WATER AND LAND USE change study

STAGE 2 COMMUNITY REPORT

WATER AND LAND USE
change study

STUDY OVERVIEW

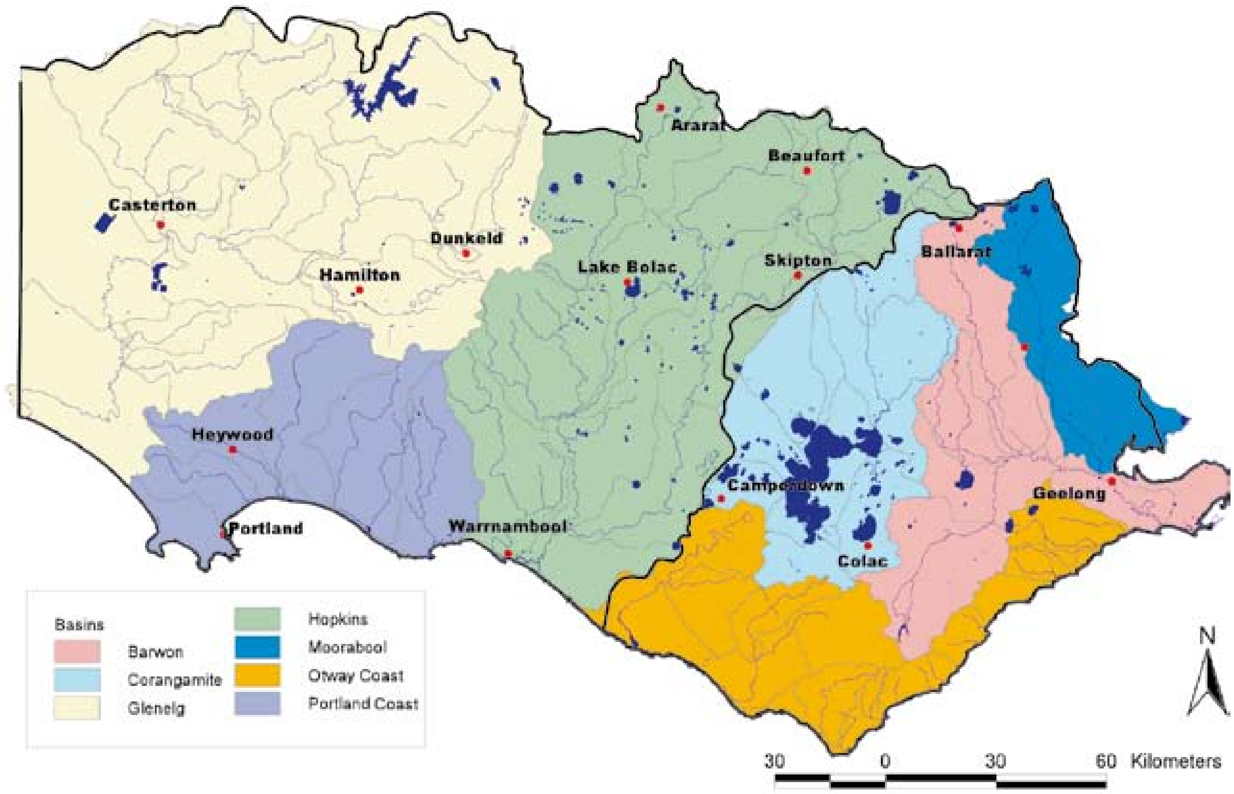
The Water and Land Use Change (WatLUC) study addresses the challenges posed by land use and hydrologic change across south-western Victoria. Land use changed rapidly across this region during the late 1990s and the early years of the current decade. Although it has recently slowed in some sectors, the scale and nature of the changes that have and are expected to take place are so great that they will transform the volume and quality of water moving through the region's landscapes. This may have profound implications for the region's water dependent ecosystems and for the way in which its water resources are managed.

THE TWO MAJOR OBJECTIVES OF THE WATLUC STUDY ARE TO:

- understand the dynamics of land use change in the region and develop some scenarios that reflect realistic land use change outcomes;
- assess the impacts of these scenarios on water movement through landscapes and on the availability and quality of water for consumptive and environmental uses.

To date, there have been two stages in the WatLUC study. The first developed methods for determining the hydrologic impacts of land use and land use change and applied them in five case study catchments. The second revised Stage 1 land use change scenarios and assessed the hydrologic changes associated with them across the entire Glenelg Hopkins and Corangamite Catchment Management Authority (CMA) regions.

WatLUC study area, showing drainage basins and sub-catchments



This summary of Stage 2 draws out some of its key messages. It provides an overview of land use in the study area and of the nature of expected land use changes. It gives examples of some of the results of hydrologic modelling and presents a consolidated picture of how land use change might affect the water resources and flow regimes of streams in the study area. Stage 2 has also identified several 'hot spot' areas: sub-catchments with flow regimes that are either already highly modified or would be substantially altered as a result of predicted changes in land use.

KEY FINDINGS FROM STAGE 2

LAND USE CHANGE

The most striking features of land use change in the study area over the last decade and a half have been the expansions in broadacre cropping, dairying and blue gum plantations into former broadacre grazing country.

Over the coming 30 years, cropping is the only major land use expected to continue to expand at close to its recent historical rate. The area of land given to dairying is likely to remain static. Beyond the next few years, there is only likely to be incremental expansion in blue gum plantations. With some new hardwood plantation development, intensification in grazing operations and implementation of regional native vegetation management plans, there is likely to be a marked increase in the area of land covered by non-woody and woody perennial vegetation.

CHANGES IN WATER FLOWS

The flow regimes of streams in the study area are already moderately to highly altered in all but a few sub-catchments in the Barwon and Otway Coast drainage basins. Summer flows are the most highly modified.

WatLUC predicts that once the 2030 land use change scenarios have achieved their full hydrological impact, the volume of flows generated in several of the study area's river basins will fall from their current average levels. Changes in land use across the study area could reduce average surface water flow generation capacity by over 600 GL/y (1 GL = 1000 ML) and recharge to deep aquifer systems by over 15 GL/y. Although these volumes are large, they represent less than 10% of current surface water flows and just 1% of current deep aquifer recharge.

Predicted changes in flow generation capacity are not evenly distributed across the study area. The largest changes are expected to occur in the south-west, in sub-catchments with high levels of new woody perennial vegetation cover (including forestry plantations and native vegetation).

Land use change is expected to further alter flow regimes, particularly in sub-catchments of the Portland Coast and Glenelg River basins. The highly regulated Moorabool River will continue to have the most modified flow regime of any in the study area, despite predictions of only relatively small changes due to land use change.

The upper catchments of the Glenelg, Barwon and Moorabool Rivers have large reservoirs that supply urban and rural water users. It is not expected that land use change will have a particularly marked effect on inflows to these storages.

Some simple 'rules-of-thumb' have been developed to estimate the potential change in sub-catchment water yield (in mm) caused by changes in some of the major land uses. For each additional 10% of a sub-catchment covered by woody vegetation, potential water yield is predicted to fall by around 20 mm/y. The corresponding water yield loss for a similar increase in perennial pasture or native grassland cover is just 3 mm/y. Each additional 1% of a sub-catchment converted to urban land use would increase water yield by about 3 mm/y.

Priority areas

The study has identified eight priority sub-catchments on the basis of already highly altered flow regime and the potential for land use change to significantly alter flow generation capacity and flow regime. They include the upper and lower Moorabool sub-catchments and several sub-catchments in the Glenelg and Portland Coast drainage basins. Further work in these areas is required to improve land use change predictions and/or better understand the implications of existing or anticipated hydrologic change.

Recommendations

IT IS RECOMMENDED THAT WATLUC STAGE 2 BE FOLLOWED UP BY FURTHER WORK TO CONSIDER:

- the implications of regional climate change projections on land use change and catchment hydrology;
- the water quality implications of land use and hydrologic change;
- the implications of land use change for land and water salinity issues in regional priority areas.

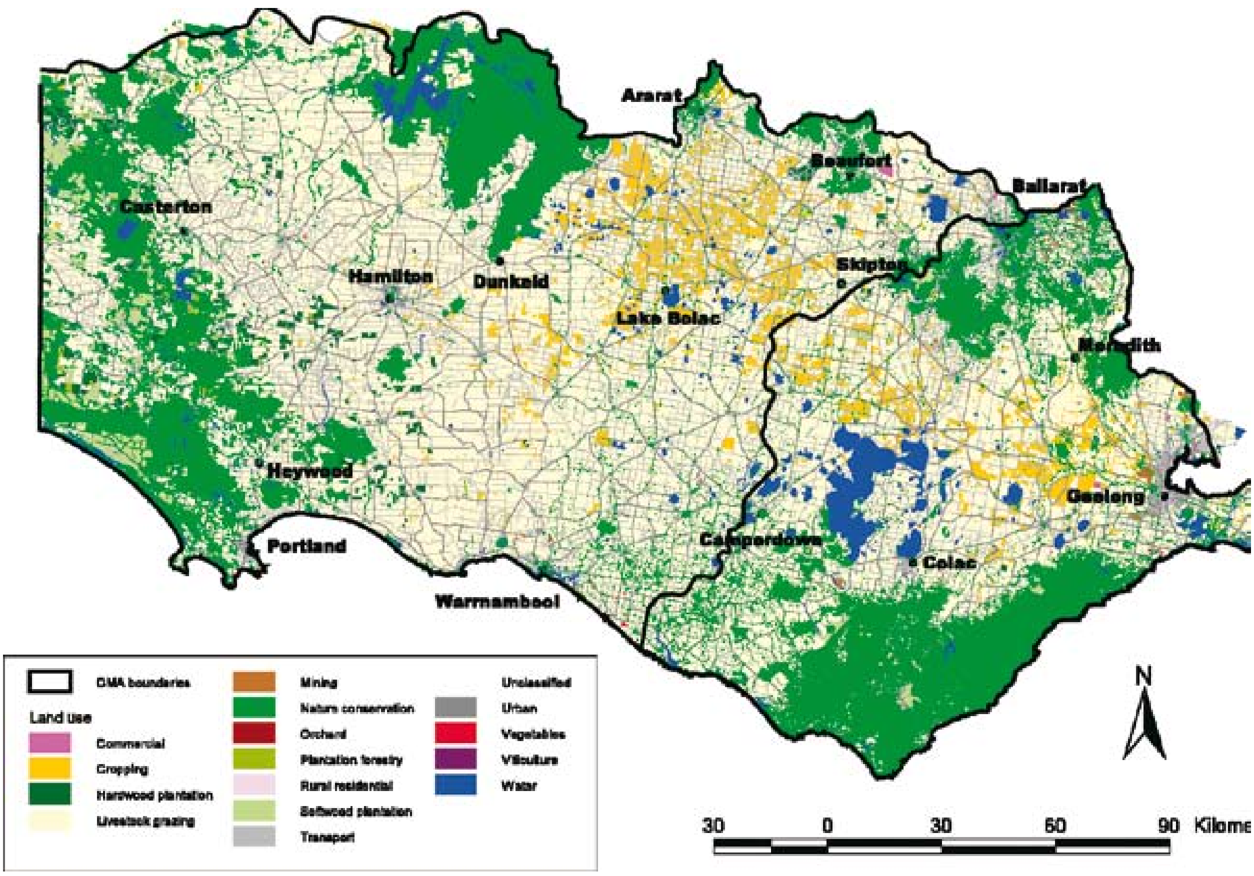
LAND USE AND LAND USE CHANGE

CURRENT

Stage 1 of WatLUC was hindered by the lack of up-to-date and detailed land use mapping. This problem was rectified prior to the commencement of Stage 2 with the publication of land use maps for the Corangamite and Glenelg Hopkins CMA regions by Primary Industries Research, Victoria.

Information from land use maps was combined with vegetation cover mapping to produce a consolidated land use map for the WatLUC study area (below). The two main forms of livestock grazing, broadacre and dairying, were not distinguished in the land use mapping.

2003 land use in the WatLUC study area



The breakdown between land uses is given in the table below. It shows that despite rapid change in land use in south-west Victoria over the last decade, livestock grazing remains the major land use, accounting for around 65% of the region. Native vegetation management in conservation reserves and state forests accounts for the second largest proportion of the region (16.6%). Cropping and plantation forestry (6.7 and 4.7%, respectively) are the next most common land uses.

LAND USE changed rapidly across south-west Victoria during the late 1990s...

2003 land use in the WatLUC study area

WATLUC LAND USE	AREA (km^2 & %)
Commercial	228 (0.6%)
Cropping	2,680 (6.7%)
Hardwood plantation	729 (1.8%)
Livestock grazing	26,112 (65.0%)
Mining	80 (0.2%)
Nature conservation, native production forests, environmental	6,649 (16.6%)
Orchard	4 (0.0%)
Rural residential	263 (0.7%)
Softwood plantation	1,177 (2.9%)
Transport	1,162 (2.9%)
Unclassified	23 (0.1%)
Urban	268 (0.7%)
Vegetables	58 (0.1%)
Viticulture	6 (0.0%)
Water	725 (1.8%)

Note: Land use mapping is believed to underestimate the actual area of hardwood plantation. The forestry industry estimates that there are now about 1010 km^2 of hardwood plantation in the region.

LAND USE CHANGE

Land use changed rapidly across south-west Victoria during the late 1990s and early years of the current decade. Establishment of hardwood forestry plantations and vineyards, expansion in grain and oilseed cropping and the development of more intensively managed dairy and other livestock grazing operations have transformed traditional broadacre grazing landscapes. While the pace of change has slowed in some sectors (e.g. plantation forestry, dairying, vineyard development), continued expansion is either likely (e.g. in cropping, urban and rural residential land uses) or encouraged through public sector investment programs (in native vegetation restoration).

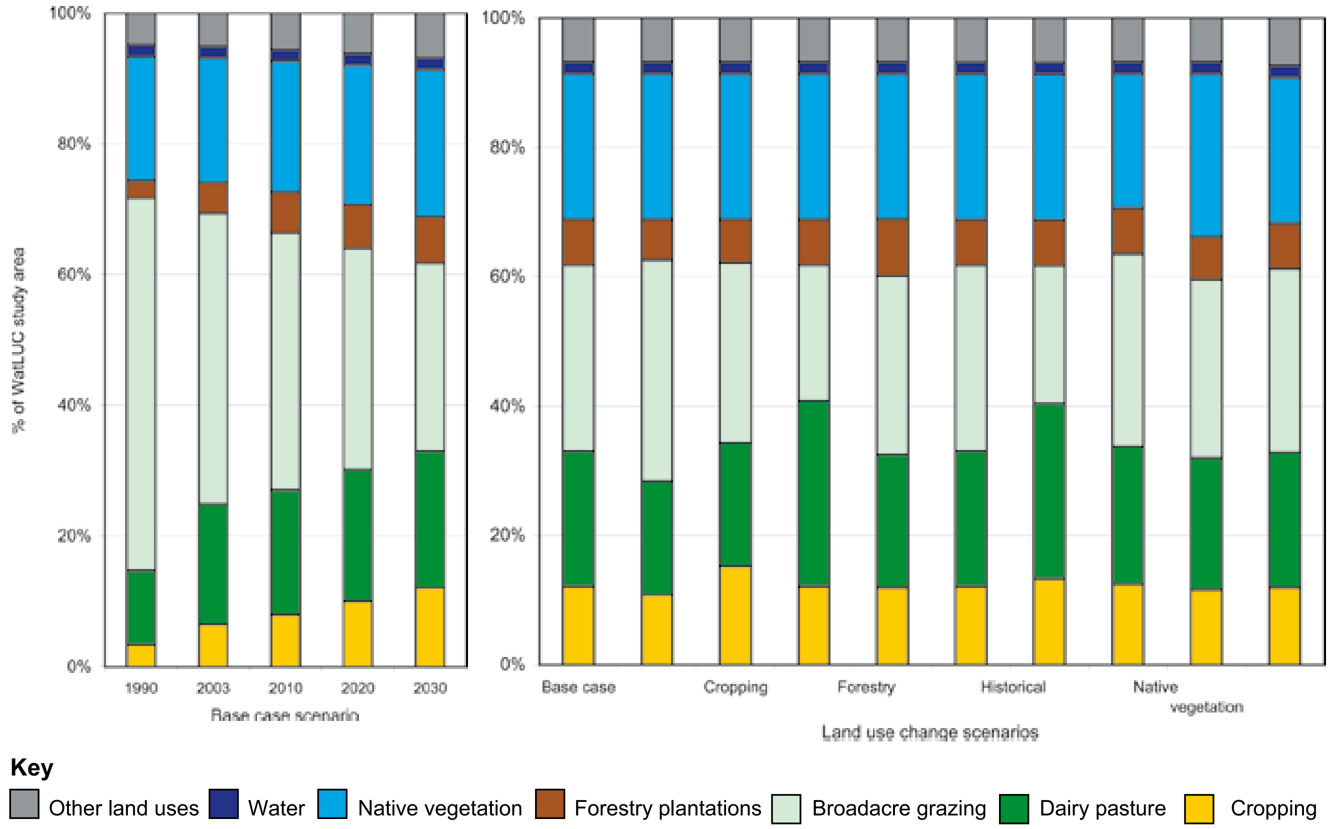
WATLUC HAS INVESTIGATED LAND USE CHANGE IN PARTICULAR SECTORS, AS FOLLOWS:

- broadacre cropping
- grazing for dairy and other livestock production
- nature conservation and native vegetation restoration
- plantation forestry, with higher and lower rainfall hardwood and softwood species
- urban and rural residential land uses
- viticulture.

Ten scenarios were developed to represent changes across the sectors. The scenarios were constructed around a 'base case' scenario which embodied industry predictions about the most likely outcome in particular sectors and reflected realistic levels of native vegetation restoration (based on resource condition targets from regional natural resource management plans). Seven industry or sector specific scenarios were derived, which represented optimistic projections of future land use change. A scenario was developed that reflected a continuation of historical (1990-2001) trends in agricultural land use. The final scenario represented achievement of minimum targets for native vegetation restoration (achieving 5% cover for endangered vegetation communities).

Land use patterns were 'back-cast' to 1990 so that estimates of hydrologic change would incorporate the most rapid phase of land use change. The ten land use change scenarios were developed for 2010, 2020 and 2030 for each of the 66 WatLUC sub-catchments.

Percentage of WatLUC study area under each major land use group, for 1990-2020 base case land use change scenarios and all 2030 land use change scenarios

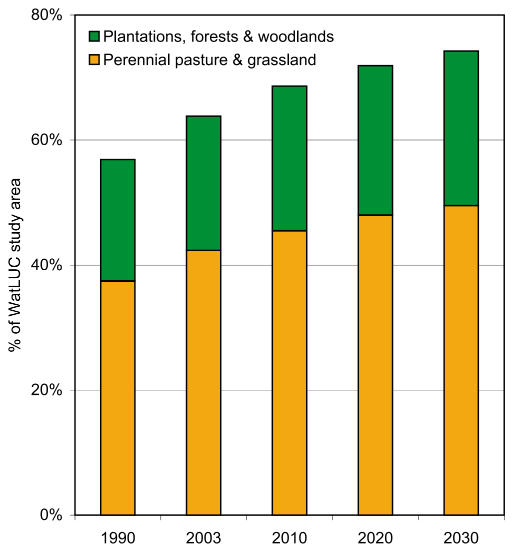


Each scenario is no more than one of an infinite set of representations of future land use. They seek to establish boundaries on the changes that are likely and so provide a useful framework for exploring the range of potential impacts on water resources and water dependent ecosystems.

The breakdown of land use into the main classes for the ten 2030 land use change scenarios and the lead up to them for the base case scenario is given above. Differences between scenarios in 2030 are relatively small in comparison to the changes over time.

The most striking features of the predicted change in land use over the region is the increase in coverage by perennial vegetation. This is associated with development of new forestry plantations, restoration of native vegetation and intensification of management of broadacre grazing land.

Change in perennial vegetation cover under base case scenario: 1990-2030



Note: Perennial pasture and grassland includes sown perennial pastures, native grasslands and grassy woodland vegetation communities.

NEW forestry plantations, restoration of native vegetation

ESTIMATING HYDROLOGIC CHANGE

MODELLING APPROACH

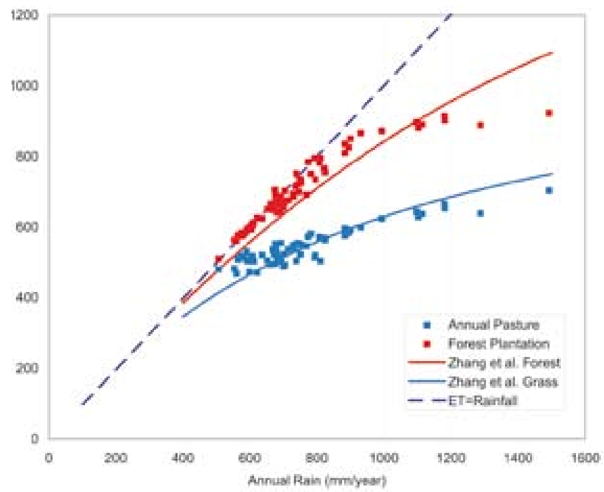
The key questions for WatLUC are: how do changes in land use affect the way in which water moves through landscapes and how does this in turn affect the availability and quality of water for consumptive and environmental uses?

A five step modelling and analysis process was developed for Stage 2 to answer the first of these questions. The process was adapted from that used in the first stage of WatLUC.

1. Represent the various land uses in a way that allows their water use characteristics to be modelled.
2. Run a soil water and salt balance model (*SoilFlux)* for each land use, soil type, depth to water table and sub-catchment climate combination.
3. Calculate the net amount of water that is either available to recharge deep aquifer systems or can discharge through the surface drainage system in each sub-catchment, accounting for the relative area of each land use, soil type and water table depth condition.
4. Estimate water available for deep aquifer recharge or surface water flow, given the predicted land uses in 1990, 2010, 2020 and 2030 under each of the 10 scenarios.
5. Based on the hydrogeology of each sub-catchment, allocate 'excess' water between deep aquifer recharge and the surface water flow.

As in the first stage of the study, the method and results were reviewed by an independent scientific expert and the WatLUC steering committee. A series of checks were also completed to verify that the methods were robust and reliable and that results fell within the expected range (see below).

WatLUC modelled values of evapotranspiration (ET) for annual pasture and forest plantations plotted against the Zhang* curves for grass and forest and the line for ET=rainfall. The graph helps to confirm the reliability of WatLUC modelling.



* Zhang *et al.* (2001) Response of mean annual evapotranspiration to vegetation changes at catchment scale. *Water Resources Research* 37,701-708.

FLOW-RELATED STRESS IN RIVER SYSTEMS

Flow Stress Ranking (FSR) has recently been developed to provide an objective analysis of how changes in flow regimes affect the ecological health of river systems across Victoria. The ranking is based on the level of flow regime modification caused by water extractions by rural, urban, and industrial users. Statistics representing five components of the flow regime (including the level of variability, the timing and amount of high and low flows) are combined into single summer, winter and annual indices of flow stress.
Flow stress indices range between 1 (natural condition) and 0 (very highly modified flow regime).

Flow stress indices were determined for current conditions and for each of the 2030 land use change scenarios.

INTERPRETING WATLUC RESULTS

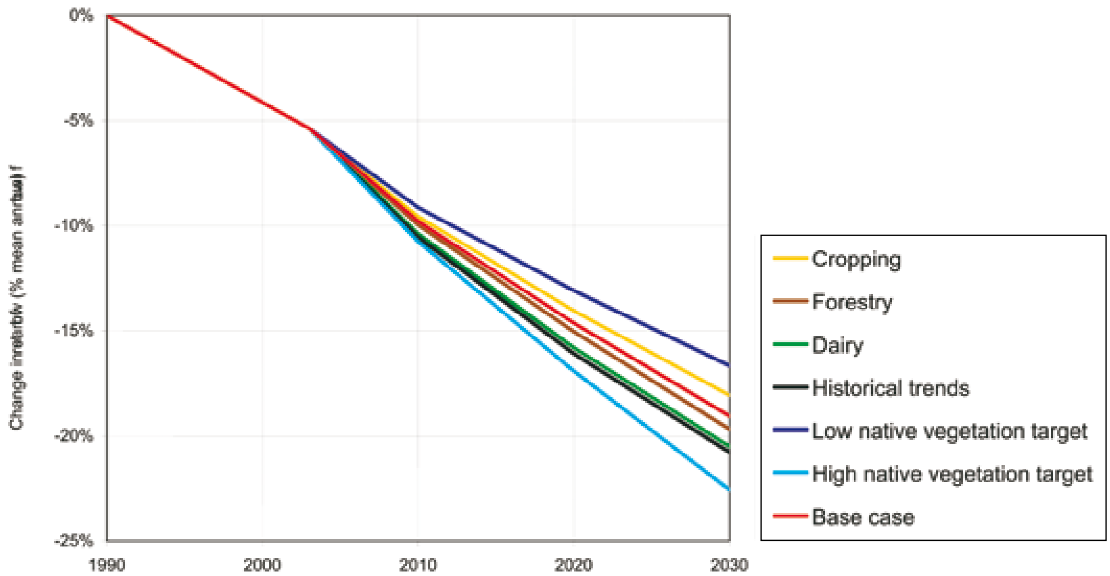
WatLUC modelling results cannot be interpreted on any smaller scale than a sub-catchment, the smallest reasonable scale for generation of the land use change scenarios.

Changes in surface water flow and deep aquifer recharge that are predicted by WatLUC modelling only represent a change in *potential* water yield within a sub-catchment or drainage basin. Farm dams, water storages and irrigation or stock diversions mean that not all of the predicted change in yield will be expressed as change in the stream flow regime or deep aquifer recharge. For this reason, hydrologic changes expressed in depth (as mm of water) or volumetric (GL/y) terms will mostly overstate the true change in water yield. Estimates of relative change with time or between land use change scenarios are likely to be more accurate.

Predicted changes in water yield have been accumulated along river basins to show where flow-related stresses originate and how they either accumulate or dissipate along a river system. The presence of water storages and inter-basin or between sub-catchment transfers of water (in channels or as groundwater flow) have not been accounted for (although groundwater flow between sub-catchments is generally considered to be insignificant).

Estimates of change in water yield or flow stress index for a scenario represent a time when the land uses are fully developed and their full hydrologic impact is expressed. This may be several years after the stated date. It takes time for some land uses, particularly those including trees, to reach 'maturity' in a hydrologic sense. It may also take some time for changes in water movement through the landscape to be expressed as changes in surface water flows or deep aquifer recharge.

Change in average total water yield in sub-catchment 36, Mustons Creek. Mean annual flow in the sub-catchment is 88 mm. Land use change scenarios with similar hydrologic response to those presented have not been included.



THE INFLUENCE OF LAND USE CHANGE ON CATCHMENT HYDROLOGY

Changes over time for sub-catchments

Each of the scenarios produces a unique pattern of land use from 2010 onwards. While they may also produce unique hydrological responses, this is not always the case. In some sub-catchments, land use patterns will only differ subtly between several scenarios and so variation in hydrologic response will be small. The water use characteristics of some land uses may not differ greatly in certain settings (e.g. crops and perennial pastures in some higher rainfall sub-catchments). In such instances, quite different land use patterns may produce similar hydrologic responses.

The graph below shows the progressive impact of several land use change scenarios on mean annual water yield in one sub-catchment (Mustons Creek in the Hopkins River basin). Once the hydrologic impacts of 2030 land use change scenarios are fully expressed, total water yield is predicted to fall by between 17 and 23% of the average prior to 1990. The graphs represent the envelope of changes in water yield that may occur in response to likely changes in land use to 2030.

Total sub-catchment water yield is predicted to decline between 1990 and 2030 in most catchments. However in a small number of urbanised catchments in the east of the study area, WatLUC modelling predicted that water yield would actually increase.

CHANGES IN SURFACE WATER FLOWS

Consistent with the subtle variations in regional land use patterns, there are only relatively modest differences in surface water flow generation capacity between the various land use change scenarios. Most changes in flow generation capacity between 1990 and 2030 are reflected by the base case scenario (see below).

The estimated total loss of surface water flow generation capacity in the entire WatLUC study area, relative to average levels prior to 1990, ranges between about 600 and 750 GL/y for all 2030 land use change scenarios. The reduction in mean annual flow for the base case is estimated to be about 650 GL/y.

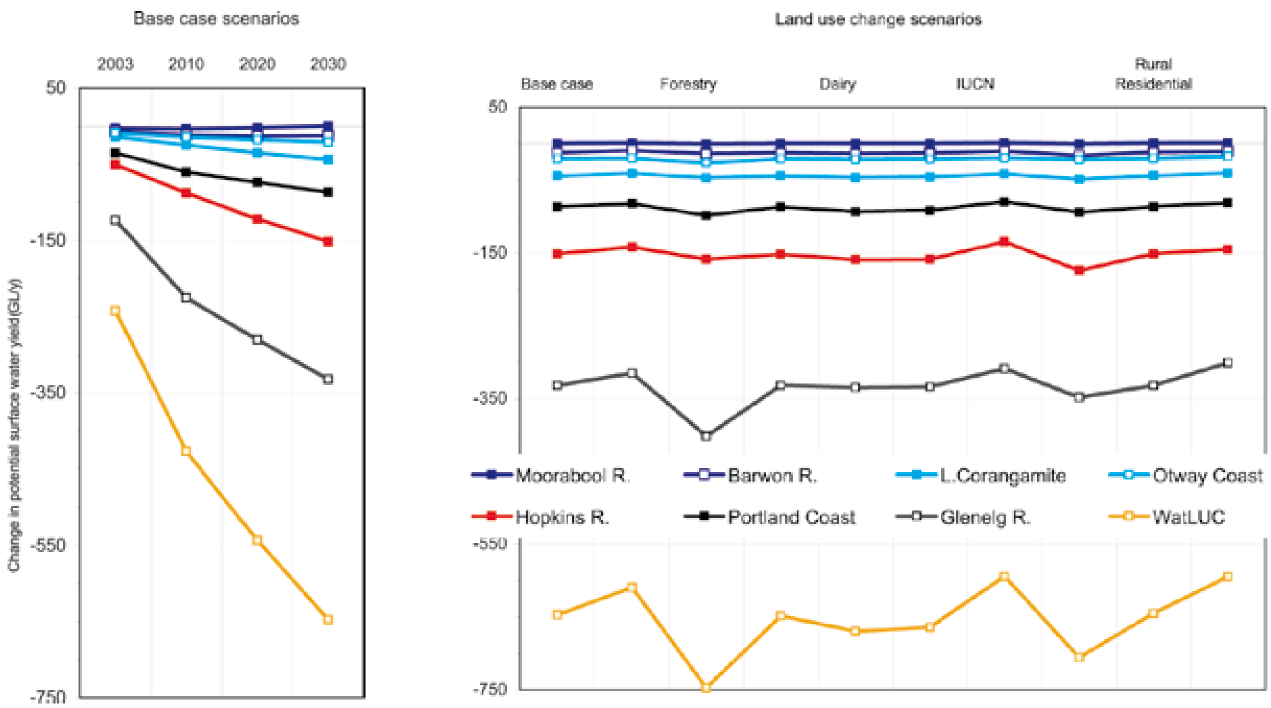
Differences in surface water flow generation capacity between land use change scenarios are most pronounced in the Glenelg drainage basins, where rainfall and current flows are relatively high and the scenarios predict significant expansion in various forms of woody vegetation cover.

Changes in the capacity to generate surface water flows are greatest in sub-catchments of the Glenelg, Portland Coast and Hopkins drainage basins. Under the 2030 base case scenario, twelve of the 22 sub-catchments are predicted to experience flow reductions over 10 GL/y, with two predicted to experience reductions in mean annual flow exceeding 50 GL/y.

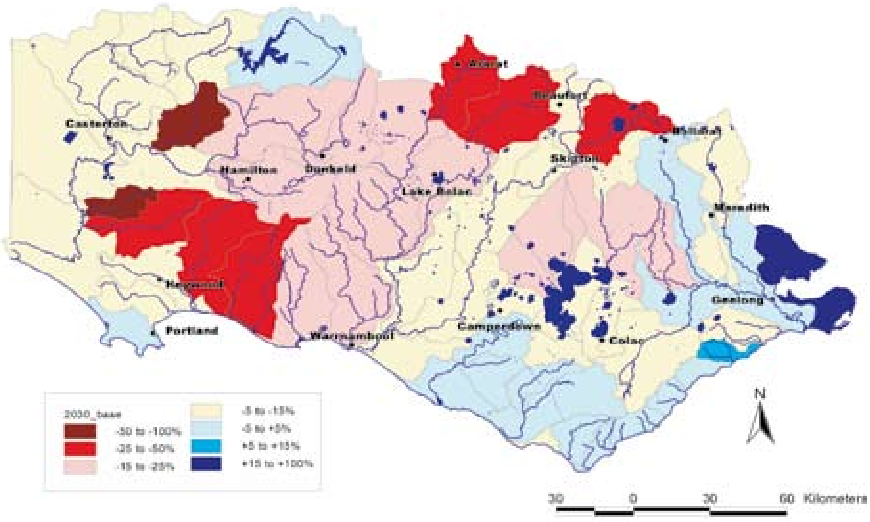
Changes in flow generation capacity along each of the river systems in the study area are shown at the top of the following page. The largest percentage changes occur in the headwaters of the river systems and in the catchments of smaller tributary streams and coastal flowing rivers. Large reductions in flow generation capacity (over 50% in some sub-catchments) are dissipated somewhat in the mid and lower reaches of the larger Glenelg and Hopkins river systems. Changes in flow in sub-catchments of the Barwon and Otway Coast drainage basins are relatively small.

URBAN DEVELOPMENT in a few sub-catchments in the east of the study area is expected to result in increased flows.

Change in surface water flow generation capacity with time and land use change scenarios for the drainage basins of south-west Victoria.



Changes in flow generation capacity between 1990 and 2030 under base case land use change scenario. Map shows the % change in mean annual flow generation capacity upstream of the outlet of each WatLUC sub-catchment.



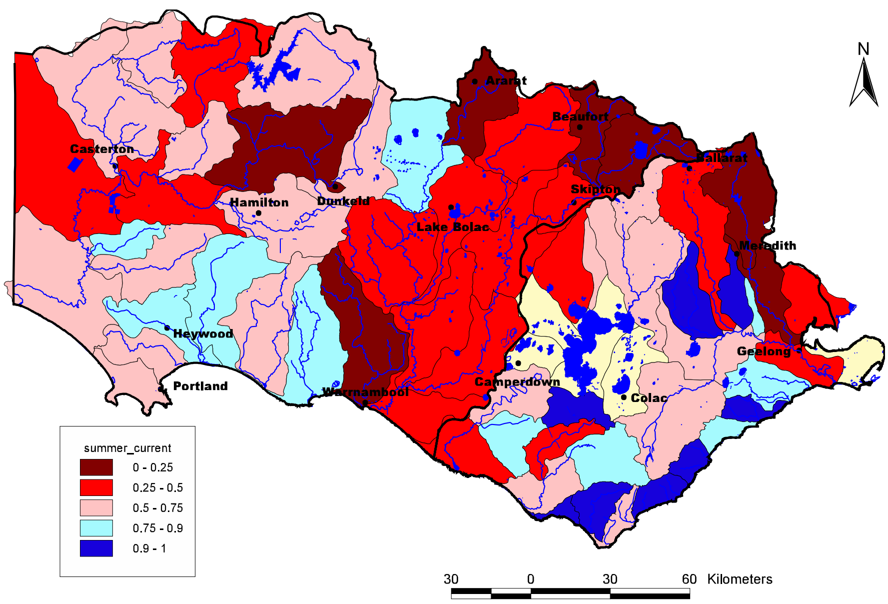
A strong correlation was identified between changes in the percentage of a sub-catchment under four broad land use classes and predicted changes in flow generation capacity. The relationship predicts that for every additional 10% of a sub-catchment occupied by woody vegetation (including forestry plantations and native forests and woodlands) or perennial pastures and grasslands (including sown perennial pastures, native grasslands and grassy woodlands), the depth of flow generated would decrease by 20.1 and 2.8 mm, respectively. An increase in urban or commercial land uses of 1% of the sub-catchment area (a realistic figure under the land use change scenarios) would increase flows by 2.6 and 3.5 mm, respectively.

Flow stress

WatLUC calculated flow stress indices (FSIs) for 61 of the study area's 66 sub-catchments. Calculations were not possible in the remaining sub-catchments because of the lack of flow data.

Under current conditions, summer flows are much more highly altered than winter flows, in terms of both the degree of alteration and the number of sub-catchments with relatively low flow stress indices (see below).

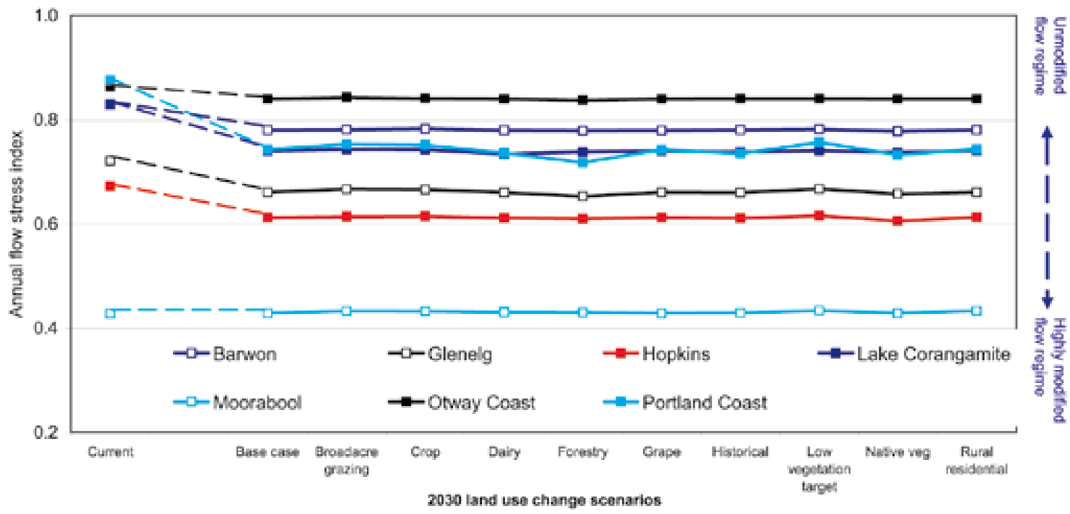
Summer FSI values for WatLUC sub-catchments under current flow conditions. Darkest red indicates highly altered flow regime. FSI could not be calculated in yellow shaded sub-catchments.



Land use change under the 2030 scenarios is predicted to exacerbate flow stress across much of the WatLUC study area (see opposite). Consistent with the relatively modest differences in flow regime, there are few predicted differences in FSI between scenarios. The Moorabool basin remains the most acutely stressed in the study area, despite the minor changes in flow generation capacity with the land use change scenarios.

Change in FSI was also correlated with measures of land use change, but not as strongly as the depth of flow. For every additional 10% of a sub-catchment under woody vegetation cover, FSI would fall by 0.05. FSI would increase by almost 0.02 for every additional 1% under commercial land use.

Annual FSI in WatLUC drainage basins under current conditions and 2030 land use change scenarios. FSI values decreasing from 1 (towards 0) indicate increasing disturbance to natural flow regime.

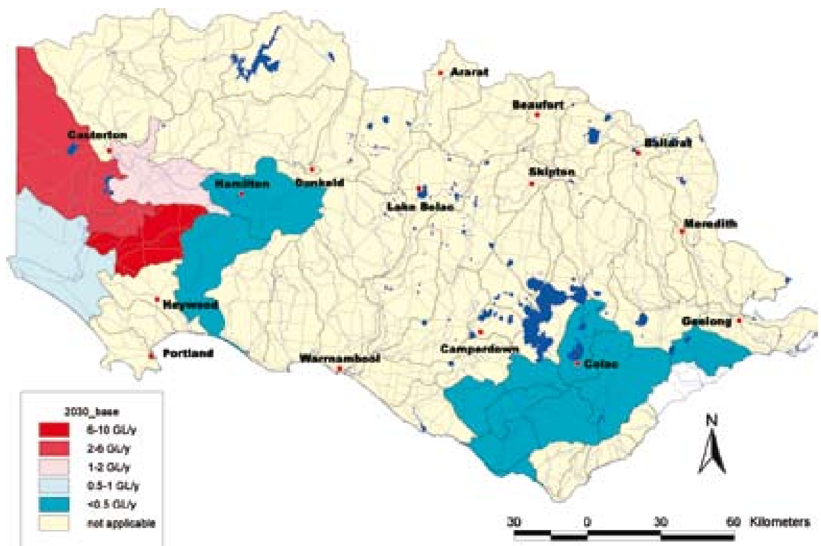


Groundwater

Recharge to deep groundwater systems is only significant in 18 of the 66 WatLUC sub-catchments. WatLUC only predicted reductions in deep aquifer recharge in the west of the region, where land use change scenarios predict large expansions in plantation forestry and other forms of wood vegetation cover.

The total estimated reduction in deep aquifer recharge for the study area was almost 18 GL/y, of which approximately 17 GL/y was in the Glenelg surface water drainage basin. This amounts to only 12% of annual average recharge to these aquifers.

Change in estimated annual recharge to deep aquifers in WatLUC sub-catchments



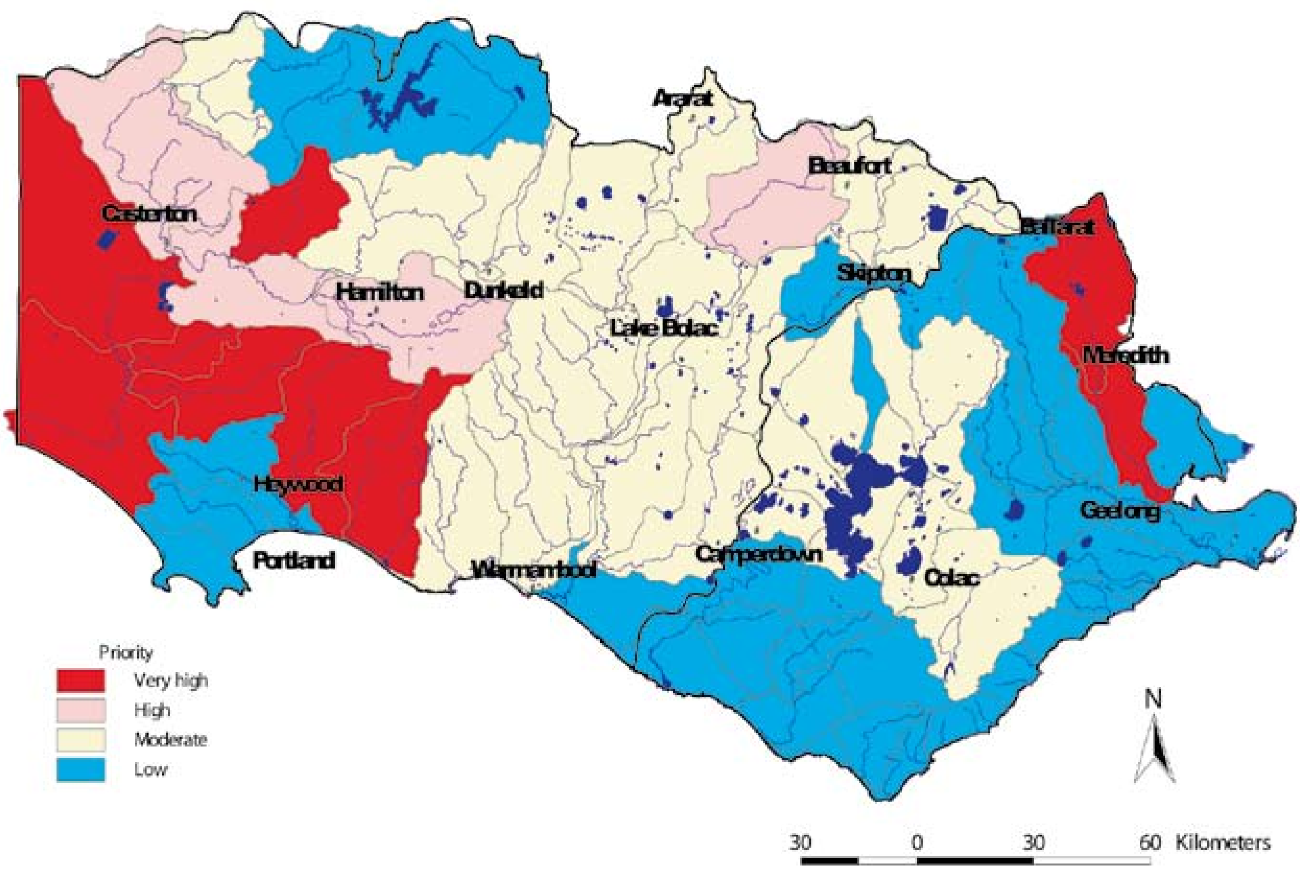
HOT SPOTS FOR HYDROLOGIC CHANGE

WatLUC has highlighted several sub-catchments where land use change since 1990 is likely to significantly alter the hydrologic regime. These areas warrant further attention; to refine the land use change scenarios, carry out more detailed hydrological modelling and improve estimates of changes in flow generation capacity and flow regime that may occur as a result of land use change.

Several broad criteria were used to identify 'hot spots' of hydrologic change, including changes in perennial vegetation cover, flow generation capacity and flow stress. This assessment process identified six priority sub-catchments (see below): the Darlots Creek and Eumerella River sub-catchments in the Portland Coast drainage basin and the Bryans Creek, Stokes, Crawford and lower Glenelg Rivers and Glenelg estuary sub-catchments in the Glenelg drainage basin.

The upper and lower Moorabool sub-catchments were only predicted to experience modest changes in land use, flow and flow regime under the land use change scenarios. However they were also included in the list of priority sub-catchments because their flow regimes are already highly altered by upper catchment storages and water diversions.

Priority sub-catchments: current flow stress and hydrologic impacts of land use change



CONCLUSIONS

Realistic land use change scenarios for the WatLUC study area predict that the pace of land use change observed in the late 1990s is unlikely to be maintained. However, it is likely that there will be continued expansion in blue gum plantations in the west of the region over the next few years and on-going growth in the area of land under cropping, native vegetation and rural residential land uses over coming decades. The main features of land use change over the 40 years from 1990 are likely to be the expansion in cropping at the expense of broadacre grazing and the increase in both woody and non-woody perennial vegetation cover.

The ten land use change scenarios anticipate different land use outcomes. Although this is not reflected in changes in water regime at the drainage basin level, there are sometimes quite pronounced differences between scenarios at the sub-catchment scale. The scale of predicted change in catchment hydrology over time far exceeds the differences between scenarios.

There is likely to be a significant reduction in the availability of surface water and groundwater resources in south-west Victoria as the result of land use change. However it is not expected that land use change will have a particularly marked effect on inflows to the region's major water storages. Over half of the surface water losses and almost all of the loss in deep aquifer recharge are expected to occur in the Glenelg drainage basin.

The flow regimes of the Moorabool and Hopkins Rivers, the Mt Emu Creek and some tributaries of the Glenelg River are already quite altered, particularly in summer. Land use change is expected to lead to further, incremental change in the flow regimes of rivers and streams throughout the study area. Again, changes to summer flows will be greater than those to winter flows. The Moorabool River will remain the most stressed of the study area's streams, despite it being largely unaffected by land use change.

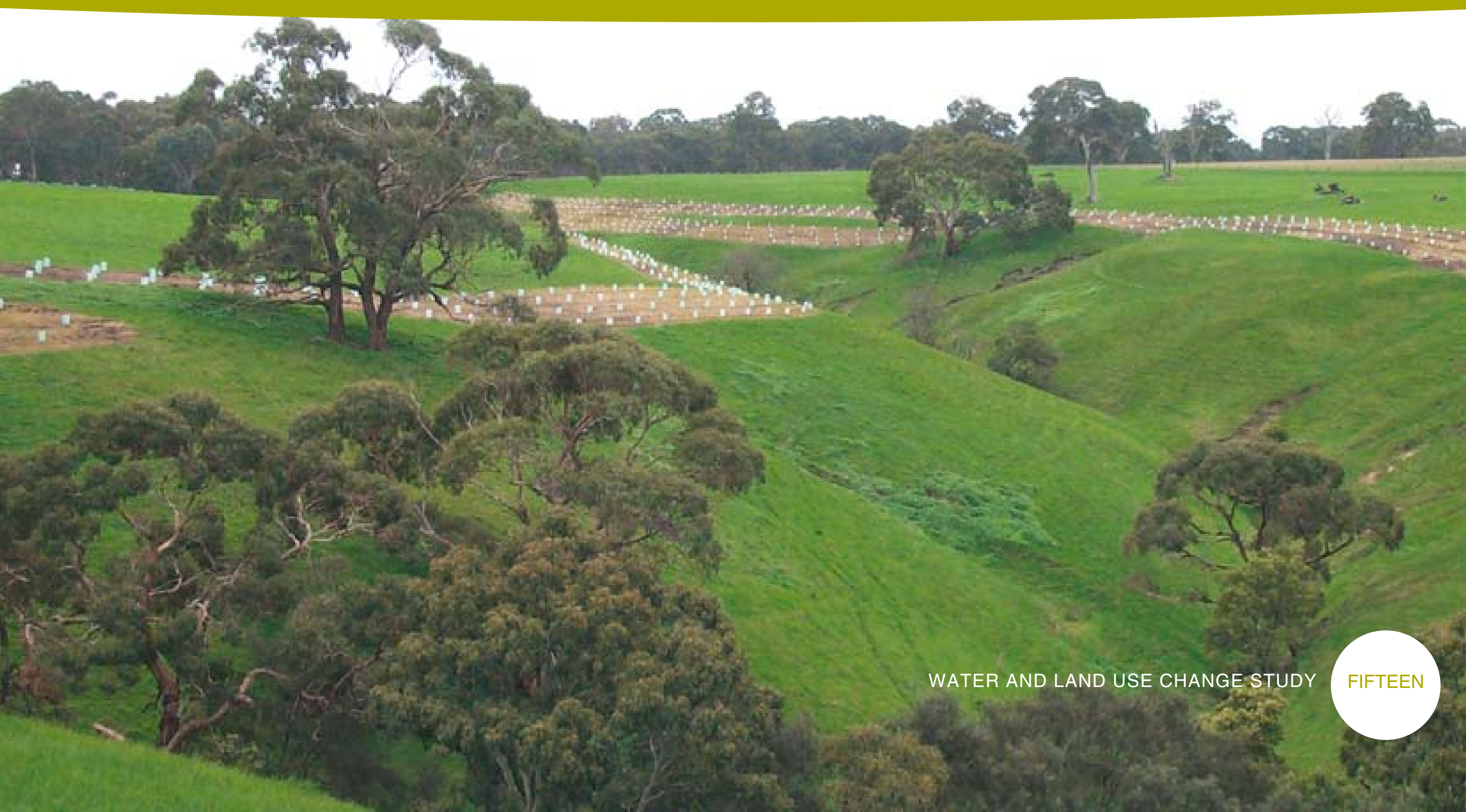
Further work to explore the nature and impact of flow stress and hydrological change should be undertaken in identified hotspot areas in the Moorabool, Glenelg and Portland Coast basins.

ACKNOWLEDGEMENTS

The Water and Land Use Change study was overseen by a Steering Committee that comprised representatives of key private and public sector stakeholder organisations. Their input to the study was invaluable. They worked to secure funding and helped to ensure that the study remained relevant to the needs and issues of south-west Victoria. Their work built on the foundation laid by earlier stakeholder representatives, who commissioned an initial scoping study and Stage 1 of the study. WatLUC was undertaken by Sinclair Knight Merz. It was coordinated by the Glenelg Hopkins Catchment Management Authority on behalf of project partners.

PROJECT PARTNERS

The project has been supported by the following organisations:
Central Victorian Farm Plantations Committee; Corangamite Catchment Management Authority; Corangamite Shire; CSIRO Forestry and Forest Products; Deakin University; Department of Land, Water and Biodiversity Conservation, South Australia; Departments of Primary Industries and Sustainability and Environment, Victoria; Glenelg Hopkins Catchment Management Authority; Golden Plains Shire; Green Triangle Regional Plantation Committee; National Action Plan for Salinity and Water Quality; Private Forestry Council of Victoria; South East Catchment Water Management Board; Southern Farming Systems; Southern Grampians Shire; Southern Rural Water Authority; Water for Growth; and WestVic Dairy.



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