be kept to a minimum to meet the flow requirements of the water dependent ecosystems, and excess infiltration should be intercepted before it reaches discharge areas and flow lines. Management actions suggested for salinity (Table 5) can have a significant impact on groundwater dependent vegetation, wetlands and other water dependent ecosystems. Some management actions will therefore be inappropriate in certain areas of the landscape. These impacts are considered when recommending specific management actions for each of the HGL units considered in Appendix A.

Finer scale soil and HGL assessment is required to be able to spatially map where to target actions in the landscape, and to avoid using actions that will have detrimental impacts. It is imperative that the impact of the overall salt loading to the groundwater and surface water (waterways) ecosystems be considered.

Table 6 provides a checklist to determine the extent of impact (high, moderate or low) of land use activities and/or management actions on water dependent ecosystems.

What are our solutions?

- Prioritise management strategies and options to protect the high ecological value water dependent ecosystems
- Undertake a detailed assessment of impacts on high ecological value water dependent ecosystems as part of the development
- Undertake a cumulative impact assessment of all water dependent ecosystems within the boundary of the Western Sydney Aerotropolis, with a focus on changes to water quality and water quantity
- Plant deep-rooted vegetation that is salt tolerant
- Ensure stormwater management actions achieve the water quality and flow objectives recommended by the NSW Government
- Apply a risk assessment framework, such as the Risk-based Framework for considering waterway health outcomes in strategic land-use planning decisions (Dela-Cruz et al. 2017)

Table 6 Impacts of land use activities and/or management actions on water dependent ecosystems*

	High impact	Moderate impact	Low impact
Changes to water quantity			
What will be the risk of a change in water levels on the water dependent ecosystem?	Reduction in water levels beyond seasonal variation, resulting in permanent loss or alteration of the defined water dependent ecosystem	Reduction in water levels beyond seasonal variation, resulting in temporary loss or alteration of the defined water dependent ecosystem	No change to water levels
What will be the risk of a change in the timing or magnitude of water level fluctuations on the water dependent ecosystem?	Fluctuation in water levels beyond established seasonal variation, resulting in permanent loss or alteration of the defined water dependent ecosystem	Fluctuation in water levels beyond seasonal variation, resulting in temporary loss or alteration of the defined water dependent ecosystem	No change in timing and magnitude of water level fluctuations
What will be the risk of changing base flow conditions (quantity/direction) on ecosystems dependent on that water?	Permanent reversal of base flow conditions	Temporary reversal of base flow conditions exceeding seasonal variation	No change in baseflow conditions

	High impact	Moderate impact	Low impact
Changes to water quality			
What is the risk of changing the chemical conditions of water?	Permanent change in parameters such as pH, dissolved oxygen, nutrients, temperature, turbidity or salinity	Temporary change	Negligible change (<5%)
Changes to aquifer integrity			
What is the risk of damage to the geologic structure?	Permanent destruction of the aquifer matrix. Major cracking/ fracturing of the bedrock/stream bed leading to complete dewatering of the GDE	Temporary adjustment to the aquifer matrix. Minor cracking/ fracturing of the bedrock/stream bed leading to partial dewatering of the GDE	No change
Changes to biological integrity			
What is the risk of alterations to the number of native species within the water dependent communities (fauna and flora)?	>10% reduction in number of species	10–5% reduction in number of species	No reduction in number of species
What is the risk of alterations to the species composition of the water dependent communities (fauna and flora)?	>10% change in species composition	10–5% change in species composition	No change in species composition
What is the risk of increasing the presence of exotic flora or fauna?	Large populations of one or more species	Species in small numbers	None exist
What is the risk of removing or altering the water dependent ecosystem habitat?	>20% removal or alteration of habitat area	10–20% removal or alteration of habitat area	No removal or alteration of habitat area

* adapted from *Risk assessment guidelines for groundwater dependent ecosystems, Volume 1 – The conceptual framework* (Serov et al. 2012)