Site Salinity Management Guidelines

SITE – SPECIFIC ASSESSMENT AND MANAGEMENT OF URBAN SALINITY RISKS

- Prepared for Mildura Rural City Council
- 2009 Revised Version
- 4 June 2009

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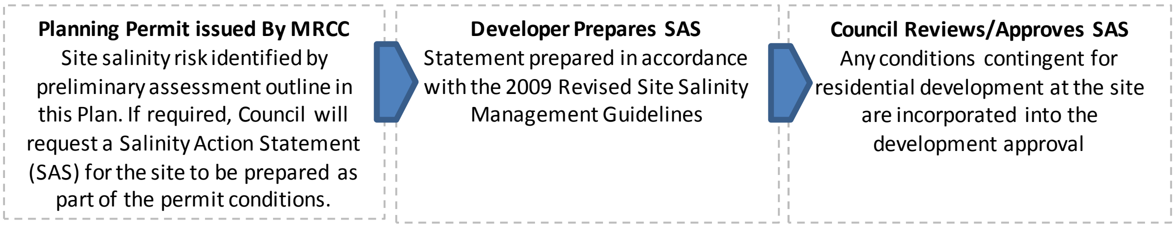
1 Introduction

This Site Salinity Management Guidelines presents the information to understand, identify and manage the potential risks associated with salinisation in the area of proposed urban expansion in Mildura. The information contained in this document is founded on the physical processes that cause urban salinity and was specifically developed from soil and groundwater data collected throughout the area of proposed urban expansion in the Mildura region.

This Plan has been prepared for use by developers and Council to guide decisions on the suitability of land for urban development and provides the salinity management actions required for development to proceed in areas that have a recognised risk of urban salinity. Figure 1.1 provides a brief overview of the role of this Plan in the site development approval process.

Figure 1.1 Role of Site Salinity Management Guidelines



Proposed urban expansion to the year 2030 in the Mildura region is planned to occur to the south west of the current Mildura urban area and in the Irymple and Nichols Point areas as illustrated in Figure 1.

1.1 Context of Urban Salinity in Mildura

Mildura is one the fastest growing regional centres in Victoria. Concerns about urban salinisation have arisen in Mildura in response to the recent trend of urban development into areas of land previously used for irrigated viticulture and dryland farming. The impacts of salinity in an urban environment can include deterioration of infrastructure including housing foundations, paths, roads, underground services and the degradation and eventual loss of vegetation.

As was the case when deep-rooted native vegetation was originally cleared to make way for agriculture, a land use change from agricultural to urban residential can result in significant implications for the water balance of the land. The change from native vegetation to irrigated agriculture resulted in a large increase in the amount of water moving below the plant root zone and recharging the underlying groundwater. The effects of this excess soil water can manifest in a twofold way:

- **Regional Groundwater**: Ultimately the excess water recharges the underlying regional groundwater and over time causes this naturally saline groundwater to rise towards the land surface. Salinisation can occur when the groundwater level rises to the extent where the capillary fringe zone[1] intersects the soil surface and salts accumulate by evaporation of groundwater. In Mildura, the degraded land in the low-lying areas adjacent to Lake Ranfurly and Lake Hawthorne are a good example of the effects of saline groundwater.

[1] The capillary fringe is the zone immediately above the groundwater level into which water may be drawn upward as a consequence of surface tension forces between the water and the soil particles, known as ‘capillary action’. When the capillary zone intersects the soil surface water can move to the soil surface via the effects of surface evaporation and dissolved salts, which are not removed by evaporation, may become concentrated at the soil surface. The height of the capillary fringe zone varies for different soil types, with sandy soils having a smaller capillary fringe (eg. 0.5 - 1.0 m) and finer textured soils such as clayey soils having a larger capillary fringe (eg. approximately 2.0 m).

- **Perched Groundwater**: In areas where a low permeability clay horizon is present in the soil profile, excess water can accumulate on top of the clay layer causing a perched groundwater layer to develop. Although perched groundwater is generally less saline than regional groundwater, waterlogging and salinity impacts can occur when the capillary fringe zone of the perched groundwater intersects the soil surface. Subsurface clay occurs extensively throughout the Mildura area and the necessity to manage perched groundwater has long been recognised by the widespread use of tile drainage beneath irrigated vineyards.

1.2 Groundwater in the Mildura Region

Multiple groundwater units exist across the Mildura region as detailed below:

- **Perched aquifers** (where encountered) is the first water layer encountered and overlies the Blanchetown Clay formation. Perched aquifers are generally encountered less than 4.0m below ground level (bgl) across the Mildura region and are commonly associated with irrigated horticulture. Perched aquifer systems are often ephemeral.
- The **Blachetown Clay** formation contains the permanent regional water table within the Mildura region and is characterised as a low permeability formation. The Blanchetown Clay formation is also referred to as an aquitard.
- The **Loxton-Parilla Sands** formation occurs beneath the Blanchetown Clay formation and is characterised as a permanent, regional aquifer unit.

For comparative purposes, the salinity ranges of regional groundwater, perched groundwater, the River Murray and seawater are provided in Table 1.1.

Table 1.1 Salinity Ranges

	Salinity (Total Dissolved Solids)
Regional Groundwater – Blanchetown Clay Formation	Up to 60,000 mg/L*
Perched Groundwater	Up to 10,000 mg/L*
Murray River @ Mildura Weir	Less than 100 mg/L
Seawater	Approximately 33,000 mg/L
Generally acceptable drinking water upper limit	1000 mg/L

*based on data from Salinity Action Statements compiled since 2004

Throughout the Mildura region, variation in depth to regional groundwater is predominantly dependent on the surface elevation variation. Thus in low lying areas such as those surrounding Lake Ranfurly, regional groundwater is encountered at shallow depths consistent with the depression of the local landscape.

1.3 Groundwater and Residential Landuse

An assessment of the potential for urban salinisation must be grounded on a site-specific understanding of the factors that cause urban salinisation and must necessarily focus on effects that may occur in the future given the physical site characteristics and likely water use and management practices. In the case of residential land use there is potential for excess soil water to be generated by over irrigation of lawns and gardens, in situ recharge of stormwater and onsite disposal of household grey water.

In light of the preceding discussion, urban salinisation may develop where:

- Regional groundwater approximates 2.0 m bgl;

- Perched groundwater occurs on top of a subsurface clay layer, where the depth to clay is less than the threshold level of 4 m bgl; and
- Inappropriate management of either regional or perched groundwater resulting in groundwater levels rising beyond maximum acceptable levels.

Adequate assessment of the urban salinity risk associated with a proposed residential development should include determination of the site-specific soil and groundwater conditions, and subsequent salinity management measures should be developed to address the identified risk.

1.4 Background to the Guidelines

In response to the threat of urban salinity in the Mildura region, the original 2004 Site Salinity Management Plan (REM, 2004) was developed to assess the potential risk of urban salinisation in areas proposed for urban development. The tool uses soil and groundwater information specific to the Mildura area to provide a consistent method for making a preliminary assessment of the level of urban salinity risk for proposed urban developments. The levels of risk range from low to very high according to the assessed potential for regional groundwater and/or perched groundwater to impact on urban development. The five levels of risk were defined as follows:

Low: Groundwater is below the threshold level of 4 m bgl and a clay layer does not occur shallower than the 4 m bgl threshold for perched groundwater potential. The resulting risk of urban salinisation is low and, in this context, this land would be most suitable for development.

Moderate: Groundwater is below the threshold level of 4 m bgl and a clay layer is present in the upper 4 m of the soil profile. While regional groundwater is not a concern in these areas, there is potential for perched groundwater to develop on top of the clay layer, which presents a considerable hazard to urban development. These areas have been assigned a moderate risk level because the hazard is relatively easy to manage with the installation of a suitable drainage system.

High(a): Groundwater is 2 - 4 m bgl and the clay does not occur shallower than the 4 m bgl threshold for perched groundwater potential. In these areas groundwater is within the zone of concern for urban development and although not currently causing salinisation, poor water management could rapidly cause the onset of saline conditions. Regional groundwater is more difficult to manage and is therefore associated with a high risk category.

High(b): Groundwater is 2 - 4 m bgl and there is potential for perched groundwater to develop on top of a clay layer in the upper 4 m of the soil profile. In addition to the hazard of perched groundwater, regional groundwater is within the zone of concern for urban development and although not currently causing salinisation, poor water management could rapidly cause the onset of saline conditions.

Very High: Groundwater is less than 2 m bgl. In these areas shallow saline groundwater is an immediate threat to urban development and some land may have already become salinised. The presence of salt tolerant plant species, would automatically classify the affected land with a very high level of risk.

Associated with each of these risk levels are specific salinity risk management actions that will ensure that urban development will not be adversely impacted, both onsite and offsite, in the future.

1.5 Purpose of the Guidelines

These Site Salinity Management Guidelines provides a framework for urban development in areas where there is potential for salinisation. The plan details the key steps required to assist in identifying the site-specific level of urban salinity risk and the subsequent actions to address the identified level of risk.

2 How To Use the Guidelines

The site-specific level of urban salinity risk for a proposed urban development can be identified and managed by applying the following key steps. This process is illustrated by the decision flow diagram presented in Figure 2.

2.1 Application of the Guidelines

2.1.1 Step 1: Application of Preliminary Assessment Tool

The first step is to use the preliminary assessment tool to identify the likely urban salinity risk level for a proposed development site. This tool involves a simple process of identifying the land parcel proposed for development on a map of the Mildura region showing the likely extent of urban salinity risk areas, as presented in Figure 3. The site-specific level of urban salinity risk can be obtained directly from this map. Where a land parcel includes more than one urban salinity risk level, the **highest risk level should be adopted** to guide further hydrogeological investigations and salinity risk management actions.

If the salinity risk is very high the applicant should reconsider development of the site or speak to Council as the development of the site may require vigorous treatments prior to being developed. Such treatments can prove expensive. If the salinity risk is moderate to high, a SAS will be required as a condition on a planning permit.

Input into Salinity Action Statement

- *Document the preliminary urban salinity risk level of the proposed development.*
- *In the event the subject site is not mapped within the Schedule to the Salinity Management Overlay, this should be clearly stated in the SAS.*

2.1.2 Step 2: Verification of Preliminary Assessment

Soil Investigations

In all cases, the level of risk provided by the preliminary assessment tool should be verified by soil investigations at a recommended density of one soil bore/test pit per hectare to a depth of at least 4 m bgl. The required number of soil investigation should be rounded up to the nearest integer. For example, a typical land parcel of about 3.9 hectares (300 x 130 m) would require four soil investigation locations. For the purposes of site investigation and in particular to adequately characterise the lithology of the site, regardless of the size of a site, a minimum of three soil investigation locations per site should be adopted.

Generally two forms of soil investigations are the most common and include:

- Soil boring using a hydraulic push tube or auger rig; or
- Test pits excavated using a backhoe or excavator.

Material retrieved from soil investigations should be logged in the field according to the Unified Soil Classification system including soil type, consistency and moisture content. Soil moisture can yield important information about the presence of perched and/or regional groundwater within 4 m bgl. If saturated (wet) soil is encountered overlying a low permeability clay then perched groundwater is present, or if the soil becomes increasingly saturated towards the base of the soil investigation then regional groundwater at shallow depths may be present.

Soil investigations (i.e. soil bores/test pits) should be left open for extended periods (1 to 2 days) to allow the accumulation of perched groundwater if present within a low permeability clay formation. This is required to assist in verification that no perched groundwater or shallow water table exists. In the event test pits or boreholes are left open for periods of time, suitable safety precautions need to be adopted to mitigate potential risk associated with open excavations/holes.

Where present, definition of the elevation of the top of the clay layer across the site is important to identify the potential for off-site impacts of perched groundwater.

The slope of the clay layer will determine the direction of perched groundwater flow. Direction of groundwater flow is important in identifying potential off-site impacts or design considerations of drainage or other salinity mitigation measures.

The information generated from soil investigations will allow the preliminary level of urban salinity risk to either be confirmed or amended to reflect the additional site-specific data. This can be achieved by comparing the information generated from the soil bores to the criteria for the risk levels used in the preliminary assessment tool as detailed in Section 2.1.1 above.

Soil Salinity Investigations

As part of the soil investigation program to characterise the lithology of the site, an assessment of soil salinity at the site should be undertaken as follows:

- Analysing soil samples from each soil investigation location for soil EC at set intervals up to 4.0m below ground level (minimum of 0 to 0.2m, 0.5m, 1.0m, 2.0m and 4.0m);
- Ensuring soil EC testing methodology is appropriate for the lithology encountered (i.e. clay or a sand);
- Comparing results to criteria applicable to the investigation area, such as those provided as Appendix A;

- Adequately characterising the nature and extent of soil salinity issues at the site (i.e. to plant growth, built structures etc); and
- Ensuring appropriate management measures are identified and form part of the development approval if required.

Soil salinity results will not alter the salinity risk classification of the site; however any identified soil salinity issues would have to be adequately characterised and managed to the MRCC's satisfaction.

Hydrogeological Assessment

As part of the site soil investigations, the presence or otherwise of a perched groundwater layer or regional groundwater layer within the upper 4.0m of the site can be assessed by identifying conditions during the excavations of soils to this depth (as discussed, this may involve leaving the excavations open for an extended period of time).

Essentially the objective of hydrogeological investigations is to identify the presence or otherwise of perched or regional groundwater within the upper 4.0m of the site.

The most straight forward way to obtain hydrogeological data for a site is through the installation of a monitoring well to a minimum depth of 4.0m screened across the majority of the well depth. This will allow for the monitoring of a perched groundwater level or identify whether regional groundwater exists within the upper 4.0m of the site. Depending on the size of the site and variability in surface topography more than one groundwater monitoring well may be required to sufficiently undertake a hydrogeological assessment of the site.

Reference to off-site hydrogeological information/data is often a cost effective means to gain groundwater data for the site. In the event off-site hydrogeological data is used to assess site conditions, all assumptions should be clearly stated along with justification stating the suitability of the adopting the non-site specific data.

The information generated from hydrogeological assessment will allow the preliminary level of urban salinity risk to either be confirmed or amended to reflect the additional site-specific data.

Input into Salinity Action Statement

- *Clearly documented soil investigation and groundwater assessment methodology including any assumptions ensuring where relevant, the basis for assumptions is provided including suitable reference documentation;*
- *If off-site data is used to infer site-specific conditions, all assumptions should be clearly stated along with justification stating the suitability of the adopting the non-site specific data;*
- *Summarise the results of the soil and groundwater assessments compared to the salinity risk categories; and*
- *Based on the verification process, clearly state the salinity risk of the site.*

2.1.3 Step 3: Required Level of Salinity Management

All Salinity Action Statements are required to incorporate a level of salinity management according to the identified level of urban salinity risk. The specific salinity management requirements that should be undertaken by the developer for each level of risk are detailed in Section 3.

The three key components of urban salinity risk management are:

- **Most importantly, minimise excess use of water,** both at the household and municipal level, to avoid, as far as possible, rising regional groundwater and the occurrence of perched groundwater under urban development. Developers and the MRCC have a role in promoting water use efficiency.
- **Prevent on site urban salinity impacts** from regional and perched groundwater that may occur.
- **Prevent off-site urban salinity impacts** from regional or perched groundwater that may occur.

There are five levels of salinity management associated with each of the urban salinity risk levels. Each level of management contains the following sections:

- **Definition of Risk:** The specific physical factors that have generated the level of risk.
- **Recommended Use:** An indication of land uses appropriate for the level of risk.
- **Required Actions:** The specific actions required to adequately and manage the level of risk.
- **Salinity Action Statement:** A statement provided by the developer detailing how each of the required actions is addressed.

A brief overview of selected options to manage urban salinity risk and minimise excess household and municipal water use is provided in Appendix B.

Input in Salinity Action Statement

- *Clearly document the management measures in accordance with the Site Salinity Management Guidelines required to address identified site salinity risks; and*
- *Identify actions to be completed prior to the completion of the development or the subdivision (ie. Installation of sub-surface drainage).*

2.1.4 *Step 4: Salinity Action Statement*

In addition to outlining the methodology and results associated with Step 1 and 2, the developer should provide a statement detailing how each of the required actions will be addressed prior to certification, statement of compliance or the completion of the development. This will ensure that adequate measures will be adopted to manage the identified level of urban salinity risk. Certain actions, such as the decommissioning of existing tile drains and the installation of new subsurface drainage for example, will be required as part of approval to proceed with site development. Further conditions in regard to required site actions are detailed in Section 3.

In addition to outlining the methodology and results associated with Step 1 and 2, the developer should provide a statement detailing how each of the required actions will be addressed before the development/subdivision is completed. This will ensure that adequate measures will be adopted to manage the identified level of urban salinity risk. Certain actions, such as the decommissioning of existing tile drains and the installation of new subsurface drainage for example, will be required as conditions on a planning permit. Examples of such conditions are detailed in Section 3.

Salinity Action Statement

- *Ensure Steps 1 to Steps 4 are completed;*
- *Do not submit Salinity Action Statements that include vague assumptions or incomplete soil and hydrogeological assessments;*
- *Discussion of site results and conclusions should be prepared in a concise and succinct manner;*
- *If any queries/issues arise during the preparation of Salinity Action Statements, rather than submitting an incomplete site assessment, Developers or nominated representatives should contact the Council to discuss and address outstanding issues; and*
- *All relevant correspondence associated with developing the Salinity Action Statement (i.e. emails to/from the Council) should be included in the Statement.*

2.2 Role and Timing

A flow chart detailing the role and responsibilities of the MRCC and developer is provided in Figure 2.1.

Figure 2.1 Preparing a Salinity Action Statement – Role & Responsibilities

Planning Permit - MRCC
Council Refer the Development to the Site Salinity Management Plan Guidelines and identifies the application requires an SAS as a permit condition

In the instance that the SAS is approved subject to conditions (required actions), a statement of compliance will be provided for the site following the successful implementation of actions(i.e. such as providing detailed design documentations)

Prepare Site Salinity Action Statement- DEVELOPER
Subject to the location of the site in the Site Salinity Risk Map (as per Figure 3) the developer may be required to incorporate the following in a SAS
- Implement site specific intrusive Investigations;
- Confirm the Site Salinity Risk Classification; and
- Identify measures required to address identified salinity risks in accordance with the guidelines.

Provide SAS for Review - MRCC
The SAS will be provided to Council for review. The review by Council or nominated proxy will identify the adequacy of the SAS in terms of the identification and management of salinity risks at the site.

Additional Information Is Required - DEVELOPER
Often SASs will not be approved if; all assumptions in the documentation have not been adequately justified; if potential issues have not been sufficiently characterised; or if nominated management measures are insufficient.

Review - MRCC
Implementation of SAS Conditions as per Permit

For Developers:

Please note that actions such as; promoting water use efficiency, decommissioning of existing tile drains, ongoing groundwater monitoring and installation of sub-surface drainage will need to be implemented prior to a statement of compliance/certificate of occupancy being issued for the site.

Water Use Efficiency

Both the MRCC and developers have a role in advising purchasers that water efficient practices are required as part of site developments where salinity risks are present. The implementation of water efficient practices is the responsibility of the individual land holder.

3 Salinity Risk Management

The specific management approaches required for each of the levels of urban salinity risk are detailed in this section.

3.1 Level 1: Low Risk

DEFINITION OF RISK

Areas at low risk of urban salinity are assumed to be those where subsurface clay is absent and regional groundwater is deeper than 4 m bgl. In these areas perched groundwater is unlikely to develop and the relatively deep regional groundwater is below the level of concern for urban development.

RECOMMENDED USE

Land identified to be at low risk of urban salinisation is recommended for all land uses providing that the required actions are implemented.

EXAMPLE RECOMMENDED PERMIT CONDITIONS

- **Promote the implementation of efficient water use practices** designed specifically to minimise the amount of water infiltrating below the plant root zone. Appendix B provides an overview of selected options by which this may be achieved. These measures will assist in ensuring that the level of urban salinity risk does not increase in the future.

SALINITY ACTION STATEMENT

No specific salinity action statement is required.

3.2 Level 2: Moderate Risk

DEFINITION OF RISK

Areas at moderate risk of urban salinity are those where subsurface clay is present within 4 m bgl but regional groundwater is deeper than 4 m bgl. In these areas there is potential for the development of perched groundwater on the clay layer, which may impact on urban development.

RECOMMENDED USE

Land identified to be at moderate risk of urban salinisation is recommended for all land uses provided that the required actions are implemented.

EXAMPLE PERMIT CONDITIONS

- **Hydrogeological investigation** including the installation of groundwater well(s), with at least one well located at the topographically low point(s) of the proposed development site, to monitor the occurrence and level of perched groundwater and assess potential off-site impacts. In some circumstances, hydrogeological investigations may not involve the installation of site specific infrastructure, however, the adopted approach must be adequately justified. Where suitable, existing off-site groundwater monitoring infrastructure can be used.
- **Decommissioning of existing tile drains** (where present) in a way that will not exacerbate the development of perched groundwater (see Appendix B)
- **Design and installation of a suitable subsurface drainage system** to manage perched groundwater that may develop and ensure that off-site impacts will not occur. An assessment to identify sub-surface drainage requirements is provided as Appendix B.

EXAMPLE RECOMMENDED PERMIT CONDITIONS

- **Promote the implementation of efficient water use practices** designed specifically to minimise the amount of water infiltrating below the plant root zone. Appendix B provides an overview of selected options by which this may be achieved. These measures will assist in ensuring that the level of urban salinity risk does not increase in the future.

SALINITY ACTION STATEMENT

The developer must provide a statement detailing how each of the required actions will be addressed in accordance with SAS conditions on the permit.

3.3 Level 3: High(a) Risk

DEFINITION OF RISK

Areas at high(a) risk of urban salinity are those where regional groundwater is within 2 - 4 m bgl but subsurface clay is absent in the upper 4 m of the soil profile. In these areas there is potential for regional groundwater to impact on urban development.

RECOMMENDED USE

Providing that the required actions are implemented, land identified to be at high(a) risk of urban salinisation is recommended for uses other than irrigated areas (eg. sports fields or parklands) or water features (eg. wetlands) that involve the retention of water. These land uses should be avoided due to the potential for rising regional groundwater levels as a result of additional water to the underlying groundwater.

It should be noted here that there is a potentially high cost involved in the reduction and maintenance of regional groundwater below a level that would impact on urban development.

EXAMPLE PERMIT CONDITIONS

- **Hydrogeological investigation** including the installation of groundwater monitoring wells(s) with at least one well located at topographically low point(s) of the proposed development site to identify and monitor the level of regional groundwater, and to assess potential impacts of groundwater on urban development. In addition, the potential off-site impacts of proposed management options must be determined and addressed. In some circumstances hydrogeological investigations may not involve the installation of site specific infrastructure, however, the adopted approach must be adequately justified. Where suitable, existing off-site groundwater monitoring infrastructure can be used.
- **Decommissioning of existing tile drains** (where present) in a way that will not exacerbate the development of perched groundwater (see Appendix B)
- **Reduction and maintenance of regional groundwater below a level that would impact on urban development.** This level is commonly at around 2 m bgl, but varies depending on soil type. Appendix B provides an overview of selected options by which this may be achieved.

EXAMPLE RECOMMENDED PERMIT CONDITIONS

- **Promote the implementation of efficient water use practices** designed specifically to minimise the amount of water infiltrating below the plant root zone. Appendix B provides an overview of selected options by which this may be achieved. These measures will assist in ensuring that the level of urban salinity risk does not increase in the future.

SALINITY ACTION STATEMENT

The developer must provide a statement detailing how each of the required actions will be addressed in accordance with SAS conditions on the permit.

3.4 Level 4: High(b) Risk

DEFINITION OF RISK

Areas at high(b) risk of urban salinity are those where regional groundwater is within 2 - 4 m bgl and subsurface clay is present within 4 m bgl. In these areas there is potential for perched groundwater to develop in addition to the potential for regional groundwater to impact on urban development.

RECOMMENDED USE

Providing that the required actions are implemented, land identified to be at high(b) risk of urban salinisation is recommended for uses other than irrigated areas (eg. sports fields or parklands) or water features (eg. wetlands) that involve the retention of water at levels which would significantly impact surrounding groundwater levels. These land uses should be avoided due to the potential for rising regional groundwater levels as a result of additional water to the underlying groundwater.

It should be noted here that there is a potentially high cost involved in the reduction and maintenance of regional groundwater below a level that would impact on urban development.

EXAMPLE PERMIT CONDITIONS

- **Hydrogeological investigation** including the installation of nested groundwater monitoring wells, with at least one set nested monitoring wells located at topographically low point(s) of the proposed development site to identify and monitor the levels of perched and regional groundwater, and to assess their potential impacts on urban development. In addition, the potential offsite impacts of proposed management options must be determined and addressed. In some circumstances hydrogeological investigations may not involve the installation of site specific infrastructure, however, the adopted approach must be adequately justified. Where suitable, existing off-site groundwater monitoring infrastructure can be used.
- **Decommissioning of existing tile drains** (where present) in a way that will not exacerbate the development of perched groundwater (see Appendix B).
- **Design and installation of a suitable subsurface drainage system** to manage perched groundwater that may develop and ensure that off-site impacts will not occur. An assessment to identify sub-surface drainage requirements is provided as Appendix B.
- **Reduction and maintenance of regional groundwater below a level that would impact on urban development.** This level is commonly at around 2 m bgl, but varies depending on soil type. Appendix B provides an overview of selected options by which this may be achieved.

EXAMPLE RECOMMENDED PERMIT CONDITIONS

- **Promote the implementation of efficient water use practices** designed specifically to minimise the amount of water infiltrating below the plant root zone. Appendix B provides an overview of selected options by which this may be achieved. These measures will assist in ensuring that the level of urban salinity risk does not increase in the future.

SALINITY ACTION STATEMENT

The developer must provide a statement detailing how each of the required actions will be addressed in accordance with SAS conditions on the permit.

3.5 Level 5: Very High Risk

DEFINITION OF RISK

Areas at very high risk of urban salinity are those where regional groundwater is shallower than 2 m bgl. In these areas regional groundwater is an immediate threat to urban development and some land may already have become salinised.

RECOMMENDED USE

Due to the very high risk of urban salinity in these areas it is recommended that no development be permitted.

EXAMPLE PERMIT CONDITIONS

N/A

SALINITY ACTION STATEMENT

N/A

4 Statement of Limitations

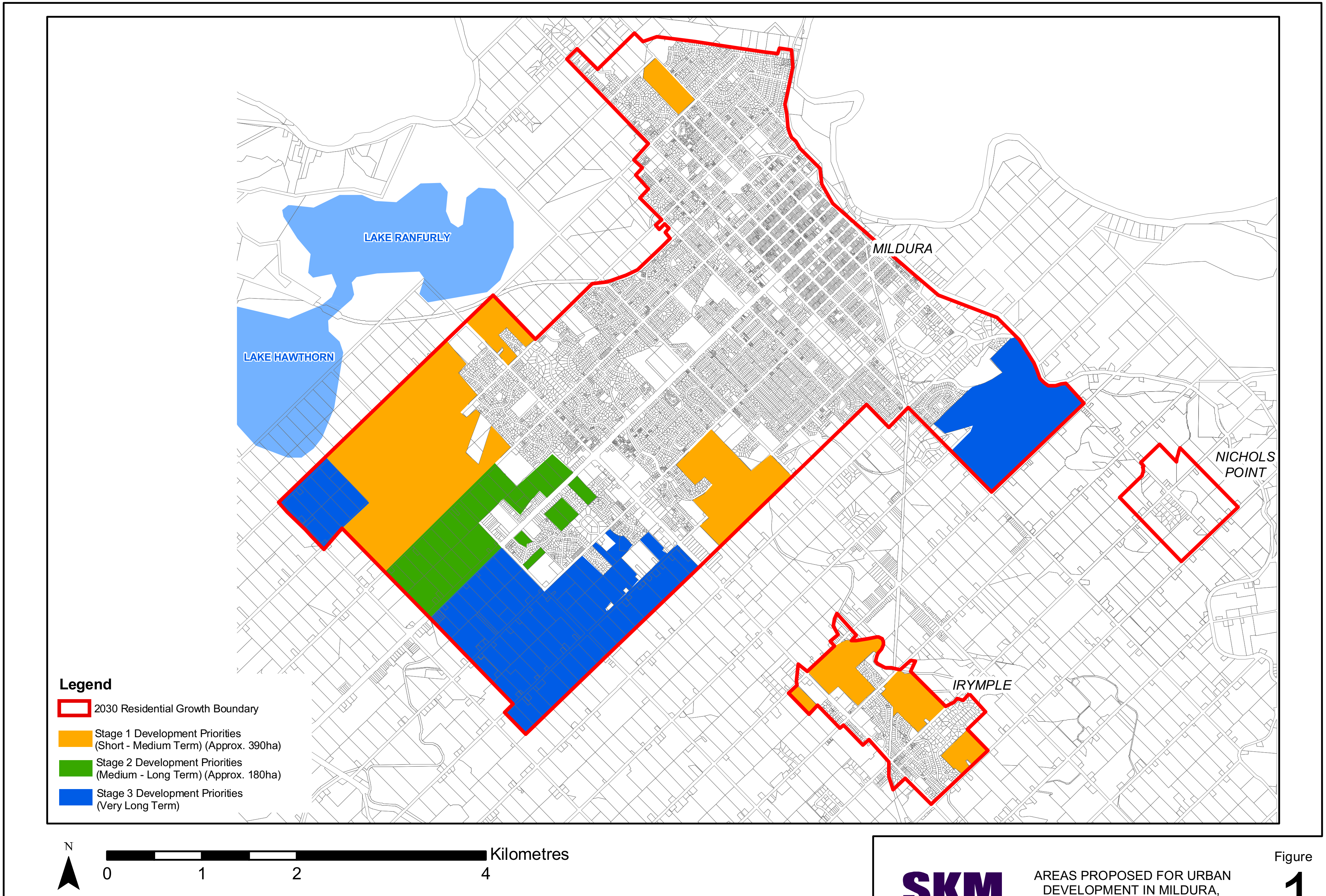
The sole purpose of this report and the associated services performed by Sinclair Knight Merz (SKM) is to outline a Plan to manage urban salinity risks in accordance with the scope of services set out in the contract between SKM and the Mildura Rural City Council (‘the Client’). That scope of services was defined by the request of the Client.

SKM derived the data in this report primarily from the data provided by the Client, and feedback provided from the Client on the existing 2004 Plan. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon information supplied by the Client, and information available in the public domain in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between SKM and the Client. SKM accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

FIGURES



Document:\\rem\Eserver\GIS\Mildura\Final maps\Proposed Development.mxd

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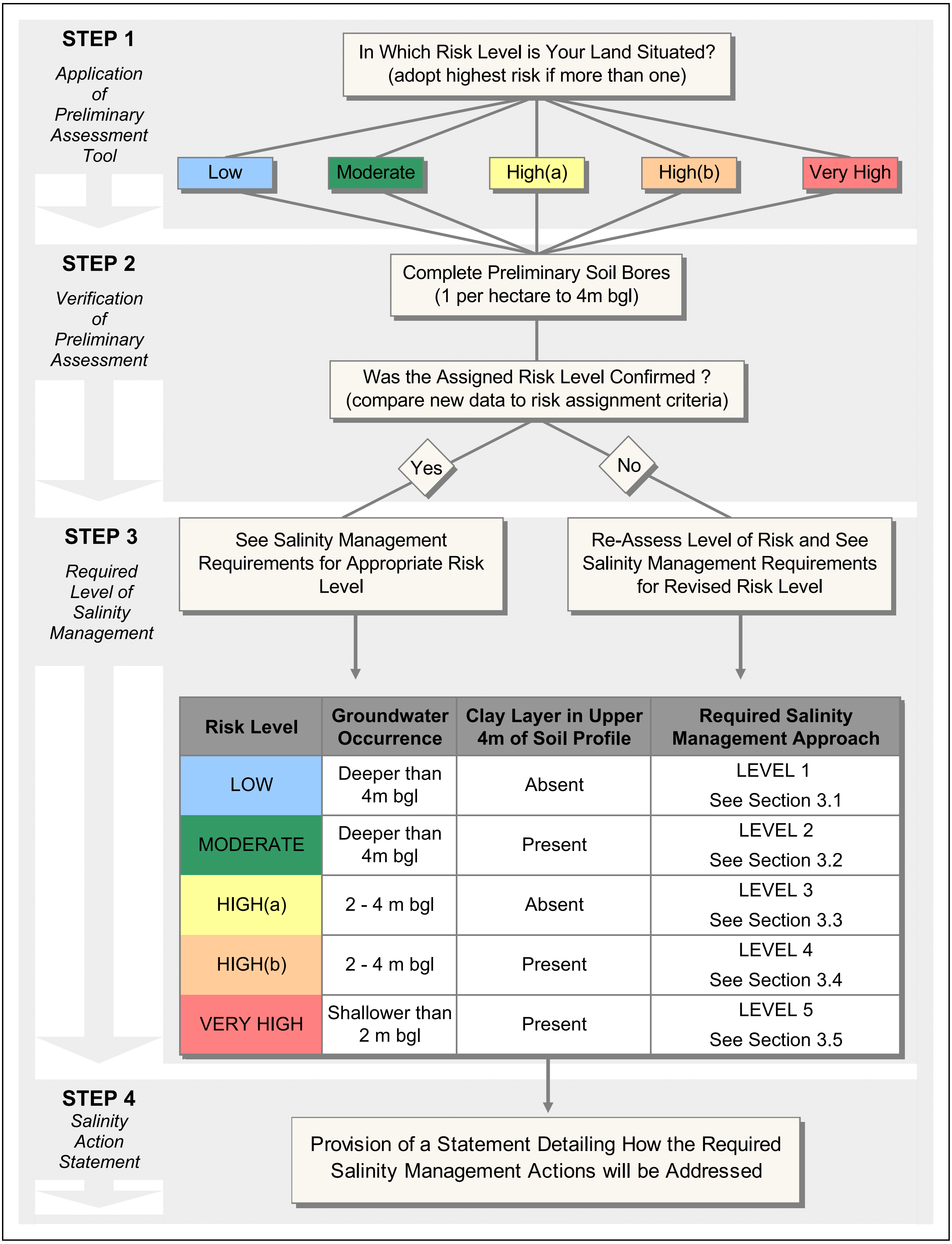
AREAS PROPOSED FOR URBAN DEVELOPMENT IN MILDURA, IRYMPLE AND NICHOLS POINT

Figure 1

Sept 2008



Risk Level	Groundwater Occurrence	Clay Layer in Upper 4m of Soil Profile	Required Salinity Management Approach
LOW	Deeper than 4m bgl	Absent	LEVEL 1 See Section 3.1
MODERATE	Deeper than 4m bgl	Present	LEVEL 2 See Section 3.2
HIGH(a)	2 - 4 m bgl	Absent	LEVEL 3 See Section 3.3
HIGH(b)	2 - 4 m bgl	Present	LEVEL 4 See Section 3.4
VERY HIGH	Shallower than 2 m bgl	Present	LEVEL 5 See Section 3.5

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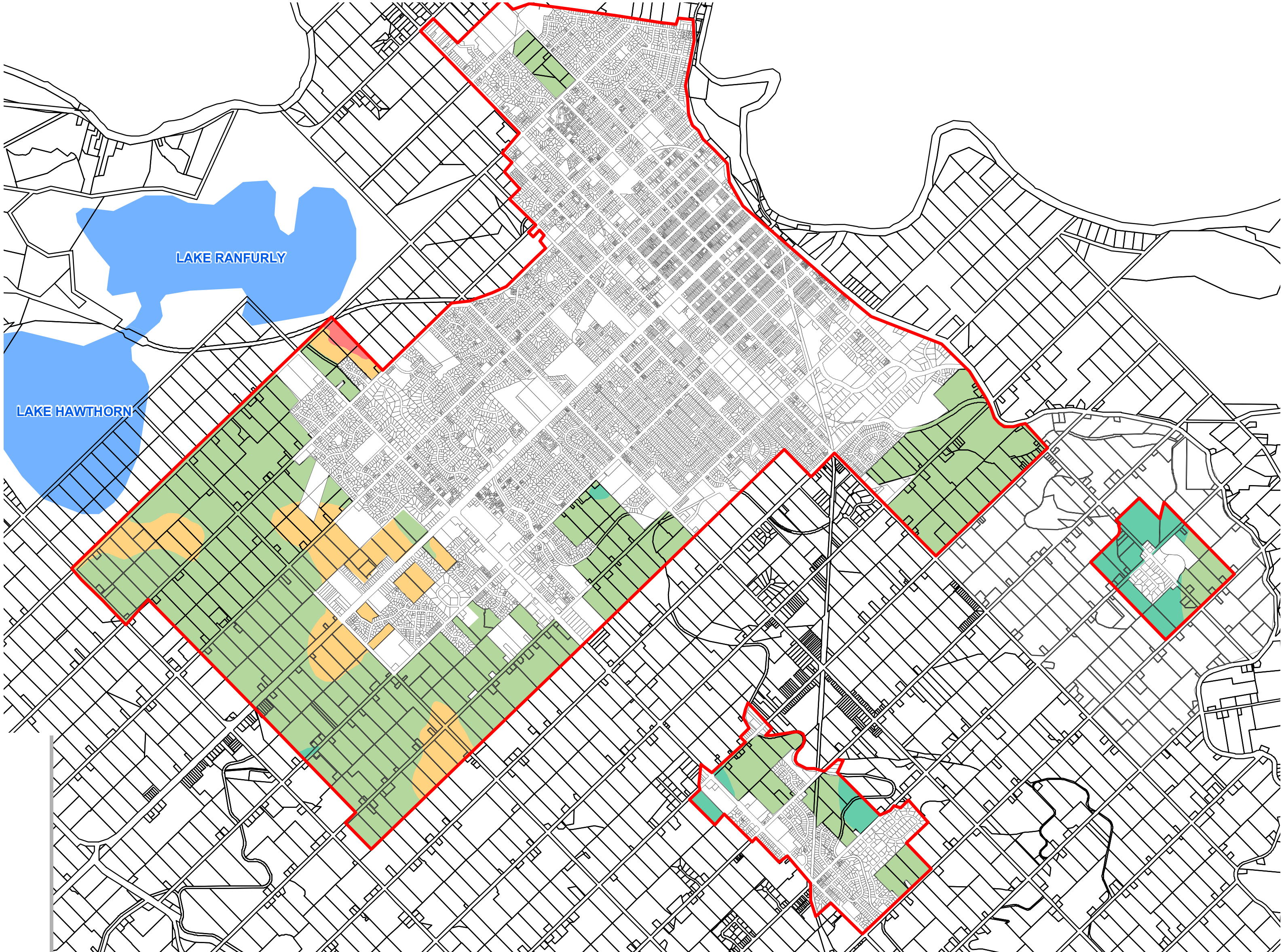
URBAN SALINITY RISK ASSESSMENT AND MANAGEMENT PROCESS FLOW CHART

Figure 2

Sept 2008



Interpreted Urban Salinity Risk

Low:	Groundwater > 4m bgl and clay layer absent in upper 4m of soil profile
Moderate:	Groundwater > 4m bgl and clay layer present in upper 4m of soil profile
High(a):	Grounwater 2 - 4m bgl and clay layer absent in upper 4m of soil profile
High(b):	Grounwater 2 - 4m bgl and clay layer present in upper 4m of soil profile
Very High:	Groundwater < 2m bgl and clay layer present/absent in upper 4m of soil profile
2030 Residential Growth Boundary	

0 750 1,500 3,000 Meters

N

SKM

INTERPRETED URBAN SALINITY RISK

Figure 3

October 2008

APPENDIX A

Soil Salinity and Urban Development

Table A.1 provides a soil salinity range and assessment of impacts on plant growth from the Land Resources Unit of Primary Industries and Resources SA "*Criteria for the Assessment of Agricultural Land: A summary of the criteria used to classify land with respect to a range of attributes with agricultural significance – Draft*".

Table A.1: Classification criteria for water table induced salinity (PIRSA)

Salinity Category	Classification Criteria			Land Class
	Water table	Vegetation indicators	Indicative ECe (dS/m) *	
Low	None	No evidence of salt effects	<2 (surface) <4 (subsoil)	1-s
Moderately low	Usually deeper than 2 m.	Subsoil salinity – deep rooted horticultural species and pasture legumes affected	<4 (surface) 4-8 (subsoil)	2-s
Moderate	Shallower than 2 m, capillary effect reaches into rootzone	Many field crops and lucerne affected. Halophytic species such as sea barley grass are usually evident.	4-8 (surface) 8-16 (subsoil)	3-s
Moderately high	Seasonally within 1 m of the surface	Too salty for most field crops and lucerne. Halophytes are common (as above plus curly rye grass salt water couch). Strawberry clover productivity is diminished.	8-16 (surface) 16-32 (subsoil)	4-s
High	Seasonally near surface	Land dominated by halophytes with bare areas. Samphire & ice plant evident. This land will support productive species such as Puccinellia, tall wheat grass etc.	16-32 (surface) >32 (subsoil)	5-s
Very high	Near surface most of year	Land is too salty for any productive plants and supports only samphire, swamp tea-tree or similar halophytes.	>32 (surface) Any	7-s
Extreme	Near or at surface most of year	Bare salt encrusted surface.	Any	8-s

* Indicative only – soil salinity levels fluctuate too widely to be used as definitive criteria.

APPENDIX B

B1 Options for Salinity Management

For development to proceed in areas that have a moderate to high risk of urban salinisation appropriate salinity risk management actions must be undertaken to address the identified level of risk.

A comprehensive urban salinity management approach should include groundwater recharge minimisation, adequate management of perched and/or regional groundwater and the use of improved construction materials to minimise potential impacts of urban salinity.

This supplementary information provides a brief overview of selected options for successful management of urban salinity risk, many of which form the basis of the actions required to address the levels of urban salinity risk detailed in the Site Salinity Management Guidelines.

Groundwater Recharge Minimisation

Promoting water use efficiency is the most effective tool available to facilitate the process of achieving real reductions in the amount of water that recharges the groundwater system in an urban environment. While there are many practical ways to reduce water requirements and improve water use efficiency, if the importance is not widely understood then achievements will be limited.

To the **extent possible,** site developers' and the MRCC should promote water use efficiency.

Landscaping Design

An immediate reduction in the water requirements of lawns, gardens and public open space can be achieved by appropriate water sensitive urban landscaping design. This may include:

- Smaller areas of lawn, a typically shallow rooted grass with high water requirements;
- Choice of lawn grass with lower water requirements;
- Choice of plants, shrubs and trees with low water requirements such as native species; and
- Choice of plants with greater root depth and capacity to use available water.

Water Use Efficiency

In all cases efficient water use practices should be adopted to minimise the potential for urban salinisation to occur. Essentially this involves matching lawn and garden watering regimes with actual plant water requirements. Options to improve water use efficiency include:

- The use of timers on all garden taps and sprinkler systems to avoid over watering, or the case where a tap is accidentally left running.
- Manual over-ride of automated watering systems when the additional water is not actually required, for example during and soon after a rain event.
- The use of soil moisture monitoring technology to inform the application of water to meet actual plant water requirements. Soil moisture probes can communicate directly with irrigation systems to create a fully automated "smart" irrigation system that operates according to plant water requirements.

Household Grey Water Disposal

Household grey water disposal in new residential developments occurs directly into the municipal system. However, this has not always been the case and in some instances on-site disposal of grey water has been facilitated by direct recharge to groundwater via a subsurface sump. While this practice may have sufficed in a low-density rural setting, in a high-density urban residential situation it is inappropriate and could result in the development of regional or perched groundwater at depths beyond desired limits.

It should be a requirement in new developments that household grey water and septic tanks are connected directly to the piped municipal sewerage system (ideally existing septic tanks would be decommissioned with a direct connection to the municipal system).

Stormwater Management

In Mildura, where there is potential for urban salinisation as a result of groundwater, stormwater management should focus on the avoidance of pooling and the prevention of *in situ* recharge in salinity risk areas. This consideration should be included in the design of stormwater management structures both at the household (eg. roof runoff) and municipal (eg. wetlands) levels.

It should be a requirement in new developments that household roof drainage is collected into rainwater tanks or connected directly to the municipal stormwater system, rather than on site disposal in sullage pits.

Perched Groundwater Management

Decommissioning Existing Tile Drains

Decommissioning of existing tile drains must ensure:

- Water discharged through existing tile drains onto the site is intercepted and redirected (i.e. from up gradient horticulture activities); and
- Sufficient decommissioning of existing historical on-site drainage system.

Subsurface Drainage

Where a subsurface low permeability clay layer occurs in the upper 4 m of the soil profile a subsurface drainage system may be required to adequately manage perched groundwater that may develop.

The requirement of sub-surface drainage at the site can be assessed using the range of spreadsheets provided as Appendix B - Table 1 to 4. Table 1 and Table 2 provide a template (guide only) to assess potential recharge associated with water use under a residential landuse setting. All assumptions used by developers in completing the water balance assessment should be adequately justified. Based on the results of the on-site Water Balance Assessment, the requirement for sub-surface can be determined. Table 3 and Table 4 provide a water balance assessment to assess the potential impacts from sites adjacent the subject site and whether there is potential from off-site water use recharging beneath the subject site. Based on the results of the off-site water balance assessment, the requirement of site sub-surface drainage can be assessed.

Design of sub-surface drainage systems

A subsurface drainage system essentially involves the installation of a linear network of conduits, historically clay tiles but more recently including perforated poly pipe, that channels perched groundwater across the slope where collection occurs and main disposal piping diverts water for off site disposal via the municipal stormwater system.

Table 5 provides a template to determine the requirements of sub-surface drainage systems to adequately manage on-site and off-site recharge.

In the USA the American Society of Civil Engineers have published standard guidelines for the design of urban subsurface drainage. In Australia subsurface drainage has been widely used in the agricultural industry, including irrigated vineyards in the Mildura region, and best management practices have been developed in this context[*].

Subsurface drainage systems developed for the agricultural industry are widely available and are directly applicable to perched groundwater management under urban development, providing that appropriate design and installation occurs.

Regional Groundwater Management

In areas where regional groundwater threatens urban development the depth to groundwater must be maintained below a level that would potentially impact on urban development.

Dewatering

Due to the regional scale of factors affecting recharge and flow of regional groundwater management options involving dewatering via subsurface drainage or pumping from wells will be ongoing and very expensive.

If salinisation occurs in existing urban developments due to regional groundwater then dewatering may be the only option available for immediate remediation and management of the problem. However, this approach is not considered appropriate for ongoing pre-emptive management of the potential urban salinity risk presented by regional groundwater.

Imported Fill

The use of imported clean fill to build up ground level and increase the depth to regional groundwater above the threshold level is potentially a viable option to allow urban development to proceed in areas where there is a regional groundwater at depths beyond desired limits.

To ensure success of this salinity risk management option it must be guided by a detailed hydrogeological investigation, both to determine the depth of fill material required across the site, which will depend on the depth to regional groundwater, and to identify and address any potential off site impacts resulting from disruption to groundwater flow.

Appropriate Construction Materials

New urban developments in areas at risk of urban salinisation should be built to withstand the effects of salinity. The use of improved construction materials is a pre-emptive measure to assist in minimising the potential impacts of salinisation on housing and other infrastructure. This may include the use of better damp coursing and marine grade concrete in housing construction.

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[*] Christen E. W., and Ayars J. E., (2001). “Subsurface Drainage System Design and Management in Irrigated Agriculture: Best Management Practices for Reducing Drainage Volume and Salt Load”, CSIRO Land and Water, Technical Report 38/01, Griffith, NSW, September 2001.

APPENDIX B – Tables 1 to 5

Table B1 On-site Water Balance (EXAMPLE ONLY)

Assume Typical Lot:	666	m2
Typical Pervious Area:	417	m2
Assumes Rainfall	65	% effective ie. 35% lost and does no enter soil for use by plant r
Assumes	263	kL/annum irrigation water applied to 417

Using data contained in Thompson (2000) Lawn water use

Note - Mean monthly irrigation value only assumes household use and does not include irrigation of Council resi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Mean Monthly Precipitation (mm)	20.70	21.20	18.20	18.50	26.30	23.20	26.30	27.60	28.20	31.00
Mean Monthly Effective Precipiatation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15
Mean Monthly Evaporation (mm)	325.50	274.40	229.40	138.00	80.60	54.00	62.00	89.90	132.00	198.40

Available Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Effective Monthly Precipitation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15
Mean Monthly Irrigation (mm)	131.88	103.08	59.99	40.79	21.60	4.80	4.80	4.80	9.60	40.79
% of annual	21	16	10	6	3	1	1	1	2	6
Mean MonthlyAvailable water (mm)	145.33	116.86	71.82	52.82	38.69	19.88	21.89	22.74	27.93	60.94

Water Use

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly Crop Factor (Holmes & Watson)	0.70	0.62	0.67	0.50	0.42	0.44	0.48	0.78	0.96	0.81

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly Crop Water Use (mm)	227.85	170.13	153.70	69.00	33.85	23.76	29.76	70.12	126.72	160.70

Balance remaining

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Balance (mm)	-82.52	-53.27	-81.88	-16.18	4.84	-3.88	-7.87	-47.38	-98.79	-99.76

Table B2 On-site Water Balance - 80% (EXAMPLE ONLY)

Assume Typical Lot: 666 m2

Typical Pervious Area: 417 m2

Assumes Rainfall 65 % effective ie. 35% lost and does no enter soil for use by plant r

Assumes 263 kL/annum irrigation water applied to 417

Using data contained in Thompson (2000)

Assume lawn water use only 80 % of potential

Note - Mean monthly irrigation value only assumes household use and does not include irrigation of Council res

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Mean Monthly Precipitation (mm)	20.70	21.20	18.20	18.50	26.30	23.20	26.30	27.60	28.20	31.00
Mean Monthly Effective Precipiatation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15
Mean Monthly Evaporation (mm)	325.50	274.40	229.40	138.00	80.60	54.00	62.00	89.90	132.00	198.40

Available Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Effective Monthly Precipitation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15
Mean Monthly Irrigation (mm)	131.88	103.08	59.99	40.79	21.60	4.80	4.80	4.80	9.60	40.79
% of annual	21	16	10	6	3	1	1	1	2	6
Mean Monthly Available water (mm)	145.33	116.86	71.82	52.82	38.69	19.88	21.89	22.74	27.93	60.94

Water Use

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly Crop Factor (Holmes & Watson)	0.56	0.50	0.54	0.40	0.34	0.35	0.38	0.62	0.77	0.65

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Monthly Crop Water Use (mm)	182.28	136.10	122.96	55.20	27.08	19.01	23.81	56.10	101.38	128.56

Balance remaining

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Balance (mm)	-36.95	-19.24	-51.14	-2.38	11.61	0.87	-1.91	-33.36	-73.45	-67.62

Table B.3 Off-site Water Balance (EXAMPLE ONLY)

Perched water development per hectare of Vineyard

Based on Irrigation rate of 4 megalitres/ha

Using data contained in Thompson (2000)

Assumes Rainfall 65% effective ie. 35% lost and does no enter soil for use by plant roots

Assumes vines + cover crop from April to September

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Precipitation (mm)	20.70	21.20	18.20	18.50	26.30	23.20	26.30	27.60	28.20	31.00	23.90	23.80
Mean Monthly Effective Precipiatation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15	15.54	15.47
Mean Monthly Evaporation (mm)	325.50	274.40	229.40	138.00	80.60	54.00	62.00	89.90	132.00	198.40	264.00	313.10

Available Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Precipitation (mm/ha)	13.50	13.80	11.80	12.00	17.10	15.10	17.10	17.90	18.30	20.10	15.50	15.50
Mean Monthly Irrigation (mm/ha)	125.00	125.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	100.00
% per month	31.25	31.25	0	0	0	0	0	0	0	0	12.5	25
Mean Monthly Available water (mm)	138.50	138.80	11.80	12.00	17.10	15.10	17.10	17.90	18.30	20.10	65.50	115.50

Water Use

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Crop Factor	0.50	0.60	0.40	0.20	0.30	0.30	0.30	0.30	0.30	0.10	0.25	0.40

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Crop Water Use (mm)	162.75	164.64	91.76	27.60	24.18	16.20	18.60	26.97	39.60	19.84	66.00	125.24

Balance remaining

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Balance (mm/ha)	-24.25	-25.84	-79.96	-15.60	-7.08	-1.10	-1.50	-9.07	-21.30	0.26	-0.50	-9.74

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Excess water per day (kL/ha/day)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00

Table B 4 Off-site Water Balance

Perched water development per hectare of Vineyard

Based on Irrigation rate of 8 megalitres/ha

Using data contained in Thompson (2000)

Assumes Rainfall 65% effective ie. 35% lost and does no enter soil for use by plant roots

Assumes vines + cover crop from April to September

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Monthly Precipitation (mm)	20.70	21.20	18.20	18.50	26.30	23.20	26.30	27.60	28.20	31.00	23.90	23.80	288.90
Mean Monthly Effective Precipiatation (mm)	13.46	13.78	11.83	12.03	17.10	15.08	17.10	17.94	18.33	20.15	15.54	15.47	187.79
Mean Monthly Evaporation (mm)	325.50	274.40	229.40	138.00	80.60	54.00	62.00	89.90	132.00	198.40	264.00	313.10	2161.30

Available Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Monthly Precipitation (mm/ha)	13.50	13.80	11.80	12.00	17.10	15.10	17.10	17.90	18.30	20.10	15.50	15.50	187.80
Mean Monthly Irrigation (mm/ha)	250.00	250.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	200.00	800.00
% per month	31.25	31.25	0	0	0	0	0	0	0	0	12.5	25	100
Mean Monthly Available water (mm)	263.50	263.80	11.80	12.00	17.10	15.10	17.10	17.90	18.30	20.10	115.50	215.50	987.80

Water Use

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Crop Factor	0.50	0.60	0.40	0.20	0.30	0.30	0.30	0.30	0.30	0.10	0.25	0.40	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Crop Water Use (mm)	162.75	164.64	91.76	27.60	24.18	16.20	18.60	26.97	39.60	19.84	66.00	125.24	

Balance remaining

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Balance (mm/ha)	100.75	99.16	-79.96	-15.60	-7.08	-1.10	-1.50	-9.07	-21.30	0.26	49.50	90.26	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Excess water per day (kL/ha/day)	32.50	35.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	16.50	29.12	

Example Drain Calculation (to intercept off-site flows)

Need to design drain to intercept up to 36 kl/ha/day (Feb balance)
Base drain design on length of vineyard ajoining development area
Assume land area generating perched water based on a 20 m width of land adjoining property boundary
Area fro 100 m adjoining property boundaryt length = 100 x 20 = 2,000 m2 or 0.2 ha
Design drain capacity to intercept a maximum of 7.2 kL/day per 100 m length
Adjust capacity based on length of adjoining property.

TABLE B5 On-Site Perched Water Development Calculations (EXAMPLE ONLY)
Spacing of Drains

Instruction: Take the highest water balance figure (conver to kL/day) and place in the square

	from	to
Establish Hydraulic Conductivitity and Select Material Type		
Clay	1.00E-07	1.00E-03
Silt, sandy silts, clayey sands	1.00E-04	1.00E-01
Silty Sands, fine sands	1.00E-03	1.00E+00
Well sorted sands, fine sands	1.00E-01	1
Well sorted Gravel	1.00E+00	10

Instruction: Select 1 and place in the square

Contact area (A) neccessary for 100% infiltration through clay layer =
Actual Contact Area A'=

Instruction: Select Hydraulic Conductivity for layer above Clay, using figures above

Hydraylic Conductivity for area Above Clay Layer m/day
Remaining Water Above Clay Layer = m/day

Instruction: Calculate Spacing of Drains

L =

Instruction: Input information from literature

Drain discharge, length / time, q = m/day
Hydraulic Conductivity K = m/day
Max Height of Water Table above Drain Centres, h = m
Actual distance of impermeable layer below drain, D = m
Effective Depth of impermeable layer, from literature, De = m
Distance between Drains, L = m

Working Example
Hooghoudt's equation:

$$q = 4 K h (2 D_e + h) / L^2$$

where q = drain discharge per m2 of soil surface area
= rate of water arrival at water table (length/time)
q= Q / A' = 0.95 / 500 = 0.0019 m/day
K = hydraulic conductivity of soil above clay layer
assume K= 0.1 m/day
h = maximum height of watertable above drain centres
assume h = 1.4 m
L = Distance between drains
D = Actual depth of impermeable layer below drains
assume D = 0.1 m
D_e= Effective depth of impermeable layer below drains
(found in literature as a function of D and L)
D_e = 0.1 m

Hence L= (4*0.1*1.4 (2*0.1+1.4) / 0.0019)$^{1/2}$
L= 22 m