Water availability for the South Esk region
CSIRO Tasmania Sustainable Yields Project

Report six of seven to the Australian Government

December 2009
About the project

Following the November 2006 Summit on the southern Murray-Darling Basin (MDB), the then Prime Minister and MDB state Premiers commissioned CSIRO to undertake an assessment of sustainable yields of surface water and groundwater systems within the MDB. The project set an international benchmark for rigorous and detailed basin-scale assessment of the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources.

On 26 March 2008, the Council of Australian Governments (COAG) agreed to expand the CSIRO assessments of sustainable yield so that, for the first time, Australia would have a comprehensive scientific assessment of water yield in all major water systems across the country. This would allow a consistent analytical framework for water policy decisions across the nation. The CSIRO Tasmania Sustainable Yields Project, together with allied projects for northern Australia and south-west Western Australia, provides a nation-wide expansion of the assessments.

In Tasmania, neither surface water nor groundwater extractions are metered in a consistent way. Consequently it was necessary to model the movement and use of water within the project area using a comprehensive suite of river models. For groundwater, three models covering key groundwater areas were also used. Flow stress rankings were used to determine the potential ecological impacts of changes in streamflow on subcatchments and key ecological sites (150 sites were selected comprising all Ramsar wetlands, estuaries with high conservation value, and river sites and riverine wetlands with high conservation value currently impacted by local extractions of water).

Reporting of the CSIRO Tasmania Sustainable Yields Project is covered by a range of products including a suite of region reports (of which this is one) and a suite of technical reports. There are seven region reports:

1. Water availability for Tasmania
2. Climate change projections and impacts on runoff for Tasmania
3. Water availability for the Arthur-Inglis-Cam region
4. Water availability for the Mersey-Forth region
5. Water availability for the Pipers-Ringarooma region
6. Water availability for the South Esk region
7. Water availability for the Derwent-South East region

For citation details of these reports see the back cover of this report and for a full list of the technical reports see the inside back cover.

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Cover: Meander Dam (CSIRO)
Introduction

This report is one in a series* from the CSIRO Tasmania Sustainable Yields Project. The terms of reference for the project required an assessment of the current and likely future extent and variability of surface water and groundwater resources in Tasmania. This information will help governments, industry and communities consider the environmental, social and economic aspects of the sustainable use and management of the precious water assets of Tasmania.

For the first time, the impacts of catchment development (commercial forestry plantations and future irrigation development), changing groundwater extraction, climate variability and anticipated climate change on water resources at a whole-of-region scale have been assessed. This was achieved through the most comprehensive hydrological modelling ever undertaken for Tasmania. Rainfall-runoff models, groundwater recharge models, river system models and groundwater models were used.

The project has drawn on the scientific knowledge and technical expertise of national and state government agencies, as well as Australia’s leading academics and industry consultants. The assessments have been subject to a comprehensive process of internal and external review, providing quality assurance on all the work performed and all the results delivered.

Oversight of this and allied projects for northern Australia and south-west Western Australia was provided by the CSIRO Water for a Healthy Country Flagship, a research initiative established to deliver the science required for sustainable management of water resources in Australia.

This report examines current and future surface water and groundwater availability for the South Esk region. There are four other region-specific reports in this series.

A sixth report examines climate and runoff for the whole of Tasmania, and a seventh summarises the project results.

For a more detailed technical analysis, readers should also refer to the associated technical reports as listed on the inside back cover of this report.

Project overview

As shown in Figure 1, the overall approach of the project included: (i) defining different climate scenarios and generating daily climate data to describe these scenarios, (ii) modelling the implications of these climate scenarios for catchment runoff and aquifer recharge, (iii) propagating the runoff and recharge implications through river system and groundwater models, (iv) assessing ecological impacts and (v) reporting the implications for water availability and water use.

Figure 1. Project framework

Scenarios assessed

The assessments of current and future water availability have been undertaken by considering four scenarios of historical, recent and future climate, and current and future development. A fifth scenario represents no consumptive extractions. All scenarios were defined by daily time series of climate variables based on different scalings of the observed climate from 1 January 1924 to 31 December 2007.

The first scenario is a historical climate scenario and is used as the baseline against which other scenarios are compared. Current levels (December 2007) of surface water and groundwater development were used. For groundwater only, results are reported using three 23-year periods selected from the historical sequence, representing a wet extreme, median and dry extreme historical climate.

The second scenario is a recent climate scenario for assessing water availability based on the climate of the recent past (1 January 1997 to 31 December 2007). Current levels of surface water and groundwater development were used.

The third scenario is a future climate scenario. Fifteen global climate models with three estimates of temperature changes due to global warming were used to provide a spectrum of possible ~2030 climates. From this spectrum, three were selected for reporting, representing a wet extreme, median and dry extreme future climate.

Current levels of surface water and groundwater development were used.

The fourth scenario is a future development scenario. This scenario used the same climate time series as the future climate scenario, but future levels of development were used. Future development consisted of 24 proposed irrigation schemes, as well as ~2030 projections of commercial plantation forests and an assumed increase in groundwater extraction to 25 percent of recharge.

The fifth scenario is a without-extractions scenario using historical climate, current infrastructure and no extractions. This allows the impact of extractions to be explicitly considered.

Project regions

Assessments are presented for five regions: Arthur-Ingles-Cam (including Flinders and King islands), Mersey-Forth, Pipers-Ringarooma, South Esk and Derwent-South East (Figure 2). Collectively these are referred to as the project area. The West Coast region shown in the figure is not covered by the project but is occasionally referred to for context.

Figure 2. CSIRO Tasmania Sustainable Yields Project regions

* A full list of project reports can be found on the inside back cover and the back cover of this report.
Under historical climate (1924 to 2007)

Averaged over the region, the mean annual rainfall under historical climate is 801 mm and the mean annual runoff is 240 mm (30 percent of the rainfall). Rainfall and runoff are winter dominated, with maximums occurring in August and minimums occurring in January or February. The South Esk region is the driest of the regions covered by the project. Rainfall and runoff are both higher in the north and west of the region and decrease moving towards the south. The region contributes 5 percent of Tasmania’s total runoff.

Mean annual streamflow for the region is 2614 GL/year. Of this, about 158 GL/year (6 percent) is extracted for use, leaving 2456 GL/year of non-extracted water. The Macquarie catchment has the highest relative level of extraction at 11 percent (35 GL/year) of the total surface water in the catchment. In the majority of catchments, the amount of water extracted is only slightly less than that allocated. The main rivers of most catchments are essentially perennial, flowing for more than 97 percent of the time.

Groundwater extraction for the region is 1 GL/year; most of which occurs in the Longford Tertiary Basin. Under the median historical climate, extraction as a percentage of recharge is about 1 percent for the Longford groundwater assessment area. Under the wet extreme historical climate, this proportion is also about 1 percent but increases to 4 percent under the dry extreme historical climate.

About 4 percent of the region’s subcatchments and six of the 23 key ecological sites (all river sites) are potentially impacted by changes in the flow regime due to current levels of catchment development.

Under recent climate (1997 to 2007)

In general, conditions under the recent climate are drier than those of the last 84 years. Mean annual rainfall over the region is 735 mm and mean annual runoff is 203 mm (reductions of 8 and 15 percent respectively relative to historical climate). Decreases are slightly greater over the east of the region and occur primarily in autumn and winter. In the west of the region, both rainfall and runoff increase slightly, particularly in spring.

The mean monthly streamflow is lower than under historical climate in all months with the exception of January and September where streamflow is slightly higher in some catchments. For the region as a whole, there is a 485 GL/year (20 percent) reduction in non-extracted water and an 8 GL/year (5 percent) reduction in extracted water.

Groundwater levels are similar to or slightly lower than those under dry extreme historical climate. Groundwater extraction as a percentage of recharge is about 6 percent for the Longford groundwater assessment area. This indicates a relatively low level of extraction.

Some 24 percent of the region’s subcatchments and 21 key ecological sites (18 river sites and three riverine wetlands) are potentially impacted by changes in the flow regime due to recent climate.

> Meander River (DPIPWE)
Under future climate (~2030)

When considering future climate the focus is on the wet extreme, median and dry extreme range of future climate. All changes are relative to historical climate.

On average, under the future climate, rainfall ranges from an increase of 2 percent to a decrease of 7 percent under the wet and dry extreme respectively, with a decrease of 3 percent under the median. Runoff ranges from an increase of 4 percent to a decrease of 11 percent under the wet and dry extreme respectively, with a decrease of 6 percent under the median future climate.

The volume of non-extracted water increases by 97 GL/year (4 percent) under the wet extreme future climate and decreases under both the dry extreme and median future climate by 152 GL/year (6 percent) and 275 GL/year (11 percent) respectively. In comparison, extractions change by much less, decreasing by 0.2 GL/year (less than 1 percent) and 5.1 GL/year (3 percent) under the wet and dry extreme respectively, and by 3.4 GL/year (2 percent) under the median future climate.

Groundwater levels are expected to be similar to those under median historical climate.

Between 4 and 7 percent of the region’s subcatchments and six key ecological sites (six river sites) are potentially impacted by changes in the flow regime under future climate and current levels of development.

Under future development (~2030)

Except where stated, changes under future development are in addition to changes under future climate.

The area of plantation forests in the region is projected to increase by about 116 km² (a 6 percent increase in total plantation forest). Averaged over the region, this increase in forest cover would lead to a decrease in runoff of 1 percent.

This reduction in runoff to rivers leads to a decrease in extractions of 5 GL/year (3 percent) under all future climate projections. Expected changes in the operation of the state’s hydro-electric system increases inflows by 1 GL/year. New extractions from proposed irrigation schemes of 53 GL/year and an additional 8 GL/year from Meander Dam lead to decreases in the volume of non-extracted water by 114 and 102 GL/year under the wet and dry extremes respectively, and by 105 GL/year under the median future climate (around 5 percent in all cases).

With appropriate commercial arrangements in place, the proposed Midlands Water Scheme (Arthurs Lake) can be supplied at all times. The proposed Midlands Water Scheme (South Esk) and Meadstone Dam can meet full demand for water in 100 percent of years. Ben Lomond Dam can meet full demand for water in more than 97 percent of years. Full demand for water can be met for more than 82 percent of years for the Caveside Scheme, 56 percent of years for the Rubicon Scheme, 41 percent of years for the Whitmore Scheme, 39 percent of years for the Quamby Scheme and 24 percent of years for the Hagley Scheme.

Future development of the groundwater resource was not modelled in this region. Between 4 and 9 percent of the region’s subcatchments and six key ecological sites (six river sites) are potentially impacted by changes in the flow regime due to future climate with future development.
The South Esk region

The South Esk region is located in the north-east midlands of Tasmania. It covers 9556 km², which is about 14 percent of the total area of the state. It is the only landlocked region of the CSIRO Tasmania Sustainable Yields Project.

Biophysical facts and figures

The main river of the region is the South Esk (the longest in Tasmania at 230 km) which flows from the north-east highlands to the Tamar River Estuary through Cataract Gorge. Its main tributaries are the Meander River, which originates in the foothills of the Great Western Tiers and joins the South Esk River near Hadspen, and the Macquarie River which drains hill country in the south of the region. Other rivers of the region include the Liffey, Elizabeth, Lake and Brumbys Creek (Figure 3 and Figure 10).

Much of the Central Plateau, an area of comparatively high elevation but with generally low relief, is located within the region and features numerous lakes including Great Lake. This area has quite distinct vegetation — strongly influenced by the altitude, climate, topographic exposure and soil drainage — with mainly alpine vegetation communities and grasslands. The remainder of the region’s natural vegetation is generally grassy forest or grassy woodland and eucalypt forest with small pockets of rainforest in the far north-east. The region is also dominated by the Ben Lomond massif.

There are only a few wetlands of national importance in the region, mainly clustered in the south-east and at Great Lake. There are no Ramsar-listed wetlands of international importance in the region.

Population and land use

In 2006, the estimated population was about 39,680 (just over 8 percent of the entire state total) including just over one-quarter of Launceston’s population. Other towns include Deloraine, Westbury, Longford and Perth.

Based on data from 2001, the dominant land uses in the South Esk region are grazing and native vegetation (Figure 3). Grazing modified pasture covers 32.0 percent of the region, native vegetation covers 25.5 percent and 4.9 percent is irrigated cropping (Table 1). Just under 160 GL/year of the region’s surface water is extracted for consumptive purposes. This is about 25 percent of total surface water resources used in the five regions of the project. The region extracts an estimated 3 percent of the total groundwater extraction within the project area (1 GL/year).

Water from Great Lake on the Central Plateau is diverted for the purposes of generating hydro-electricity. There are also extractions made for irrigation purpose from the lower reaches of the Macquarie River, between Cressy and Longford, and from the lower Meander River.

The Central Plateau and other highland areas are used for wilderness recreation and tourism.
Table 1. Broad land use of the South Esk region in the year 2001 (Source: Department of Primary Industries, Water and Environment, GIS Section, 2001)

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>percent</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>25.5%</td>
</tr>
<tr>
<td>Forestry</td>
<td>21.6%</td>
</tr>
<tr>
<td>Grazing and dryland cropping</td>
<td>43.4%</td>
</tr>
<tr>
<td>Grazing modified pastures</td>
<td>32.0%</td>
</tr>
<tr>
<td>Livestock grazing</td>
<td>11.5%</td>
</tr>
<tr>
<td>Dryland cropping</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>43.4%</strong></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>Irrigated pastures</td>
<td>0.3%</td>
</tr>
<tr>
<td>Irrigated cropping</td>
<td>4.9%</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>5.2%</strong></td>
</tr>
<tr>
<td>Water</td>
<td>3.3%</td>
</tr>
<tr>
<td>Other</td>
<td>0.9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Figure 3. Land use of the South Esk region in the year 2001
The South Esk region covers about 14 percent of Tasmania and receives 9 percent of its rainfall.

Under the historical climate, the mean annual rainfall and modelled runoff averaged over the South Esk region are 801 mm and 240 mm respectively (Table 2), making it the driest of the project regions (both in terms of what it receives as rainfall and yields as runoff). Rainfall and runoff are both greater in the north and west of the region where elevations are higher and decrease towards the south (Figure 4 and Figure 7). Both rainfall and runoff are winter-dominated with maximum mean monthly rainfall (90 mm) and maximum mean monthly runoff (47 mm) occurring in August. Minimum mean monthly rainfall (47 mm) occurs in February and minimum mean monthly runoff (6 mm) occurs in January (Figure 5 and Figure 8). Under historical climate, the region contributes 5 percent of Tasmania’s total runoff.

In general, the recent past (1997 to 2007) has been drier than the historical 84-year period (Table 2) with less rainfall (a decrease of 66 mm) and less runoff (a decrease of 37 mm). Percentage decreases are greater in the east of the region and occur primarily in autumn and winter. In the west of the region both rainfall and runoff increase slightly, particularly in spring.

Conditions under the future climate range from slightly wetter to drier than under the historical climate with rainfall ranging from 2 percent wetter to 7 percent drier and runoff ranging from an increase of 4 percent to a decrease of 11 percent. Median reductions in rainfall and runoff are 3 percent and 6 percent respectively. Reductions in rainfall and runoff are likely to be higher across the south-west of the region with little change across the north of the region (Figure 6 and Figure 9).

Currently there are 2068 km² of plantation forests in the South Esk region. The area of plantation forests across the region is projected to increase by about 116 km² (a 6 percent increase in total plantation forest). Averaged over the region, this increase in forest cover leads to a decrease in runoff of 1 percent.

Further information on changes in rainfall and runoff for this region as well as the rest of Tasmania can be found in the companion document Climate change projections and impacts on runoff for Tasmania.
Table 2. Rainfall and runoff in the South Esk region under historical and recent climate and changes under future climate relative to historical climate

<table>
<thead>
<tr>
<th></th>
<th>Historical climate</th>
<th>Recent climate</th>
<th>Future climate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wet</td>
</tr>
<tr>
<td></td>
<td>mm</td>
<td>percent change from historical climate</td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>801</td>
<td>735</td>
<td>2%</td>
</tr>
<tr>
<td>Runoff</td>
<td>240</td>
<td>203</td>
<td>4%</td>
</tr>
</tbody>
</table>

Figure 7. Mean annual runoff over the South Esk region under historical climate

Figure 8. Mean monthly runoff averaged over the South Esk region under historical and future climate

Figure 9. Spatial distribution over the South Esk region of percent change in mean annual runoff under future climate relative to historical climate
Why the interest in surface water?

Water in creeks, rivers, lakes, reservoirs and farm dams on the land surface is known collectively as surface water. Its importance lies in the role it plays in sustaining life in general and as a key asset within a range of natural and managed environments. Surface water critically influences habitat for numerous aquatic and riparian plants, fish and the invertebrates they depend on, and other aquatic wildlife such as platypus and waterbirds. It is also important for people – providing water for drinking and domestic use, watering stock, irrigating crops, generating power and use by industry. In Tasmania surface water is especially important for tourism and outdoor recreation based activities. Drought, climate change, and future forestry and irrigation developments may all impact surface water resources of a region. To better understand such impacts, and to effectively manage them into the future, it is necessary to assess the current levels and characteristics of surface water availability and to identify the possible threats to it. This section considers the issues from a human-use point of view; the likely impacts on aquatic ecology are considered later in the report.

Surface water management in Tasmania

In Tasmania, surface water quality and supply is regulated by legislation, policies and strategies. A catchment’s water resources can be managed through the application of a Water Management Plan. Each plan outlines environmental, social, cultural and economic objectives for the relevant water resources and describes a management regime that best gives effect to these objectives. Water management provisions within a plan include guidelines and rules for surface water allocations (both licensed and unlicensed) within a framework that identifies objectives related to environment, water use and development, water management, and recreational and commercial activities that are dependent on the water resources.

Plans cover many aspects of surface water including entitlements, unlicensed storages, unlicensed extractions, environmental flows and releases, diversions and storages. They relate to water used for domestic supply, livestock consumption, firefighting, ecosystems, irrigation, commercial purposes and hydro-electricity supply. Prescriptions of water volume and timing are defined at various ‘sureties’ (surety is the probable availability, actual or relative, of a water allocation in any year allowing for the natural variability of the water supply).

Understanding the language of surface water

The following terminology is used throughout this report:

- Extractions (or extracted water) – water extracted for consumptive use
- Non-extracted water – the water remaining in the catchment after extractions have been taken
- Streamflow – the flow in a river or stream at any one particular point in the catchment
- End-of-system streamflow – the water that flows out of the catchment (generally to the sea). It is equal to the non-extracted water minus any losses to evaporation and takes into account diversions into or out of the catchment
- Total streamflow – all of the water in rivers and streams within the catchment
- Inflow – surface water runoff flowing into a defined catchment

Assessing the characteristics and availability of surface water: the process

River system models describing current infrastructure, water demands and water management rules were used to assess the implications of changed inflows for surface water availability and the reliability of water supply to users. This enabled estimates of streamflow to be made for the project regions under the five scenarios.

The modelling process included consideration of water allocations and extractions, streamflow routing and environmental flows, and it incorporated grid-based runoff, rainfall and evaporation data. Catchment-based modelling was undertaken on a daily time step and the runoff from each subcatchment was routed through the river network to the next subcatchment downstream. The process recognised that the natural and managed behaviour of rivers means that variability in runoff is not uniformly translated to variability in streamflow and water uses.

Some catchments included areas covered by Tasmania’s hydro-electric system. Therefore catchments with river systems downstream of hydro-electricity storages included inputs (such as flows through power stations and spills from storages) to the river models from Hydro Tasmania’s system model. The hydro-electricity system is modelled separately as it is operated as an integrated system taking into consideration the National Electricity Market and demand.
Surface water characteristics of the region

The five catchments and main storages of the South Esk region are shown in Figure 10. Details of all the catchments in the region are given in Table 3. Surface water provides drinking water for most of the people living in the region including a large portion of the 71,402 people living in Launceston who depend on water from the South Esk River. Streamflows in the South Esk catchment are relatively unregulated. However, the other catchments in the region have a large degree of regulation within them. Lake Leake releases water into the upper Elizabeth River and Tooms Lake releases water into the upper Macquarie River. Woods Lake is a large reservoir on the Lake River. It receives water from Arthurs Lake and via an inter-catchment transfer from the Ouse River (in the Derwent-South East region). Water from Arthurs Lake is also pumped to Great Lake where it is used to generate hydro-electricity at Poatina Power Station from where it is released to Brumbys Creek. Finally, Meander Dam is a new storage on the Meander River used to supply hydro-electricity generation and irrigation. All of the flow from the region discharges into Lake Trevallyn, a reservoir to supply hydro-electricity generation near Launceston. There are over 490 km$^2$ of irrigated agriculture in the South Esk region, the majority of which is dependent on surface water (a small portion is also sourced from groundwater which is covered in a subsequent section in this report).

The South Esk region is heavily affected by inflows from Tasmania’s hydro-electric system, particularly the Great Lake and Brumbys catchments. There are nine new irrigation developments proposed for this region and these are discussed on subsequent pages.

Environmental release requirements are in place for the Meander and Trevallyn dams. Minimum environmental flows are in place for the Maquarie River. In the Meander, Macquarie and South Esk catchments, ‘cease-to-take’ rules apply, meaning that extractions from the river must be ceased when flow in the river at a specified location falls below a set minimum.

Table 3. Catchments of the South Esk region

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Area (km$^2$)</th>
<th>Mean annual rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meander</td>
<td>1564</td>
<td>1003</td>
</tr>
<tr>
<td>Great Lake</td>
<td>396</td>
<td>1246</td>
</tr>
<tr>
<td>Brumbys</td>
<td>1491</td>
<td>814</td>
</tr>
<tr>
<td>Macquarie</td>
<td>2726</td>
<td>607</td>
</tr>
<tr>
<td>South Esk</td>
<td>3351</td>
<td>805</td>
</tr>
</tbody>
</table>

Figure 10. Catchments and surface water features of the South Esk region.
Surface water under historical climate

Historically, the region has a mean annual streamflow of about 2614 GL/year, and a relatively low level of extraction of about 158 GL/year which is 6 percent of the total surface water in the region. The relative level of extraction varies between catchments up to a maximum of 11 percent of the total flow in the Macquarie catchment due primarily to extractions for irrigation. Total streamflow in each catchment below hydro-electricity schemes in the region is shown in Figure 11. Note that as all the regions flow into the Brumbys catchment before being discharged into Trevallyn Reservoir, the Brumbys catchment represents all of the water in the pie chart (Figure 11). The Great Lake and Brumbys catchments are impacted by Tasmania’s hydro-electric system.

Mean annual end-of-system streamflow for the region is 2458 GL/year; (158 GL/year is lost to extractions and 2 GL/year gained from rainfall over reservoirs). There is a high level of variability between years, ranging from 1033 to 5148 GL/year. Total annual extractions for the region are less variable with an average of 158 GL/year, ranging from a minimum of 130 GL/year to a maximum of 191 GL/year over the 84-year historical period.

In most catchments, the average amount of water extracted is only slightly less than that allocated. For example, for the Meander catchment an average of 32.9 GL is allocated each year, and 30.9 GL is extracted. The exception is the Macquarie catchment where 102.1 GL/year are allocated but only 34.7 GL/year is extracted. This represents the application of rules that determine when allocated water can be extracted. However, in the absence of information on actual extraction from rivers, the river models assume the full allocation of each water licence is divided evenly over the applicable months. In reality, irrigators may have on-stream storages that can be used to store water for use when there is less water in the river system and thus will extract water from the river when it is available. The methods used in the river modelling may therefore underestimate the volume of water actually being extracted. This is particularly true of low priority allocations in the Macquarie catchment. Full details are given in the associated technical report River modelling for Tasmania Volume 4: the South Esk region.

The rivers of all of the catchments in the region are essentially perennial, flowing for more than 97 percent of the time.

Water availability under historical and future climate

This section describes how future climate is likely to affect surface water availability in the South Esk region. It looks at projected changes relative to the historical climate for extracted and non-extracted water, end-of-system flows and extraction reliability. Current levels of surface water and groundwater development are used.

Extracted and non-extracted water

Under future climate, there may be slightly more or considerably less non-extracted water available than under the historical climate. Under the wet extreme future climate, the volume of non-extracted water increases in every year except one, by an average of 97 GL/year (4 percent). Under the median future climate, decreases occur every year, by an average of 152 GL/year (6 percent). Under the dry extreme future climate, every year decreases occur every year by an average of 275 GL/year (11 percent).

In contrast, the volume of surface water extracted in the region is not expected to change by as much. This reflects the low level of water use in the region and the extraction rules currently in place. Under the wet extreme future climate, extractions increase in 60 percent of years, but overall extractions decrease by 0.2 GL/year (less than 0.2 percent). Under the median future climate, extractions decrease every year, by an average of 3.4 GL/year (2 percent). Under the dry extreme future climate, decreases are also expected in every year by an average of 5.1 GL/year (3 percent).

The relative volumes of extracted and non-extracted water under historical climate and the projected changes under wet extreme, median and dry extreme future climate are shown in Figure 12 for the region and in Figure 13 for each of the region’s catchments. Generally, streamflow under the wet extreme is greater than under the historical climate and streamflow under the median and dry extremes are drier than the historical climate but the reductions in the volumes of non-extracted water are greater than those in the volumes of extracted water. The exception occurs for the wet extreme where the volume of non-extracted water goes up but the volume of extracted water goes down. Note that the graph for the Brumbys catchment represents the total end-of-system flow for the region (thus non-extracted water here is the same as in Figure 12), however, the extractions represent only those extractions that occur in the Brumbys catchment.

![Figure 11. Share of surface water in the South Esk region by catchment below hydro-electricity schemes](chart.png)
Figure 12. Extracted and non-extracted shares of water for the South Esk region under historical and future climate.

Figure 13. Extracted and non-extracted shares of water for each catchment of the South Esk region under historical and future climate.

> Meander Dam spillway (Hydro Tasmania Consulting)
End-of-system flow

End-of-system flow represents water remaining in the catchment after all extractions and diversions have been made. It is the water available for the environment and for potential future increases in extractions.

The expected changes in the volumes of extracted and non-extracted water under future climate relative to the historical climate impact end-of-system streamflows. In general, the end-of-system streamflow decreases in most months of the year except for July and August when it increases. Typical examples are shown in Figure 14 for the South Esk and Meander catchments. The impact of the current extraction regime on low flows can be seen in the South Esk catchment where historical low flows are less than they would have been without extractions. By comparison, although overall flows are lower in the Meander catchment due to extractions, low flows are elevated due to releases from Meander Dam during periods of low flow. A full description of these responses for all catchments can be found in the associated technical report River modelling for Tasmania Volume 4: the South Esk region.

> Huntsman Lake (CSIRO)

Figure 14. Mean monthly end-of-system streamflow and daily flow duration curve for the South Esk and Meander catchments under historical and future climate. Streamflow without extractions is also shown.
Extraction reliability

Water users need to know about the reliability of available water to efficiently manage their enterprises. The expected changes in streamflows attributable to climate change have very little impact on the volumes of water allocated for extraction in the Meander, Brumbys or Macquarie catchments. This is shown in Figure 15 (b) which indicates no difference between historical and future allocations for the Meander catchment. For the South Esk catchment however, climate change is expected to lead to a reduction in allocated water in most years as is seen in Figure 15 (a). However, not all allocations can be met in all years. As shown in Figure 15, in the drier years (towards the right-hand edge of the graphs), allocated volumes are not always able to be extracted. For the South Esk catchment, around 90 percent of allocations can be met in the driest year and this does not change substantially under future climate. Little change is also seen in the Brumbys or Macquarie catchments. Conversely, the Meander catchment shows reductions of up to 10 percent in the proportion of allocations that can be met under future climate, particularly in drier years. A full description for all catchments can be found in the associated technical report River modelling for Tasmania Volume 4: the South Esk region.

Figure 15. Allocation and extraction reliability for the South Esk and Meander catchments under historical and future climate
Impact of recent climate on surface water

Changes in surface water availability under recent climate (1997 to 2007) relative to historical climate include reductions in the volumes of both extracted and non-extracted water. Mean monthly streamflow is lower than the long-term mean in all catchments in all months (with the exception of January and September where streamflow is higher in some catchments). Streamflows are generally lower with a 20 percent decrease (485 GL) in the mean annual volume of non-extracted water for the region as a whole. The volume of surface water extracted decreases by 5 percent (8 GL/year). These changes are shown in Figure 16.

Impact of future development on surface water

Currently there are 2068 km² of plantation forestry in the South Esk region. In future, the area of plantation forests across the region is likely to increase by about 117 km² (a 6 percent increase in total plantation forest) by 2030. Most of this increase is expected to be in the Meander catchment. As a result, the largest change in mean annual inflows under future development is in the Meander catchment with an expected reduction of 1.8 percent (Table 4). As most of this reduction in streamflow is in low flows, extractions in the Meander catchment are reduced by 14.5 percent. For the other catchments in the region, reductions in inflows and extractions are minor and have little impact on end-of-system streamflows.

The location of the proposed irrigation schemes are shown in Figure 17. Details of these schemes, along with their modelled reliabilities is shown in Table 5. The Midlands Water Scheme (Arthurs Lake) can be supplied at all times with the appropriate commercial arrangement with Hydro Tasmania in place. The Midlands Water Scheme (South Esk) is opportunistic, relying on flows in the South Esk River. Under all future climate projections, both this scheme and the proposed new Meadstone Dam can meet full demand for water in all years. The Ben Lomond Dam can meet full demand for water for 97 to 100 percent of years. The Caveside, Rubicon, Quamby and Hagley Schemes all rely on extractions from the Meander River and are modelled together. In addition, releases from the Meander Dam in the model are not optimised to meet irrigation demands. Despite this, full demand for water can be met for 82 to 90 percent of years for Caveside, 56 to 69 percent of years for Rubicon, 39 to 52 percent of years for Quamby and 24 to 34 percent of years for the Hagley Scheme. The Whitemore Scheme can supply all of the required water in 41 to 57 percent of years. Table 5 only reports the frequency of years where 100 percent of demand can be met. This statistic however does not indicate how much water can be extracted in the years where 100 percent of demand cannot be met. For example, Figure 18 shows that in the very worst year, the Whitemore scheme can still extract 65 percent of the annual demand whereas the Quamby scheme can only extract around 15 percent. A full description of results for all proposed irrigation schemes can be found in the associated technical report River modelling for Tasmania Volume 4: the South Esk region.
Table 5. Characteristics of proposed irrigation developments in the South Esk region

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of water</th>
<th>Mean annual demand</th>
<th>Frequency of years where full demand is met</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ML/year</td>
<td>Wet extreme future climate</td>
</tr>
<tr>
<td>Midlands Water Scheme (Arthurs Lake)</td>
<td>Arthurs Lake</td>
<td>38,351</td>
<td>100%</td>
</tr>
<tr>
<td>Midlands Water Scheme (South Esk)</td>
<td>South Esk River</td>
<td>9,000</td>
<td>100%</td>
</tr>
<tr>
<td>Meadstone Dam</td>
<td>New 30,000 ML dam on St Pauls River</td>
<td>8,000</td>
<td>100%</td>
</tr>
<tr>
<td>Ben Lomond Dam</td>
<td>New 23,000 ML dam on Ben Lomond Rivulet</td>
<td>15,000</td>
<td>100%</td>
</tr>
<tr>
<td>Caveside Scheme</td>
<td>Meander River downstream of Meander Dam</td>
<td>4,500</td>
<td>90%</td>
</tr>
<tr>
<td>Rubicon Scheme</td>
<td>Meander River downstream of Meander Dam</td>
<td>6,000</td>
<td>69%</td>
</tr>
<tr>
<td>Quamby Scheme</td>
<td>Meander River downstream of Meander Dam</td>
<td>3,000</td>
<td>52%</td>
</tr>
<tr>
<td>Hagley Scheme</td>
<td>Meander River downstream of Meander Dam</td>
<td>2,500</td>
<td>34%</td>
</tr>
<tr>
<td>Whitemore Scheme</td>
<td>Poatina tailrace downstream of Poatina Power Station</td>
<td>5,500</td>
<td>57%</td>
</tr>
</tbody>
</table>

Figure 18. Extraction reliabilities for the proposed Whitemore and Quamby irrigation developments in the South Esk region
Why the interest in groundwater?

Water that occurs below the surface of the earth is known as groundwater and is available throughout most of Australia. Groundwater is held in the saturated pore spaces and fractures of soil and rock and is classified according to the rock types or aquifers in which it occurs. In Tasmania, groundwater resources are not evenly distributed and quality and yield can be highly variable, depending on the aquifer type, the topographic location and the rainfall. Tasmania’s groundwater tends to be found in igneous, sedimentary and metamorphic rocks, as well as unconsolidated sediments. It is tapped by more than 8000 wells, supplying water for irrigation, town water, domestic use, stock watering, mining and other commercial purposes. Data and knowledge are limited, and while it is estimated that less than 5 percent of the state’s groundwater is currently in use, there is uncertainty about how much extra utilisation could be sustained.

Increasing demands to utilise Tasmania’s groundwater resources are driving the need for better understanding about groundwater availability. This is necessary for effective management into the future. This section describes the current levels and characteristics of groundwater availability and identifies potential future groundwater resource availability for key aquifers in the South Esk region.

Groundwater management in Tasmania

Legislation currently makes only broad provision for managing groundwater in Tasmania. However, a regulatory framework is currently being developed that will include a system for the licensing of groundwater use and result in the development and application of groundwater management plans. Groundwater extraction in Tasmania is not metered but a system to license well drillers has recently been implemented.

Assessing the characteristics and availability of groundwater: the process

The groundwater assessment and modelling component of this project involved collating existing data and knowledge to report on the occurrence, status and possible future condition of groundwater resources in the five regions.

Where regions were covered by a dynamic numerical groundwater flow model, a quantitative assessment of the impacts of recent and future climate and development was undertaken. This enabled detailed assessments of changes in diffuse recharge (and associated changes in groundwater levels) and interactions between surface water and groundwater resources. Where groundwater models were available, assessments were made of the impacts of climate change and development on the flows of water to and from streams. However, where groundwater models were not available, the potential impacts were assessed in terms of changes in diffuse groundwater recharge alone.

Surface–groundwater interactions can play an important role in the water budgets of each catchment. Groundwater discharge to streams is often crucial for maintaining ecosystem health during warm, dry summer months. Where possible, this project has determined the nature of surface–groundwater interactions for the main reaches of river networks.

Only areas with significant groundwater resources were assessed, with a total of 21 groundwater assessment areas (GAAs) identified over the project area. Boundaries of GAAs were not always contiguous with the project regions.

Constraints on the assessments of groundwater availability in the South Esk region

As for most of Tasmania, there is a lack of long-term, high-quality groundwater monitoring data for this region. The absence of reliable groundwater extraction data and a regional groundwater level monitoring network introduces great uncertainty into any quantitative assessment of the groundwater resources.
Groundwater characteristics of the region

There is only one groundwater assessment area (GAA) in the region as shown in Figure 19. Note that the Spreyton, Kimberley-Deloraine and Mole Creek GAAs fall primarily in the adjoining Mersey-Forth region and thus are discussed in that report. Groundwater salinities are shown to indicate where groundwater extraction occurs. Surface–groundwater interactions have also been mapped showing reaches of streams that are gaining groundwater or losing surface water.

The sediments of the Longford Tertiary Basin form the major aquifer of the region. Outside of the Longford Tertiary Basin, most groundwater extraction occurs in the south of the region, where it is extracted from Permian and Triassic fractured rock aquifers (Figure 20).

Groundwater extraction is estimated to be about 1 GL/year, most of which is taken for irrigation from the sediments of the Longford Tertiary Basin.

There are a number of groundwater management concerns in the region. Groundwater salinity is somewhat higher in the eastern parts of Tasmania and dryland salinity is known to occur in the South Esk region, for example at Cressy in the Longford GAA, at Tunbridge, and in the Conara-Epping Forest area. The higher levels of groundwater salinity are most likely due to relatively low rainfall and consequent lower groundwater recharge rates.

Figure 19. Groundwater features of the South Esk region

Irrigated crops in the Meander catchment (CSIRO)
Groundwater responses to climate and development

For groundwater modelling, three 23-year periods were selected from the historical sequence, representing a wet extreme, median and dry extreme historical climate. Similarly, to represent the wet extreme, median and dry extreme future climate, three 23-year periods were selected from recharge model outputs derived using 15 global climate models and three global warming scenarios.

There is a noticeable decline in modelled mean annual rates of diffuse groundwater recharge over the 84-year historical period (1924 to 2007). Under climate of the recent past (1997 to 2007), groundwater recharge rates are the lowest of the historical period, 22 percent of the historical mean for the Longford GAA (it was assumed there was no change in land use over this period). Recharge rates under future (~2030) climate are likely to be within the range of rates experienced during the historical period, ranging between 103 and 121 percent of the historical mean for the Longford GAA.

Because groundwater extraction in this region is so low, extractions as a percentage of recharge are also low (Table 6). This means that under future climate it is likely that there would be potential for future groundwater development in the region, however, precautionary estimates of sustainable extraction limits are required in the interim.

Table 6. Extraction as a percentage of recharge for groundwater assessment areas in the South Esk region under recent and historical climate

<table>
<thead>
<tr>
<th>Groundwater assessment area</th>
<th>Recent climate</th>
<th>Historical climate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet extreme</td>
<td>Median</td>
</tr>
<tr>
<td>Longford</td>
<td>6%</td>
<td>1%</td>
</tr>
</tbody>
</table>

The level of groundwater technical assessment for this region is lower than that for other regions. This is due to the lack of both detailed historical data and an appropriate groundwater model for quantitative analysis of climate change and development. A full description of the technical aspects of the groundwater assessment process and results can be found in the associated technical report *Groundwater assessment and modelling for Tasmania*. 

Figure 20. Schematic diagram of the South Esk region
Why the interest in the region’s ecology?

Water resource development can impact freshwater ecosystems by changing the flow regime components of the river system — the seasonality and amplitude of seasonal flow variations, the nature of low flows and high flows, and the total volumes of flow. Similarly, changes in climate may also impact river flow regimes. Various water reform initiatives (at both national and state levels) have led to significant decisions being taken on the allocation and management of water resources. Water is a basic necessity of all life and balancing competing demands for consumptive use and ecosystem health is a substantial challenge. Understanding the potential ecological impacts of water resource development and changes in climate will assist managers to strike that balance. This section considers the issues from an ecological point of view; human-use issues are considered in the section about surface water.

Determining likely ecological impacts: the process

Analysis was undertaken at a subcatchment level within each of the five project regions. Key sites of concern were also identified and then assessed to determine their likely condition under the four scenarios of future climate and development and the fifth without-extractions scenario. Impact assessment was based on the degree of change from a reference condition: largely unmodified, slightly modified, moderately modified, substantially modified and severely modified. The reference condition is what the flow regime would have been like without extractions but with current levels of infrastructure in place.

Key ecological sites were identified using the Conservation of Freshwater Ecosystem Values (CFEV) database. Only river sites, riverine wetlands and estuaries of exceptional value with the ‘Very High’ Integrated Conservation Value rating class were considered. Additionally, for rivers and riverine wetlands, sites with conservation features currently under pressure or at risk from local abstraction were selected.

The nature and location of likely impacts were determined through an assessment of river condition using an approach based on the Tasmanian River Condition Index (TRCI) method incorporating the Flow Stress Ranking (FSR) procedure, which links flow components to important ecological processes. The TRCI provides a rapid qualitative ‘snapshot’ assessment of river condition based on physical stream form, streamside habitat and hydrological connectivity. FSR is a tool that provides a quantitative assessment of the potential stress of a river. An FSR assessment indicates where changes in the flow regime are likely to occur, and it is this change that has the potential to impact the environment. FSR scores are grouped to give the rating of condition. Sites that rate as moderately or substantially modified are classified as potentially impacted. Some of those potential impacts could be mitigated through environmental flow legislation, but this is not considered in this project.

To model future development, FSR assessments included modelled time series inputs that incorporated an increase in the area of plantation forest cover and the consequent potential change in streamflow. Altered flow regime patterns due to proposed irrigation developments were also considered.

A full description of the assessment process is found in the associated technical report Ecological impacts of water availability in Tasmania.

Ecological management in Tasmania

The management of Tasmania’s ecological resources is addressed by a mix of legislation, policies and strategies. Specific coverage for the provision of water for ecosystems is found in the Water Development Plan for Tasmania which aims to promote ecologically sustainable water development opportunities for Tasmania into the future. Within the context of this plan, the Conservation of Freshwater Ecosystem Values (CFEV) initiative was established to develop a framework for the management, development and conservation of freshwater-dependent ecosystem values. Through a comprehensive audit of the state’s freshwater ecosystems, CFEV identified where aquatic values exist and their priority for management.

In Tasmania a range of organisations use the CFEV framework to prioritise, plan and manage natural resources. Typically, assessments take a strategic approach with the aim of providing increased confidence on behalf of government, industry and the community that high priority freshwater values are appropriately considered in the development, conservation and management of Tasmania’s water resources. CFEV is used to assess the ecological sustainability of future water-related developments, to protect significant freshwater values, and to assist in focusing freshwater management efforts to protect and/or restore high conservation value ecosystems.
Ecological impacts of surface water

River condition

The Flow Stress Ranking procedure is a useful tool to measure potential stress to river condition by describing the degree of modification to the flow regime. Assessments for the South Esk region were undertaken in 195 subcatchments.

Under recent climate, 21 percent of the subcatchments in the South Esk region have moderately modified conditions, compared to 4 percent under historical climate. Additionally, 3 percent of catchments have substantially modified conditions compared to none under historical climate. The percentage of subcatchments with slightly modified conditions has also increased substantially compared to the historical climate, and there are just 16 percent of subcatchments with largely unmodified conditions under recent climate (Figure 21).

Under future climate, the wet extreme is similar to historical climate. However under the median, 6 percent of subcatchments are moderately modified or substantially modified. Under the dry extreme this increases to 7 percent. Future development adds to these stresses, increasing the percentage of moderately modified or substantially modified catchments under the dry extreme to 9 percent.

The future irrigation developments proposed for the region (see Figure 17 and Table 5) may move catchment condition at the end of Brumbys catchment from moderately modified condition into substantially modified condition and may therefore have an impact on the ecology of this area. The river sites that may be impacted by this are those on the South Esk River and are discussed later in this section. Catchment condition at the end of South Esk and Meander catchments may move to slightly modified condition, but this will have little impact on the ecology of these areas.

![Figure 21. Percentage of subcatchments impacted by changes in catchment condition due to climate and development in the South Esk region](image-url)
Potentially impacted sites and associated ecosystems

The 23 key ecological sites of the South Esk region are shown in Figure 22. Sites that are likely to be potentially impacted by recent climate, future climate or development (as highlighted in Figure 22) were determined through the application of river condition assessments – sites that rate as moderately modified are classified as potentially impacted (no key ecological sites rate as substantially modified in any of the project regions). This is shown in Figure 23 and is summarised in Table 7. As the recent drought has been so severe, if a key ecological site is potentially impacted under any scenario, it is always potentially impacted under the recent climate. All catchments in the region have moderately modified conditions under recent climate with the exception of Great Lake which was not considered in this assessment. There are six river sites at the end of the South Esk River, eleven river sites on Lake River, and one river site at Tomb Hill, as well as three riverine wetlands that are potentially impacted under recent climate. There are no Ramsar wetlands or estuaries in this region.

All of the river key ecological sites on the South Esk River are potentially impacted under all scenarios. No other site is potentially impacted under any scenario apart from recent climate.

Figure 22. Key ecological sites of the South Esk region
Each of the potentially impacted sites in the region (Table 7) has associated special values that may be threatened by climate change and/or development. These are listed in Table 8. Because high flows, low flows and seasonal flows are likely to change, some degree of impact on instream ecosystem components (such as macrophytes, macroinvertebrates, fish and platypus) and riparian and floodplain areas (such as riparian vegetation and wetland plants) could be expected. The values identified in potentially impacted habitats in this region include Duck-billed Platypus, hydribid snails, freshwater fish and important sites for waterbirds such as Weedy Lagoon.

Note that there may be other sites in the South Esk region at risk of impacts under future climate, droughts and future development. The key ecological sites chosen for this project were only those with a very high integrated conservation value and, for rivers and riverine wetlands, those at greatest risk of impact from current water extraction levels.

Table 7. Potentially impacted key ecological sites in the South Esk region

<table>
<thead>
<tr>
<th>Site name</th>
<th>Recent climate</th>
<th>Historical climate</th>
<th>Future climate</th>
<th>Future climate with future development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet extreme</td>
<td>Median</td>
<td>Dry extreme</td>
<td>Wet extreme</td>
</tr>
<tr>
<td>River</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Esk River (6 sites)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lake River (south) (11 sites)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomb Hill</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverine wetland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weedy Lagoon (2 sites)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarks Lagoon</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Crosses represent potential impact on key ecological sites. Blank cells represent sites that are not impacted under each respective scenario.
Figure 23. Change in river condition under recent, historical and future climate and development relative to reference conditions in the South Esk region.

Flow Stress Rankings:
- Substantially modified
- Moderately modified
- Slightly modified
- Largely unmodified

Impacted key ecological sites:
- River
- Riverine wetland

Future climate

Future climate with future development
Table 8. Special values of potentially impacted key ecological sites in the South Esk region

<table>
<thead>
<tr>
<th>Site name</th>
<th>Special values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td></td>
</tr>
<tr>
<td>South Esk River</td>
<td>Purple Loosestrife, Hairy Anchor Plant, Lesser Joyweed, Bristly Knottweed, Round Leaf Mint Bush, Clasping-leaf Heath, South Esk Pine, Small Rasp Fern, riparian flora communities, shrubby Eucalyptus ovata forest, Hydrobiid Snail (Cataract Gorge), Freshwater mussel (north and south)</td>
</tr>
<tr>
<td>Lake River (southern sites)</td>
<td>Ferny Buttercup, Drooping Sedge, Poison Lobelia, Midlands Wattle, Clasping-leaf Heath, lowland Poa grassland, riparian flora communities, shrubby Eucalyptus ovata forest, Eucalyptus rodwayi forest, Duck-billed Platypus</td>
</tr>
<tr>
<td>Lake River (northern sites)</td>
<td>Drooping Sedge, Clasping-leaf Heath, lowland Poa grassland, Duck-billed Platypus</td>
</tr>
<tr>
<td>Tomb Hill</td>
<td>Austral Pillwort, Duck-billed Platypus</td>
</tr>
<tr>
<td>Riverine wetland</td>
<td></td>
</tr>
<tr>
<td>Weedy Lagoon (2 sites), Clarks Lagoon</td>
<td>Swamp Wallaby Grass, marginal herbfield/grassland, Duck-billed Platypus</td>
</tr>
</tbody>
</table>

* Special values include rare and threatened species and communities, important geomorphic features, sites of high species diversity and sites of ecological significance such as migratory bird sites. Many are recognised through legislation and current management. They were developed as part of the Conservation of Freshwater Ecosystem Values initiative.
Technical reports


All technical reports are available for download from <www.csiro.au/partnerships/TasSY.html>.

Contributors
The following people contributed to the production of this report through their involvement in the CSIRO Tasmania Sustainable Yields Project:

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All region reports and a glossary are available for download from <www.csiro.au/partnerships/TasSY.html>.

Enquiries

More information about the CSIRO Tasmania Sustainable Yields Project can be found at <www.csiro.au/partnerships/TasSY.html>. This information includes the full terms of reference for the project and all associated reporting products.


CSIRO and the Flagships program

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