

# Tasmanian Groundwater Flow Systems for Dryland Salinity Planning

by M. Latinovic, W. L. Matthews, C. Bastick, S. Lynch, P. Dyson and E. Humphries

## Contents

Groundwater Flow Systems .....	3
Options for salinity management .....	5
<i>Recharge management</i> .....	5
<i>Engineering – water table management</i> .....	6
<i>Managing saline resources – discharge areas</i> .....	7
Tasmanian Groundwater Flow Systems .....	8
1. <i>Local flow systems in Quaternary sedimentary rocks (talus and till)</i> .....	10
2. <i>Local to intermediate flow systems in Quaternary sedimentary rocks</i> .....	11
3. <i>Local to intermediate flow systems in undifferentiated Quaternary to         Tertiary sedimentary rocks</i> .....	12
4. <i>Local flow systems in high-relief Jurassic dolerite</i> .....	13
5. <i>Local flow systems in high-relief Permian and Triassic sedimentary rocks</i> .....	14
6. <i>Local flow systems in granites</i> .....	16
7. <i>Local flow systems in high-relief folded and fractured Proterozoic and Palaeozoic rocks</i> .....	17
8. <i>Intermediate flow systems in Tertiary sedimentary rocks</i> .....	18
9. <i>Intermediate to local flow systems in Tertiary basalt</i> .....	20
10. <i>Intermediate to local flow systems in low-relief Jurassic dolerite</i> .....	21
11. <i>Intermediate flow systems in low-relief Permian and Triassic sedimentary rocks</i> .....	23
12. <i>Intermediate flow systems in low-relief folded and fractured Proterozoic and Palaeozoic rocks</i> .....	25
13. <i>Regional and local flow systems in Tertiary sedimentary rocks</i> .....	26
References .....	28
<b>Appendix 1: Characterisation attributes</b> .....	29
<b>Appendix 2: Methodology used in map production</b> .....	30

## Introduction

A workshop on defining Tasmanian groundwater flow systems as a strategic framework for managing dryland salinity was held from 25 to 27 July 2001. The workshop was convened by the Department of Primary Industries, Water and Environment and Mineral Resources Tasmania, and was attended by 23 people interested in groundwater and the management of salinity.

Phil Dyson, Consulting Hydrogeologist, conducted the workshop. Phil Dyson was a joint author of the report *Australian Ground Water Flow Systems Contributing to Dryland Salinity* and has run similar workshops in other Australian States.

Those who attended part or the entire workshop were:

- Phil Dyson, Consulting Hydrogeologist (workshop facilitator and technical consultant);
- Colin Bastick, Regional Land Management Officer, DPIWE (Convenor);
- Loyd Matthews, formerly geologist and groundwater specialist, Mineral Resources Tasmania;
- Miladin Latinovic, geologist and groundwater specialist, MRT;
- Simon Lynch, GIS Land Resources, DPIWE (map preparation);
- Adrian Waite, Senior Geologist, MRT;
- Mike Walker, Project Officer Salinity, DPIWE;
- Esta Kokoris, Project Officer Salinity Modelling, DPIWE;
- Chris Grose, Senior Land Resource Management Officer, DPIWE;
- Jacqui Knee, Project Officer Sustainability, DPIWE;
- Liz Bond, Resource Assessment Officer Sustainability;
- John Maynard, Davey and Maynard, Agricultural Consultant;
- David Armstrong, Armstrong Agricultural Services;
- Astrid Ketellar, Armstrong Agricultural Services, Agricultural Consultant;
- David Wright, Catchment Officer, DPIWE;
- Michael Hart, Food Agriculture Fisheries, DPIWE;
- Sven Meyer, Hydrologist, Forestry Tasmania;
- Bill Cotching, Regional Land Management Officer, DPIWE;
- Geoff Peters, Honours student, University of Tasmania;
- Robert Phillips, Principal Water Management Officer;
- Sebastian Burgess, Greening Australia;
- Louise Gilfedder, Nature Conservation Branch, DPIWE;
- Kristin Jaehne, Bushcare Officer.

The following discussion is to be used for the development of the Tasmanian Salinity Strategy and describes the process of defining a set of Tasmanian groundwater flow systems, and sets out some of the basic assumptions that underpin that definition.

## Groundwater Flow Systems

A groundwater flow system is a landscape entity that includes all aspects of a single groundwater flow path. It is a fundamental unit that needs to be considered when management options for dryland salinity control are being selected. Groundwater flow systems (GFS) characterise similar landscapes in which similar groundwater processes contribute to similar salinity issues, and where similar salinity management options apply.

A groundwater system starts at the recharge area, and finishes at a discharge area – it fully describes all elements of a flow path. The boundary around a GFS is the point where no subsurface flow occurs.

Groundwater flow systems are not land management units, but rather they are part of the layers that describe such units. For example, when salt export rates are overlaid on the GFS distribution, it might be evident that two catchments in the same GFS have widely different salt export rates, and it would be prudent to manage them differently. Similarly, when soil landscape data are combined with GFS distribution, different management options will become evident.

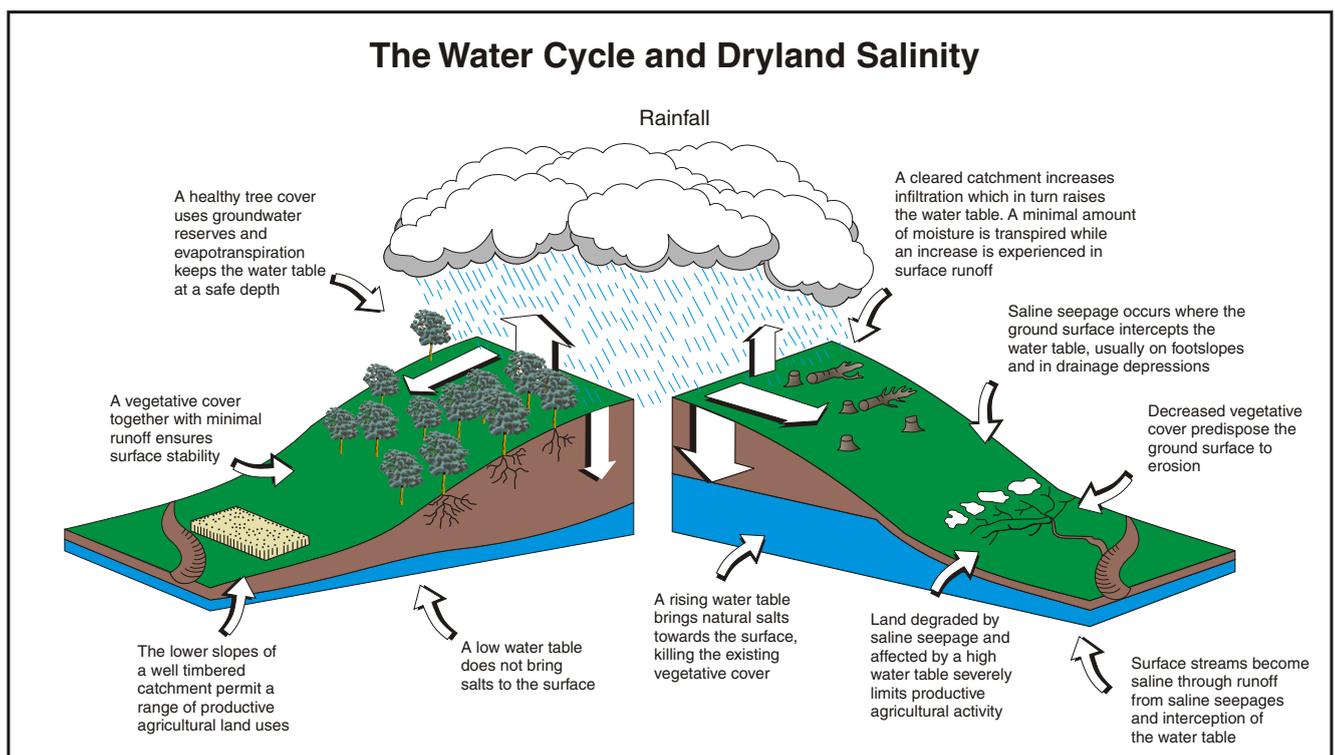
The fundamental property of a groundwater flow system is its ability to respond to change. *Response* refers to the time taken to achieve a balance between the amount of water flowing into, and out of, the groundwater system. Under constant recharge conditions, a balance is maintained between the inflow and outflow volumes. If these conditions change (for example, from land use change or climatic variability), the balance is disturbed. A rise in groundwater levels indicates recharge increases and it is theorised that this

increase is a shift in the overall distribution of recharge towards higher rates. A new equilibrium state is attained once the new recharge distribution is established over time. The period of time for this new state to be attained is termed the *equilibrium response time*, and is assumed to be of the order of decades for local flow systems, and upwards of hundreds of years for regional flow systems.

The concept of response time is important for designing management and monitoring systems, because we ideally need to know how close the system is to reaching a new equilibrium before setting management objectives and performance indicators. If the system is close to equilibrating, management objectives can be identified on the basis of a more-or-less stable salinity with a given level of degradation. If the system is tens or hundreds of years away from equilibrating, the extent and impacts of dryland salinity are likely to worsen considerably in that period, with major implications for what management objectives may be feasible and what monitoring approaches are appropriate.

### Attributes that define a Groundwater Flow System

Groundwater Flow Systems can be defined by a series of attributes that describe how they will respond to different recharge regimes, and that describe how they will express any imbalance in their water budget. These attributes include information about the hydraulic properties of the aquifer, as well as information on their landscape expression.



Attributes such as the hydrogeology and the slope can be used to spatially define the various flow systems using available catchment information. Other attributes can be used to describe the likely success or otherwise of management options. A complete listing of the attributes, and their rankings and explanations, is given in the tables for each flow system.

### **Limitation of current knowledge**

In the process of defining the groundwater flow systems some obvious knowledge gaps regarding key processes have been defined. These processes related to the way in which salt was generated from the landscape into the stream network (whether it was wash-off or base-flow generated), what the response time for an equilibrium change in the hydrological conditions was in a quantifiable sense, and the general response of the system to changes in distribution of recharge.

### **Ranking of management objectives**

There are five main objectives which should be met when managing dryland salinity. These are:

- to protect whatever pristine landscapes exist;
- to minimise the area of land affected by salinity;
- to reduce salt concentrations in streams;
- to reduce salt load; and
- to increase productivity from salinised resources (land and water).

### **Management options**

Possible management options are outside the scope of this report, but could be developed at a later date.

### **Targeted action**

The framework for dryland salinity management will be built around the three-tiered notion of control, contain and adapt. That is, control dryland salinity where possible, but accept that in some areas a policy of containment may be necessary given the size of the

problem, and in yet other cases, an adaptation to salinity will be required. Within this broad framework it is important to interpret the landscape within the context of groundwater flow systems, and to target management options such that the broad objectives are achieved.

### **Integration with other issues**

Dryland salinity is not the sole degradation issue facing Australian landscapes. With this in mind, it is critical to ensure that the integration issues associated with the implementation of management options are addressed explicitly. That is, dryland salinity, in some cases, will be contributing to other degradation issues, such as stream turbidity, vegetation decline, and that proper management of salinity will contribute to the management of these other issues. Equally, dryland salinity will be one symptom of a broader process that has many other symptoms. In some cases it will be necessary to solve the broader underlying issue before effective management of salinity can occur. In some cases there will be a need to solve some related issues so that dryland salinity management can be effective (for example, soil acidity in a perennial landscape).

### **Where is the GFS process?**

There are some issues that will need to be acknowledged during the use of Groundwater Flow Systems as a framework for dryland salinity action. It needs to be recognised that, to a certain degree, the GFS attributes are semi-qualitative and perhaps subjective. This will need to be managed in terms of quality control by those in the local area that have the requisite knowledge to validate a part of the GFS distribution. It is also true that the GFS definition process is in an evolutionary stage. As more and more information becomes available, and the dryland salinity managers become more definite about outcomes and objectives, the GFS process will adapt.

Much of the information contained in this document is supported by the outcomes of the National Land and Water Audit's *Australian Dryland Salinity Assessment 2000*, which used similar technical processes.

## Options for Salinity Management

The options that could be used for salinity management have been split into three categories – recharge management, engineering options for water table management, and managing saline resources in an attempt to manage discharge areas and in turn obtain some productive benefit.

The first of these categories presents a range of measures to reduce the amount of water entering deep drainage and thus reducing groundwater recharge. These options relate to biological measures aimed at utilising more water and improving soil structure. In doing so, the water holding capacity of the soil is improved and less water enters deep drainage. Combined, these actions will have the effect of reducing leakage and rates of groundwater rise.

The second set of options relate to engineering interventions specifically designed to manage water tables, either through managing surface water to control flows or mitigate waterlogging, or through groundwater pumping. These options fall into two broad categories; those which are relatively cheap and simple to set up (e.g. surface earth works) and those that are far more expensive and larger scale operations (e.g. groundwater pumping and salt interception schemes) (Sinclair Knight Merz, 2000). Both are designed to reduce water table height.

The third set of options acknowledges that salts are a natural and inevitable part of the landscape, and living with salinity is a way to manage it. These options relate to the productive use of saline lands and whilst not directly reducing the impacts, increased vegetation cover has the effect of reduced surface water run-off and lessening the amount of recharge occurring on site. A productive benefit is also incorporated into this group of options.

Many of the options discussed have not been tested in Tasmania, and at this stage their use should be considered with care.

### Recharge management

#### **Improved pasture agronomy**

In Tasmania this includes well managed perennial pastures, both native and introduced, and runout pastures where most of the perennial species have been lost due to drought or insect attack. Opportunities exist to increase the perenniality of run-out pastures as well as to improve the productivity of perennial pastures, as this will promote efficient and effective water use, enhance soil quality through complex root structures, soil biota and structure. Improved pasture agronomy can be encouraged through improving soil fertility and grazing management, reducing/eliminating fallow periods and reduced tillage. These features will have the effect of improving the water holding capacity of the soil

profile, reducing leakage and encouraging healthier and more persistent pasture growth.

#### **Advantages**

- Land use is complimentary.
- Adoption rates have the potential to be high where the cost of improving productivity is less than the value of extra production.
- Gives cash flow if well managed.
- Water use will increase and make a difference to recharge.

#### **Limitations**

- Improving productivity often requires better management.
- May only deliver marginal benefits in terms of recharge, especially where rainfall is greater than 600 mm.

#### **Improved agronomy for annual crops**

This involves a range of different management systems that are designed for improved water use. These systems include reducing/eliminating fallow periods, reduced tillage and alley cropping. Improved crop land agronomy is a viable option in those areas where cropping is already a dominant land use. Although current best management practices for cropping areas will have marked benefits to crop health and production, the benefits with recharge control may not be sufficient to mimic perennial vegetation water use efficiency. *Increased cropping should not be promoted as a preferred management option for salinity management.*

#### **Advantages**

- Potential for high rate of adoption.
- Costs can be kept to a minimum.
- Solutions don't require substantial land use change.
- Productivity is likely to increase.

#### **Limitations**

- Difficult to significantly reduce recharge under annual crops.
- Is dependent on skilful management and widespread adoption.
- Episodic or prolonged rainfall is not used by annuals.
- Is highly dependent on soil type.

#### **Improved water use efficiency in irrigation areas**

This includes irrigation scheduling, laser levelling and recycling, and conversion of flood irrigation to spray

or drip systems. These management options have the potential to play a significant role in managing localised high groundwater levels and on the mainland have proven to be highly effective in irrigation districts within a catchment.

### **Woody perennial vegetation (WPV)**

This includes all native vegetation plantings that are being established for land management purposes or conservation values. These plantings include revegetation works at a range of scales including wind breaks, smaller scale Landcare-type plantings, larger scale hilltop plantings, and strategic break of slope interception plantings. Vegetation retention, managing for natural regeneration and the re-introduction of native vegetation is also included in this category.

### **Plantation forestry (PF)**

This includes larger scale farm forestry development for groundwater interception purposes and plantation forestry blocks (native and introduced). This category is regarded as different to woody perennial vegetation in that it has recognised market value and the trees will be removed and replanted at some point in the future.

#### **Advantages**

- Effective in controlling recharge in some locations (WPV) (PF).
- Multitude of benefits (WPV).
- Public and private returns (WPV) (PF).
- Potentially sustainable income sources (PF).

#### **Disadvantages**

- Uncertainty about market prospects (PF).
- Time lag involved/cash flow – need to harvest trees for return on investment – affect on recharge control (PF).
- Cultural change required (WPV) (PF).
- Costs of establishment and the need for infrastructure (PF).
- How to integrate trees into current farming systems (WPV) (PF).
- Fewer options for lower rainfall areas (PF).
- Risk of fire (WPV) (PF).
- Loss of productive land (short term) (WPV) (PF).
- Potential adverse effects on catchment run-off in some circumstances.

## **Engineering — water table management**

Engineering options have the potential to be effective for recharge control and groundwater management. Each of these options addresses some component of

water table management. Engineering options should only be considered if they are cost effective, are protecting key assets, have limited off-site effects, effluent disposal issues have been considered, and where biological options are not viable.

Some engineering options require a great deal of investment, which is often the limiting factor in their establishment. Deep subsurface drainage, groundwater pumping and salt interception schemes are really only viable when they are established to protect key assets within the catchment (e.g. domestic and irrigation water supply, urban infrastructure and biological diversity in wetland areas). These management options are constrained by suitable soils and aquifers; they need to be both permeable and transmissive (ability to transmit water). Effluent disposal is another important characteristic.

Some options, including surface and subsurface drainage, are relatively cheap to develop, although they have the potential to transfer the problem to other areas, hence having a range of off-site impacts.

### **Surface drainage**

This includes raised-beds and shallow and deeper open drains and ditches.

#### **Advantages**

- Low cost – often cheaper than taking land out of production.
- Causes minimal disruption to land-use.

#### **Disadvantages**

- Value for controlling waterlogging may be limited in some areas.
- Off-site impacts need to be considered, especially if water is saline.

### **Subsurface drainage**

#### **Advantages**

- Effective for removal of groundwater from waterlogged areas.
- Can lower water tables sufficiently to enable productive use of affected area.

#### **Disadvantages**

- Much more costly than surface drainage.
- Storage or disposal of collected water can be costly.
- In rare situations there may be a risk in Tasmania of subsurface drainage causing soil dispersion and acid water discharges.

### **Groundwater pumping**

#### **Advantages**

- If pumping works, salinisation problems can be minimised.

- Capital assets in towns can be protected.

#### ***Disadvantages***

- Capital cost is high and expensive to set up and maintain.
- Applicable areas are limited to high yielding aquifers.
- Only treats the symptoms.
- Limited area of influence.
- If using water for irrigation it must be carefully managed.
- Systems that leak can cause recharge.
- Disposal issues.

### **Managing saline resources — discharge areas (including production benefits)**

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In specific situations productive use options may be profitable and productive. In other areas it is unlikely that productive use options for managing saline resources will have significant benefits for salinity control within the catchment; they will simply be a form of responsive management that address the symptoms not the cause. Value from discharge site management will be seen in reduced saline 'wash-off' from affected areas, improved groundcover and a localised reduction in water table height. These three things may have measurable benefits both in reducing stream salinity concentration and salt load.

Currently, the majority of saline areas are left to worsen. Options for salt tolerant grasses, horticulture and silviculture may have positive outcomes to the landholder.

The salinity situation in some areas of Tasmania will worsen before it improves. Developing and implementing both saline industries and managing saline resources will be essential for the future management of salinity throughout the catchment.

The characteristics of these areas include:

- The land is typically unproductive or under current systems which are producing poorly;
- 'wash-off effects' can be significant;
- Water tables are generally high;
- Affected areas are getting worse;
- Significant off-site effects; and
- Saline areas can often lead to large scale erosion.

#### ***Halophytic vegetation***

These are terrestrial plants adapted to grow in saline conditions.

#### ***Salt-tolerant grasses/pastures***

A range of grasses/pastures are able to exist and grow in saline areas including Tall Fescue, Phalaris, Puccinellia, Strawberry/Balansa/Palestine Clover.

#### ***Saline horticulture and silviculture***

Some horticultural and silvicultural plants can tolerate saline conditions. A fair amount of work has gone into silvicultural options for saline areas, although the correct species to use will depend on the site. Advice on suitable species and establishment techniques should be sought before proceeding.

#### ***Salt harvesting***

Salt harvesting is an option where sufficiently high concentrations of salt can be achieved through evaporation basins. This is a viable option where the right conditions prevail. There are currently no evaporation basins in Tasmania.

#### ***Saline aquaculture***

Given the right conditions and high enough salt concentrations, marine fish and crustaceans can be grown in terrestrial evaporation basins. Successful mainland trials and existing mainland enterprises have grown snapper, whiting, mulloway, flathead and prawns. In lower salt concentrations, native freshwater fish including yellow belly and silver perch can be grown (both having low-moderate salt tolerance).

## Tasmanian Groundwater Flow Systems

Thirteen Groundwater Flow Systems have been identified in Tasmania\*. A summary of each system is provided in the following section. These summaries detail the geological, hydrogeological and geomorphological characteristics of each system. The information provided should be used to design appropriate salinity management options for affected areas within known groundwater flow systems.

The hydrogeological characteristics of these groundwater flow systems were mostly derived from information held in the Mineral Resources Tasmania groundwater database as at December 2001.

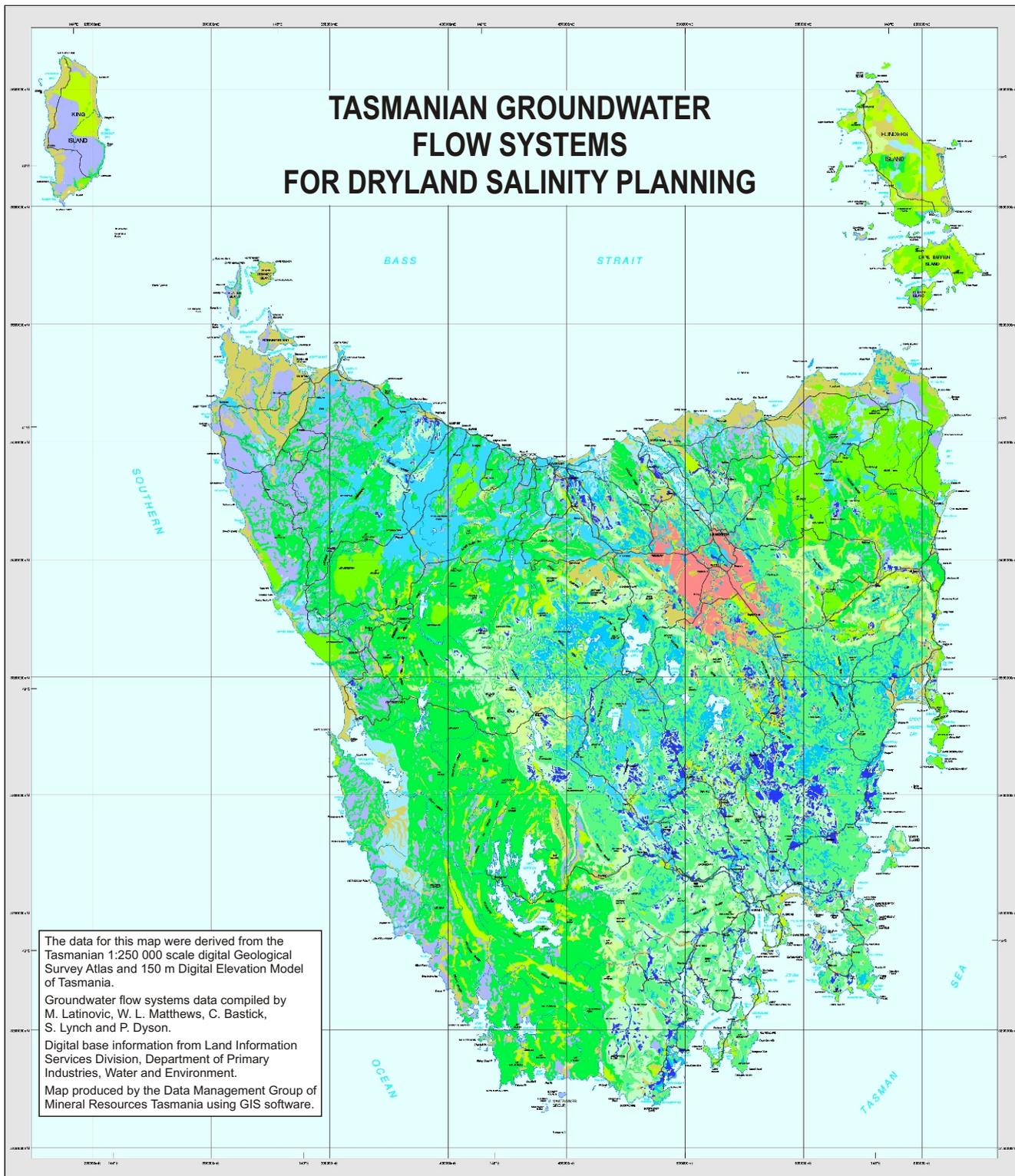
The thirteen systems are:

1. Local flow systems in Quaternary sedimentary rocks (talus and till);
2. Local to intermediate flow systems in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium);
3. Local to intermediate flow systems in undifferentiated Quaternary to Tertiary sedimentary rocks;
4. Local flow systems in high-relief Jurassic dolerite;
5. Local flow systems in high-relief Permian and Triassic sedimentary rocks;
6. Local flow systems in granites;
7. Local flow systems in high-relief folded and fractured Proterozoic and Palaeozoic rocks;
8. Intermediate flow systems in Tertiary sedimentary rocks;
9. Intermediate to local flow systems in Tertiary basalt;
10. Intermediate to local flow systems in low-relief Jurassic dolerite;
11. Intermediate flow systems in low-relief Permian and Triassic sedimentary rocks;
12. Intermediate flow systems in low-relief folded and fractured Proterozoic and Palaeozoic rocks;
13. Regional and local flow systems in Tertiary sedimentary rocks.

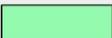
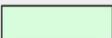
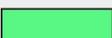
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\* The *Tasmanian Groundwater Flow Systems for Dryland Salinity Planning* map is published at 1:500 000 scale. The map included in this report is for indicative purposes only. Printed copies of the map are available from Mineral Resources Tasmania.

# TASMANIAN GROUNDWATER FLOW SYSTEMS FOR DRYLAND SALINITY PLANNING



## LOCAL FLOW SYSTEMS

-  Local flow systems in Quaternary sedimentary rocks (talus and till)
-  Local to intermediate flow systems in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium)
-  Local to intermediate flow systems in undifferentiated Quaternary to Tertiary sedimentary rocks
-  Local flow systems in high-relief Jurassic dolerite
-  Local flow systems in high-relief Permian and Triassic sedimentary rocks
-  Local flow systems in high-relief granitic rocks
-  Local flow systems in high-relief folded, fractured Proterozoic and Palaeozoic rocks

## INTERMEDIATE FLOW SYSTEMS

-  Intermediate flow systems in Tertiary sedimentary rocks
-  Intermediate to local flow systems in Tertiary basalt
-  Intermediate to local flow systems in Jurassic dolerite
-  Intermediate to local flow systems in low-relief Permian and Triassic sedimentary rocks
-  Intermediate flow systems in low-relief folded, fractured Proterozoic and Palaeozoic rocks

## REGIONAL FLOW SYSTEMS

-  Regional flow systems in Tertiary sedimentary rocks

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## 1: Local flow systems in Quaternary sedimentary rocks (talus and till)

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### Regions

Dolerite talus occurs around steep slopes, particularly on or directly below dolerite-capped mountains and plateaux (Great Western Tiers, Ben Lomond, Fingal Tier, central southwest mountains and Central Plateau). Till occurs mainly in an area around Lake St Clair and Lake King William (a total area of around 2615 km<sup>2</sup>).

### Critical attributes that determine groundwater behaviour in response to land management\*

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Scale	local
Landform	steep slopes, foothills and undulating high plains
Regolith	talus, rocky soils
Groundwater aquifers	intergranular
Hydraulic conductivity (m/day)	1
Aquifer transmissivity (m <sup>2</sup> /day)	5
Specific yield (%)	3–5
Flow length (km)	1
Confined/unconfined	unconfined and confined
Catchment size (ha)	up to 10 000
Annual rainfall (mm)	1000–3000
Land use	reserves
Groundwater salinity range	0.03–0.8 dS/m (21–560 mg/L)
Salt store	very low
Salinity occurrence	n/a
Salinity rating (soil)	n/a
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local
Base flow/wash off	base flow
Equilibrium response time	slow–fast
Impacts	n/a
Salinity risk ranking	nil

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\* See Appendix 1 for definitions of characterisation attributes.

### Discussion

Talus typically occurs on steep slopes whereas till occurs in relatively flat, higher country. Talus and till generally consist mainly of boulders at the surface with an increasing clay component with depth.

The aquifers are mainly intergranular and unconfined. Groundwater flow is rapid at the surface but slow at deeper levels.

Springs typically occur on midslopes where the talus is soil free, or at the base where it overlies less permeable material (e.g. Triassic mudstone).

Salt stores in these materials are usually low and groundwater quality is good. In low rainfall areas there may be some salt stores and poorer water quality.

Groundwater response time following land use change is likely to be rapid.

In some areas the groundwater derived from these systems could have off-site effects as a result of recharging groundwater systems down-gradient of these systems.

The main issue for management options is the need to consider off-site impacts, whether these relate to the impact of increased vegetation on reducing runoff, and thus increasing stream salinity levels; or the impacts of extracted/drainaged groundwater on stream salinity levels.

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## 2: Local to intermediate flow systems in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium)

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### **Regions**

These recent sedimentary deposits are commonly found in the coastal regions (coastal plains and dune systems), with alluvial and windblown sediments generally more dominant in the inland parts of Tasmania (total area of approximately 6080 km<sup>2</sup>).

### **Critical attributes that determine groundwater behaviour in response to land management**

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Scale	local to intermediate
Landform	flat to undulating
Regolith	sand, peat and clay
Groundwater aquifers	intergranular
Hydraulic conductivity (m/day)	3–12
Aquifer transmissivity (m <sup>2</sup> /day)	up to 50
Specific yield (%)	20
Flow length (km)	up to 5
Confined/unconfined	unconfined and confined
Catchment size (ha)	up to 2000
Annual rainfall (mm)	400–2000
Land use	grazing, cropping, mining, reserves
Groundwater salinity range	0.1–30 dS/m (70–21 000 mg/L)
Salt store	low–moderate
Salinity occurrence	drainage lines, swales, sand, low-lying clay flats
Salinity rating (soil)	S0–S2
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local
Base flow/wash off	base flow and wash off
Equilibrium response time	moderate to fast
Impacts	local and off site
Salinity risk ranking	nil–moderate

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### **Discussion**

This groundwater system is characterised by coastal plains, dune systems and alluvial sediments which consist predominantly of sand, gravel, sandy clay, clay and occasionally peat. These typically occur in broad open plains or within linear river valleys, where only occasionally have significant thicknesses of alluvium accumulated. The typical thickness of the major coastal sandy aquifers is within a range of 5 to 15 metres (Seven Mile Beach, Nine Mile Beach, South Arm, Bridport area, etc.), with the thickness of these sediments in other areas being variable and usually less than five metres.

Good groundwater aquifers consist of sand and gravel and are unconfined or semi-confined. The presence of silt and clay is usually a limiting factor, resulting in decreased yields and lower permeability and hydraulic conductivity values. Groundwater level is usually within three metres of the surface, although in some areas of the dune systems it can be much deeper below the dune peaks. Groundwater flow generally follows the surface topography.

Groundwater salinities are variable but are mainly low in good aquifers but moderate to poor in the localised sandy clay aquifers (shallow aquifers in low rainfall areas, swamps, lagoons and aquifers close to the coast with the base of the aquifers below sea level). Vegetation indicator species and bare saline soils may develop where saline groundwater discharges on the surface.

Water usually discharges at topographic lows or at the break of slope. Discharges also occur in the river valleys because of lateral movement of groundwater to surface water systems. In some areas these groundwater systems have the potential to be developed as significant groundwater resources (Nine Mile Beach and Seven Mile Beach for example).

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### 3: Local to intermediate flow systems in undifferentiated Quaternary and Tertiary sedimentary rocks

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#### Regions

Undifferentiated Quaternary and Tertiary sedimentary deposits are commonly found in the coastal regions of Flinders Island and King Island (coastal plains and aeolian dunes) with alluvial, windblown, glacial and slope sediments generally more dominant in the inland parts of Tasmania. The approximate areal extent of these sedimentary rocks is about 3677 km<sup>2</sup>.

#### Critical attributes that determine groundwater behaviour in response to land management

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Scale	local to intermediate
Landform	flat to undulating, steep slopes, foothills and undulating high plains
Regolith	talus, rocky soils, sand, peat, clay, gravel and pebbles
Groundwater aquifers	intergranular
Hydraulic conductivity (m/day)	1-5
Aquifer transmissivity (m <sup>2</sup> /day)	5-50
Specific yield (%)	3-20
Flow length (km)	up to 25
Confined/unconfined	unconfined and confined
Catchment size (ha)	0.17-28 300 (97.5% <2000 ha)
Annual rainfall (mm)	400-3000
Land use	reserves and pasture
Groundwater salinity range	0.03-30 dS/m (21-21 000 mg/L)
Salt store	low-moderate
Salinity occurrence	drainage lines, swales, break of slope, some low-lying clay flats
Salinity rating (soil)	S0-S2
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local
Baseflow/wash off	base flow and wash off
Equilibrium response time	low to fast
Impacts	local and off site
Salinity risk ranking	nil-moderate

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#### Discussion

This undifferentiated groundwater system comprises two previously described groundwater systems, *local to intermediate flow systems* in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium) and *local flow systems* in Quaternary sedimentary rocks (talus and till). Their further separation may be achieved only after the base geological data is altered in a way that will allow this to happen.

These intergranular groundwater aquifers consist mainly of sand, gravel and boulders. They are usually unconfined and confined aquifers. The presence of silt and clay is usually a limiting factor, resulting in decreased yields and lower permeability and hydraulic conductivity values. Groundwater levels are probably at shallow depth below the surface and groundwater flow generally follows the surface topography. Groundwater salinity is variable but mainly low in good aquifers in high rainfall areas (southwestern and western Tasmania) but moderate to poor in the localised sandy clay aquifers (shallow aquifers in low rainfall areas – Southern Midlands, and swamps and lagoons of King Island and Flinders Island).

## 4: Local flow systems in high-relief Jurassic dolerite

### Regions

Jurassic dolerite mainly occurs in the central, southeastern and central northern parts of Tasmania (between the Central Plateau, Ben Lomond and the Tasman Peninsula) over an area of 12 655 km<sup>2</sup>. Small areas occur around the Campbell Range in western Tasmania.

### Critical attributes that determine groundwater behaviour in response to land management

Scale	local
Landform	mountains and steep slopes
Regolith	soil and talus
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	0.1-1
Aquifer transmissivity (m <sup>2</sup> /day)	5-100
Specific yield (%)	1
Flow length (km)	1-3
Confined/unconfined	unconfined
Catchment size (ha)	variable (minimum 0.4 ha)
Annual rainfall (mm)	600-2000
Land use	forestry reserves and minor agriculture, mining
Groundwater salinity range	0.14-16.0 dS/m (105-11 200 mg/L)
Salt store	low
Salinity occurrence	rare
Salinity rating (soil)	n/a
Temporal distribution of recharge	seasonal/annual
Spatial distribution of recharge	uniform
Base flow/wash off	n/a
Equilibrium response time	slow to fast
Impacts	n/a
Salinity risk ranking	low

### Discussion

Jurassic dolerite is a common rock in the eastern half of Tasmania where it is generally intrusive into older Permian and Triassic rocks, although it can occasionally be seen intruding older rocks. Dolerite occurs mainly as sills and dykes, which in places have had a profound effect on the physical properties of the surrounding rocks.

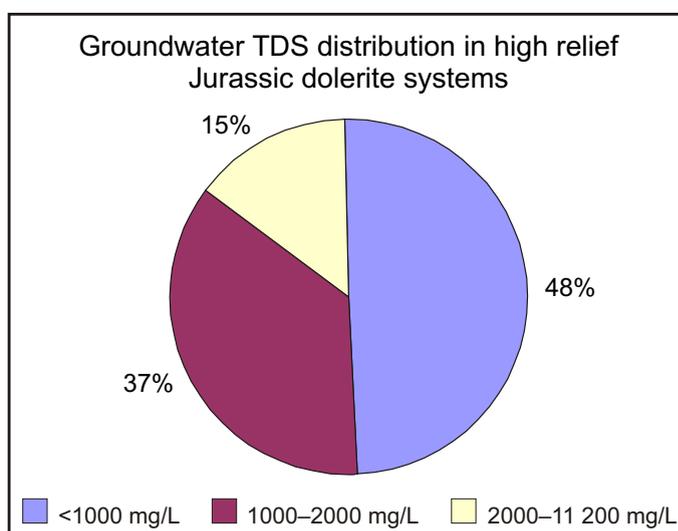
Groundwater in dolerite is usually stored in the rock fractures (secondary porosity). Depending on the level of fracturing and weathering, dolerite may act as an aquitard (low-permeable units) or an aquifer (permeable groundwater storage units). Unconfined to semi-confined fractured aquifers are mainly characteristic of dolerite. Inclined fractured zones or horizontal joint systems will result in the development of semi-confined aquifers.

Groundwater flow is generally slow in areas of dolerite with a low fracture density, with increased flow in highly fractured areas (e.g. fault lines, intensive fracture systems, etc.). The quantity and quality of groundwater in dolerite is usually directly related to the level of fracturing and the average annual rainfall. Groundwater quality is variable, with 48% of available salinity data (total dissolved solids) in a range of 105-1000 mg/L and another 37% between 1000- 2000 mg/L, with the remaining 15% above 2000 mg/L (up to 11 200 mg/L in the Sorell area).

Springs typically occur between the middle and lower points of the sloping land where fractures intersect the terrain surface.

The regolith developed on dolerite is generally thin, as erosion and weathering rates are similar. Where fracturing is intense, the depth of weathering can be much greater resulting in a thicker regolith.

The potential for salt stores in dolerite is generally regarded as low, particularly where the regolith is



thin, but there is some potential for larger stores where deep weathering has taken place. Salt stores are present within the regolith in low rainfall and low permeability areas (for example Little Swanport, Sorell and Tunbridge, where moderate to poor quality water has been encountered), and also in groundwater contained in fractured zones.

Standing water levels have been monitored by Mineral Resources Tasmania in dolerite at Little Swanport.

Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. It is also expected to be usually near or within the area where groundwater occurs.

Groundwater response times following land use change are likely to be variable and related to local aquifer characteristics; mainly fast in steeper high- fractured areas but moderate to slow in moderately steep, less-fractured areas.

In some areas the groundwater derived from these systems could have off-site effects as a result of recharging groundwater systems down-gradient.

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## **5: Local flow systems in high-relief Permian and Triassic sedimentary rocks**

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### ***Regions***

Permian and Triassic sedimentary rocks mainly occur in southeast Tasmania, in northern Tasmania between Launceston and Wynyard, and in northeast Tasmania. This system extends over an area of approximately 5600 km<sup>2</sup>.

### ***Critical attributes that determine groundwater behaviour in response to land management***

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Scale	local
Landform	steep hills
Regolith	soil and talus
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	5-10
Aquifer transmissivity (m <sup>2</sup> /day)	<150
Specific yield (%)	2-4
Flow length (km)	<5
Confined/unconfined	confined and unconfined
Catchment size (ha)	<500
Annual rainfall (mm)	500-2000
Land use	reserves, forestry, minor agriculture, mining
Groundwater salinity range	0.14-8.5 dS/m (100-5980 mg/L)
Salt store	low-moderate
Salinity occurrence	n/a
Salinity rating (soil)	n/a
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	n/a
Equilibrium response time	fast
Impacts	n/a
Salinity risk ranking	low

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### ***Discussion***

This groundwater flow system occurs in Permian and Triassic (Parmeener Supergroup) sedimentary rocks which consist mainly of mudstone, siltstone sandstone, tillite and conglomerate. The Lower Permian succession consists of varying thicknesses of till and conglomerate at the base (up to about 550 m thick) followed by mudstone, pebbly sandstone and siltstone. The upper part consists of pebbly mudstone and siltstone. Much of the Permian rocks were deposited under marine conditions in a glacial environment, with two thin freshwater sequences in the middle and at the top. The Triassic rocks are mainly of fluviolacustrine origin with occurrences of volcanoclastic materials and minor occurrences of volcanic rocks. These layered sedimentary rocks usually have low dip angles. These rocks have been intruded by dolerite at many locations, resulting in relatively small-sized areas where these flow systems occur.

The regolith of soil and talus on these units is variable but, particularly on the Permian units in the low rainfall areas, is thin. Mudstone units within the Triassic rocks develop quite thick soil layers.

Aquifers are mainly unconfined to confined fractured rock aquifers, although some of the coarser-grained units (sandstone units in the Triassic and Permian and conglomerate in Permian rocks) act partially as intergranular aquifers. However even in the sandstone units the major flow through the rock appears to be in the joints and bedding plane system. These rocks show little or no folding but have been affected by faulting, causing joint systems to develop. Because of their higher primary porosity (intergranular), Permian and Triassic sedimentary rocks are regarded as better and more prospective aquifers than dolerite.

Groundwater flow rates are controlled by high to moderate hydraulic gradients. High hydraulic gradients occur in steeper terrain and groundwater flows from individual hills and discharges where the hydraulic gradient reduces at the foot of slopes. Groundwater is often held under pressure and usually rises in boreholes above the point where the groundwater has been struck during drilling. Artesian water is sometimes encountered in the Spreyton, Huonville and Bothwell areas.

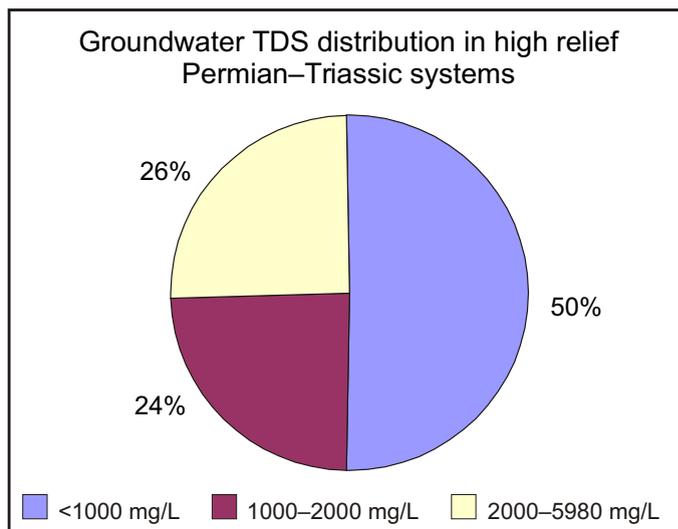
Salt stores in Permian and Triassic sedimentary rocks are generally regarded as low to moderate. Salt stores and salinity problems are minor or absent in high rainfall areas, although salt stores have developed in the low rainfall/high evaporation areas. Some localised salt stores may exist in the area between Ross and South Arm, as groundwater of poor quality has been encountered in several boreholes. Groundwater quality is variable, with 50% of available salinity data (total dissolved solids) being in a range of 97–1000 mg/L, 24% between 1000–2000 mg/L, with the remaining 26% above 2000 mg/L (up to 5980 mg/L east of Ross).

Residual salt stores from marine deposits of the Permian do not appear to exist. There have been reports of some salt layers within Triassic sedimentary rocks but none have been confirmed.

Groundwater discharge and salinity typically occur where higher permeability fractured rocks rest over less permeable materials, causing groundwater seepages where the interface is exposed in erosional surfaces. Springs occur where more fractured zones abut zones with lower fracture intensity or low permeability units, such as Triassic mudstone. They can also develop where units with significant intergranular permeability overlie units with low permeability.

Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. In some areas the groundwater derived from these systems could have off-site effects as a result of recharging groundwater systems down-gradient.

Water levels are monitored in these flow systems at Lilydale and Snug. A monitoring borehole at Huonville is artesian.



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## 6: Local flow systems in granites

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### **Regions**

Granitic rocks mainly occur in northeast Tasmania, with other occurrences in southern and western Tasmania. These rocks extend over an area of approximately 3970 km<sup>2</sup>.

### **Critical attributes that determine groundwater behaviour in response to land management**

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Scale	local
Landform	steep to undulating hills
Regolith	colluvium
Groundwater aquifers	colluvium and weathered fractured granite
Hydraulic conductivity (m/day)	1
Aquifer transmissivity (m <sup>2</sup> /day)	5-10
Specific yield (%)	10
Flow length (km)	2
Confined/unconfined	unconfined
Catchment size (ha)	500
Annual rainfall (mm)	900-2000
Land use	forestry, reserves and minor agriculture, mining
Groundwater salinity range	0.1-2.4 dS/m (75-1700 mg/L)
Salt store	low
Salinity occurrence	break of slope
Salinity rating (soil)	S1-S2
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	mid-lower slopes
Base flow/wash off	base flow and wash off
Equilibrium response time	fast to moderate
Impacts	on site
Salinity risk ranking	low

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### **Discussion**

There is limited information available on the quality of groundwater aquifers in this system. Based on available data, groundwater quality is generally good, with the majority of TDS values being below 500 mg/L (minimum 75 mg/L) and only one record with TDS greater than 1000 mg/L at Coles Bay (1700 mg/L).

These systems are dominated by weathered granitic bodies, and as such have well developed colluvial slopes surrounding them. They typically comprise unconfined colluvial aquifers which are overlain by remnant clay and weathered bedrock surfaces on the mid and lower slopes. Groundwater recharge occurs on the mid-slope areas at the head of the colluvial material and is seasonal in nature. Groundwater migrates from the slopes of catchments towards adjacent valley floors, and is transmitted largely by the underlying weathered profile.

Groundwater discharge and salinity typically occur in valley floors and at breaks of slope. Salt storages in these landscapes are thought to be low. Off-site impacts, in the form of increased salt loads in streams, are not regarded as significant. The response time of the system with predominant colluvial aquifers is fast, while the response time for fractured granite aquifers is probably moderate to slow.

The issues for managing eventual salinity in these systems are the low permeability of the aquifers (and thus the time frames involved in draining the aquifers sufficiently to lower groundwater levels) and the difficulty of locating sustainable groundwater supplies in a hydraulically variable aquifer.

## 7: Local flow systems in high-relief folded and fractured Proterozoic and Palaeozoic rocks

### Regions

Proterozoic and Palaeozoic rocks mainly occur in western and northeastern Tasmania, with smaller areas in northern and southern Tasmania. They extend over an area of approximately 17 940 km<sup>2</sup>.

### Critical attributes that determine groundwater behaviour in response to land management

Scale	local
Landform	steep hilly
Regolith	soil and weathered rock
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	1-2
Aquifer transmissivity (m <sup>2</sup> /day)	50-100
Specific yield (%)	3-5
Flow length (km)	<5
Confined/unconfined	unconfined to semiconfined
Catchment size (ha)	<500
Annual rainfall (mm)	700-3000
Land use	reserves, forestry, minor agriculture, mining
Groundwater salinity range	0.07-5.2 dS/m (46-3626 mg/L)
Salt store	low
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S1 and S2
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	both
Equilibrium response time	fast
Impacts	local and off site
Salinity risk ranking	low

### Discussion

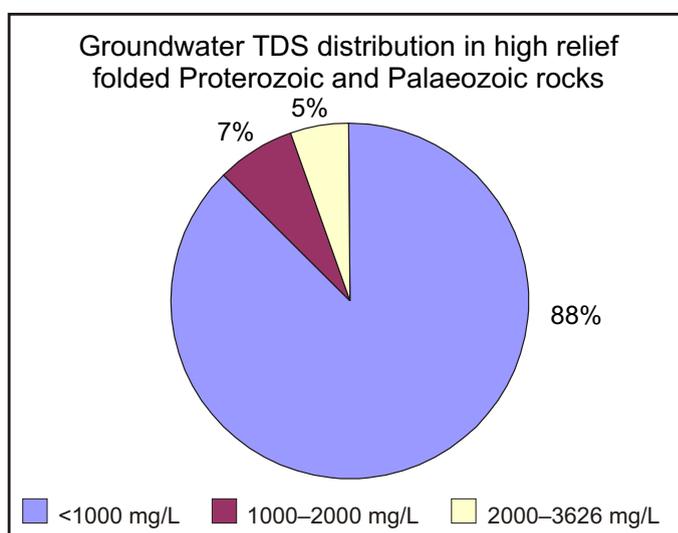
Sedimentary and metamorphic rocks are the main lithological members of this system, with some occurrences of volcanoclastic and volcanic rocks. Because of the age of these rocks, they have been exposed to various folding and faulting episodes and as result have been fractured to varying degrees. Fractured aquifers with significant hydraulic conductivity values occur in competent rocks in many locations. In the less competent rocks, such as schist of Precambrian age, hydraulic conductivity values can be lower.

Fractured unconfined and semiconfined aquifers in this system are regarded as reliable aquifers in most parts of Tasmania, with yields in a range from 0.03 to 25 L/s (mean 2.13 L/s). Springs can occur at locations where high intensity fractured rock zones abut less fractured areas. Springs in carbonate rock areas are related to karst systems and at some locations can be artesian (for example west of Smithton). Aquifers can be semi-confined at many locations as a result of the attitude of the fracture pattern carrying the water.

Groundwater flow is controlled by high hydraulic gradients. In steeper terrain, groundwater flows from individual hills and discharges where the hydraulic gradient reduces at the foot of slopes. Groundwater flow occurs via fractures in the rocks. Groundwater is often under pressure and standing water levels are usually above the point where the groundwater has been struck during drilling.

Groundwater quality is good, with 88% of available salinity data (total dissolved solids) being in a range of 46-1000 mg/L. The mean TDS is 560 mg/L, with most of the TDS values usually well below 500 mg/L.

Salt stores in the system are generally regarded as low, especially in western Tasmania where rainfall is high. Salinity problems developed in these systems



are relatively isolated, with occurrences noted in far northwestern Tasmania, on Flinders Island and in northeast Tasmania. There may be some salt stores in northeast Tasmania between Pipers Brook and Weymouth, as groundwater of moderate to poor quality (1–2000 mg/L, maximum 3090 mg/L TDS) has been encountered and some evidence of salt affected land has been observed in the past.

The regolith developed on these rocks can be variable in thickness but is usually relatively thin, resulting in a limited potential for salt stores in this zone of the profile.

Groundwater discharge and salinity typically occur where higher permeability fractured rocks rest over less permeable materials, causing groundwater seepages where the interface is exposed on erosional surfaces. Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. In some areas the groundwater derived from these systems could have off-site effects as a result of recharging groundwater systems down gradient.

Groundwater monitoring boreholes are located at Montagu, Togari, Mooreville Road, South Forest and Pipers River.

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## **8: Intermediate flow systems in Tertiary sedimentary rocks**

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### ***Regions***

These flow systems mainly occur around Devonport, Launceston and Gladstone in northern Tasmania, on Flinders Island, in the Coal River–Orielton area in southern Tasmania, and at Macquarie Harbour in western Tasmania. They cover an area of approximately 2060 km<sup>2</sup>.

### ***Critical attributes that determine groundwater behaviour in response to land management***

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Scale	intermediate
Landform	dissected plain and infilled valleys
Regolith	clay, sand, sandy clay and gravel
Groundwater aquifers	sand and gravel
Hydraulic conductivity (m/day)	10–200
Aquifer transmissivity (m <sup>2</sup> /day)	40–3200
Specific yield (%)	20
Flow length (km)	up to 30
Confined/unconfined	confined and unconfined
Catchment size (ha)	50 000
Annual rainfall (mm)	450–3000
Land use	grazing, cropping, reserves in west
Groundwater salinity range	0.06–12.2 dS/m (45–8518 mg/L)
Salt store	low north and west, moderate–high south
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	margins and within the catchments
Base flow/wash off	base flow and wash off
Equilibrium response time	slow
Impacts	on and off site
Salinity risk ranking	low–moderate north, moderate–high south

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### ***Discussion***

These groundwater flow systems occur mainly in non-marine lacustrine and alluvial Tertiary sequences, which mainly consist of interbedded clay, silty and sandy clay, sand, gravel and conglomerate. These sedimentary rocks have been deposited in basins formed by faulting, warping and erosion.

These groundwater flow systems underlie flat to undulating regions around Tasmania. The aquifers in northeastern and western Tasmania (Scottsdale and the area south of Strahan) consist mainly of sand and gravel. Aquifers in the Coal River and Tamar River valleys consist mainly of fine to medium-grained sand and sandy clay derived from the weathering of Triassic and Permian sandstone, with minor gravel layers. These aquifers are usually confined and occasionally unconfined. They occur at varying depths of up to 100+ m below the surface.

Sand and gravel horizons in the Tertiary sedimentary rocks form intergranular aquifers that often have high yields in the range of 0.06 to 15.5 L/s (mean 2.4 L/s). The highest yielding zones are in old buried river channels (deep leads), which in the Scottsdale Basin contain extensive gravel and coarse sand derived mainly from the weathering of granite. These deep leads are marked on the hydrogeological and geological maps of the Scottsdale Sedimentary Basin (Moore, 1990, 1992). The geology and hydrogeology of Coal River Basin has been described by Leaman (1971).

Groundwater salinity (expressed as total dissolved solids) in most of northern Tasmania is usually well below 500 mg/L (in a range from 45 to 2760 mg/L with a mean TDS of 313 mg/L). In southern Tasmania and the Tamar Valley, groundwater salinity is usually greater than 2000 mg/L and is in the range from 330 to 8518 mg/L (mean 2800 mg/L).

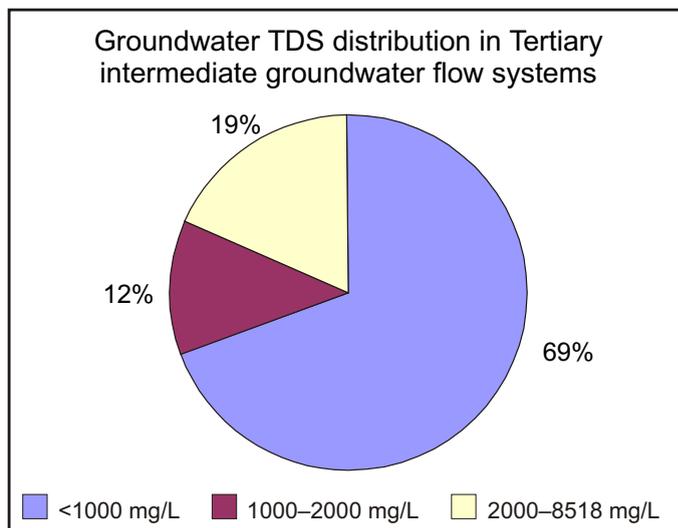
The major confined aquifers probably contribute little to spring activity, except perhaps where they come close to the surface. Springs are probably mainly associated with the minor near-surface unconfined and semi-confined aquifers.

Recharge to the major aquifers is not known but probably occurs where the aquifer systems intersect the surface and around the basin margins.

Salt stores are low in western Tasmania as a result of the high rainfall, while in the northeast they are predominately low with the possibility of some localised areas of moderate salinity. Salinity occurrences are often localised low in the topography along the drainage lines and break in slopes, again usually low in the topography. Salinity problems are particularly common in the low rainfall areas of the Coal River Valley but less so in northeast Tasmania. Salinity is also an issue at some localities on Flinders Island but is unlikely to be a problem around Macquarie Harbour because of the high rainfall. The Tamar Valley is regarded as an area with moderate to high salt stores and may be prone to dryland salinity.

Local Quaternary unconfined systems, overlying these intermediate systems, may be contributing to the salinity problems within the groundwater flow systems in the Tertiary sedimentary rocks.

Groundwater levels are monitored in this groundwater flow system at Waterhouse and Scottsdale.



## 9: Intermediate to local flow systems in Tertiary basalt

### Regions

Tertiary basaltic rocks occur throughout the northern and eastern half of Tasmania as bodies of variable size, with the major occurrences being in northwest Tasmania. They extend over an area of approximately 4056 km<sup>2</sup>.

### Critical attributes that determine groundwater behaviour in response to land management

Scale	intermediate to local
Landform	undulating to steep
Regolith	soil and talus
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	5–20
Aquifer transmissivity (m <sup>2</sup> /day)	up to 200
Specific yield (%)	3–5
Flow length (km)	up to 20
Confined/unconfined	unconfined and confined
Catchment size (ha)	up to 2000
Annual rainfall (mm)	400–2000
Land use	cropping, grazing, forestry, reserves, mining
Groundwater salinity range	0.04–18.9 dS/m (30–13 224 mg/L)
Salt store	very low to high
Salinity occurrence	drainage lines
Salinity rating (soil)	S0–S2
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	base flow
Equilibrium response time	moderate
Impacts	off site
Salinity risk ranking	nil–moderate

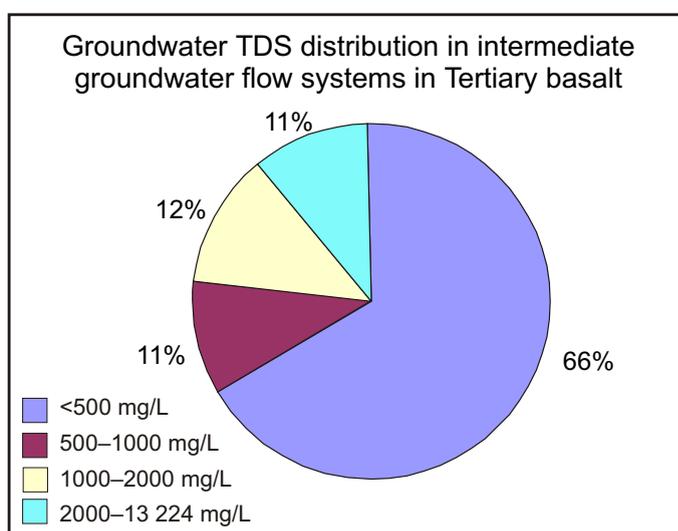
### Discussion

Tertiary basalt is a common rock in northwestern Tasmania where it forms lava plains that are dissected by the major rivers (Mersey, Blythe, Emu, etc.). The exposures are dominated by subaerial flows, which have filled Tertiary drainages with lava from numerous volcanic centres. Tertiary basalts also occur in the northeast, southern Midlands, Central Plateau and southern Tasmania. A small area of basalt occurs on Flinders Island.

Basalts are one of the more prospective Tasmanian groundwater sources, especially in the northwest. The best aquifer in southern Tasmania is the Sorell basalt aquifer. Groundwater is stored in fractures and the vesicular zones of the basalts, and occasionally in the unconsolidated sediments that sometimes separate two basalt flows. Confined basalt aquifers may be developed where basalt flows are interbedded with less permeable sedimentary rocks. Orientation of the joint systems can also result in semi-confined conditions, although groundwater in basalt is often largely unconfined.

The quality of the groundwater in basalt is usually directly related to the local rainfall. Groundwater is generally of good quality, with 66% of available salinity data in a range from 30 to 500 mg/L (mainly in northern Tasmania). A further 11% of available records are in a range between 500 and 1000 mg/L, 12% between 1000 and 2000 mg/L, with the remaining 11% above 2000 mg/L (up to 13 224 mg/L in the Richmond area, probably the average of a sample from basalt and Tertiary sedimentary rock aquifers).

The regolith (soil and talus) developed on basalt can be quite thick, particularly in the northern areas, although in drier areas the depth of cover over rock can be quite shallow. Salt stores can occur within the regolith and within the groundwater contained in the



rock. If significant salt store occurs it is usually in the low rainfall, high evaporation regions. Salt stores in basalts are generally regarded as low in northern Tasmania, while in the Midlands and southern areas they are in a range from low to high.

The following table indicates groundwater quality in Tasmanian basalt aquifers and in the three major areas of occurrence:

	<i>Tasmania</i>	<i>North</i>	<i>SE Midlands</i>	<i>South</i>
Minimum TDS (mg/L)	30	30	218	670
Maximum TDS (mg/L)	13 224	6 800	2 380	13 224
Mean TDS (mg/L)	863	360	1 463	2 647
Number of analyses	156	116	11	29

Note: the high mean value in the south is due to several high values recorded throughout the area (in the Sorell area TDS values are mainly in the range from 1000-2000 mg/L).

Springs in basalt areas occur where variations in permeability within the rock result in groundwater coming to the surface, particularly on the middle of slopes. A very common location for springs is at the base of flows where the basalt is in contact with low permeability material such as Tertiary clay or Triassic mudstone.

Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. Groundwater contained in these systems would have off-site effects at discharges at the lowest point of the system or laterally in drainage lines that intersect these basalt aquifers.

Groundwater response times following land-use change is likely to be moderate to slow, depending on the local hydrogeological properties of the basalt.

Groundwater level monitoring boreholes in basalt are located at Pawleena Road (Sorell), Hampshire, Hagley and Winnaleah. A series of boreholes have been monitored in the Devonport–Port Sorell–Sassafras area (Cromer, 1993).

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## **10: Intermediate to local flow systems in low-relief Jurassic dolerite**

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### **Regions**

These systems occur in Jurassic dolerite in the central, southeastern and middle northern parts of Tasmania over an area of approximately 1845 km<sup>2</sup>. They are usually located within the previously described *Local flow systems in high-relief Jurassic dolerite* with major occurrences in the area between the Central Plateau and East Coast.

### **Critical attributes that determine groundwater behaviour in response to land management**

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Scale	intermediate to local
Landform	plateaus and foothills
Regolith	soil and talus
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	0.1–1
Aquifer transmissivity (m <sup>2</sup> /day)	5–100
Specific yield (%)	1
Flow length (km)	1–20
Confined/unconfined	semiconfined and unconfined
Catchment size (ha)	variable (0.4–8475)
Annual rainfall (mm)	400–2000
Land use	forestry reserves and agriculture, minor mining
Groundwater salinity range	0.13–10.0 dS/m (91–6990 mg/L)
Salt store	low–high
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	episodic to seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	base flow and wash off
Equilibrium response time	slow to moderate
Impacts	mainly off site
Salinity risk ranking	low–moderate

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## Discussion

Jurassic dolerite is a common rock in the central and eastern half of Tasmania where it is generally intrusive into older Permian and Triassic rocks, although it can occasionally be seen intruding older rocks. Dolerite occurs mainly as sills and dykes which in places have had profound effect on the physical properties of the surrounding rocks.

The aquifers are fractured rock aquifers and the aquifer characteristics (such as transmissivity, aquifer yield) are dependent on the degree of fracturing and the interconnection of the fractures. A little over 50% of all boreholes drilled in dolerite produce some or useable quantities of groundwater. Fractured, mainly unconfined to semi-confined aquifers, are characteristic for dolerite. Groundwater flow is generally slow in areas of low fracture density with rapid flow rates in highly fractured areas (fault lines, intensive fracture systems, etc.).

The quantity and quality of groundwater in dolerite is usually directly related to the level of fracturing and the average annual rainfall. Groundwater quality is variable, with 35% of available salinity data (total dissolved solids) in a range of 91–1000 mg/L and another 48% between 1000 and 2000 mg/L, with the remaining 17% above 2000 mg/L (up to 6990 mg/L on Wanstead Hill south of Conara). A value of 9270 mg/L from a bore east of Tunbridge may represent water from either deeply-weathered dolerite or Tertiary boulder beds.

Springs typically occur where fractures intersect the ground surface, at breaks of slope, and in drainage lines.

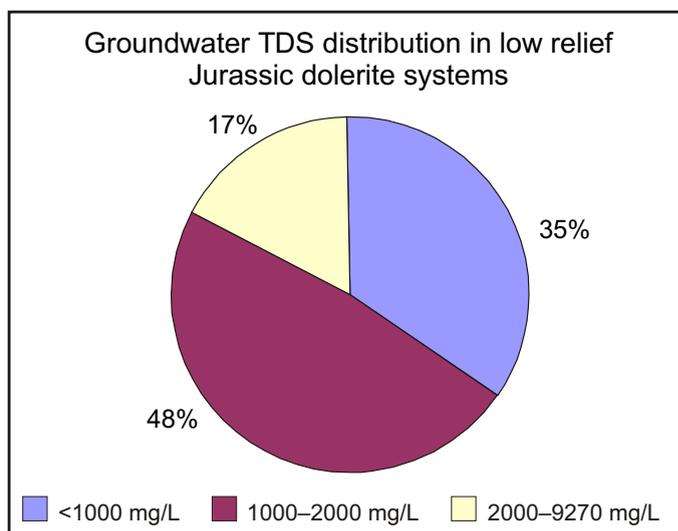
Salt stores in dolerite are generally regarded as low on the Central Plateau (high rainfall areas). In low rainfall areas, such as between Conara and Tunbridge, there may be some salt stores as moderate to poor water quality has been encountered in a few boreholes. In general the regolith developed on dolerite is usually quite thin but deep weathering is occasionally developed where fracturing is intense, and can be of considerable thickness. The salt store can be within the regolith and within the groundwater in the fractured rock.

Standing water levels in dolerite are monitored by Mineral Resources Tasmania at Port Arthur.

Groundwater response time as result of land use change is likely to be variable from slow to moderate and will depend on the aquifer's characteristics.

As a fractured aquifer, recharge is expected to be usually seasonal and within the area where groundwater occurs. The highest recharge in the system occurs where the fractured rocks crop out or have minimal soil cover.

In some areas the groundwater derived from these systems could have off-site effects as a result of recharging groundwater systems down-gradient.



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## 11: Intermediate flow systems in low-relief Permian and Triassic sedimentary rocks

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### Regions

This flow system mainly occurs in Permian and Triassic sedimentary rocks in southeast Tasmania, with smaller areas north of Launceston and south of Wynyard. It extends over an area of approximately 805 km<sup>2</sup>.

### Critical attributes that determine groundwater behaviour in response to land management

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Scale	local
Landform	undulating slopes and valleys
Regolith	soil and talus
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	5–10
Aquifer transmissivity (m <sup>2</sup> /day)	<150
Specific yield (%)	2–4
Flow length (km)	<5
Confined/unconfined	confined and unconfined
Catchment size (ha)	<500
Annual rainfall (mm)	500–2000
Land use	forestry, grazing, horticulture and minor cropping
Groundwater salinity range	0.06–11.1 dS/m (41–7790 mg/L)
Salt store	low–moderate
Salinity occurrence	break of slope and drainage lines
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	both
Equilibrium response time	moderate
Impacts	on site and off site
Salinity risk ranking	low–moderate

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### Discussion

This groundwater flow system occurs in Permian and Triassic (Parmeener Supergroup) sedimentary rocks. The main lithological units are tillite, conglomerate (at base), siltstone, pebbly siltstone and sandstone (Permian), with sandstone and mudstone making up the Triassic rocks. The Permian rocks were deposited under glacial conditions and are largely marine deposited rocks, with some freshwater deposits in the middle and at the top of the sequence. The Triassic rocks are mainly of fluvio-lacustrine origin with minor occurrences of volcanoclastic and volcanic rocks. These rocks have been intruded by dolerite at many locations, resulting in relatively small-sized areas where these flow systems occur.

The regolith of soil and talus on these units is variable but is thin where Permian units occur in areas of low rainfall. Mudstone units within the Triassic sedimentary rocks develop quite thick soil layers.

Aquifers are mainly unconfined or confined fractured rock aquifers although some of the coarser grained units (sandstone units in Triassic rocks and tillite, conglomerate and sandstone in Permian rocks) act partially as intergranular aquifers. Even in the sandstone units the major flow through the rock appears to be in the joints and bedding plane system. These rocks show little or no folding but have been affected by faulting, causing joint systems to develop. Because of their higher primary porosity (intergranular), Permian and Triassic sedimentary rocks are regarded as better and more prospective aquifers than dolerite and granite.

Groundwater flow rates are controlled by low to moderate hydraulic gradients. In steeper terrain, groundwater flows from individual hills and discharges where the hydraulic gradient reduces at the foot of slopes. Groundwater flow occurs via fractures in the sedimentary rocks. Groundwater is usually under pressure and standing water levels are often above the point where the groundwater has been struck during drilling.

Groundwater quality is variable, with 69% of available salinity data (total dissolved solids) being in a range of 41–1000 mg/L, 20% between 1000 and 2000 mg/L, with the remaining 20% above 2000 mg/L (up to 7790 mg/L at Barnes Bay on Bruny Island).

Groundwater discharge and salinity typically occur where higher permeability fractured rocks rest over less permeable materials, causing groundwater seepages where the interface is exposed on erosional surfaces. Springs occur where more fractured zones abut zones with lower fracture intensity, or abut low permeability units such as

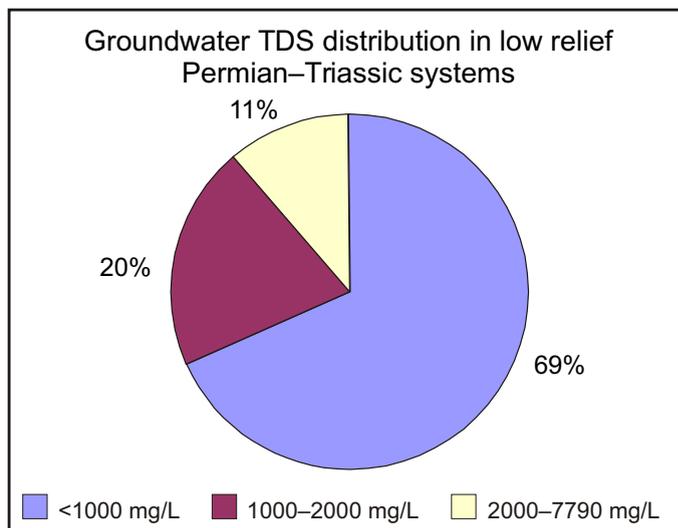
Triassic mudstone. They can also develop where units with significant intergranular permeability overlie units with low permeability.

Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. Groundwater contained in these systems could have on-site and off-site effects as a result of recharging groundwater systems down-gradient.

Salinity problems in these flow systems are not related to their mode of deposition. Marine deposited rocks (Permian) in the higher rainfall areas usually have good quality groundwater to 100+ m depths. The areas where salt loads/salinity problems occur appear to be largely related to climatic conditions that have prevailed in the immediate past. The Triassic rocks are a freshwater-deposited sequence which develops salinity problems in similar regions to the Permian rocks.

Salt stores in the Permian and Triassic rocks are generally regarded as low to moderate. In high rainfall areas salt stores and salinity problems are minor or absent. Salt stores have developed in the low rainfall- high evaporation areas of southeast Tasmania. As a result, salinity problems are known at a number of locations in these units in this region. Other salt stores occur in low rainfall areas near Tunbridge, Runnymede, and in the area between Stonor and Tiberias, where groundwater of poorer quality has been encountered.

Water levels are monitored in this flow system at Calder, St Marys, Ross, Tunnack, Melton Mowbray, Buckland and Dodges Ferry. Two boreholes, one at Spreyton and the other at Bothwell, are artesian boreholes with water levels just below the ground surface in some periods of the year.



## 12: Intermediate flow systems in low-relief folded and fractured Proterozoic and Palaeozoic rocks

### Regions

These systems occur mainly in Proterozoic and Palaeozoic rocks in western Tasmania and on King Island, with smaller areas in northeast, northern and southern Tasmania. They extend over an area of approximately 4745 km<sup>2</sup> and are usually located within the previously described *Local flow systems in high-relief folded fractured Proterozoic and Palaeozoic rocks*.

### Critical attributes that determine groundwater behaviour in response to land management

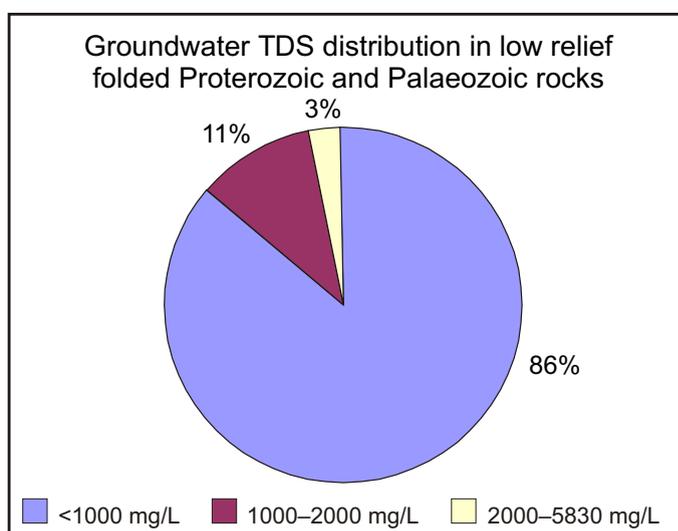
Scale	intermediate
Landform	rolling hills
Regolith	soil and weathered rock
Groundwater aquifers	fractured rock
Hydraulic conductivity (m/day)	1-2
Aquifer transmissivity (m <sup>2</sup> /day)	50-100
Specific yield (%)	3-5
Flow length (km)	20
Confined/unconfined	unconfined, semi-confined to confined
Catchment size (ha)	50 000
Annual rainfall (mm)	700-3000
Land use	reserves, forestry, minor agriculture, mining
Groundwater salinity range	0.1-8.3 dS/m (68-5830 mg/L)
Salt store	low
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	local and regional
Base flow/wash off	base flow and wash off
Equilibrium response time	slow to moderate
Impacts	local and off site
Salinity risk ranking	low-moderate

### Discussion

Sedimentary and metamorphic rocks are the main members of this system, with occurrences of volcanoclastic, volcanic and ultramafic rocks. Because of their age these rocks have been exposed to various folding and faulting episodes, and as result have been fractured to varying degrees. Competent rocks form fractured aquifers with significant hydraulic conductivity values in many locations. In the less competent rocks, such as schist of Precambrian age, hydraulic conductivity values can be lower.

Fractured unconfined and semiconfined aquifers in this system are regarded as prospective in most parts of Tasmania, with yields in a range from 0.03 to 30 L/s (mean 1.76 L/s). Springs can occur at locations where high intensity fractured rock zones abut less fractured areas. Springs in areas of carbonate rock are related to karst systems and at some locations can be artesian (for example west of Smithton). Aquifers can be semi-confined at many locations as a result of the attitude of the fracture pattern carrying the water.

Groundwater flow rates are controlled by low to moderate hydraulic gradients. In flat terrain groundwater flow is generally slow because of the reduced hydraulic gradient. Groundwater flow mainly occurs via fractures through the rocks and perhaps to a limited extent through intergranular flow in some of the less metamorphosed units (e.g. sandstone in Silurian-Devonian units). Groundwater is often under pressure and standing water levels are usually above the point where the groundwater has been struck during drilling.



Groundwater quality is good, with 86% of available salinity data (total dissolved solids) being in a range of 68–1000 mg/L, 11% between 1000 and 2000 mg/L, with the remaining 3% above 2000 mg/L (up to 5830 mg/L south of Bridport). Mean TDS is 603 mg/L, with most of the TDS values usually well below 500 mg/L.

Salt stores are generally regarded as low within this groundwater flow system. Salinity problems developed in this system are relatively isolated, with occurrences in far northwest Tasmania, northeast Tasmania and Flinders Island. There may be some salt stores in the areas around Pipers Brook, Weymouth and Bridport, where groundwater of moderate to poor quality (1000–2000 mg/L, maximum 5830 mg/L) has been encountered and some evidence of salt affected land has been observed.

The regolith developed on these rocks can be variable in thickness but is usually relatively thin, resulting in a limited potential for salt stores in this part of the profile.

Groundwater discharge and salinity typically occur at break of slopes and in drainage lines.

Recharge is seasonal and highest in the system where the fractured rocks crop out or have minimal soil cover. Groundwater contained in this system would have an on-site effect but in some areas it could have off-site effects as a result of recharging groundwater systems down-gradient.

Groundwater-monitoring boreholes in this system are located at Trowutta, Beulah, Branxholm and Chudleigh.

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### **13: Regional and local flow systems in Tertiary sedimentary rocks**

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#### ***Regions***

These flow systems occur in Tertiary sedimentary rocks in the area between Launceston, Westbury and south to Campbell Town, over an area of 860 km<sup>2</sup>.

#### ***Critical attributes that determine groundwater behaviour in response to land management***

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Scale	regional
Landform	dissected plain
Regolith	clay, sand, sandy clay, gravel
Groundwater aquifers	sand and gravel
Hydraulic conductivity (m/day)	10–100
Aquifer transmissivity (m <sup>2</sup> /day)	40–1600
Specific yield (%)	20
Flow length (km)	up to 60
Confined/unconfined	confined, semi-confined
Catchment size (ha)	250 000
Annual rainfall (mm)	650–800
Land use	grazing and cropping
Groundwater salinity rang	0.25–7.5 dS/m (175–5250 mg/L)
Salt store	low-moderate west, moderate-high east
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	margins
Base flow/wash off	base flow and wash off
Equilibrium response time	slow
Impacts	on site and off site
Salinity risk ranking	low-moderate west, moderate-high east

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#### ***Discussion***

This groundwater flow system occurs in the freshwater sequence in the Longford Tertiary Basin. This sequence consists mainly of interbedded clay, silty and sandy clay, sand, gravel and conglomerate, with minor lignite beds and fragments.

The system underlies the flat to undulating region around the South Esk River (east of Conara) and the lower reaches of its tributaries (Meander River and Macquarie River). The aquifers in the western sub-basin consist of fine to medium-grained sand, while in the southern part of the eastern sub-basin fine siliceous gravel beds are the more common aquifers. The aquifers are mainly confined, with occasional occurrences of unconfined aquifers. Their

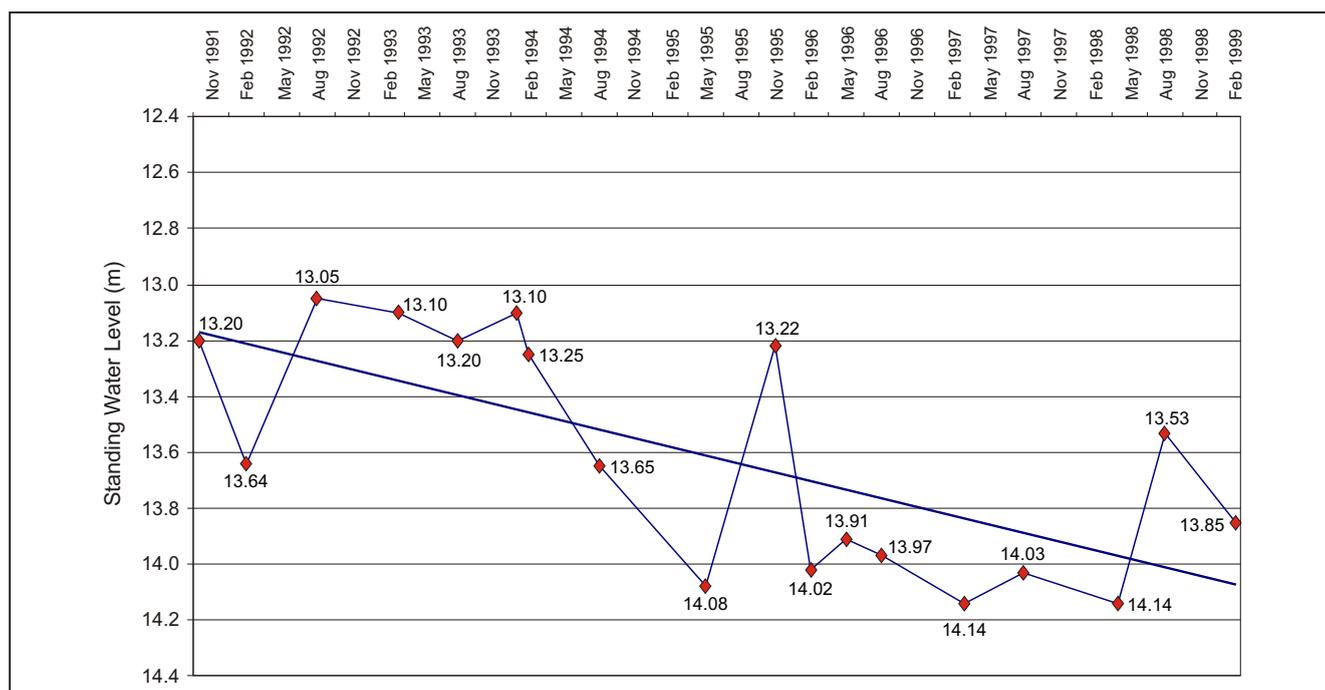
vertical distribution for a depth of 150 m from the surface has been described by Matthews (1983), with indications of possible aquifers at greater depths. The two main aquifers in the Cressy area occur at depths of 80 and 110 metres.

Recharge areas for these aquifers have not been identified. It is thought that recharge may occur around the margins of the basin or in some cases possibly through the fractured clay layers encountered during the investigation drilling program. The artesian areas between Longford and south of Cressy are located in topographically low regions (e.g. eroded areas around streams). The relationship between deeper and shallow perched aquifers is unknown and needs to be better understood in order to manage dryland salinity.

The standing water level recorded in a Mineral Resources Tasmania monitoring borehole near Cressy (fig. 2) shows a minor decrease in level (within a range from 13–14 m) over the last ten years.

Local, usually unconfined systems located on top of the regional system, are contributing to the salinity problems within the Tertiary Longford Basin (Dell, 2000). A typical example of a local system occurs at Chinta Road, near Powranna. This is described below.

Scale	local
Landform	gently undulating low hilly terrain (land system 394121)
Regolith	clay (Tertiary to Quaternary)
Groundwater aquifers	clay
Hydraulic conductivity (m/day)	0.0013–0.2
Aquifer transmissivity (m <sup>2</sup> /day)	5
Specific yield (%)	3–5
Flow length (km)	3–5
Confined/unconfined	unconfined
Catchment size (ha)	1000
Annual rainfall (mm)	640
Land use	grazing and cropping
Groundwater salinity range	2–15 dS/m (1400–10 500 mg/L)
Salt store	high
Salinity occurrence	drainage lines and break of slope
Salinity rating (soil)	S2 and S3
Temporal distribution of recharge	seasonal
Spatial distribution of recharge	general (potentially high on terrace)
Base flow/wash off	base flow and wash off
Equilibrium response time	slow
Impacts	on site and off site
Salinity risk ranking	moderate to high



**Figure 2**  
Standing Water Levels recorded in Cressy monitoring borehole, 1991–1999

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[16 December 2003]

## APPENDIX 1

### Characterisation attributes: definitions of the relative ratings applied to groundwater flow systems within fact sheets

<i>Attributes</i>	<i>Rating</i>	<i>Meaning/value</i>
Scale (of groundwater processes)	Local	Groundwater flows over distances less than five kilometres within the confines of sub-catchments
	Intermediate	Groundwater flow over distances of 5 to 30 kilometres and may occur across sub-catchment boundaries
	Regional	Groundwater flow occurs over distances exceeding 50 kilometres at the scale of river basins
Aquifer Transmissivity (ability to transmit groundwater through the aquifer)	Low	Less than 2 m <sup>2</sup> /day
	Moderate	2 m <sup>2</sup> /day to 100 m <sup>2</sup> /day
	High	Greater than 100 m <sup>2</sup> /day
Groundwater Salinity	Low	Less than 1.5 dS/m (3 dS/m in NLWA)
	Moderate	Ranging from 1.5–3 dS/m (3–15 dS/m in NLWA)
	High	Greater than 3 dS/m (15 dS/m in NLWA)
Catchment Size	Small	Less than 10 km <sup>2</sup>
	Moderate	Ranging from 10 km <sup>2</sup> to 500 km <sup>2</sup>
	Large	Greater than 500 km <sup>2</sup>
Annual Rainfall	Low	Less than 400 mm
	Moderate	Ranging from 400 mm to 800 mm
	High	Greater than 800 mm
Salinity Rating	S1	Loss of production
	S2	Saline land covered with salt tolerant volunteer species
	S3	Barren saline soils, typically eroded with exposed sub-soils
Equilibrium response time (to Land Management)	Slow (Low NLWA)	Salinity benefits accrue over time frames that exceed 50 years
	Moderate	Salinity benefits accrue over time frames ranging from 30 to 50 years
	Fast (High NLWA)	Salinity benefits accrue over time frames less than 30 years

*Note:*

1. Throughout this document it is assumed that the conversion from dS/m to mg/L is 1 dS/m ≈ 700 mg/L.
2. Most groundwater concentrations recorded by MRT are in mg/L and have been converted using this relationship to dS/m.

## APPENDIX 2

### Methodology used in map production

#### Datasets

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The data used comprised:

1. 1:250 000 scale digital geology of Tasmania, August 2001; Mineral Resources Tasmania.
2. 150 m Digital Elevation Model (DEM) of Tasmania, September 2001; developed by S. Lynch and M. Brown, Land Resource Assessment, Department of Primary Industries, Water and Environment, Launceston.

#### Method

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The DEM was generated using 1:25 000 scale (10 m) contour data with 'Topogrid' within ArcInfo8.1®. The DEM was converted into a slope class map with two slope classes only: 0-3° and greater than 3°. The slope model was overlain onto the geology dataset. It was from this coverage that the groundwater flow systems were queried.

Discussions were held within the group at the workshop to ascertain the expected groundwater response/s and types for the geological units within Tasmania. By using field knowledge, borehole data and drilling records, the different groundwater systems were defined and subsequently refined to the final group of 13 categories. The final hydrogeological units were extracted (from the GIS) using geology and/or slope.

The classification process selected geological units based on the slope and/or geology classes. In summary, those units with a slope greater than 3° were classified as 'local groundwater flow systems', whilst units with a slope less than 3° tended to be 'intermediate groundwater flow systems'. The regional groundwater flow system was classified based on its characteristic uniformity and size.

#### Description of ArcInfo items

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##### *gwftas.pat:*

<i>Item Name</i>	<i>Info def</i>	<i>Description</i>
CLASS	4,4,I	Number code referring to Groundwater Flow Class
DESC	100,100,C	Text description of Groundwater Flow Class (as per final definition on map)
RGB	12,12,C	Colour makeup of each Groundwater Flow Class (as per original DPIWE map)
SYMBOL	4,5,B	Reference to colour in shade set.

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#### Limitations

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The final published map has a nominal scale of 1: 500 000. However as the source data used to classify this map was the 1:250 000 scale digital geology of Tasmania, and the 150 m DEM of Tasmania, the digital dataset may be used up to a scale of 1:250 000. Any use beyond this scale is not recommended as geology and slope would have simplified the landscape units beyond practical use. If information beyond 1: 250 000 scale is required, it is recommended that the area be re-examined using more detailed information.