North East Greenhouse Alliance

# Historical climate, climate change and water availability

North East Victoria Adapting to a Low Water Future: Project Context Setting – Deliverable 1

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Authors Dr Craig Beverly (DPI)
Mr Mark Hocking (Hocking et al Pty Ltd)

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# EXECUTIVE SUMMARY

North East Greenhouse Alliance (NEGHA) has identified the necessity to develop a regional climate change adaptation strategy for its region of influence. Under the Strengthening the Basin Communities component of the Water for the Future programme, the Australian Government has funded the 'Adapting to a Low Water Future' project proposed by the NEGHA. The objective of the project is to develop a strategy to manage climate change risks and vulnerabilities with respect to water availability. It is envisaged that developing adaptive actions to mitigate the risks and building resilience within communities will enable the region to better respond to a low water future. Specifically this study reviewed and analysed historical climate, climate change and water availability within the North-East CMA region. A methodology developed by DPI was used to interpolate climate scenarios generated by CSIRO to daily climate sequences for each of the climate stations within the study area. These daily climate sequences were incorporated into existing surface water and groundwater models to assess the major impacts of climate change on water availability projections to 2030 and 2070. The modelling approach adopted in this study used a suite of physically based farming system models and a fully distributed multi-layered groundwater model and is shown to offer fine scale, CMA wide regional estimates across a range of designated future climate scenarios.

Specific conclusions from this study are:

1. Large uncertainties are associated with climate change predictions, both at the point scale and catchment scale. These uncertainties are introduced due to variability in the underpinning data, simulation model constructs and assumptions adopted with model applications.
2. Significant variations in climate change impacts on water availability have been previously reported, and in some cases contrast the predictions derived in this study. This reinforces the degree of uncertainties associated with the derivation of the hydrological impact of future climate scenarios.
3. Under the low 2030 climate condition flows would be reduced by between 2% and 14% depending upon landscape position and dynamics. In order of increasing impact, Wangaratta Shire would be least impacted (-2%) followed by the Alpine Shire (-3%), then Indigo Shire (-9%), Wodonga Shire (-10%) and Towong Shire (-11%). Key river basins would similarly be impacted with reduced flows ranging from 1% to 14%. In order of increasing impact, the Ovens catchment would be least impacted (-2%), followed by the Kiewa (-6%), the Mitta catchment (-9%) and the Upper Murray basin (-12%).
4. Under the dry extreme 2030 climate condition flows would be reduced by between 10% and 25% across the North-East CMA region. In order of increasing impact, Alpine Shire would be least impacted (-12%) followed by the Wangaratta Shire (-13%), then Indigo and Wodonga Shires (-20%) and Towong Shire (-21%). The corresponding reduction in river basin flows range between 10% and 28%. In order of increasing impact, the Ovens catchment would be least impacted (-13%), followed by the Kiewa (-14%), the Mitta catchment (-20%) and the Upper Murray basin (-23%).
5. Under the low 2070 climate condition flows would be reduced to approximately those predicted under the dry extreme 2030 climate conditions with reductions ranging

between 9% and 24%. In order of increasing impact, Wangaratta and Alpine Shires would be least impacted (-12%), followed by the Indigo Shire (-19%), then the Wodonga Shire (-20%) and Towong Shire (-21%). Key river basins would also be impacted with reduced flows ranging from 9% to 26%. In order of increasing impact, the Ovens catchment would be least impacted (-12%), followed by the Kiewa (-14%), the Mitta catchment (-19%) and the Upper Murray basin (-22%).

6. Under the dry extreme 2070 climate condition flows would be reduced across the North-East CMA region by between 34% and 61%. In order of increasing impact, the Alpine Shire would be least impacted (-41%), followed by the Wangaratta Shire (44%), Indigo Shire (-48%), then the Wodonga Shire (-50%) and Towong Shire (-52%). Key river basins would similarly be impacted with reduced flows ranging from 33% to 65%. In order of increasing impact, the Kiewa catchment would be least impacted (-41%), followed by the Ovens (-44%), the Mitta catchment (-52%) and the Upper Murray basin (-55%).
7. The groundwater resource within the North-East CMA region is unlikely to be sustainable based on the simulation of groundwater dynamics using the provided groundwater entitlement data under full allocation assumptions.
8. An understanding of landscape dynamics is critical in estimating the impact of climate change on water availability, productivity and groundwater sustainability.

On the basis that the IPCC original climate change projections have been revised, this study recommends undertaking more detailed modelling using the recently updated CCAM Mark 3.6 pattern of change data from CSIRO. Enhancement of the existing groundwater model to better capture temporal groundwater dynamics and sustainable extraction limits has also been identified as a key recommendation.

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# 1 INTRODUCTION AND AIMS

North East Greenhouse Alliance (NEGHA) has identified the necessity to develop a regional climate change adaptation strategy for its region of influence. Under the Strengthening the Basin Communities component of the Water for the Future programme, the Australian Government has funded the 'Adapting to a Low Water Future' project proposed by the NEGHA. The objective of the project is to develop a strategy to manage climate change risks and vulnerabilities with respect to water availability. It is envisaged that developing adaptive actions to mitigate the risks and building resilience within communities will enable the region to better respond to a low water future.

The work carried out by this consultancy constitutes the first phase of the 3-phase project. The aim of this initial phase is to establish the context for responding to a low water future in the North-East region of Victoria. The project will review the predicted climatic variability and associated water security issues for the North-East region and identify vulnerable groups or sectors. It is expected that the project findings will inform the second phase - climate change risk assessment and adaptation planning.

**Study objectives**

The objective of this study is to develop an understanding of the water availability and water security in the North East region and the capacity of the region (and its constituents) to respond to adverse climate change impacts. Specifically, the consultancy will aim to:

1. review and analyse historical climate, climate change and water availability;
2. review and analyse the water user groups, their access to water and current usage statistics;
3. review and analyse current water demand drivers, trends and related behaviours; and
4. carry out a preliminary assessment of the vulnerabilities to climate change induced water stress.

This study will review and analyse historical climate, climate change and water availability:

1. collate all relevant published information related to climate change induced water stress for the North-East region;
2. develop an understanding of climate variability and attending impacts for the North-East region;
3. establish four climate change scenarios incorporating emission levels, rainfall and temperature variations;
4. provide a method for assessing the major impacts of climate change on water availability projections to 2030 and 2070;
5. evaluate the four climate change scenarios developed in (3);
6. provide selected information in the given format;
7. provide an electronic version of the data used as well as the source data;

8. provide a narrative explanation of key external variables such as environmental commitments, priority of access and seasonal factors (minimum flow expectations) contribute to the water availability in the region; and
9. outline the limitations of data and information available including knowledge gaps.

**Methodology**

The consultancy collated climate, streamflow and selected groundwater hydrograph data from the relevant custodians including the Bureau of Meteorology, North East Water, Goulburn-Murray Water, MDBA, DSE, CSIRO, SKM and GHD. Numerous surface water and groundwater studies were sourced, as was all streamflow, groundwater hydrograph and spatial data layers within the study area. The recently developed groundwater model of the Ovens Valley by GHD and the CSIRO Sustainable Yields modelling reports were used in this review as a reference data set.

Upon collation of the climate data, analysis was undertaken to assess and report climate variability. A methodology has been developed by the project team to interpolate climate scenarios developed by CSIRO to daily climate sequences for each of the climate stations within the study area. These daily climate sequences were incorporated into existing surface water and groundwater models to assess the major impacts of climate change on water availability projections to 2030 and 2070.

**Acknowledgements**

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# 2 PREVIOUS CLIMATE CHANGE STUDIES

This section summarises key findings from previous climate change studies undertaken within the North-East CMA region. The specific relevant studies are:

1. CSIRO Murray Darling basin Sustainable Yields project
2. Water Availability in the Ovens study undertaken by CSIRO as part of the Murray-Darling Basin Sustainable Yields project
3. The Ovens valley water resource appraisal commissioned by Goulburn-Murray Water to GHD
4. Northern Region Sustainable Water Strategy
5. The Victorian Climate Change Adaptation Program
6. North East Water Water Supply Demand Strategy
7. DSE: Estimating the impacts of climate change on Victoria's runoff.

It is noteworthy that no study was identified that specifically assessed the likely impact of climate change on biodiversity within the North-East region of Victoria.

In most cases the previous studies adopted future climate scenarios based on the global warming predictions released by the International Panel of Climate Change (IPCC) in 2001. These global warming predictions were reported in the IPCC Fourth Assessment and are described below as background information.

## 2.1 IPCC Fourth Assessment

In 2001 the International Panel of Climate Change (IPCC) released a series of global warming scenarios describing future emissions of greenhouse gases and aerosols based on different socio-economic assumptions. Using the predicted increase in atmospheric concentration of greenhouse gasses the IPCC also generated a series of projected modified global temperatures for each of the various scenarios presented below.

### 2.1.1 B1 scenario: Low emission growth scenario

The B1 scenario represents the lower emission growth projection and assumes that there is a rapid shift to less fossil-fuel intensive industries. Under this scenario it is assumed that there will be a weak increase in $CO_2$ emissions until 2040 and thereafter a decline. $CO_2$ concentrations approximately double by 2100 relative to pre-industrial levels. A global temperature increase of 1.8$^{o}$C relative to 1990 is predicted with a range from 1.1 to 2.9$^{o}$C likely.

### 2.1.2 A1B scenario: Medium emission growth scenario

The A1B scenario represents the medium emissions growth projection and assumes that there is a balanced use of different energy sources. $CO_2$ emissions are assumed to increase moderately until 2030 and decline by the middle of the 21st century. By 2100 a global temperature increase of 2.8$^{o}$C relative to 1990 is predicted with a range from 1.7 to 4.4$^{o}$C likely

#### 2.1.3 A1F1 scenario: High emission growth scenario

The A1F1 scenario represents the high emissions growth projection and assumes a continuation of economic growth based on continued dependence on fossil fuels. $CO_2$ concentrations are assumed to triple by 2100 relative to pre-industrial levels. Additionally, a global temperature increase of 4.0$^{o}$C relative to 1990 is predicted with a range from 2.4 to 6.4$^{o}$C likely. This scenario represents the highest level of late 21st century emissions that were considered to be plausible in 2000. However, recent evidence indicates that $CO_2$ emissions have been growing at a more rapid rate and that this scenario is now considered the medium projection.

To account for regional impacts of climate change, CSIRO developed the CCAM model which is a global atmosphere-only model that predicts mean-monthly pattern of change per degree of global warming for temperature, rainfall and solar radiation. Two versions of the CCAM model have been developed (Mark 2 and Mark 3) utilising different parameterisations of physical processes. Outputs from each of these models are presented on a 50km x 50km grid and require application of downscaling processes to be relevant at a finer resolution.

## 2.2 CSIRO Murray Darling Basin Sustainable Yields

In late 2006 CSIRO was commissioned by the then Prime Minister and MDB Premiers to report on the sustainable yields of surface and groundwater systems within the MDB. Eighteen (18) regions were assessed with separate reports prepared for each region. The assessments were framed around four scenarios of climate and development based on the available 111 years of daily climate data. Each of the four scenarios is presented below with associated key findings relevant to the North-East CMA region of Victoria.

#### 2.2.1 Scenario A: Historical climate and current development

This scenario represented the baseline condition to be used for comparison with other scenarios and was based on the historical climate from mid-1895 to mid-2006 assuming the current level of water resource development.

#### 2.2.2 Scenario B: Recent climate and current development

This scenario is based on the recent climate sequence recorded for 1997 to 2006. It is used to evaluate the consequence of a long-term continuation of the recent severe drought in south eastern Australia and is assumed to be a reference for the climate change scenarios.

#### 2.2.3 Scenario C: Future climate and current development

This scenario considered climate change at 2030 based on three global warming estimates derived using 15 of the global climate models summarised in the fourth assessment report of the Intergovernmental Panel on Climate Change. The assessments focused on the median of the range with the uncertainty estimates based on the reported 'wet extreme' and 'dry extreme' within the same range.

### 2.2.4 Scenario D: Future climate and future development

This scenario incorporated the likely future development and the 2030 climate. The future development accounted for growth in farm dam capacity, expansion of commercial forestry plantations and increase in groundwater extractions. It is noteworthy that the projections of future farm dams and commercial forestry plantations were based on 'best guesses' whereas the projections of future groundwater extractions represent maximum allowable use under existing water sharing arrangements.

### 2.2.5 Key findings

Estimates of the impact of future climate on water resource within the North-East CMA region were only derived for the Ovens catchment, and only for 2030. Tabled below are the predicted effects of climate change by 2030 on water availability within the Ovens catchment.

7Table 2.2.1. 2030 climate change surface water impacts in the Ovens basin.

| Attribute | Units | Historical climate | 2030 climate | | |
|---|---|---|---|---|---|
| | | | Wet extreme | Median | Dry extreme |
| Surface water availability | GL/year | 1,776 | 1,802 | 1,542 | 974 |
| Total surface water use | GL/year | 25 | 25 | 25 | 26 |
| | | | | | |
| Bulk entitlements @ 100% | GL/year | 37.23 | | | |
| % of years with 100% allocation | % | 63 | 75 | 63 | 40 |
| % of years with 50% allocation | % | 100 | 100 | 100 | 98 |
| % of years with 0% allocation | % | 0 | 0 | 0 | 0 |

Table 2.2.2. CSIRO estimates of groundwater use for the Ovens catchment

| | |
|---|---|
| 2004/05 groundwater use | 12.3 GL |
| 2004/05 groundwater use as a percentage of total average water use | 33% |
| 2004/05 groundwater use as percentage of total water use in year of lowest surface water use | 45% |
| Possible 2030 groundwater use | 23.0 GL |
| 2030 groundwater use as a percentage of total average water use | 48% |
| 2030 groundwater use as percentage of total water use in year of lowest surface water use | 60% |

Table 2.2.3. CSIRO estimates of surface water availability for the Ovens catchment

| | No development, historical climate | Current development, historical climate | Current development, recent climate |
|---|---|---|---|
| Total inflows | 1,970.3 | 1,970.3 | 1,462.3 |
| Total losses | 194.6 | 193.3 | 159.0 |
| Total surface water diversions | - | 25.4 | 25.6 |
| Induced streamflow loss to g/w | - | 0.0 | 0.0 |
| Total end-of-valley surface flow | 1,775.7 | 1,751.6 | 1,277.7 |
| Average surface water availability | 1,775.5 | - | 1,303.2 |
| Relative level of surface water use | - | 1% | 2% |

Table 2.2.4. CSIRO estimates 2030 surface water availability for the Ovens catchment assuming current development.

| | Median 2030 climate | Wet extreme 2030 climate | Dry extreme 2030 climate |
|---|---|---|---|
| Total inflows | 1,718.1 | 1,995.0 | 1,103.7 |
| Total losses | 175.1 | 191.0 | 130.8 |
| Total surface water diversions | 25.4 | 25.3 | 26.0 |
| Induced streamflow loss to g/w | 0.0 | 0.0 | 0.0 |
| Total end-of-valley surface flow | 1,517.6 | 1,778.7 | 946.9 |
| Average surface water availability | 1,542.1 | 1,802.0 | 973.8 |
| Relative level of surface water use | 2% | 1% | 3% |

Table 2.2.5. CSIRO estimates 2030 surface water availability for the Ovens catchment assuming future development.

| | Median 2030 climate | Wet extreme 2030 climate | Dry extreme 2030 climate |
|---|---|---|---|
| Total inflows | 1,707.4 | 1,984.3 | 1,093.1 |
| Total losses | 174.6 | 191.0 | 130.6 |
| Total surface water diversions | 25.3 | 25.2 | 25.8 |
| Induced streamflow loss to g/w | 0.0 | 0.0 | 0.0 |
| Total end-of-valley surface flow | 1,507.5 | 1,768.1 | 936.7 |
| Average surface water availability | 1,542.1 | 1,802.0 | 973.8 |
| Relative level of surface water use | 2% | 1% | 3% |

## 2.3 CSIRO Water Availability in the Ovens Study

This report described the assessment undertaken for the Ovens region as part of the CSIRO Murray-Darling Basin Sustainable Yields Project commissioned in late 2006 by the then Prime Minister and MDB Premiers. The water availability study included rainfall-runoff modelling, river system modelling and groundwater assessment for each of the four climate scenarios adopted in the basin-wide CSIRO Murray-Darling Basin Sustainable Yields Project, namely:

| | | |
|---|---|---|
| Scenario A | Historical climate and current development: | This scenario represented the baseline condition to be used for comparison with other scenarios and was based on the historical climate from mid-1895 to mid-2006 assuming the current level of water resource development. |
| Scenario B | Recent climate and current development | This scenario is based on the recent climate sequence recorded for 1997 to 2006. It is used to evaluate the consequence of a long-term continuation of the recent severe drought in south eastern Australia and is assumed to be a reference for the climate change scenarios. |
| Scenario C | Future climate and current development | This scenario considered climate change at 2030 based on three global warming estimates derived using 15 of the global climate models summarised in the fourth assessment report of the Intergovernmental Panel on Climate Change. The assessments focused on the median of the range with the uncertainty estimates based on the reported 'wet extreme' and 'dry extreme' within the same range. |
| Scenario D | Future climate and future development | This scenario incorporated the likely future development and the 2030 climate. The future development accounted for growth in farm dam capacity, expansion of commercial forestry plantations and increase in groundwater extractions. It is noteworthy that the projections of future farm dams and commercial forestry plantations were based on 'best guesses' whereas the projections of future groundwater extractions represent maximum allowable use under existing water sharing arrangements. |

The rainfall-runoff modelling was based on application of the lumped conceptual daily SIMHYD model with a Muskingum routing method. This model was chosen as it is simple and has relatively few parameters (only 6) which are typically derived though optimisation techniques based on matching observed monthly runoff series and daily flow duration characteristics. The rainfall-runoff model was calibrated against 1975 to 2006 streamflow.

The river system assessment was based on REALM modelling with accounting for farm dam impacts, groundwater pumping, storage behaviour, diversions and consumptive water use. This model was recently updated by Sinclair Knight Merz for the Victorian Department of Sustainability and Environment and operates on weekly time steps. The model represents the Ovens river system and includes over 300 links and over 240 nodes arranged into 15 river sections (11 river sections on the King River and 4 river sections on the Buffalo River) and accounts for small tributaries and various supporting water accounting functions.

The groundwater assessment estimated the impacts of climate and development on groundwater management units (GMUs) and was based on groundwater recharge modelling. Rainfall-recharge modelling was undertaken for all GMUs and adopted scaling factors for different soil and land use conditions. These scaling factors were used to scale recharge for given changes in rainfall. In high priority regions, numerical groundwater models were used (refer Section 3.1). However in the Ovens study no numerical groundwater models was used, instead the groundwater response was estimated using the simplified rainfall-recharge approach, a simple water balance analysis and an indicator based on the ratio of extraction to rainfall recharge.

### 2.3.1 Key findings

The impacts of the 2030 climate change predictions on water balance components in the Ovens catchment are summarised in Table 2.3.1 and show that mean annual runoff will vary between a 44% reduction to a 1% increase relative to historic conditions. The corresponding variability in soil evaporation and plant performance (evapotranspiration) is estimated to be an 11% reduction to a 3% increase. This demonstrates the considerable uncertainity in the climate change impact estimates as acknowledged in the Ovens assessment report (CSIRO, 2008). It is also noteworthy that the future development had negligible impact on catchment averaged mean annual runoff and evapotranspiration. Other key findings pertain to the river system modelling which predicted the following:

1. Current average water availability is 1776 GL/year. The current level of use is very low: 25 GL/year (1.4%) is diverted for use including 19 GL/year (1.1%) for irrigation.
2. The main storages in the region are Lake William Hovell and Lake Buffalo. Regulated supply provides for 58% of the total bulk entitlement and licensed volume.
3. The Ovens region uses four levels of water restrictions: levels 1 and 2 are mild restrictions; levels 3 and 4 are severe restrictions. For Wangaratta, mild water restrictions are currently activated in less than 5% of years as are severe restrictions. For Bright, mild water restrictions are currently activated in 37% of years while severe restrictions are activated in 10% of years.
4. If the climate of the last ten years were to persist, water availability and end-of-system flows would be reduced by 27% but average surface water use would be unaffected. However, mild and severe water restrictions would be activated more

frequently for both Wangaratta and Bright due to increases in demand as a result of lower rainfall and high evaporation.

5. Under the best estimate 2030 climate water availability and end-of-system flows would be reduced by 13% with negligible impact on average surface water use. Water supply to Bright would require mild water restrictions in 41% of years and severe restrictions in 14% of years. The frequency of water restrictions for Wangaratta would be largely unaffected.
6. Under the wet extreme 2030 climate water availability would increase slightly, but reduced demand would mean surface water diversions would be slightly lower. Water restrictions for Bright would be activated less frequently. Under the dry extreme 2030 climate water availability would be reduced by 45% and demand would increase due to reduced rainfall and increased evaporation, resulting in a slight increase in average surface water use. End-of-system flows to the Murray River would be reduced by 46%. Water supply to Bright would require mild restrictions in 62% of years and severe restrictions in 21% of years. Water supply to Wangaratta would require mild restrictions in 18% of years and severe restrictions in 14% of years.
7. Projected growth in commercial forestry plantations in the region is negligible, and the projected 8% increase in farm dams would have only minor impact on future runoff.

The key finding from the groundwater assessment is that groundwater can provide a secure water source during drier periods. Whereas groundwater is an important source of water under average flow years, this significance increases under drier future conditions. Table 2.3.2 summarises the groundwater extractions as a percentage of total available water (surface and groundwater) for low flow periods under future climate scenarios. However it is noted in the report that these extraction limits are very sensitive to the ratio of extraction to recharge estimates and by definition the recharge estimates which do not explicitly account for spatially explicit land use, land management, soil and catchment location.

Table 2.3.1. CSIRO water balance for the Ovens catchment by scenario.

| Scenario | Rainfall | Runoff | Evapotranspiration |
|---|---|---|---|
| | mm | | |
| A | 1004 | 231 | 773 |
| | percentage change from A | | |
| B | - | -26% | - |
| Cdry | -19% | -44% | -11% |
| Cmid | -4% | -13% | -2% |
| Cwet | +3% | +1% | +3% |
| Ddry | -19% | -44% | -11% |
| Dmid | -4% | -13% | -2% |
| Dwet | +3% | +1% | +3% |

Table 2.3.2. CSIRO estimates of groundwater extractions as a percentage of total available water (surface and groundwater) for low flow periods under future climate scenarios.

| | Lowest 1-year period | Lowest 3-year period | Lowest 5-year period | Average |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| A | 45% | 40% | 39% | 33% |
| B | 44% | 39% | 38% | 32% |
| Cdry | 48% | 39% | 37% | 32% |
| Cmid | 45% | 39% | 39% | 33% |
| Cwet | 45% | 40% | 39% | 33% |
| Dry | 64% | 55% | 53% | 47% |
| Dmid | 60% | 55% | 54% | 48% |
| Dwet | 61% | 55% | 54% | 48% |

## 2.4 GHD Ovens Valley Water Resource Appraisal

In 2009 Goulburn-Murray Water commissioned GHD to undertake a water resource appraisal of the Ovens valley. The Ovens Valley Water Resource Appraisal project aimed to further the understanding of groundwater resources within the Ovens catchment, located in north-eastern Victoria. As stated in the report, this study has necessarily included surface water within the 'whole-of-catchment' conceptualisation because of the known high degree of interaction between groundwater and the Ovens River (and other watercourses).

The project involved development of a regional conceptual model of the catchment through the collation of existing information and knowledge and analysis of recent data.

In the Ovens catchment, the licensing and regulation of water resources for anthropogenic use are managed by Goulburn-Murray Water (G-MW), while North-East Catchment Management Authority (NECMA) is responsible for the natural resource, G-MW's role as the licensing authority requires it to understand the impacts of groundwater extraction on both the aquifers and the surface water bodies within the Ovens catchment. The aim of the study was to therefore evaluate impacts of groundwater extraction on both the aquifers and the surface water bodies within the Ovens catchment.

The modelling framework adopted a similar approach to that used by Beverly et al. (2005) and used PERFECT for the rainfall-runoff-recharge calculations, using daily observations of rainfall and potential evaporation to simulate the partitioning of rainfall into runoff and recharge, depending on mapped distributions of soils, land use, topographic slope and shallow geology. The groundwater component was modelled using MODHMS, a variant on the widely-used MODFLOW code, which has been used to simulate groundwater flow and interaction between surface water and groundwater. This model takes the outputs from the PERFECT modelling (i.e. recharge and in-stream runoff) and simulates groundwater and surface water flow through the system described by the conceptual model, including the multilayered aquifer system (shallow Shepparton Formation, Deep Lead and bedrock aquifers) and the extensive network of streams that drain these aquifers.

Predictive scenarios were undertaken to investigate the modelled impact of groundwater extraction on flows in the significant watercourses in the catchment. The predictive scenarios run during this project focussed on possible future groundwater extraction regimes and a few plausible climate change scenarios. A model run using the historic 1980-2008 climate sequence and the current pattern of groundwater extraction was assumed as the baseline against which to compare all other scenarios. The extraction scenarios considered were:

1. the current level (i.e. in 2009) of entitlement is used ('Current Entitlement');
2. the current PCV is being used ('Full PCV'); and
3. there is no licensed groundwater extraction and the only extraction is for Domestic and Stock (D&S) purposes ('No Licensed Extraction').

Simulation results suggested relatively small impacts of extraction in the Upper Ovens WSPA, although the narrow valleys mean that there is a short lag time between extraction and impact on the river, and that most (i.e. ~85%). of the extracted volume manifests itself as stream depletion in the long-run. The remainder comes from harvesting groundwater that would otherwise have been evaporated or transpired, i.e. extraction has reduced water levels to a level where evapotranspiration no longer occurs at the rate it would without the extraction. A summary of the modelled gains/losses in stream flow during low flow periods along the key reaches each extraction scenario are presented in Tables 2.4.1 and 2.4.2.

Table 2.4.1. Modelled gains/losses in stream flow during lowflow periods along the Upper Ovens for each extraction scenario.

| | Harrietville to Bright | Bright to Eurobin | Eurobin to Myrtleford |
|---|---|---|---|
| No licensed extraction | 13.3 ML/day | 17.9 ML/day | -4.8 ML/day |
| Current extraction | 12.8 ML/day (-0.5%) | 17.6 ML/day (-0.3%) | -5.2 ML/day (-0.4%) |
| Current entitlement | 12.8 ML/day (-0.5%) | 16.2 ML/day (-1.7%) | -8.5 ML/day (-3.7%) |
| Full PCV | 12.8 ML/day (-0.5%) | 15.6 ML/day (-2.3%) | -9.5 ML/day (-4.7%) |

Table 2.4.2: modelled gains/losses in flow during lowflow periods in the key reaches of the Ovens and King Rivers for each extraction scenario.

| | Myrtleford to Whorouly | Garden Ck to King | Wangaratta to Peechelba | Moyhu to Wangaratta |
|---|---|---|---|---|
| No licensed extraction | -7.2 ML/day | -3.3 ML/day | 1.1 ML/day | -13.8 ML/day |
| Current extraction | -9.6 ML/day (-2.4%) | -7.0 ML/day (-3.7%) | -1.5 ML/day (-2.6%) | -14.3 ML/day (-0.5%) |
| Current entitlement | -16.3 ML/day (-9.1%) | -15.2 ML/day (-11.9 %) | -4.4 ML/day (-5.5%) | -15.9 ML/day (-2.1%) |
| Full PCV | -18.1 ML/day (-10.9%) | -19.1 ML/day (-15.8%) | -10.3 ML/day (-11.4%) | -18.7 ML/day (-4.9%) |

The climate scenarios used the same baseline run for comparison, and used the predicted change in rainfall, number of rain-days, and potential evaporation in 2050, as suggested in the following scenarios and sourced from CSIRO's OzClim programme (Page and Jones, 2001, and Ricketts and Page, 2007):

1. 'Most likely' 2050 B1 Scenario1 - (Warmer with Little Change in Precipitation);
2. 'Likely' 2050 A1Fi Scenario2- (Hotter and Drier); and
3. a continuation of the last 12 years3 - (extended drought).

2050 was selected based on the 50-year planning horizon of the Northern Sustainable Water Strategy (SWS). Results are summarised in Table 2.4.3.

Table 2.4.3. Assessment of predicted rainfall and catchment yields under climate scenarios.

| | Rain (mm/yr) | Recharge (mm/yr) | Interflow (mm/yr) | Runoff (mm/yr) | Total yield (mm/yr) | % reduction from historic |
|---|---|---|---|---|---|---|
| Historic | 1465 | 189 | 243 | 44 | 476 | - |
| Last 12 years | 1346 | 143 | 179 | 33 | 355 | 10 |
| 2050 B1 | 1265 | 110 | 139 | 30 | 278 | 30 |
| 2050 A1F1 | 998 | 31 | 39 | 12 | 82 | 45 |

The B1 scenario indicated little change from long-term historic conditions, and less impact than the continuation of the Last 12 Years. Under both these scenarios the PCV was considered to remain a valid measure of sustainable limit, although flow-based management rules could be put in place to further protect low flows. This study concluded that were climate to alter in the manner predicted by the A1F1 scenario (i.e. in a world still reliant on fossil fuel), then runoff and recharge will be reduced, resulting in significant depletion in stream flow across the catchment, necessitating further review of PCVs and any management rules.

## 2.5 Northern Region Sustainable Water Strategy

In 2006 the Victorian Government announced the Our Water Our Future initiative aimed at assessing water availability across Victoria over the next 50 years. The Northern Region Sustainable Water Strategy was subsequently developed. A component of this Strategy was to identify and assess the future threat to water resources in northern Victoria, including the impacts arising from climate change and climate variability. The Strategy adopted the CSIRO's low, medium and high climate change scenarios and a more severe scenario based on a continuation of the extreme conditions experienced sine July 1997. All four scenarios were compared to long-term averages with allowance for predicted population changes, water extraction, regulated rivers, land use changes, bushfires and interception activities such as small farm dams.

### 2.5.1 Base Case: Long term average based on July 1890 to June 2007

This scenario represented the baseline condition to be used for comparison with other scenarios and was based on the historical climate from mid-1890 to mid-2007 assuming the current level of water resource development.

### 2.5.2 Scenario A: Based on CSIRO low climate change predictions

This scenario represents the lower emission growth projection and assumes that there is a rapid shift to less fossil-fuel intensive industries. Under this scenario it is assumed that there will be a weak increase in $CO_2$ emissions until 2040 and thereafter a decline. $CO_2$ concentrations approximately double by 2100 relative to pre-industrial levels. A global temperature increase of 1.8 $^{o}$C relative to 1990 is predicted with a range from 1.1 to 2.9 $^{o}$C likely.

### 2.5.3 Scenario B: Based on CSIRO medium climate change predictions

The medium scenario represents the medium emissions growth projection and assumes that there is a balanced use of different energy sources. $CO_2$ emissions are assumed to increase moderately until 2030 and decline by the middle of the 21st century. By 2100 a global temperature increase of 2.8 $^oC$ relative to 1990 is predicted with a range from 1.7 to 4.4 $^oC$ likely

### 2.5.4 Scenario C: Based on CSIRO high climate change predictions

This scenario represents the high emissions growth projection and assumes a continuation of economic growth based on continued dependence on fossil fuels. $CO_2$ concentrations are assumed to triple by 2100 relative to pre-industrial levels. Additionally, a global temperature increase of 4.0 $^oC$ relative to 1990 is predicted with a range from 2.4 to 6.4 $^oC$ likely. This scenario represents the highest level of late 21st century emissions that were considered to be plausible in 2000. However, recent evidence indicates that $CO_2$ emissions have been growing at a more rapid rate and that this scenario is now considered the medium projection.

### 2.5.6 Scenario D: Based on continuation of recent inflow July 1997 to June 2007

This scenario assumes continuation of inflows based on July 1997 to June 2007 historical data.

### 2.5.7 Key findings

The key findings focused on river system inflows. With regards to the North-East CMA region the key river systems considered were the Kiewa and Ovens. The forecast 2055 change in inflows relative to long term averages are summarised in Table 2.5.1.

Table 2.5.1. Forecast changes in total inflows (compared with long term averages) at 2055

| River system | A – Low climate change | B – Medium climate change | C – High climate change | D – Continuation of low inflows |
|---|---|---|---|---|
| Kiewa | -5% | -19% | -32% | -23% |
| Ovens | -6% | -24% | -41% | -33% |

## 2.6 The Victorian Climate Change Adaptation Program

In 2008 the Victorian Government initiated a joint departmental strategy involving DPI and DSE to report on the likely impacts of climate change at 2030 and 2070 on water availability, farm and primary production, biodiversity and communities. A series of regional climate change profiles were developed and are available online from www.climatechange.vic.gov.au. These profiles were aimed to providing an overview of the likely impacts and were not intended for impact analysis or developing adaptation responses. The climate change projections underpinning this strategy were collated by CSIRO on behalf of the Victorian Government. The projections were consistent with the Australian climate change projections released in 2007 incorporating results from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007).

The predictions for 2030 were based on the median emission scenario whereas the 2070 projections were based on the lower and higher emission scenarios. For each emission scenario ranges of uncertainty were reported reflecting different results derived from up to 23 global climate models. All results were reported relative to a 30 year period centred on 1990.

### 2.6.1 Key findings

The key findings from this study relevant to the North-East CMA region pertain to average annual runoff in key river basins (Table 2.6.1), future seasonal climate projections (Table 2.6.2) and broad climatic variations (Table 2.6.3).

Table 2.6.1. Variation in average annual runoff in key river basins.

| | 2030 | 2070 |
|---|---|---|
| Kiewa River | -20% | -5% to -50% |
| Oven River | -25% | -5% to -50% |
| Upper Murray | -20% | -5% to -50% |

Table 2.6.2. Future seasonal climate projections for the North-East region

| | 2030 | 2070 |
|---|---|---|
| Spring | Warmer by 0.3 to 1.6$^{o}$C | Warmer by 0.8 to 5.0$^{o}$C |
| | Precipitation decrease +3 to -15% | Precipitation decrease +10 to -40% |
| Summer | Warmer by 0.3 to 2.0$^{o}$C | Warmer by 0.8 to 6.0$^{o}$C |
| | Precipitation change uncertain +15 to -15% | Precipitation change uncertain +40 to -40% |
| Autumn | Warmer by 0.3 to 1.6$^{o}$C | Warmer by 0.8 to 5.0$^{o}$C |
| | Precipitation change uncertain +10 to -10% | Precipitation change uncertain +25 to -25% |
| Winter | Warmer by 0.2 to 1.4$^{o}$C | Warmer by 0.7 to 4.3$^{o}$C |
| | Precipitation decrease +3 to -10% | Precipitation decrease +10 to -25% |

Table 2.6.3. Summary of projected climate changes for the North-East region

| | |
|---|---|
| Temperature | Annual warming of 0.3 to 1.6oC by 2030 and 0.8 to 5.0oC by 2070 |
| | Day time maximum temperatures and night time minimum temperatures will rise at a similar rate |
| | Warming will be similar throughout the seasons |
| | A 10 to 60% in crease in the number of hot days (over 35oC) by 2030 and a 20 to 300% increase by 2070 on the plains. The rate of increase will be greater in the mountains. |
| | A 0 to 50% reduction in the number of frost days by 2030 and a 50 to 100% decrease by 2070. |
| Precipitation | Annual precipitation decrease of +3 to -10% by 2030 and +10 to -25% by 2070 |
| | Extreme heavy rainfall events likely to become more intense |
| Drought | Droughts are likely to become more frequent and longer, particularly in winter-spring |
| | Dry conditions that currently occur on average one in every five winter-springs may increase up to one in three years by 2030 |
| | Due to hotter conditions droughts are likely to become more intense |
| Snow | The total alpine area with an average of at least one day of snow cover per year is expected to decrease by 10 to 39% by 2020 and 22 to 85% by 2050. Areas with at least 30 days of snow cover are expected to decrease by 14 to 54% by 2020 and 30 to 93% by 2050. Areas with at least 60 days of snow cover are expected to decrease by 18 to 60% by 2020 and 38 to 96% by 2050. |
| Water resources | Increased evaporation rates |
| | Drier soil likely even if precipitation increases |
| | Decrease average run-off into streams |
| Fire | Hotter, drier conditions likely to increase bushfire risk |

## 2.7 North East Water Water Supply Demand Strategy

In 2005 North East Water established a project team to develop a Water Supply-Demand Strategy (WSDS) in response to the Victorian Government's Our Water Our Future action plan. The aim of the Strategy was to determine the expected long-term water demand for each of the water supply systems operated by North East Water and to identify the range of water supply-demand options based on economic, environmental and social criteria. Options considered included balancing water supply and demand, reducing water consumption, recycling, using alternative supplies and securing additional supplies through water trading and infrastructure programs.

### 2.7.1 Key findings

The predicted impacts of climate change on runoff in North-East Victorian basins (Table 2.7.1) were provided by DSE from work undertaken by CSIRO (Jones and Durack, 2005) based on the median climate change scenario.

Table 2.7.1. Predicted decline in runoff based on a median climate change scenario

| Basin | 2030 | 2055 |
|---|---|---|
| Kiewa River | -9% | -19% |
| Ovens River | -12% | -24% |
| Upper Murray River | -9% | -19% |

A step change climate change scenario was also undertaken and results suggest that the reduction in stream flows for the step-change scenario is worse for all systems than the median climate change scenario reported above. The modelling shows the security of the regulated Ovens system is unaffected under the step climate change scenario. However the unregulated Upper Ovens system is impacted as shown in the Table 2.7.2.

Table 2.7.2. Upper Ovens system reliability assuming step climate change

| System | 2004/5 existing reliability | 2004/5 step climate change reliability | 2054/55 step climate change reliability |
|---|---|---|---|
| Myrtleford | 86% | 80% | 80% |
| Harrietville | 68% | 62% | 59% |
| Bright | 68% | 62% | 59% |

In summary, to maintain 90% reliability, a Bulk Entitlement of greater than 130% of demand will be required.

## 2.8 Victorian DSE: Estimating the impacts of climate change on Victoria's runoff

In 2005 the Victorian Greenhouse Unit of the Victorian Department of Sustainability and Environment commissioned CSIRO to estimate the impacts of climate change on water yield (surface runoff and baseflow) within key Victorian water supply catchments. A simple hydrological model was used to estimate how mean annual flow may alter due to changes in rainfall and evapotranspiration under the low, median and high climate change scenarios for 2030 and 2070. The analysis did not consider variations in population demand, groundwater extractions or other externalities. This study was aimed at providing an indication of the direction and magnitude of possible changes in water supply. As such the approach simply applied the modified climate scenarios to the baseline calibrated model.

### 2.8.1 Key findings

The key finding from this study which is relevant to the North-East CMA region is the estimated change in runoff within the Kiewa River, Ovens River and Upper Murray River basins. Table 2.8.1 summarises the predicted change in runoff relative to historical conditions for 2030 wet, 2030 dry, 2070 wet and 2070 dry climate change scenarios.

Table 2.8.1. Change in runoff (% of annual average) for 2030 and 2070

| | Runoff (GL) | Developed Yield (GL) | 2030 wet (%) | 2030 dry (%) | 2070 wet (%) | 2070 dry (%) |
|---|---|---|---|---|---|---|
| Kiewa River | 679 | 9 | 0 | -20 | -5 | >-50 |
| Ovens River | 1,692 | 26 | 0 | -25 | -5 | >-50 |
| Upper Murray River | 2,803 | 838 | 0 | -20 | -5 | >-50 |

# 3 PREVIOUS COMPANION STUDIES

This section presents companion studies with relevant information that could be utilised in future climate change studies within the North-East CMA region. These companion studies either have a study area that extended beyond the North-East CMA region or did not explicitly consider climate change scenarios. The specific relevant studies are:

1. Southerine Riverine Plains groundwater model developed by CSIRO/SKM as part of the Murray-Darling Basin Sustainable Yields project
2. The DSE ecoMarkets project focusing on groundwater

## 3.1 Southerine Riverine Plains groundwater model

The Southern Riverine Plains (SRP) groundwater model was developed for the Murray-Darling Basin Authority Sustainable Yields Project and covers an area of approximately 1,800,000 ha. The model includes the major irrigation districts of Victoria including the Shepparton Irrigation District, the Campaspe region and the Loddon-Avoca regions (Figure 3.1.1). Also included is the New South Wales extent of the Murray region.

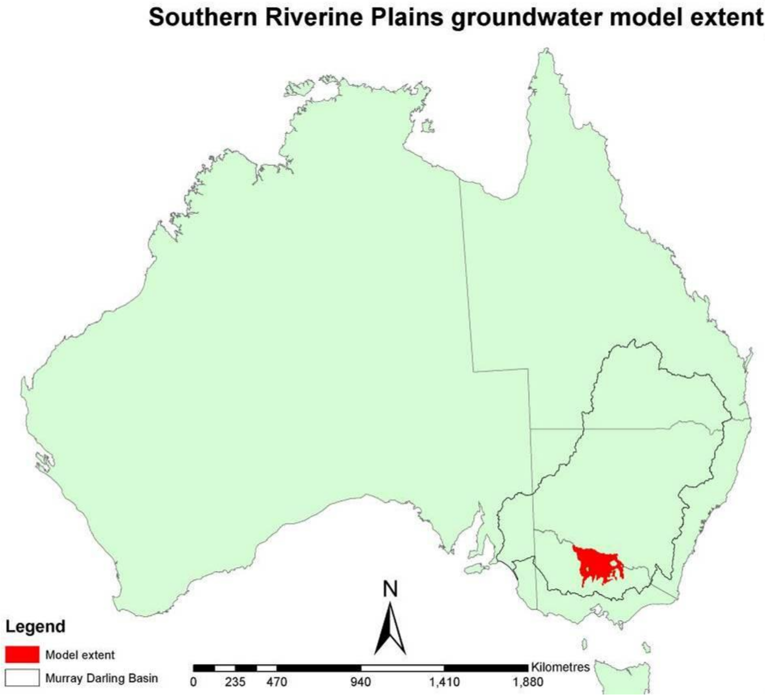



Figure 3.1.1: Location of the SRP study area in relation to the Murray-Darling Basin.

The Southern Riverine Plains is an area in which development of the groundwater resource has increased since the mid 1990s from 250 GL/yr to a peak of 400 GL in 2002/2003. In response to this increased development and in the context of prolonged drought and surface water supply shortages, this groundwater model was developed to provide a better understanding of the groundwater resource and its interaction with surface water resources under current and future climate conditions.

The SRP groundwater model covers an active area of 3,482,400 ha within the Murray-Darling Basin spanning either side of the Murray River between Yarrawonga and Swan Hill (Figure 3.1.2). Hydrogeologically the model includes the major parts of the Loddon River, Campaspe River, Goulburn River, Broken River, Wakool River, Edward River and Billabong Creek as reported in CSIRO (2008).

The groundwater management units within the model are the Murray (NSW), Loddon-Avoca (Vic), Campaspe (Vic), Goulburn-Broken (Vic) and Ovens (Vic). The Murray region includes the Lower Murray groundwater management unit (GWMA016) and the Katunga Water Supply Protection Area in addition to a small area around Gunbower Forest. The Loddon-Avoca region includes the Mid-Loddon GMA whereas the Campaspe region includes the Campaspe Deep Lead WSPA and Ellesmere GMA. The Goulburn-Broken region includes the Mid-Goulburn GMA, Kialla GMA and Goorambat GMA. The Shepparton WSPA spans the Murray, Campaspe and Goulburn-Broken regions and refers specifically to the Shepparton Formation aquifer. In total the model covers nine individual groundwater management units and four regions. It also includes possible groundwater-dependent ecosystems including Gunbower Forest, Koondrook-Perricoota Forest and the Barmah Forest.

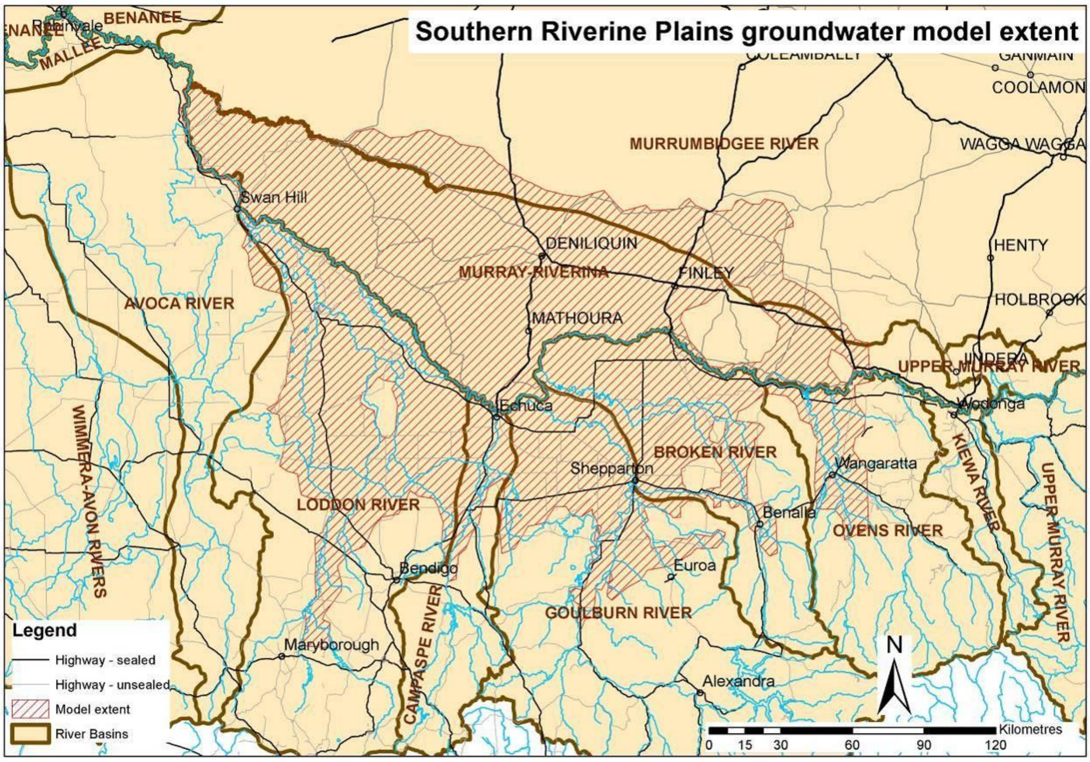



Figure 3.1.2: Active extent of the SRP groundwater model (shaded).

Upon calibration of the groundwater model to historical groundwater discharge and observation data for the period 1990 to 2006, the model was used to estimate the likely groundwater response under nine future scenarios. The nine scenarios are summarised in Table 3.1.1 and each scenario was run for 222 years so as to approach a 'dynamic equilibrium' state representing the long-term impact of stresses.

Irrigation was assumed to remain constant at rates and areas as per the 2004/2005 irrigation season. Recharge reduction factors were applied to all recharge areas as follows:

Scenario A – 1.00

Scenario B – 0.75

Scenarios Cdry and Ddry – 0.66

Scenarios Cmid and Dmid – 0.97

Scenarios Cwet and Dwet – 1.14

Without development scenarios – 1.00

Annual extraction rates were modified for Scenario D, with no groundwater extractions considered in the without development scenario.

The study reported groundwater water balance for specific groundwater management units (Campaspe Deep Lead WSPA, Ellesmere GMA, Goorambat GMA, Katunga WSPA, Kialla GMA and Lower Murray NSW GWMA016, Mid-Goulburn GMA, Mid-Loddon GMA and Shepparton WSPA) and regions (Campaspe, Goulburn-Broken, Loddon-Avoca and Murray). A typical water balance for the Goulburn-Broken region is summarised in Table 3.1.2.

Table 3.1.1. Summary of scenarios used in the Sustainable Yields groundwater modelling.

<table>
<tr><td>A</td><td rowspan="5">Models current state of water resource development in the MDB. This includes current average annual surface water and groundwater diversions and current rates of irrigation.</td><td>Historical climate conditions from the period July 1895 to June 2006 (111 years)</td></tr>
<tr><td>B</td><td>Climatic conditions of the past ten years. For the Southern Riverine Plains region this represents drought conditions.</td></tr>
<tr><td>Cdry</td><td>A future climate scenario based on climate change predictions resulting in a drier climate compared to historical conditions.</td></tr>
<tr><td>Cmid</td><td>A future climate scenario based on best estimate or median levels of climate change. In the Southern Rivererine Plains this results in a slightly drier climate.</td></tr>
<tr><td>Cwet</td><td>A future climate scenario based on climate change predictions resulting in a wetter climate compared to historical conditions.</td></tr>
<tr><td>Ddry</td><td rowspan="3">Models an inferred future state of water resource development.</td><td>As per Cdry</td></tr>
<tr><td>Dmid</td><td>As per Cmid</td></tr>
<tr><td>Dwet</td><td>As per Cwet</td></tr>
<tr><td>Without development</td><td>This scenario attempts to recreate conditions prior to the development of the groundwater resource.</td><td>As per scenario A</td></tr>
</table>

Table 3.1.2. Groundwater balance for the Goulburn-Broken region.

| Groundwater balance | Without | A | B | Cdry | Cmid | Cwet | Ddry | Dmid | Dwet |
|---|---|---|---|---|---|---|---|---|---|

| | development | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | GL/y | | | | | | | | |
| Inflow | | | | | | | | | |
| Diffuse recharge | 111.0 | 110.8 | 94.9 | 89.3 | 108.9 | 119.5 | 88.9 | 108.5 | 119.4 |
| Head-dependent boundary | 0.0 | 0.1 | 0.2 | 0.3 | 0.1 | 0.1 | 1.1 | 0.6 | 0.5 |
| River recharge to groundwater | 45.6 | 51.9 | 44.5 | 45.0 | 48.5 | 49.4 | 56.6 | 58.0 | 57.8 |
| Groundwater inflows | 36.8 | 32.6 | 32.0 | 31.7 | 32.5 | 32.9 | 30.7 | 31.2 | 31.5 |
| Total inflows | 193.4 | 195.4 | 171.6 | 166.3 | 190.0 | 201.9 | 177.3 | 198.3 | 209.2 |
| Outflows | | | | | | | | | |
| Groundwater pumping | 0.0 | 24.9 | 24.8 | 24.7 | 24.9 | 24.9 | 41.2 | 42.9 | 43.7 |
| Head-dependent boundary | 3.1 | 2.3 | 1.6 | 1.4 | 2.2 | 2.5 | 1.1 | 1.7 | 2.1 |
| Groundwater outflows | 56.4 | 70.3 | 70.1 | 70.3 | 70.3 | 70.4 | 76.7 | 75.5 | 75.0 |
| Groundwater evapotranspiration | 95.3 | 71.3 | 59.4 | 56.1 | 69.1 | 76.1 | 48.0 | 59.2 | 65.3 |
| Discharge to drains | 7.7 | 4.0 | 2.7 | 2.2 | 3.9 | 4.8 | 0.8 | 1.6 | 2.3 |
| Discharge to rivers | 30.8 | 22.5 | 13.1 | 11.7 | 19.6 | 22.9 | 9.8 | 17.4 | 20.6 |
| Total outflows | 193.3 | 195.3 | 171.7 | 166.4 | 190.0 | 201.6 | 177.6 | 198.3 | 209.0 |
| Total river losses to groundwater | 14.8 | 29.4 | 31.4 | 33.3 | 28.9 | 26.5 | 46.8 | 40.6 | 37.2 |

## 3.2 DSE ecoMarkets project

In 2008 the ecoMarkets project was initiated by the Victorian Department of Sustainability and Environment as an extension of the highly successful BushTender and EcoTender programmes. ecoMarkets is the term used to describe a range of market-based systems that aim to address environmental decline through the allocation of public money for multiple environmental outcomes. The approach relies on biophysical information of the likely impacts of intervention at the farm scale on catchment outcomes. As such, this approach adopted catchment modelling for the provision of this information to simulate both surface water and groundwater dynamics. To support this project, groundwater models were developed for all Victorian CMA regions. The North-East CMA ecoMarkets groundwater model was developed by Hockingetal. Pty Ltd (2010a) to simulate groundwater movement within each of the principal aquifers of the region. The rational of the project was to provide a tool for assessing the impacts of land use change on the catchment water balance. Specifically the model was developed to predict changes in the volume of base flow, areas of land subject to a shallow watertable and, by inference, areas subject to land salinity under changed land use.

The following model layers and geology groups have been aligned in a six-layer framework. The model has been developed in finite difference format (regular gridding). It features a regular cell size of 200m, totalling 496,214 solution points occupying 769 rows and 932 columns, and comprises of 6 layers and 2,977,284 active cells.

Model calibration was achieved by attempting to match observed groundwater level with simulated groundwater levels in monthly time steps over the calibration period between 1990 and 1999. The transient calibration follows-on from a calibrated steady-state simulation (Hocking et al. 2010b). Annual average calibrated time-varying water balance between 1990 and 1999 is presented in Figure 3.2.1 below. Results suggest the main export of groundwater from the catchment is groundwater base flow, evaporation, groundwater pumping and groundwater outflow respectively.

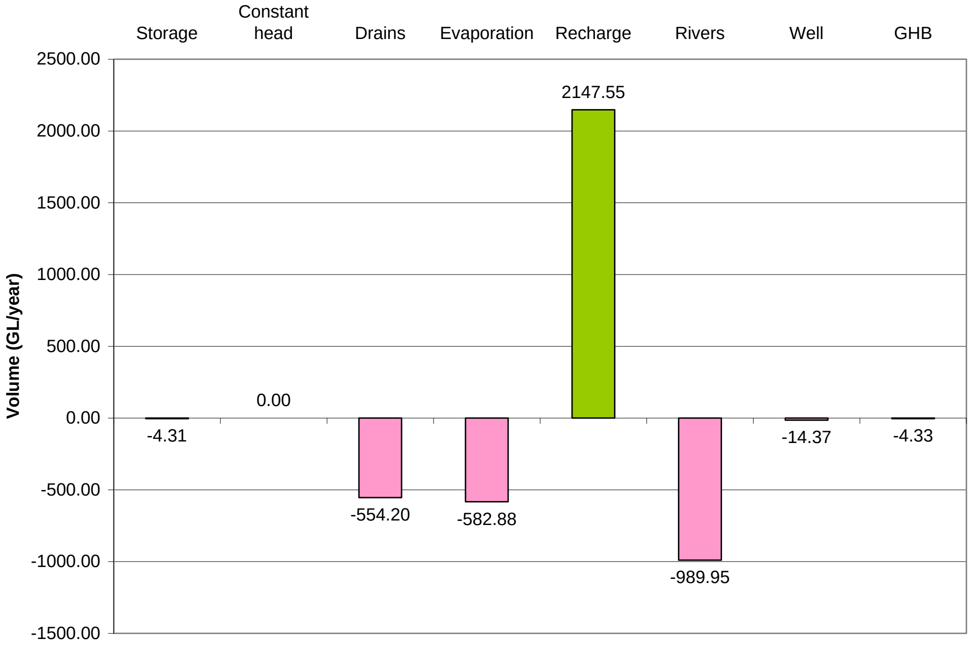



Figure 3.2.1. Annual average calibrated time-varying groundwater balance between 1990 and 1999 for the North-East CMA region.

Simulated versus observed groundwater level data statistics determined a scaled Root Mean Square (RMS) over time generally remained less than 3 % across the calibration (1990–1999) and validation (2000–2005) periods.

Hocking et al. (2010a) considers the application of the North-East CMA regional groundwater model has the capacity to predict changes in the water balance, however there are a number of potential limitations which should be kept in mind, specifically;

- There should be no long-term scenario prediction of the transient model (e.g. > 15 years), as no data validation has been undertaken beyond this period. Also, underlying groundwater trends may impact model prediction capacity beyond this period.
- Only relative water balance changes should be considered, not absolute changes. That is, due to scale, complexity, availability of calibration data and project time limitations, model calibration is not at sufficient detail to warrant absolute values.

- The application of the North-East CMA region steady-state groundwater model may be used for impact assessment of land use change as calibrated recharge rates provided reasonable recharge estimates, and therefore redistribute the groundwater balance proportionately.
- When considering land use change scenarios, the area of change should be no less than, say 10 hectares, as scale generalisations and solver tolerance is unlikely to accurately identify changes in the catchment groundwater balance.

It is also noteworthy that no landuse or climate change scenarios were undertaken as part of this project. However this model is of finer spatial scale and incorporates additional aquifer interactions than the CSIRO Southern Riverine Plains groundwater model, has greater extent than the GHD Oven Valley groundwater model whilst adopting the same groundwater conceptualisation and therefore is a useful comparator of recharge and groundwater dynamic estimates under climate change conditions.

# 4 DPI CLIMATE CHANGE PREDICTIONS

The IPCC (2001) attributes most of the global warming observed over the last 50 years to greenhouse gases released by human activities. To estimate future climate change, the IPCC (SRES, 2000) prepared 40 greenhouse gas and sulfate aerosol emission scenarios for the 21st century that combine a variety of assumptions about demographic, economic and technologic driving forces likely to influence such emissions in the future. In the proceeding change analyses, three-climate scenarios (low, mid and high) inline with B2, A2 and A1F1 scenarios, respectively, of the IPCC (SRES, 2000) were generated using CSIRO's global atmosphere models (McGregor and Dix, 2001; Hennessy et al., 2006) integrated with annual global warming values (oC) (Figure 4.1).

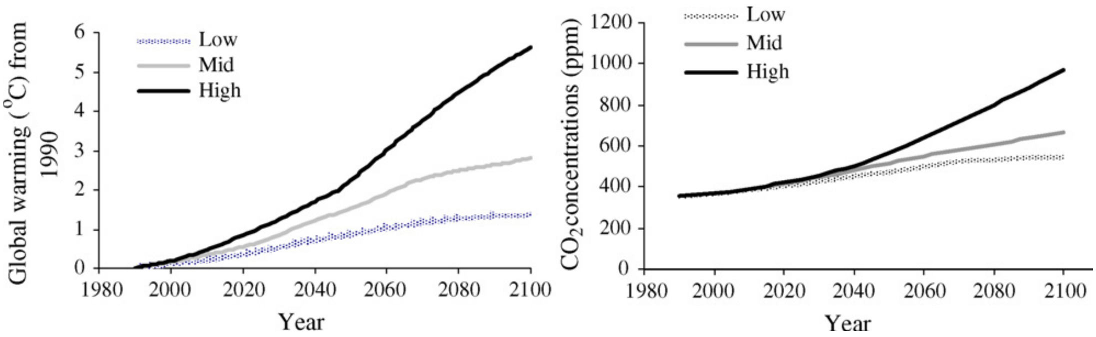



Figure 4.1. The annual global warming values (oC) and CO2 concentrations (parts per million) for low, mid and high scenarios for years between 2000 and 2100 are relative to the IPCC (2001) standard 1990 baseline.

The CSIRO's global atmosphere model (CCAM) simulation is driven by CSIRO's Mark2 and Mark3 climate models, henceforth called CCAM (Mark2) and CCAM (Mark3). Both perform well over south-east Australia, although CCAM (Mark2) has a better simulation of average temperature. Hence, slightly more confidence can be placed in results from CCAM (Mark2). Climate projections from each model are considered independent since the Mark2 and Mark3 models have different parameterisations of physical processes. Regional climate change patterns from each model were expressed as a change per degree of global warming. This allows the results to be linearly scaled for any future year using the IPCC (2001) global warming estimates (Mitchell, 2003), which include the full range of IPCC SRES (2000) scenarios of greenhouse gas and aerosol emissions, and the full range of IPCC (2001) uncertainty in climate sensitivity to these emissions (Whetton, 2001). The regional climate change patterns underpinning the DPI climate change projections for the North-East CMA region are shown in Figures 4.2 to 4.5 for rainfall, minimum temperature, maximum temperature and solar radiation respectively.

The historical sequence provides a reference or base line for current-non climate changed environment comparisons to some future environment. The comparisons, however, can be made in many ways and is somewhat dependent on the type of future data generated. DPI has adopted two methods. The first was the method of Suppiah et al. (2001) as applied by

Anwar et al. (2007) to provide a continuous sequence that represents the non-stationery nature of climate change, i.e. increasing global warming trend each year applied to the historical sequence. The historical sequence is the basis of the future climate where autocorrelation is maintained. The advantage of this method is that it provides a realistic and smooth and complete sequence of weather data for analyses of an incremental nature over time. The disadvantage of the method is that stochastic variations consistent with a specific climate change scenario are not considered.

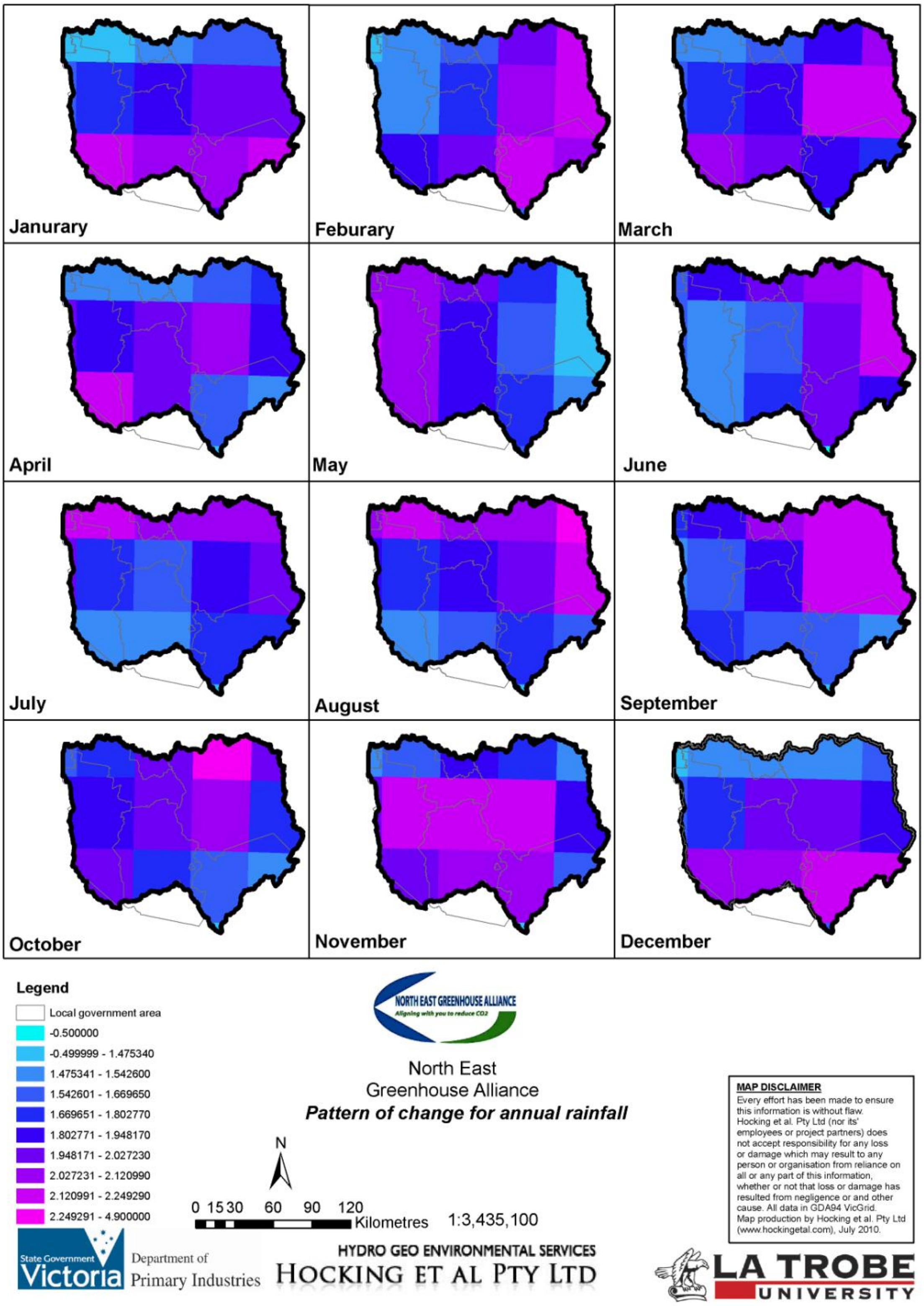



Figure 4.2: The regional rainfall climate change patterns for the North-East CMA region.

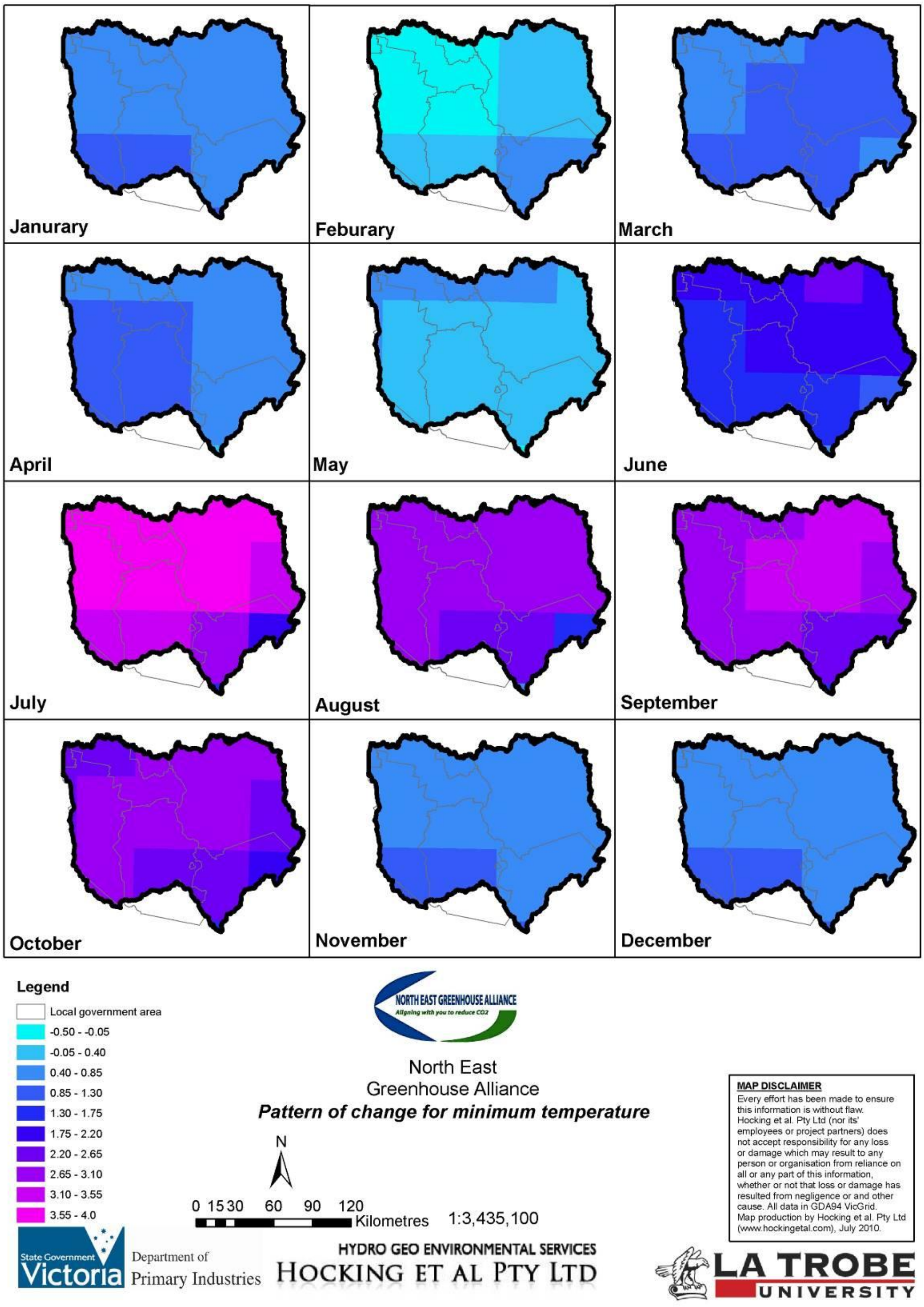



Figure 4.3: The regional minimum temperature climate change patterns for the North-East CMA region.

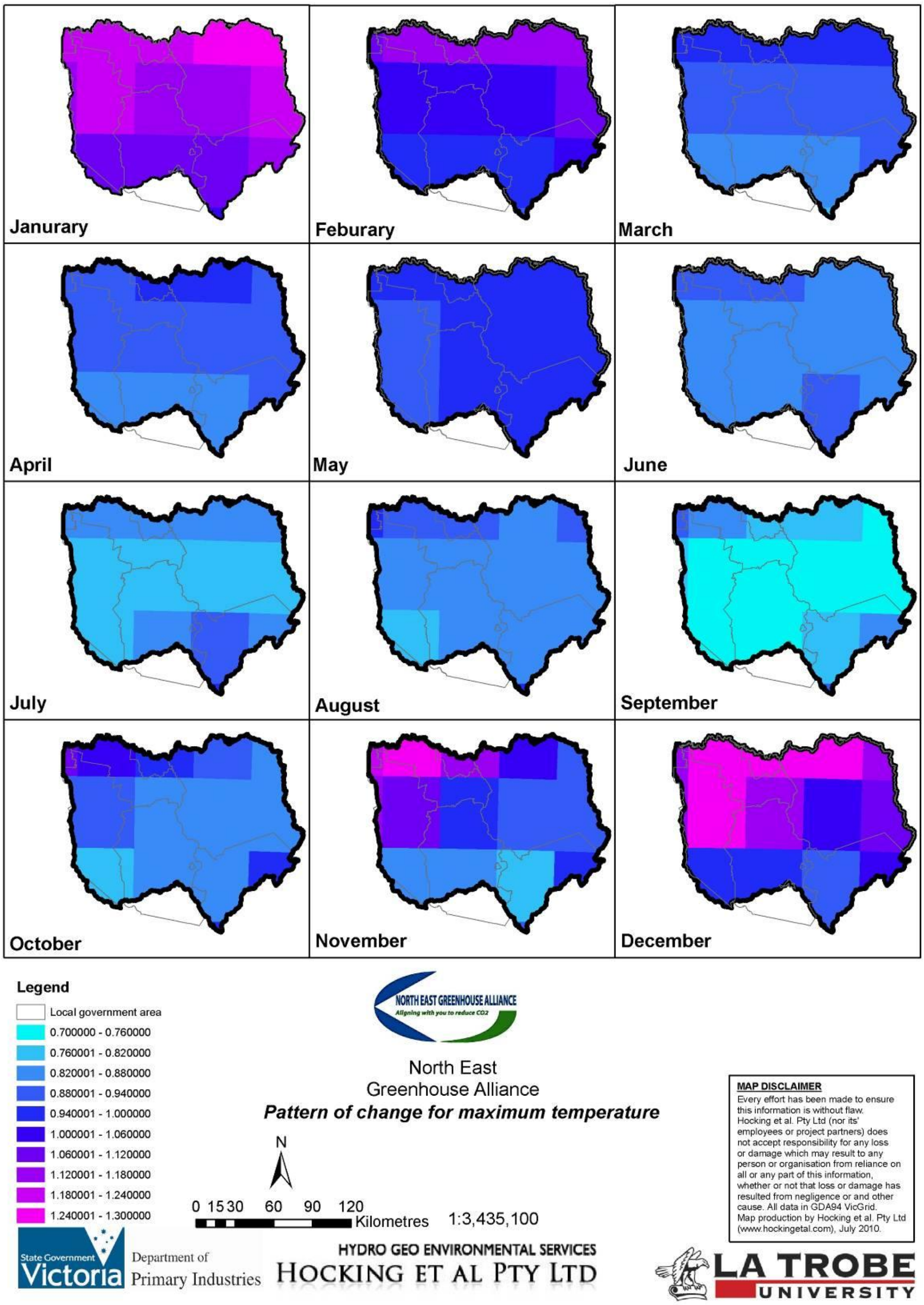



Figure 4.4: The regional maximum temperature climate change patterns for the North-East CMA region.

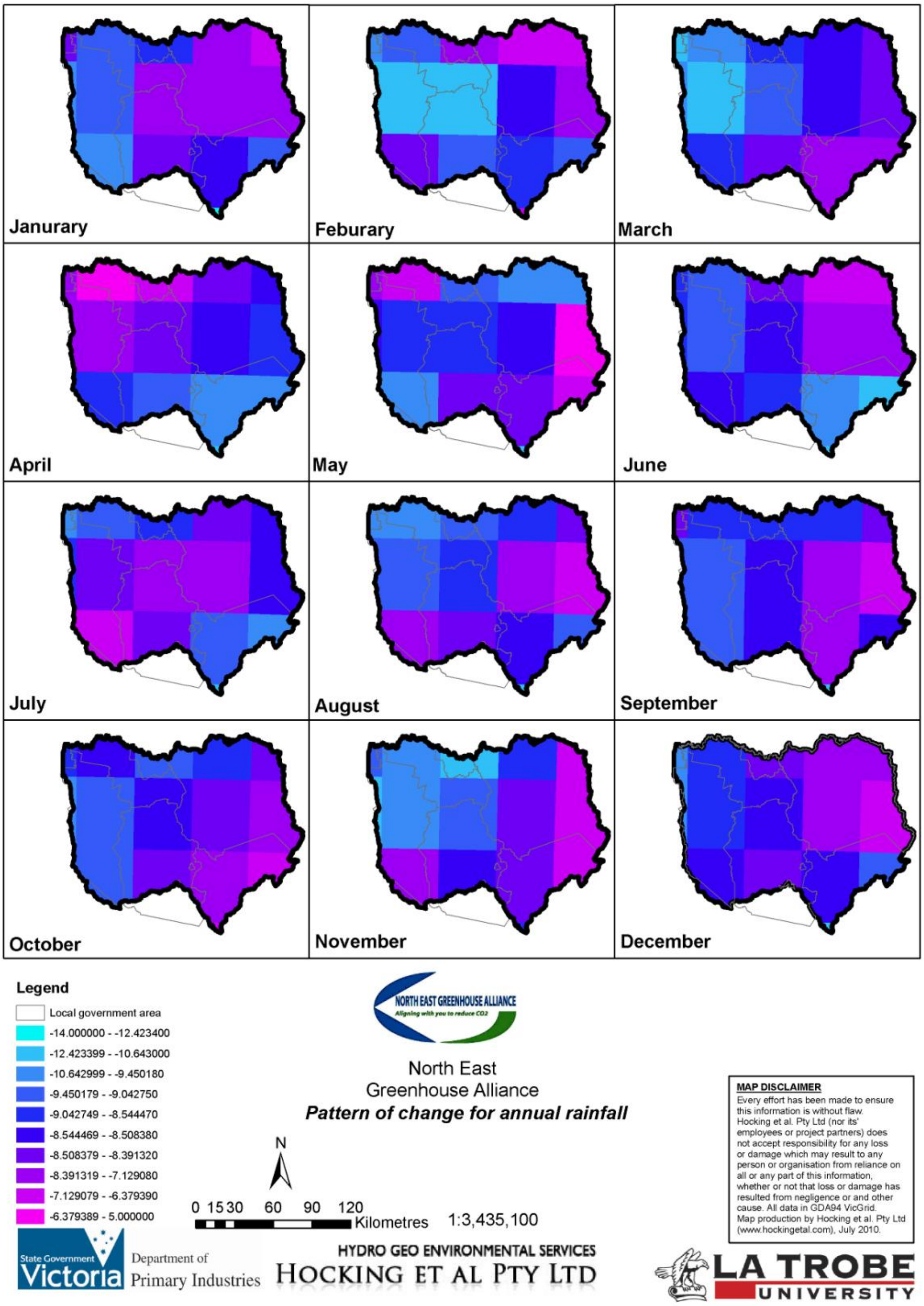



Figure 4.5: The regional solar radiation climate change patterns for the North-East CMA region.

## 4.1 Basic downscaling

DPI (O'Leary and Christy, 2009) has developed two methods to generate future daily climate sequences for biophysical models. The choice of method depends on the nature and structure of the question being asked. The two methods are summarised as follows:

1. Method A (Table 1) is used when we are determining the impact of climate change over time series of numerous years. The aim of this method is to fix the daily climate sequence which at present uses past historic variance and incrementally change the $CO_2$, temperature, radiation and rain pattern of change impacts over time. For example if we were testing the impact of climate change on a groundwater systems which takes 20 years to respond to any change imposed then Method A should be used.
2. Method B (Table 2) is used when we are determining the impact of climate change at a single point in time in the future (say 2030 for example). The aim of this method is to fix the $CO_2$, temperature, radiation and rain pattern of change impacts to that future point in time and change many years of daily climate data to represent the year 2030. This method allows the prediction of the distribution of biophysical response over a range of years.

The process of deriving future daily climate sequences requires the determination of patterns of climate change per degree of global warming on a monthly basis for four climate variables (rainfall, maximum and minimum temperature, and solar radiation) across Victoria (Hennessy et al., 2006). In this application the pattern was applied to 71 years (1935–2005) of daily data for each of the 71 climate stations within the study region (obtained from SILO patch-point, http://plum.nre.vic.gov.au/silo/) to create a 71-year future scenario from 2000 to 2070 by Method B.

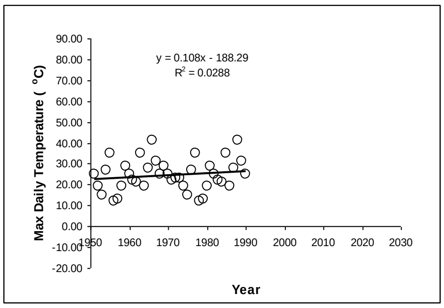
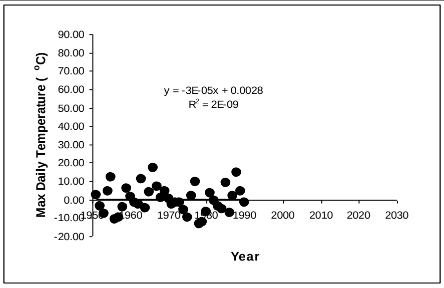
Table 1 shows the Method A procedure applied to generate daily future climate scenarios for maximum temperature. A similar procedure was performed for minimum temperature, rainfall and solar radiation applying the relevant monthly pattern of change and global warming value to each observed daily matrix. This procedure identifies changes in the monthly maximum and minimum temperatures, rainfall and solar radiation and these changes (positive or negative) which are subsequently applied in the methodology to create daily future climate (2000–2070) scenarios. As such this method assumes that the identical sequence of the de-trended historical data (1935–2005) is applied to future climate but the monthly means are amended to reflect the future climate scenarios. Minimum and maximum temperature patterns have units of $^{o}C/^{o}C$ and base climatology (average temperature for 1961–1990) units are $^{o}C$. Rainfall patterns have units in $\%/^{o}C$ and base climatology (average rainfall for 1961–1990) units are mm. Solar radiation patterns have units of $\%/^{o}C$ and base climatology (average radiation for 1961–1990) units are MJ/m2.

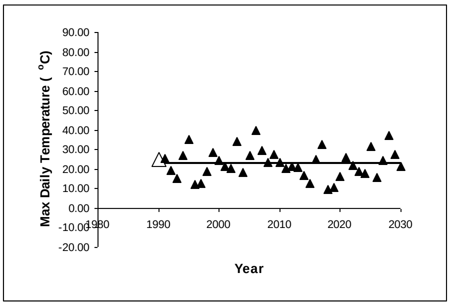
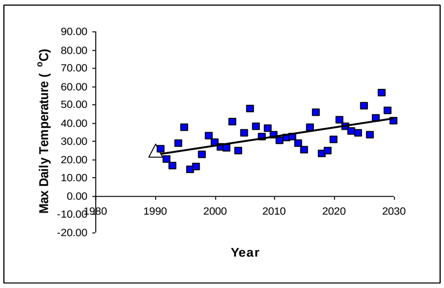
To deal with stochastic options that give a realistic analysis representative of any particular future year, e.g. 2030 or 2070, a sequence of years is needed to represent the future year (Method B, Table 2). We achieved this by applying the de-trended historical data referenced to the base year to the particular year of interest by applying the global warming factor for that year to the whole data sequence so that it is shifted vertically (in this maximum temperature example). This means that for each future year we have a sequence of weather data having the same number of years as the historical data. This method allows the climate change effect to be analysed without confounding between individual years.

Both methods assume that the autocorrelation between years that exists in the historical data are applied to all sequences applied to any future years. They, however, does not address extreme events that are predicted to increase in intensity and frequency due to progressive climate change.

The results reported in this study based on the DPI derived climate scenarios were developed using Method B.

Table 1. Method A to create daily future climate (2000–2070) scenarios using the outputs from CSIRO's global atmosphere models (CCAM-Mark2 and CCAM-Mark3). This is the method of Anwar et al. (2007) and provides a sequence of weather data consistent with a specific climate change scenario.

| Step | Mathematical and graphical expression |
|---|---|
| Create an anomaly series with no time-trend for all climate stations. | xJan19yy = xJan19yy(observed) _ TJan *(19yy-1935) _ MJan |
| First, calculate trends for each calendar month for each station, then subtract the trend-increment from the daily data. This de-trended time-series will have a monthly mean of M. | Example: Determine trend in historical time series.   Figure 1. Example historical trend over time in maximum daily temperature for January. |
| Second, subtract M to create a monthly anomaly time-series with a mean of zero, e.g., assume the January mean is MJan and the max temp trend is TJan °C /year at a each station, and the first year of record is 1935, then the de-trended anomaly value for the xth day of January in year 19yy is xJan19yy. |   Figure 2. Example de-trended maximum daily temperature for January. |
| Estimate a baseline value (Baseline1990) for the year 1990, for each calendar month, based on the observed linear monthly trend from 1935 to 1990. This is needed to anchor the projections from the IPCC reference year of 1990. | Baseline1990Jan = MJan + TJan * (1990–1935)/2 |

| | |
|---|---|
| | <br>Figure 3. Example de-trended maximum daily temperature for January raised to the reference year 1990 and projected into the future. |
| Xjan19yy is the de-trended xth day of January maximum temperature for year 19yy for each station (as above) (°C). Example B is 9 January 1965. | B = [37 °C] |
| Incorporate CSIRO's global atmosphere models (CCAM-Mark2 and CCAM-Mark3) 50_50 km gridcell pattern (Pat) for Victoria. | Pat = [1.1 1.1 1.1 1.1 1.0 1.01.0 0.9 0.8] PatB = [1.0] |
| Pat is the January pattern of change for maximum temperature (°C per degree of global warming) from the climate model across Victoria. PatB is the selected Cell representing a climate station. | |
| The global warming database (°C) contains low, mid and high values for each year (2000–2070) and was used to scale de-trended observed daily data from years 1935 to 2005 for each climate station. | 2000 low00 mid00 high00<br>2001 low01 mid01 high01<br>.<br>. 2030 low30 mid30 high30<br>.<br>2070 low70 mid70 high70 |
| Generate a daily maximum temperature scenario using the low global warming scenario. x is the day of the month. Values for the first (second, third, etc.) year in the de-trended observed time-series are scaled by the first (second, third, etc.) year in the global warming dataset. The process is the same for mid or high global warming scenario—this procedure was repeated for mid and high scenarios. | xJan2000 = xJan1935 + baseline1990Jan + (Pat * low00)<br>xFeb2000 = xFeb1935 + baseline1990Feb + (Pat * low00)<br>…<br><br>xJan2001 = xJan1936 + baseline1990Jan + (Pat * low01)<br>xFeb2001 = xFeb1936 + baseline1990Feb + (Pat * low01)<br>…<br><br>xJan2070 = xJan2005 + baseline1990Jan + (Pat * low70)<br>xFeb2070 = xFeb2005 + baseline1990Jan + (Pat * low70)<br><br><br>Figure 4. Example global warming factor applied for each year to the de-trended maximum daily temperature for January that had been raised to the reference year 1990 and projected into the future. |

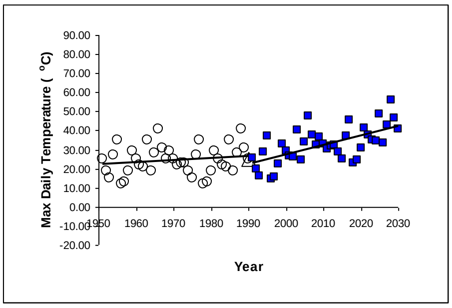
<table>
<tr><td></td><td>

Figure 5. Comparison of the historical (circles) and high global warming scenario (squares) daily maximum temperature for January.</td></tr>
<tr><td>To the right is a hypothetical example for 9 January 2030 maximum temperature ($^{o}C$) derived from de-trended data for 9 January 1965 and the high global warming scenario</td><td>Assuming B and PatB values from above, and assuming high30 = 1.5 in the global warming database, then Jan2030high = [37.9 $^{o}C$]</td></tr>
</table>

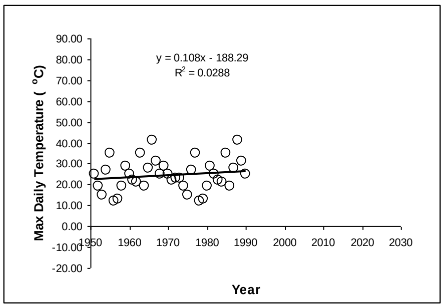
<table>
<tr><td colspan="2">Table 2. Method B to create daily future climate scenarios for a single future year (e.g. 2030) using the outputs from CSIRO's global atmosphere models (CCAM-Mark2 and CCAM-Mark3). This is a variation of Method A and provides a sequence of weather data weather data having the same number of years as the historical data for any future year of interest. Note that both methods are identical until the point of adding the global warming database value.</td></tr>
<tr><td>Step</td><td>Graphical expression</td></tr>
<tr><td>Create an anomaly series with no time-trend for each climate station.</td><td>xJan19yy = xJan19yy(observed) _ TJan *(19yy-1935) _ MJan</td></tr>
<tr><td>First, calculate trends for each calendar month for each climate station, then subtract the trend-increment from the daily data. This de-trended time-series will have a monthly mean of M.</td><td>Example: Determine trend in historical time series.


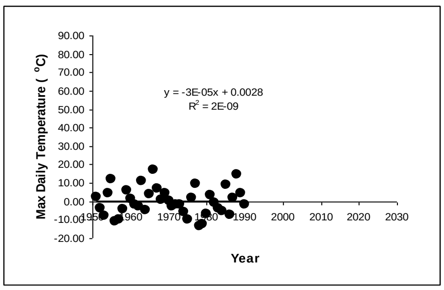
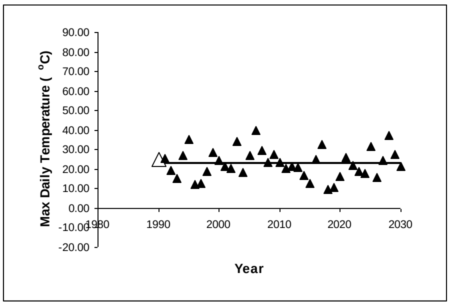
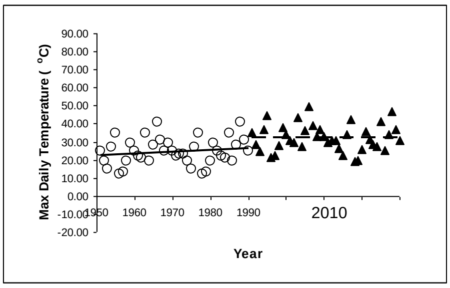
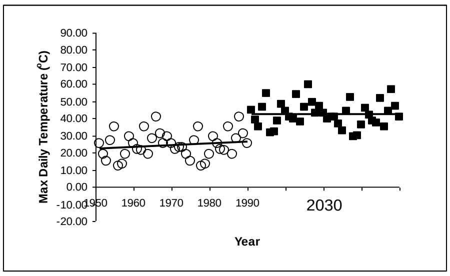
Figure 1. Example historical trend over time in maximum daily temperature for January.</td></tr>
<tr><td>Second, subtract M to create a monthly anomaly time-series with a mean of zero, e.g., assume the January mean is MJan and the max temp trend is TJan $^{o}C$ /year at each climate station, and the first year of record is 1935, then the de-trended anomaly value for the xth day of January in year 19yy is xJan19yy.</td><td>

Figure 2. Example de-trended maximum daily temperature for January.</td></tr>
<tr><td>Estimate a baseline value (Baseline1990) for the year 1990, for each calendar month, based on the observed linear monthly trend from 1935 to 1990. This is needed</td><td>Baseline1990Jan = MJan + TJan * (1990–1935)/2</td></tr>
</table>

| | |
|---|---|
| to anchor the projections from the IPCC reference year of 1990. | <br>Figure 3. Example de-trended maximum daily temperature for January raised to the reference year 1990 and projected into the future. |
| Xjan19yy is the de-trended xth day of January maximum temperature for year 19yy for each climate station (as above) ($^{o}$C). Example B is 9 January 1965. | B = [37 $^{o}$C] |
| Incorporate CSIRO's global atmosphere models (CCAM-Mark2 and CCAM-Mark3) 50_50 km gridcell pattern (Pat) for Victoria (see example Figure 2). | Pat = [1.1 1.1 1.1 1.1 1.0 1.01.0 0.9 0.8] PatB = [1.0] |
| Pat is the January pattern of change for maximum temperature ($^{o}$C per degree of global warming) from the climate model across Victoria. PatB is the selected Cell representing a climate station. | |
| The global warming database ($^{o}$C) contains low, mid and high values for the year (2030) and was used to scale de-trended observed daily data from years 1935 to 2005 for each climate station. | . 2030 low30 mid30 high30 |
| Raise or decrease the de-trended data by the respective pattern of change for the specific location and global warming factors for future year of interest. | <br>Figure 6. The de-trended data from the base year has been amended by the global warming and pattern of change factors representative of the year 2010. |
| Each year of interest (e.g. 2030) requires a data sequence comparable to the historical sequence. | <br>Figure 7. The de-trended data from the base year has been amended by the global warming and pattern of change factors representative of the year 2030. |

## 4.2 Change in rainfall and temperature from the historical climate pattern

The projected climate change scenarios are based on 1935-1990 historical climate data using the Method B described above. This enables a comparison of the daily climate change scenario data with the baseline historical data. This section presents the departure from the historical annual rainfall and mean daily temperature climate pattern under the assumed 2030 and 2070 climate regimes for each of the local government areas within the North-East region of Victoria. The aggregated climate data was generated based on a derived Voronoi diagram that maps the spatial extent of each climate station within each local government area. Data from all climate stations identified within each shire were aerially weighted to derive an aggregated climate data set for each climate regime and subsequently used in the comparisons presented below.

Figures 4.2.1 to 4.2.10 show the spatially averaged change in mean annual rainfall (mm/yr) and average daily temperature ($^{o}$C) relative to the 1990 condition for the Alpine, Indigo, Towong, Wangaratta and Wodonga shires respectively. The climate station annual variability used to derive the time series traces reported in Figures 4.2.1 to 4.2.10 is reported in Appendix A. Also presented in Appendix A in Figures A.1 to A.14 are the spatial representation of mean annual rainfall and temperature variations under the adopted climate change scenarios assigned to each climate station extent based on the derived Voronoi diagram. Table 4.2.1 summarises the mean annual rainfall (mm/yr) and average daily temperature ($^{o}$C) for each local government area under various climate change projections. The corresponding relative changes to 1935-1990 conditions in mean annual rainfall (mm/yr) and average daily temperature ($^{o}$C) for each local government area under various climate change projections are summarised in Table 4.2.2. Results suggest that the Alpine shire consistently is most impacted with regards to temperature for each climate projection whereas the order of rainfall impact varies between regions and future scenarios.

Table 4.2.1. Mean annual rainfall (mm/yr) and average daily temperature ($^{o}$C) for local government areas within the North-East CMA region under various climate projections.

| | Historic | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | 1935-1990 | Low | Medium | High | Low | Medium | High |
| | Mean annual rainfall (mm/yr) | | | | | | |
| Alpine | 1371 | 1319 | 1303 | 1282 | 1285 | 1225 | 1145 |
| Indigo | 773 | 752 | 741 | 728 | 730 | 692 | 641 |
| Towong | 981 | 956 | 944 | 929 | 932 | 889 | 831 |
| Wangaratta | 925 | 901 | 888 | 873 | 875 | 831 | 771 |
| Wodonga | 740 | 719 | 709 | 696 | 698 | 662 | 613 |
| | Mean daily temperature ($^{o}$C) | | | | | | |
| Alpine | 12.1 | 12.7 | 13.0 | 13.4 | 13.4 | 14.6 | 16.2 |
| Indigo | 14.5 | 15.1 | 15.5 | 15.9 | 15.9 | 17.2 | 18.9 |
| Towong | 13.4 | 13.9 | 14.3 | 14.7 | 14.6 | 15.8 | 17.5 |
| Wangaratta | 13.8 | 14.4 | 14.8 | 15.2 | 15.1 | 16.4 | 18.1 |
| Wodonga | 14.8 | 15.4 | 15.8 | 16.2 | 16.2 | 17.5 | 19.2 |

Table 4.2.2. Percentage change in mean annual rainfall (mm/yr) and average daily temperature (°C) for local government areas within the North-East CMA region under various climate projections.

| | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|
| | Low | Medium | High | Low | Medium | High |
| | Percentage change in mean annual rainfall (%) from 1935-1990 conditions | | | | | |
| Alpine | -3.8 | -5.0 | -6.5 | -6.3 | -10.6 | -16.5 |
| Indigo | -2.7 | -4.1 | -5.8 | -5.5 | -10.4 | -17.1 |
| Towong | -2.5 | -3.7 | -5.3 | -5.0 | -9.4 | -15.2 |
| Wangaratta | -2.6 | -4.0 | -5.7 | -5.4 | -10.2 | -16.6 |
| Wodonga | -2.8 | -4.2 | -5.9 | -5.6 | -10.5 | -17.2 |
| | Percentage change in mean daily temperature (%) from 1935-1990 conditions | | | | | |
| Alpine | 4.8 | 7.6 | 11.1 | 10.5 | 20.4 | 33.8 |
| Indigo | 4.3 | 6.8 | 9.9 | 9.4 | 18.3 | 30.4 |
| Towong | 3.8 | 6.3 | 9.6 | 9.0 | 18.2 | 30.7 |
| Wangaratta | 4.5 | 7.1 | 10.2 | 9.7 | 18.8 | 31.0 |
| Wodonga | 4.1 | 6.5 | 9.7 | 9.1 | 18.0 | 30.0 |

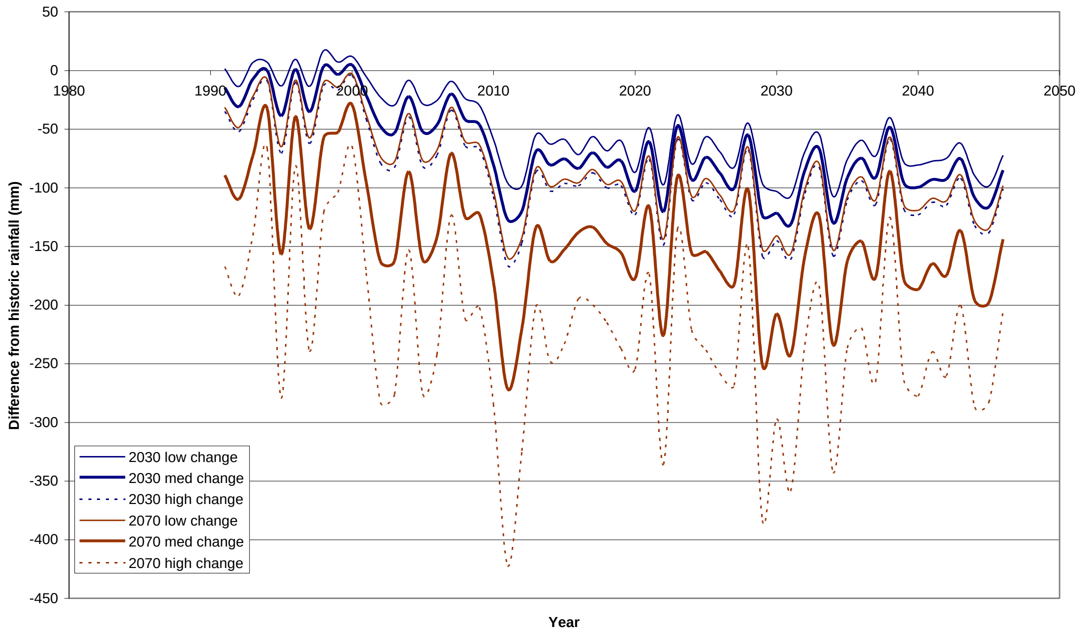



Figure 4.2.1. Spatially averaged variation in rainfall relative to 1990 annual rainfall (mm) for the Alpine Shire under various climate change scenarios.

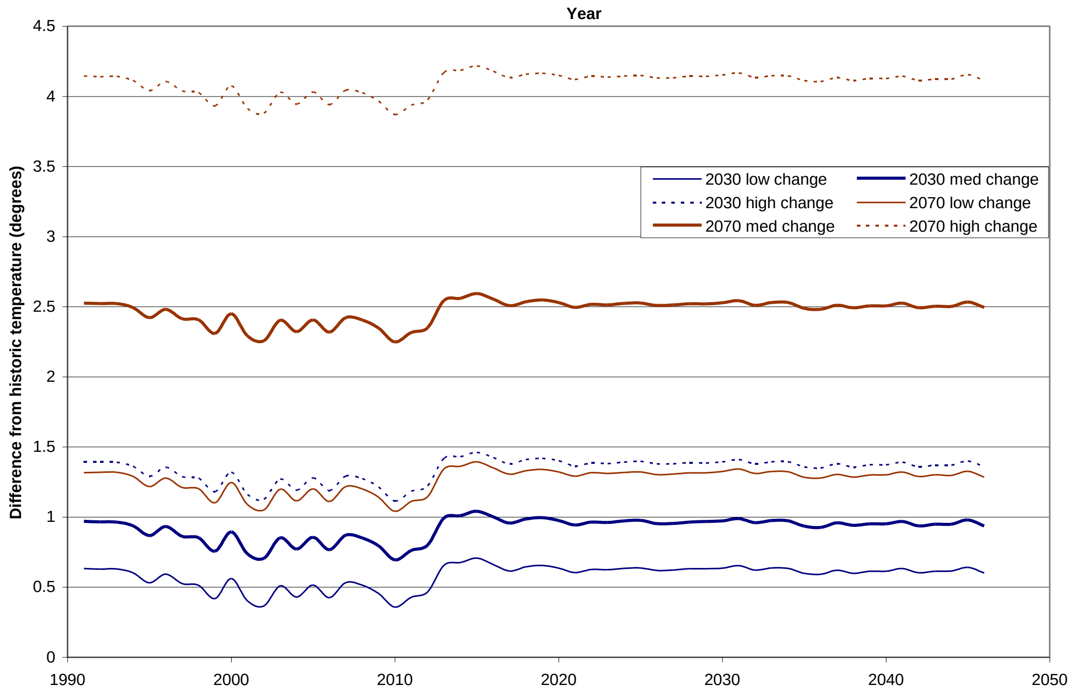



Figure 4.2.2. Spatially averaged variation in mean daily temperature (°C) relative to 1990 mean daily temperature for the Alpine Shire under various climate change scenarios.

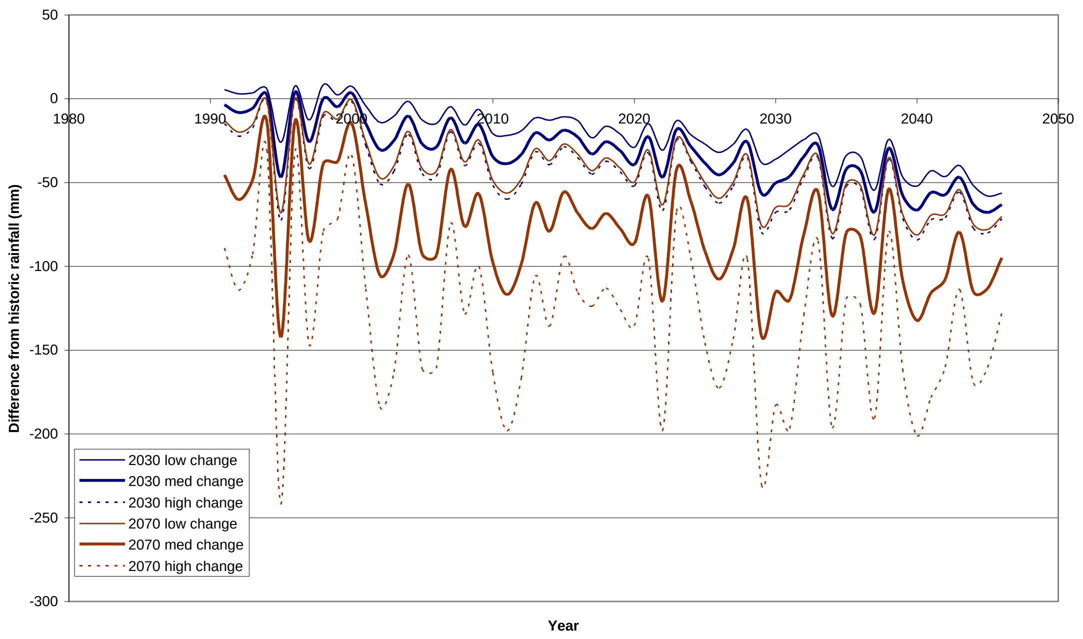



Figure 4.2.3. Spatially averaged variation in rainfall relative to 1990 annual rainfall (mm) for the Indigo Shire under various climate change scenarios.

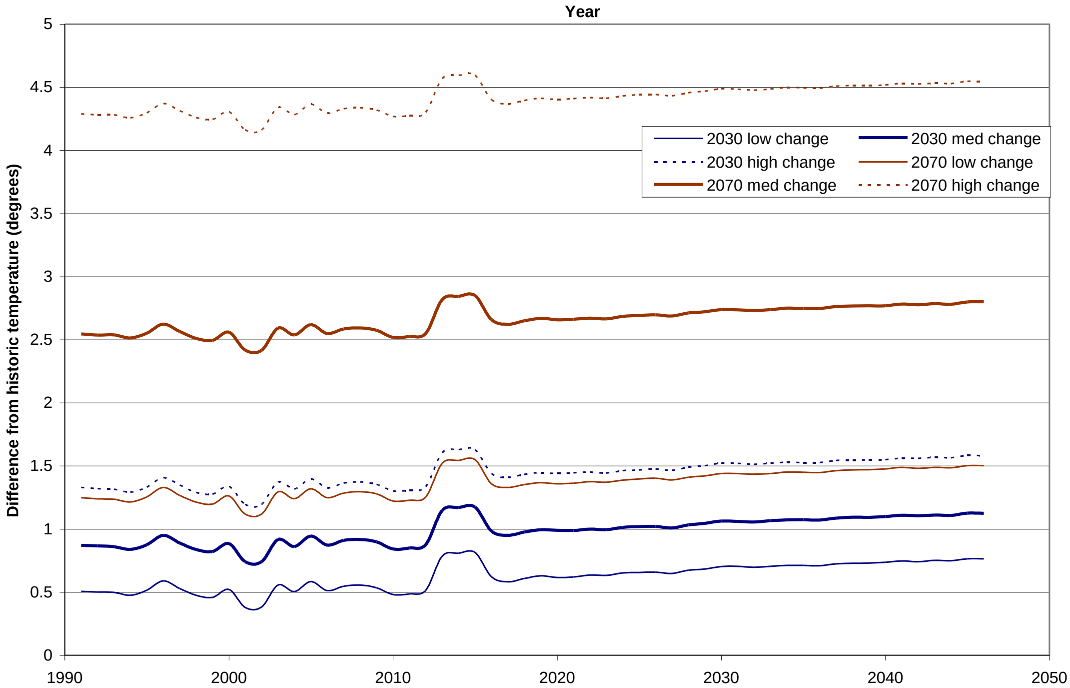



Figure 4.2.4. Spatially averaged variation in mean daily temperature (°C) relative to 1990 mean daily temperature for the Indigo Shire under various climate change scenarios.

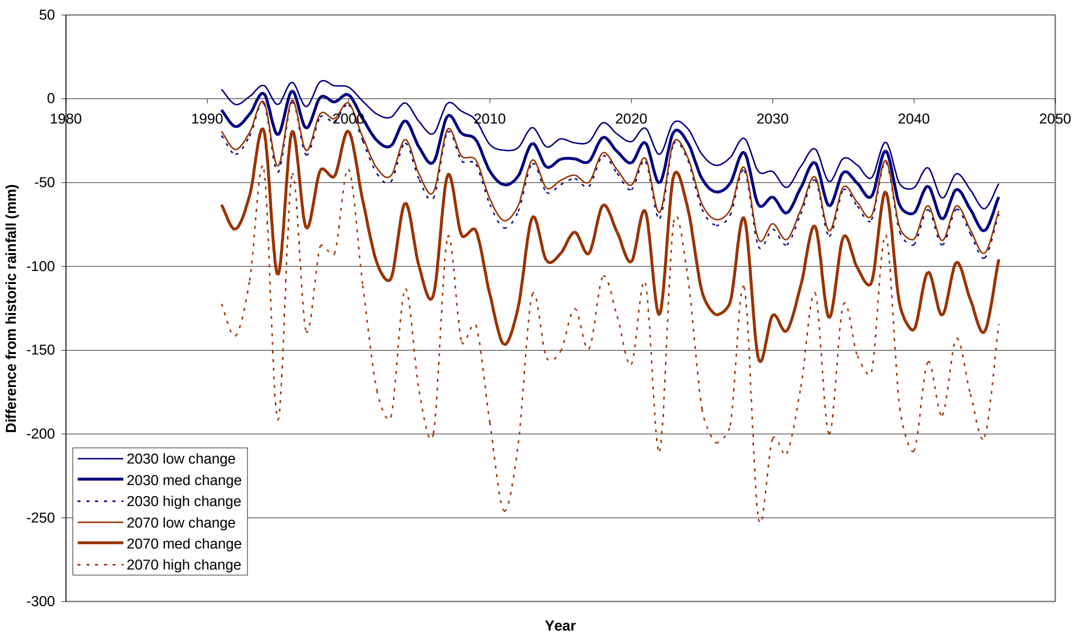



Figure 4.2.5. Spatially averaged variation in rainfall relative to 1990 annual rainfall (mm) for the Towong Shire under various climate change scenarios.

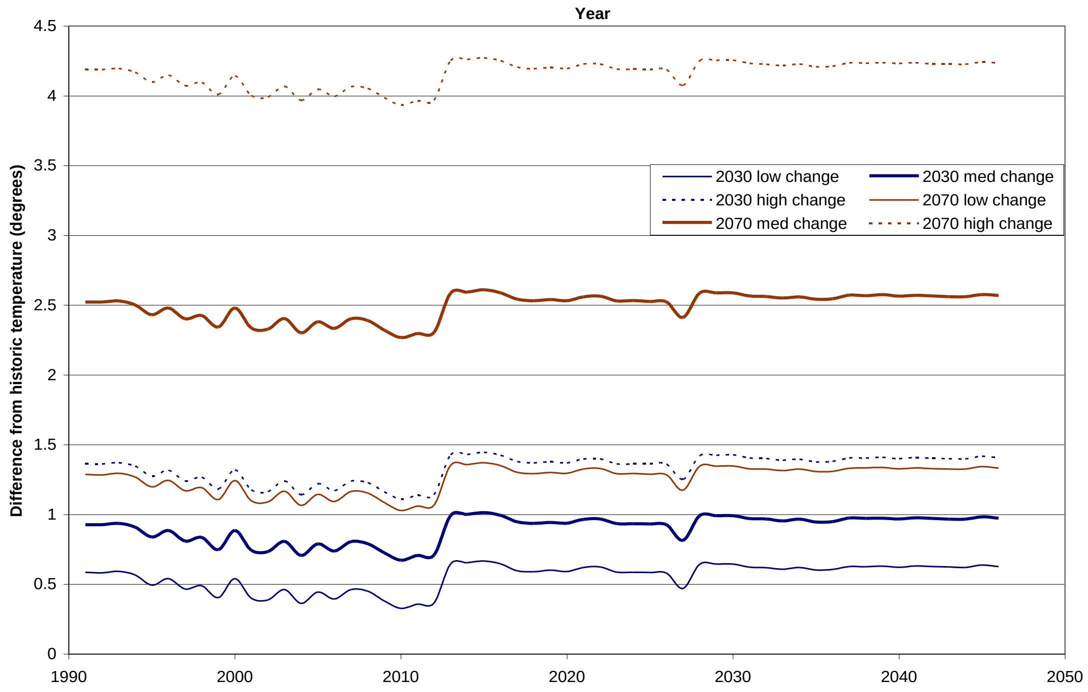



Figure 4.2.6. Spatially averaged variation in mean daily temperature (°C) relative to 1990 mean daily temperature for the Towong Shire under various climate change scenarios.

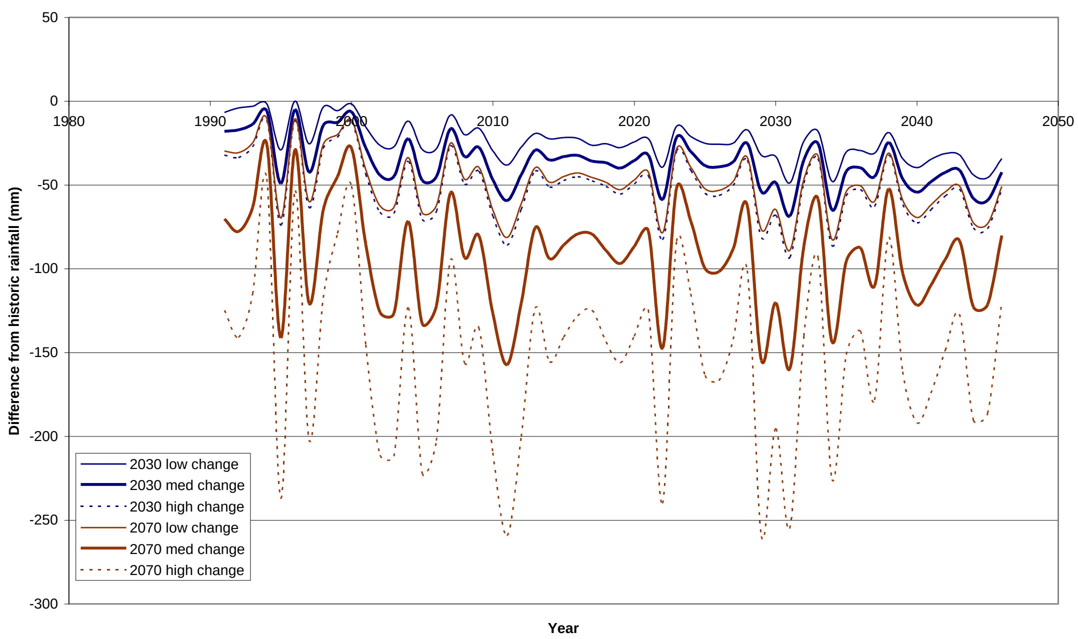



Figure 4.2.7. Spatially averaged variation in rainfall relative to 1990 annual rainfall (mm) for the Wangaratta Shire under various climate change scenarios.

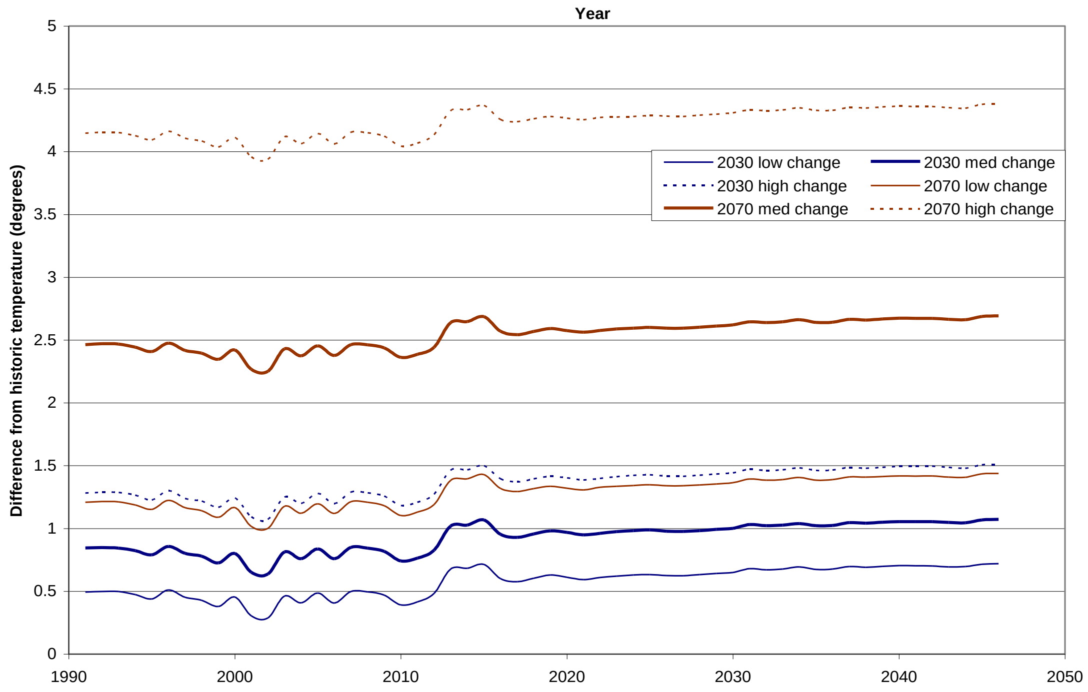



Figure 4.2.8. Spatially averaged variation in mean daily temperature (°C) relative to 1990 mean daily temperature for the Wangaratta Shire under various climate change scenarios.

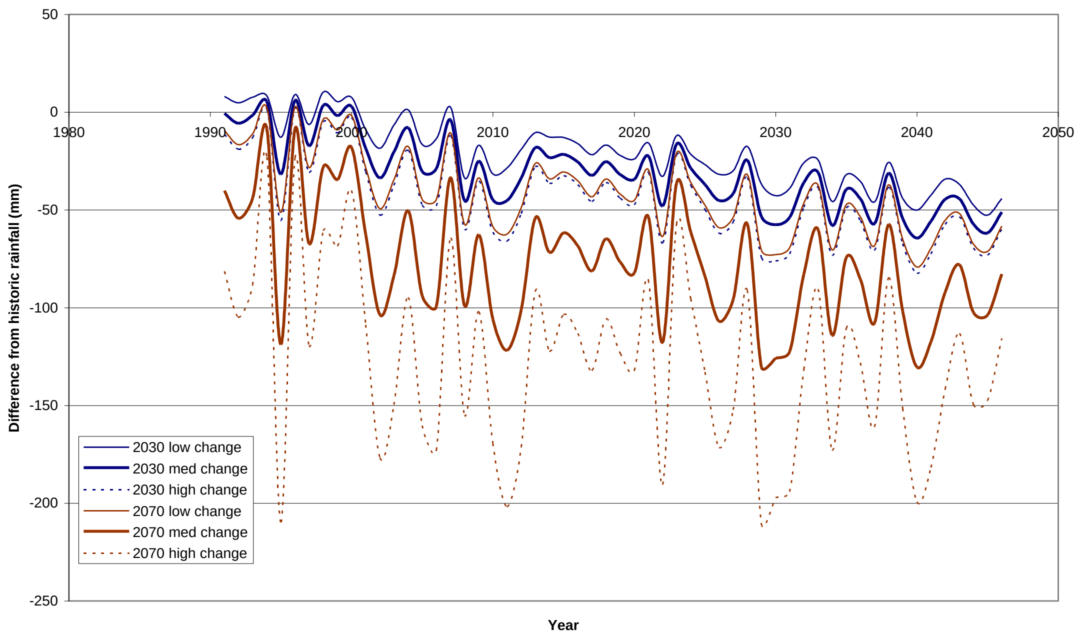



Figure 4.2.9. Spatially averaged variation in rainfall relative to 1990 annual rainfall (mm) for the Wodonga Shire under various climate change scenarios.

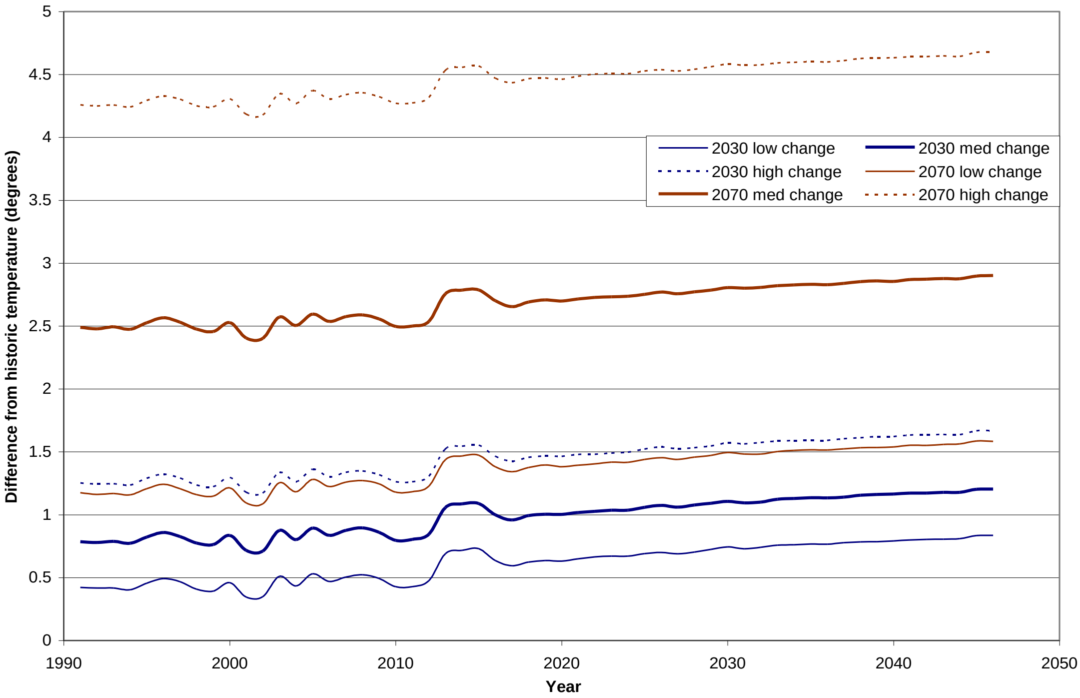



Figure 4.2.10. Spatially averaged variation in mean daily temperature (°C) relative to 1990 mean daily temperature for the Wodonga Shire under various climate change scenarios.

## 4.3 Results – water balance summaries

Summarised below are the percentage variation in water balances relative to historical 1957 to 2005 conditions under current and future climate scenarios for the North-East CMA region, local government areas and specific catchments. The future climate scenarios accounted for elevated $CO_2$ impacts on vegetation response under reduced rainfall and increased temperature and solar radiation conditions.

### 4.3.1 Mean annual water balance for NE CMA region

The variations in mean annual water balance components from historic (1957-2005) for the entire North-East CMA region are summarised in Table 4.3.3.

Table 4.3.3: North-East CMA region future climate percentage change in water balance from historical (1957-2005).

| | 1995- | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | 2005 | Low | Medium | High | Low | Medium | High |
| Rainfall | -4 | -3 | -4 | -5 | -5 | -10 | -16 |
| Runoff | -4 | -23 | -28 | -33 | -31 | -44 | -55 |
| Evapotranspiration | 2 | -0.4 | -0.2 | -0.1 | 0.1 | -0.1 | -2 |
| Recharge | -11 | -7 | -10 | -14 | -14 | -25 | -38 |
| Streamflow | -14 | -5 | -9 | -14 | -13 | -25 | -39 |
| Total flow | -17±3 | -7±2 | -12±2 | -18±3 | -17±3 | -31±6 | -49±9 |

### 4.3.2 Mean annual water balance for LGA regions

The variations in mean annual water balance components from historic (1957-2005) for LGA regions within the North-East CMA boundaries are summarised in Table 4.3.4. The change in mean annual rainfall (mm/y) for each LGA region for the 2030 and 270 climate change scenarios are graphically shown in Figure 4.3.12 and Figure 4.3.13 respectively. Also shown is the 1995-2005 condition. The corresponding recharge variations are shown in Figure 4.3.14 and Figure 4.3.15 whereas the streamflow impacts are shown in Figure 4.3.16 and Figure 4.3.17.

Table 4.3.4: NE CMA LGA future climate percentage change in water balance from historical (1957-2005).

| | 1995-2005 | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | | Low | Medium | High | Low | Medium | High |
| Alpine Shire | | | | | | | |
| Rainfall | -5.8 | -1.2 | -2.5 | -4.1 | -3.8 | -8.3 | -14.3 |
| Runoff | -3.0 | -21.8 | -26.1 | -31.2 | -29.4 | -41.6 | -51.6 |
| Evapotranspiration | 2.1 | 0.1 | 0.7 | 1.3 | 1.3 | 2.6 | 2.4 |
| Recharge | -11.1 | -4.0 | -6.8 | -10.3 | -9.8 | -19.0 | -30.1 |
| Streamflow | -14.8 | -2.0 | -5.5 | -9.7 | -9.1 | -20.5 | -33.7 |
| Total flow | -17.6±3 | -3.1±1 | -7.2±2 | -12.3±3 | -11.6±2 | -25.3±5 | -41.2±8 |
| Indigo Shire | | | | | | | |
| Rainfall | -1.4 | -3.5 | -4.9 | -6.6 | -6.3 | -11.2 | -17.8 |
| Runoff | 2.6 | -11.6 | -15.5 | -20.0 | -18.8 | -29.9 | -40.3 |
| Evapotranspiration | 2.3 | -1.3 | -1.6 | -2.1 | -2.0 | -3.9 | -7.8 |
| Recharge | -8.3 | -7.3 | -10.8 | -15.1 | -14.3 | -25.3 | -37.3 |
| Streamflow | -8.6 | -7.6 | -11.3 | -15.7 | -15.0 | -26.2 | -38.2 |
| Total flow | -10.7±2 | -9.4±2 | -14.1±3 | -19.5±4 | -18.6±4 | -32.5±6 | -47.5±9 |
| Towong Shire | | | | | | | |
| Rainfall | -2.0 | -3.5 | -4.7 | -6.2 | -6.0 | -10.3 | -16.1 |
| Runoff | -2.5 | -29.4 | -34.3 | -39.9 | -37.8 | -50.9 | -60.9 |
| Evapotranspiration | 2.5 | -0.2 | 0.1 | 0.3 | 0.4 | 0.4 | -1.4 |
| Recharge | -8.0 | -8.8 | -12.1 | -16.1 | -15.5 | -25.9 | -37.2 |
| Streamflow | -9.4 | -8.7 | -12.6 | -17.3 | -16.7 | -29.0 | -42.6 |
| Total flow | -11.4±2 | -10.9±2 | -15.6±3 | -21.3±4 | -20.6±4 | -35.5±6 | -51.9±9 |
| Wangaratta Shire | | | | | | | |
| Rainfall | -4.5 | -1.4 | -2.8 | -4.5 | -4.2 | -9.1 | -15.7 |
| Runoff | -1.5 | -20.0 | -24.9 | -30.4 | -28.1 | -41.0 | -50.0 |
| Evapotranspiration | 1.8 | -1.0 | -1.1 | -1.2 | -1.1 | -2.1 | -5.0 |
| Recharge | -13.6 | -4.2 | -8.0 | -12.5 | -11.8 | -23.8 | -37.3 |
| Streamflow | -16.8 | -0.7 | -4.7 | -9.6 | -8.9 | -21.4 | -35.1 |
| Total flow | -20.2±3 | -1.8±1 | -6.8±2 | -12.7±3 | -11.9±3 | -27.4±6 | -44.4±9 |
| Wodonga Shire | | | | | | | |
| Rainfall | -1.2 | -4.1 | -5.5 | -7.2 | -6.9 | -11.7 | -18.3 |
| Runoff | -5.1 | -6.4 | -11.0 | -16.5 | -15.4 | -28.8 | -41.1 |
| Evapotranspiration | 2.3 | -2.5 | -2.9 | -3.4 | -3.4 | -5.5 | -9.8 |
| Recharge | -9.1 | -7.5 | -11.2 | -15.7 | -15.0 | -26.2 | -38.2 |
| Streamflow | -9.4 | -7.6 | -11.6 | -16.5 | -15.7 | -27.9 | -40.5 |
| Total flow | -11.7±2 | -9.5±2 | -14.4±3 | -20.4±4 | -19.5±4 | -34.5±7 | -50.1±10 |

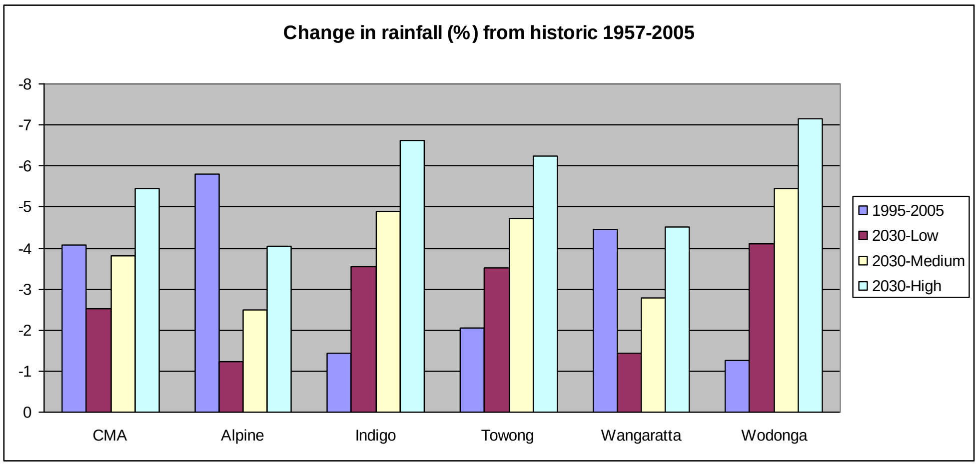



Figure 4.3.12. Change in rainfall (%) under 2030 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

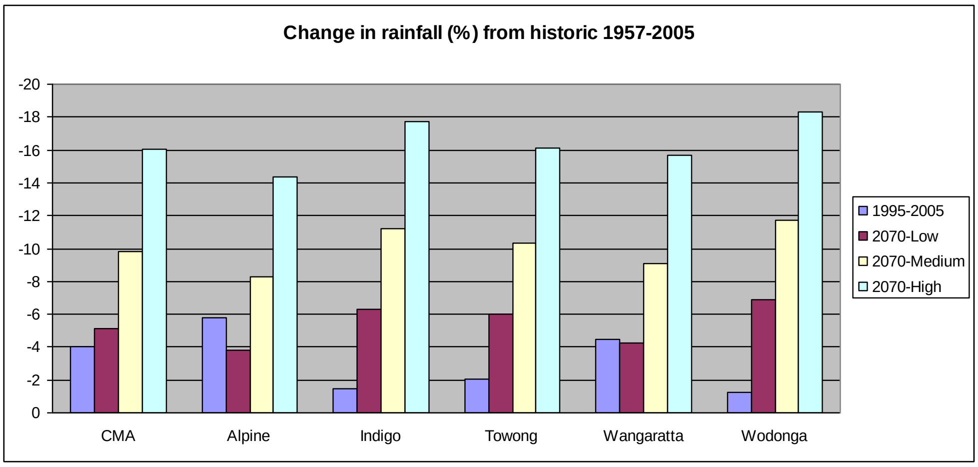



Figure 4.3.13. Change in rainfall (%) under 2070 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

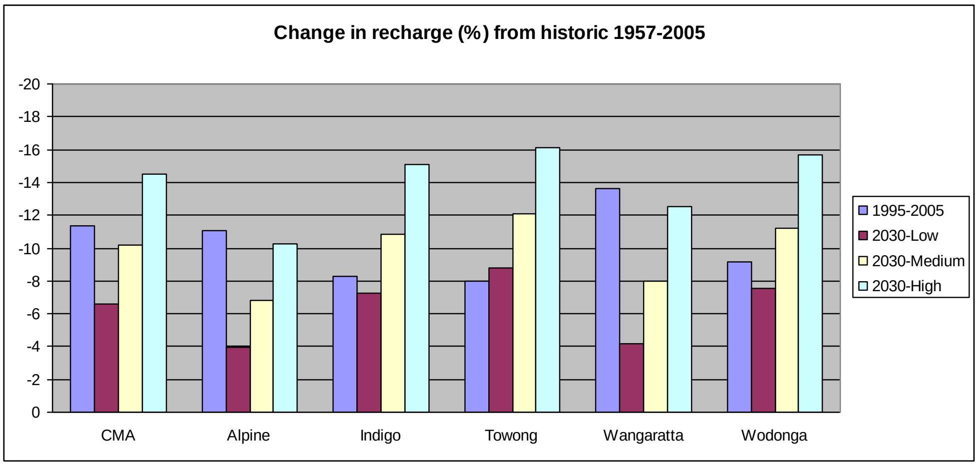



Figure 4.3.14. Change in recharge (%) under 2030 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

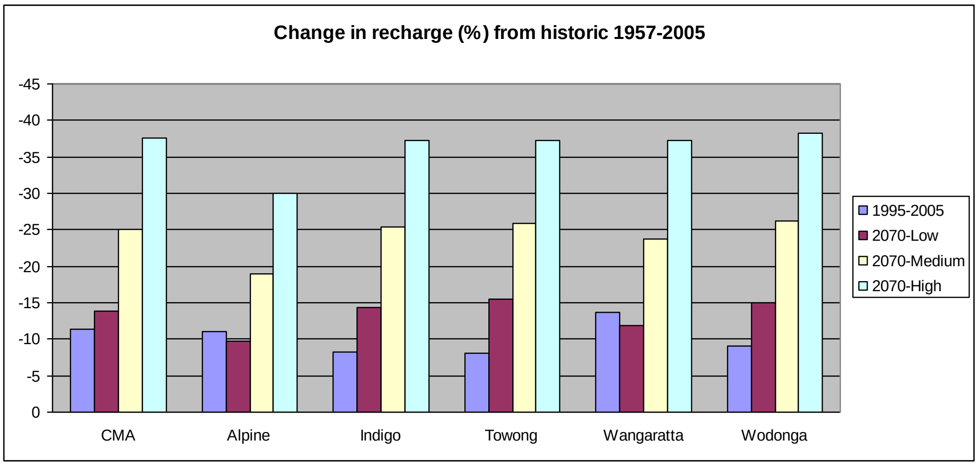



Figure 4.3.15. Change in recharge (%) under 2070 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

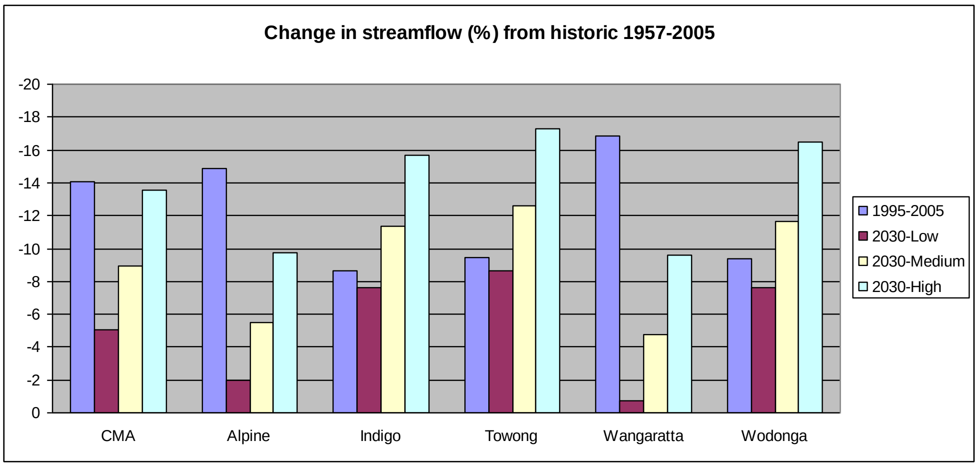



Figure 4.3.16. Change in streamflow (%) under 2030 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

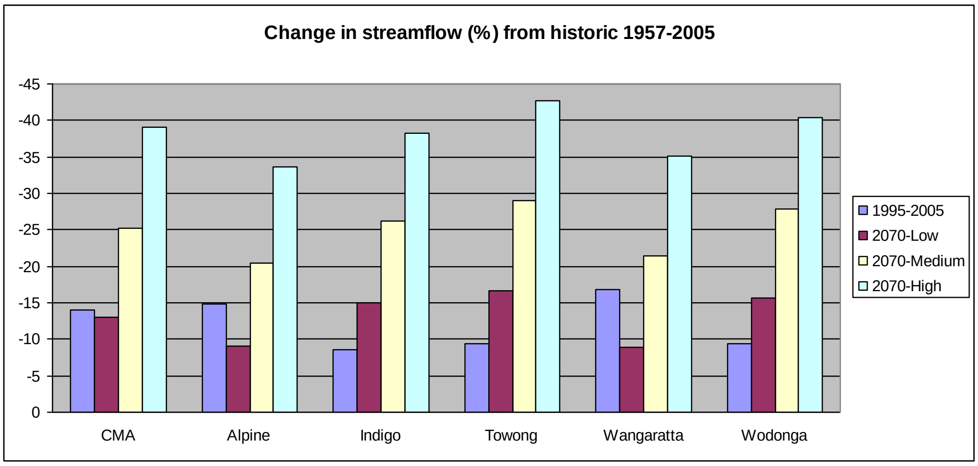



Figure 4.3.17. Change in streamflow (%) under 2070 climate change scenarios for each local government area. Also shown is the 1995-2005 response.

### 4.3.3 Mean annual water balance for the key catchments

The variations in mean annual water balance components from historic (1957-2005) for key catchments are summarised in Table 4.3.5. The change in mean annual rainfall (mm/y) for each key catchment region for the 2030 and 270 climate change scenarios are graphically shown in Figure 4.3.18 and Figure 4.3.19 respectively. Also shown is the 1995-2005 condition. The corresponding recharge variations are shown in Figure 4.3.20 and Figure 4.3.21 whereas the streamflow impacts are shown in Figure 4.3.22 and Figure 4.3.23.

Table 4.3.5: NE CMA river basin future climate percentage change in water balance from historical (1957-2005).

| | 1995- | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | 2005 | Low | Medium | High | Low | Medium | High |
| Kiewa basin | | | | | | | |
| Rainfall | -4.6 | -2.7 | -3.9 | -5.5 | -5.2 | -9.8 | -15.8 |
| Runoff | -2.5 | -18.2 | -22.3 | -27.1 | -25.4 | -37.2 | -47.5 |
| Evapotranspiration | 2.3 | -1.0 | -0.7 | -0.6 | -0.5 | -0.7 | -2.4 |
| Recharge | -8.6 | -5.7 | -8.7 | -12.2 | -11.6 | -20.9 | -31.3 |
| Streamflow | -13.8 | -4.1 | -7.3 | -11.2 | -10.6 | -20.9 | -32.8 |
| Total flow | -16.0±2 | -5.5±1 | -9.5±2 | -14.3±3 | -13.5±3 | -26.1±5 | -40.6±8 |
| Mitta basin | | | | | | | |
| Rainfall | -4.7 | -3.1 | -4.4 | -6.0 | -5.7 | -10.4 | -16.7 |
| Runoff | -7.6 | -25.4 | -30.4 | -36.4 | -34.1 | -48.2 | -59.5 |
| Evapotranspiration | 2.6 | -0.2 | 0.2 | 0.5 | 0.6 | 0.8 | -0.7 |
| Recharge | -12.8 | -7.4 | -11.1 | -15.5 | -14.9 | -26.4 | -39.1 |
| Streamflow | -16.1 | -7.0 | -11.1 | -15.9 | -15.3 | -28.1 | -42.6 |
| Total flow | -19.3±3 | -8.9±2 | -13.9±3 | -19.8±4 | -19.0±4 | -34.7±7 | -52.4±10 |
| Ovens basin | | | | | | | |
| Rainfall | -4.2 | -1.2 | -2.6 | -4.2 | -3.9 | -8.7 | -15.1 |
| Runoff | -0.3 | -19.7 | -24.4 | -29.7 | -27.8 | -40.2 | -49.8 |
| Evapotranspiration | 1.9 | -0.6 | -0.5 | -0.4 | -0.3 | -0.7 | -2.7 |
| Recharge | -11.5 | -4.6 | -8.3 | -12.7 | -12.0 | -23.7 | -36.9 |
| Streamflow | -14.3 | -0.9 | -4.8 | -9.6 | -8.9 | -21.3 | -35.1 |
| Total flow | -17.2±3 | -2.1±1 | -6.9±2 | -12.8±3 | -11.9±3 | -27.2±6 | -44.1±9 |
| Upper Murray basin | | | | | | | |
| Rainfall | -2.4 | -3.8 | -5.0 | -6.6 | -6.3 | -10.7 | -16.6 |
| Runoff | -7.1 | -30.8 | -36.2 | -42.3 | -39.8 | -54.0 | -64.4 |
| Evapotranspiration | 2.3 | -0.2 | 0.0 | 0.2 | 0.3 | 0.1 | -1.7 |
| Recharge | -11.0 | -9.9 | -13.7 | -18.2 | -17.6 | -29.3 | -41.9 |
| Streamflow | -10.2 | -9.6 | -13.6 | -18.4 | -17.8 | -30.4 | -44.5 |
| Total flow | -13.0±3 | -12.1±2 | -17.0±3 | -23.0±5 | -22.2±4 | -37.7±7 | -55.0±10 |

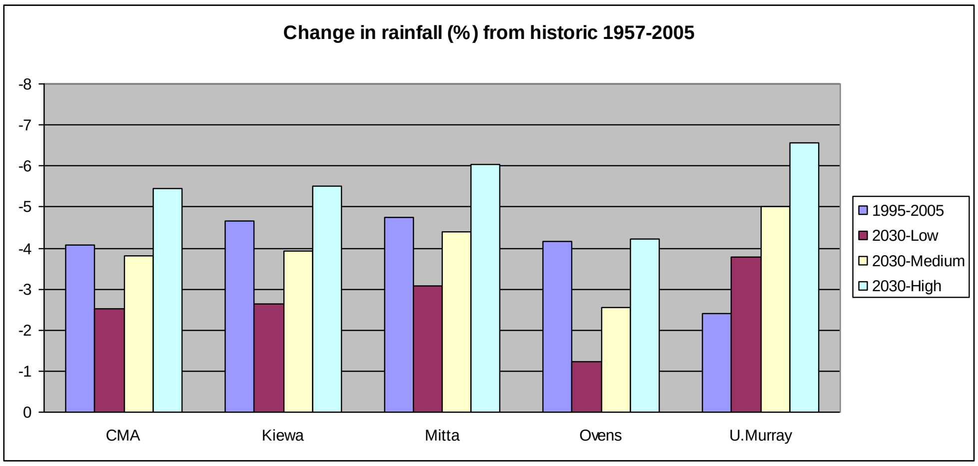



Figure 4.3.18. Change in rainfall (%) under 2030 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

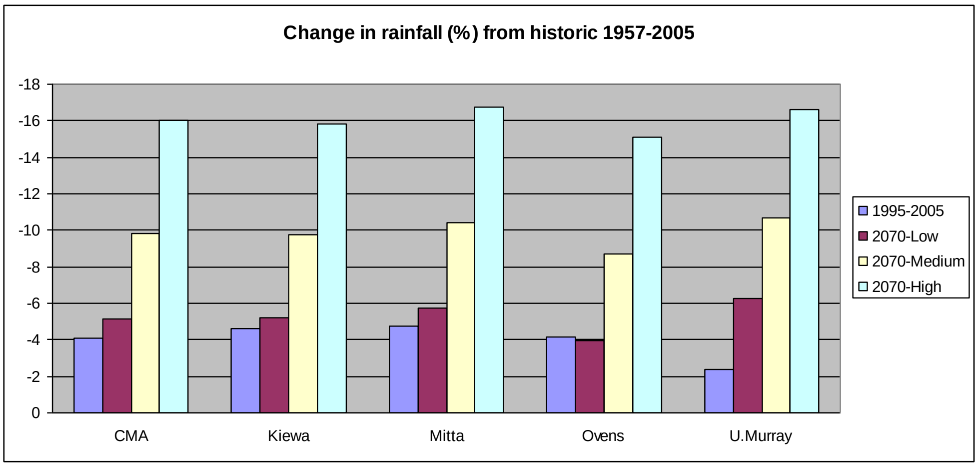



Figure 4.3.19. Change in rainfall (%) under 2070 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

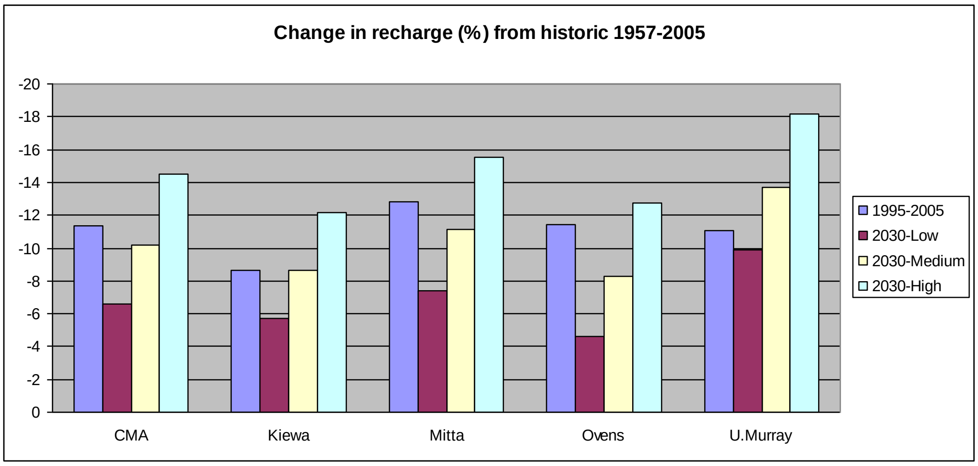



Figure 4.3.20. Change in recharge (%) under 2030 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

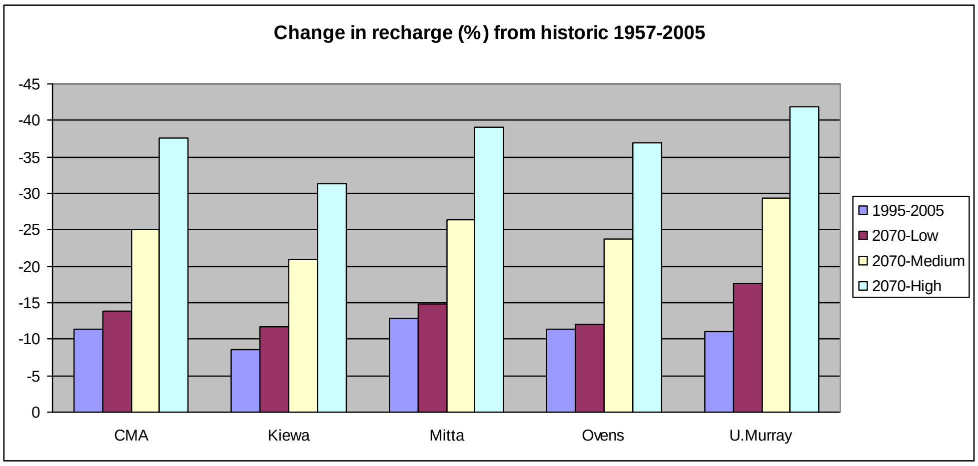



Figure 4.3.21. Change in recharge (%) under 2070 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

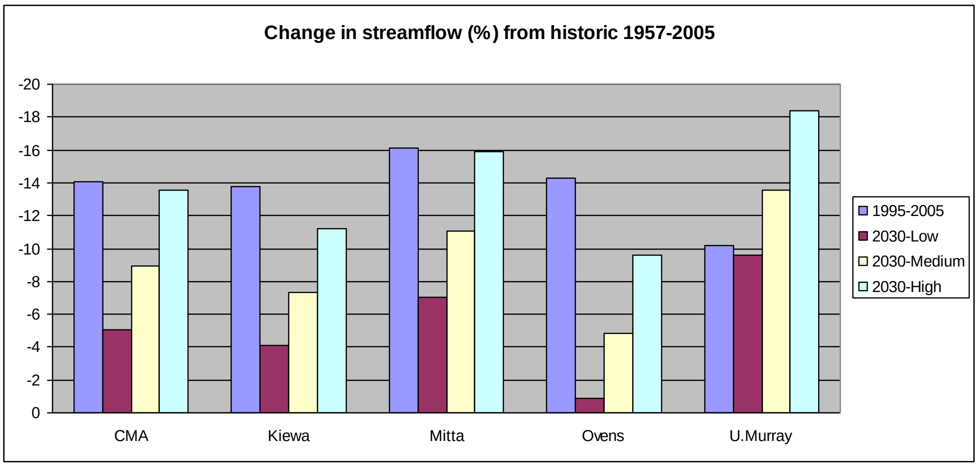



Figure 4.3.22. Change in streamflow (%) under 2030 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

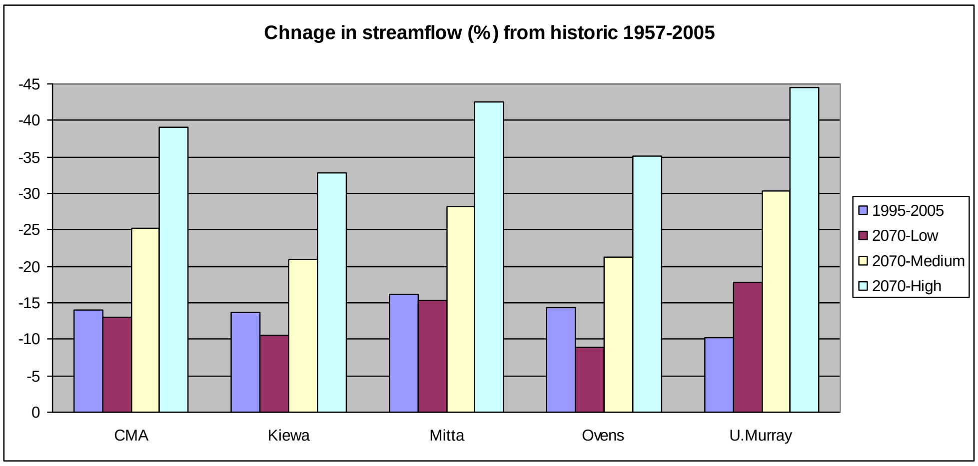



Figure 4.3.23. Change in streamflow (%) under 2070 climate change scenarios for key river basins. Also shown is the 1995-2005 response.

### 4.3.4 Groundwater response under climate change scenarios

The likely impact of climate change on groundwater dynamics was evaluated using the multi-layered fully distributed groundwater model MODFLOW (McDonald and Harbaugh, 1988) and was developed by Hockingetal Pty Ltd. The groundwater conceptualisation adopted a six-layer framework accounting for the dominant geological groups, specifically the Coonambidgal Formation, upper and lower Shepparton Formations, Calivil Formation, the deeply weathered geology and the Palaeozoic basement. The grid resolution was 200m x 200m and as such this model has a finer spatial scale and more detail than the CSIRO Southern Riverine Plains groundwater model and greater extent than the GHD Ovens Valley model. Groundwater extraction data were provided by Goulburn-Murray Water. Whereas the groundwater model used in this study has been calibrated for the period 1990-2000, results reported hereafter are based on steady state solutions thereby representing the dynamic-equilibrium state in accord with the CSIRO Sustainable Yields project. The model conceptualisation is summarised in Appendix C and the groundwater mass balance under current conditions is shown in Figure 4.3.24.

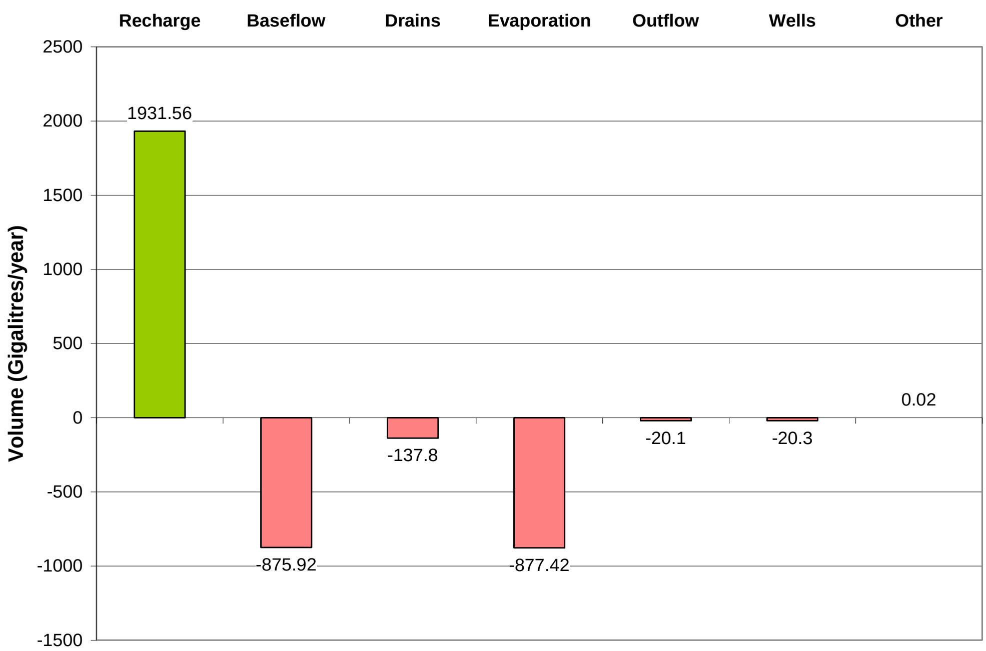



Figure 4.3.24. Groundwater mass balance under current conditions.

The calibrated groundwater model was used to initially assess the sustainable extraction volumes assuming 100% and 50% entitlements. Results are summarised in Figure 4.3.25 and clearly show that the groundwater resource under current conditions can only sustain in the order of 57% of entitlement extraction volumes. That is, of the 53.9 GL/yr entitlements only 31.1 GL/yr can be extracted. This implies that the groundwater resource is currently in the order of 40% over-allocated.

Modelling also suggests that were all entitlements to be reduced by 50% irrespective of landscape position to 26.9 GL/yr, only 20.3 GL/yr could be sustained. This highlights the importance of landscape position and the need to target revision of entitlements on a case by case basis.

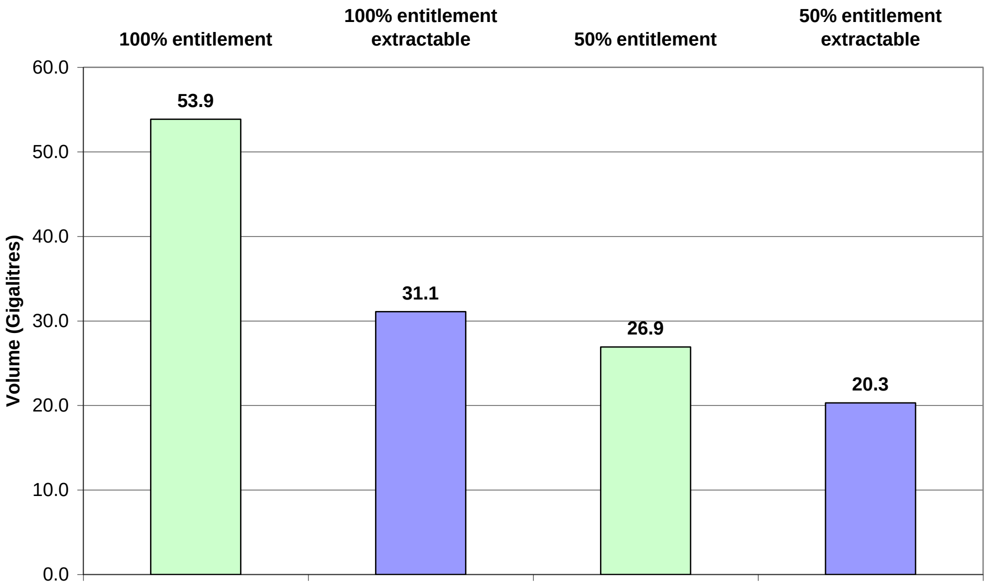



Figure 4.3.25. Sustainable extraction volumes assuming 100% and 50% entitlements.

On the bases that the assumption of 100% entitlements is not sustainable, the 50% entitlement condition was used to assess the impact of climate change on sustainable groundwater extraction volumes. Spatially assigned recharge was derived under each of the climate scenarios considered. The mean annual recharge (mm/yr) under historical climate conditions is shown in Figure 4.3.26 whereas the recharge under the 2030 medium and 2070 medium climate change conditions are shown in Figure 4.3.27 and Figure 4.3.28 respectively. The corresponding spatially averaged recharge variations relative to the historical conditions are summarised in Table 4.3.1 above. Figure 4.3.29 shows the variation in sustainable groundwater extraction volumes under modified recharge regimes due to climate change. Modelling suggests that reductions in the sustainable groundwater extraction volumes will vary between 700 ML/yr (or 3% of the 50% entitlement condition) to 1000 ML/yr (or 5% of the 50% entitlement condition).

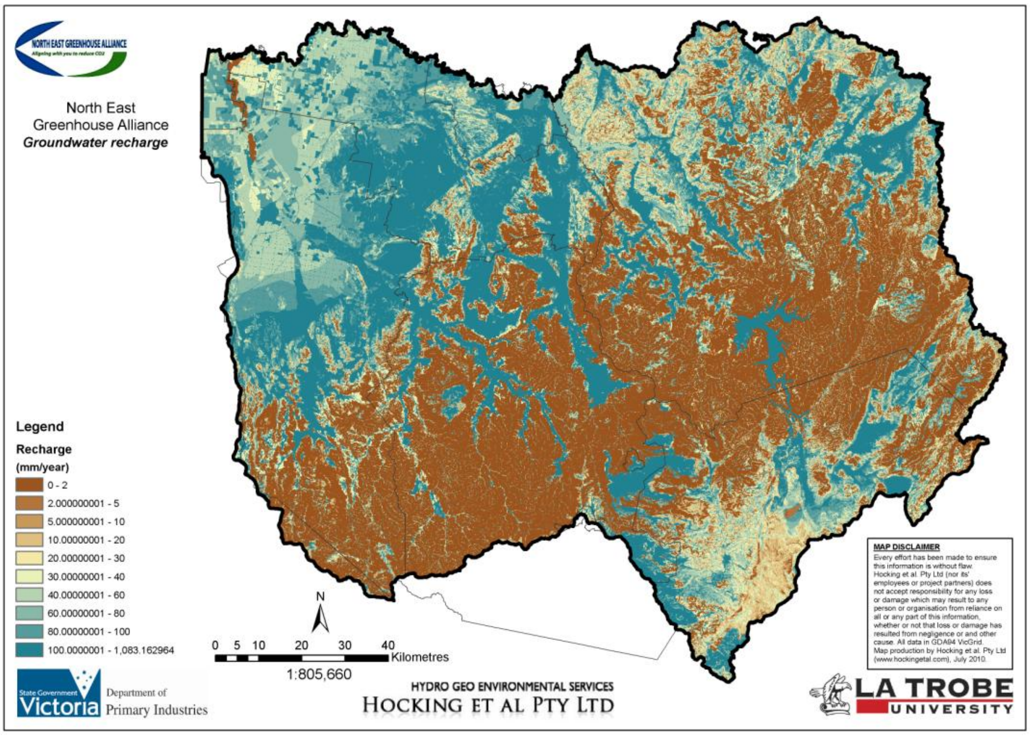



Figure 4.3.26. Mean annual groundwater recharge (mm/yr) under current conditions.

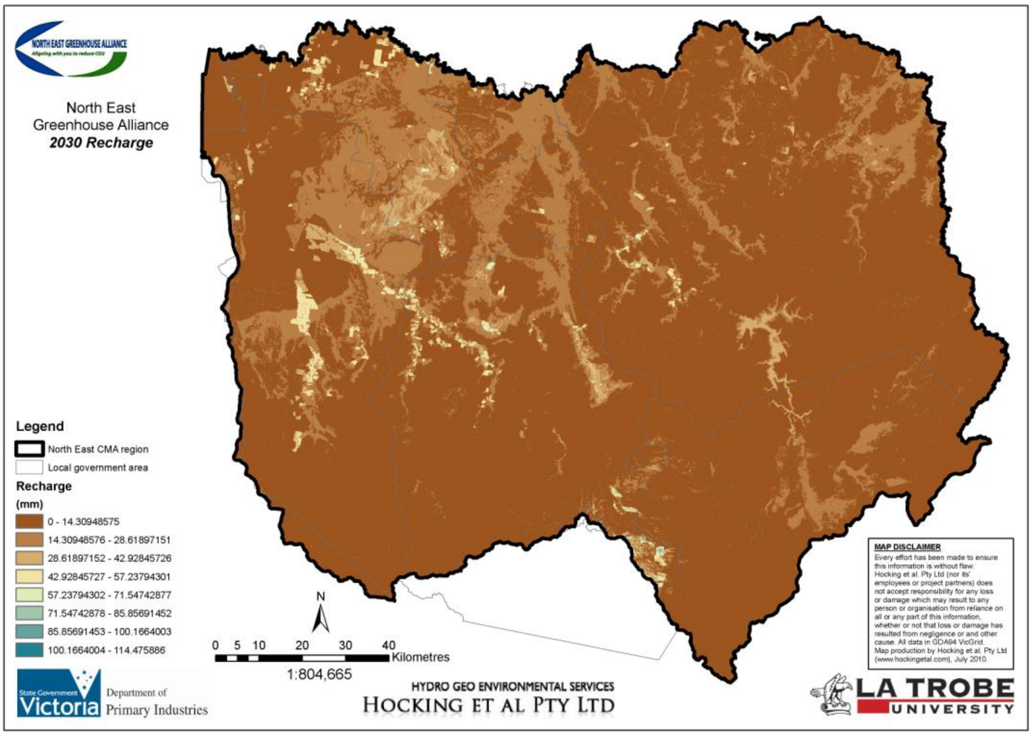



Figure 4.3.27. Mean annual groundwater recharge (mm/yr) under 2030 medium climate change conditions.

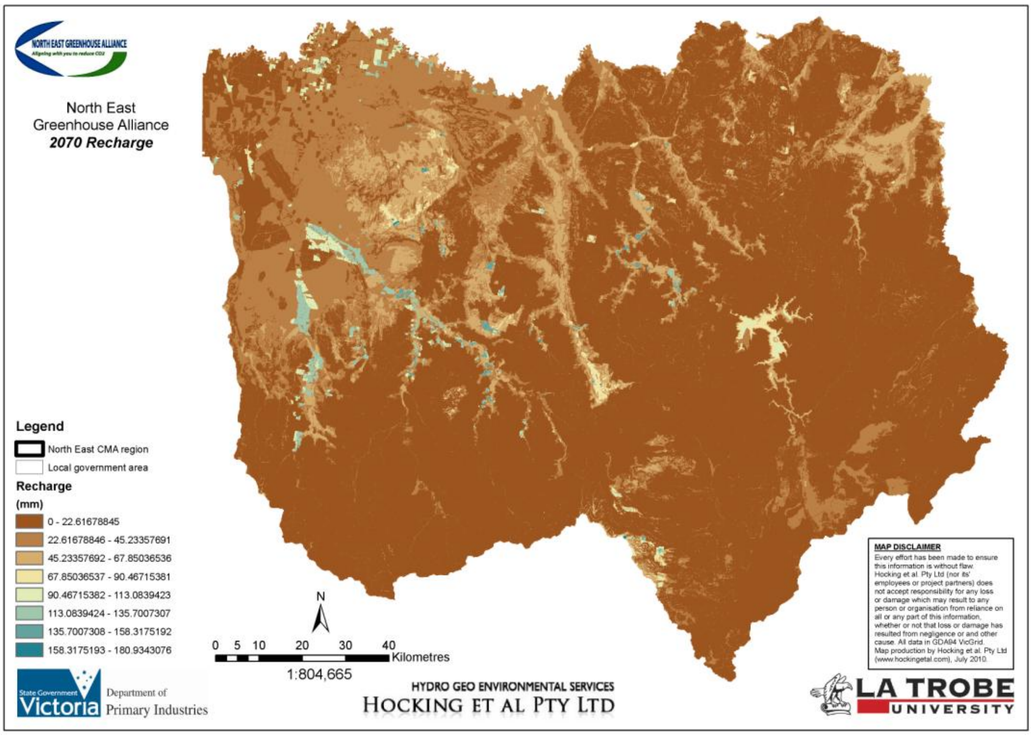



Figure 4.3.28. Mean annual groundwater recharge (mm/yr) under 2070 medium climate change conditions.

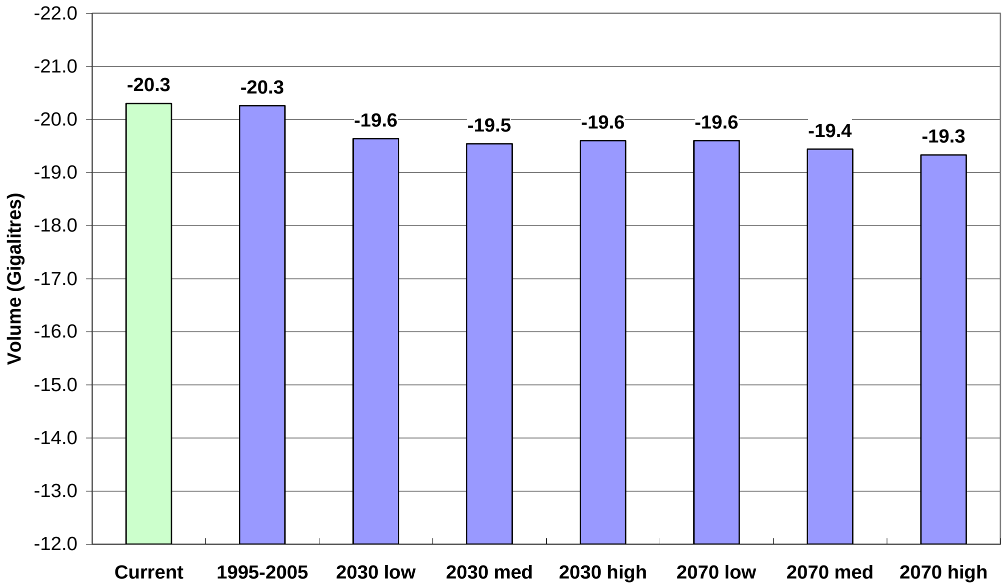



Figure 4.3.29. Impact of climate change on sustainable groundwater extraction volumes.

The change in total groundwater volume under different climate scenarios are summarised in Tables 4.3.6 and 4.3.7 for the entire North-East region and Local Government Areas within the North-East CMA region respectively. The corresponding changes in groundwater elevation relative to current condition for each scenario are shown in Figure 4.3.30 to Figure 4.3.36.

Table 4.3.6. Change in groundwater storage (GL) from current condition under various climate scenarios for the total North-East CMA region.

| Scenario | Change in groundwater storage from current |
|---|---|
| 1995-2005 | 5222 |
| 2030 low | 2507 |
| 2030 med | 5042 |
| 2030 high | 8823 |
| 2070 low | 4806 |
| 2070 med | 8975 |
| 2070 high | 14737 |

Table 4.3.7. Change in groundwater storage (GL) from current condition under various climate scenarios for Local Government Areas within the North-East CMA region.

| Scenario | Alpine Shire | Wangaratta Rural City | Indigo Shire | Wodonga Rural City | Towong Shire |
|---|---|---|---|---|---|
| 1995-2005 | 1752 | 547 | 114 | 31 | 1333 |
| 2030 low | 475 | 86 | 180 | 44 | 1440 |
| 2030 med | 742 | 202 | 245 | 61 | 5545 |
| 2030 high | 1069 | 345 | 343 | 82 | 2506 |
| 2070 low | 1039 | 317 | 327 | 78 | 2399 |
| 2070 med | 2049 | 777 | 604 | 136 | 4105 |
| 2070 high | 3415 | 1353 | 980 | 215 | 6398 |

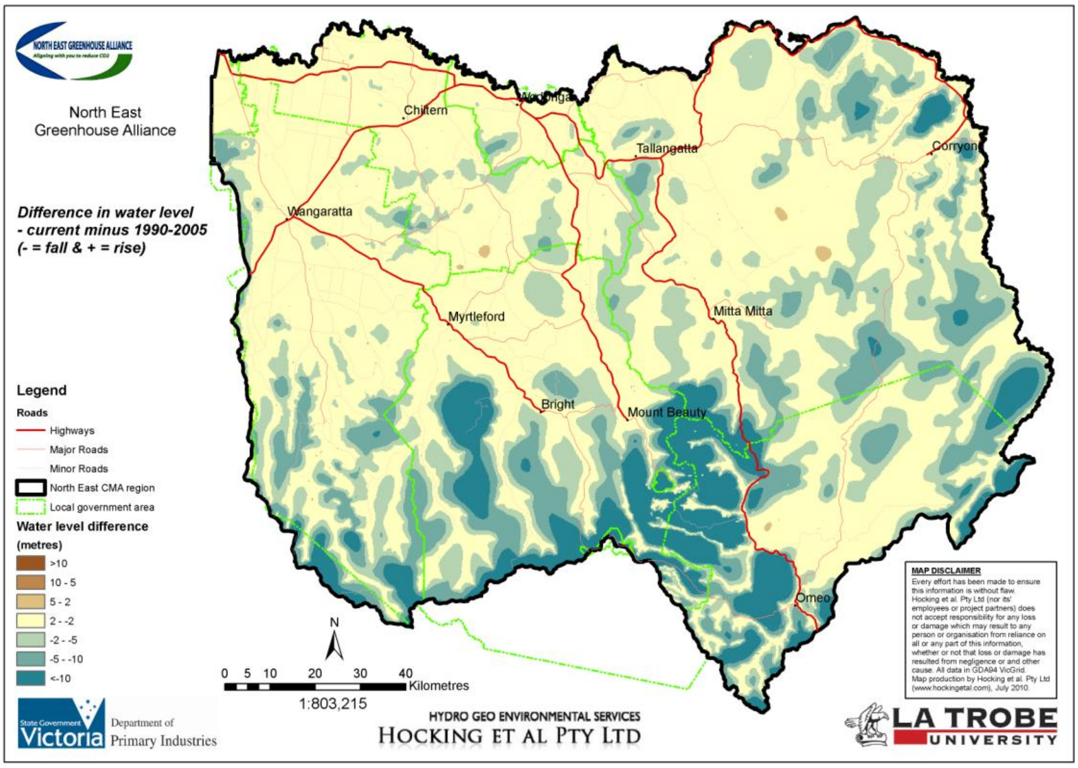



Figure 4.3.30. Change in watertable elevation from current condition assuming 1990-2005 historical climate.

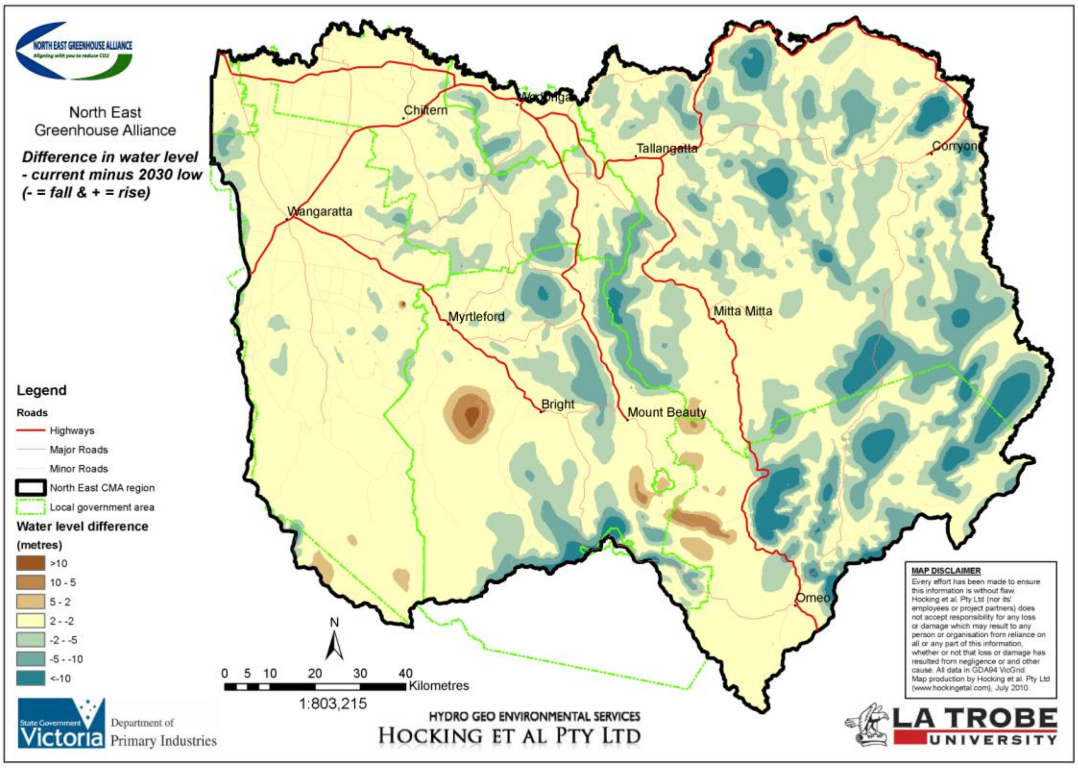



Figure 4.3.31. Change in watertable elevation from current condition under 2030 low climate scenario.

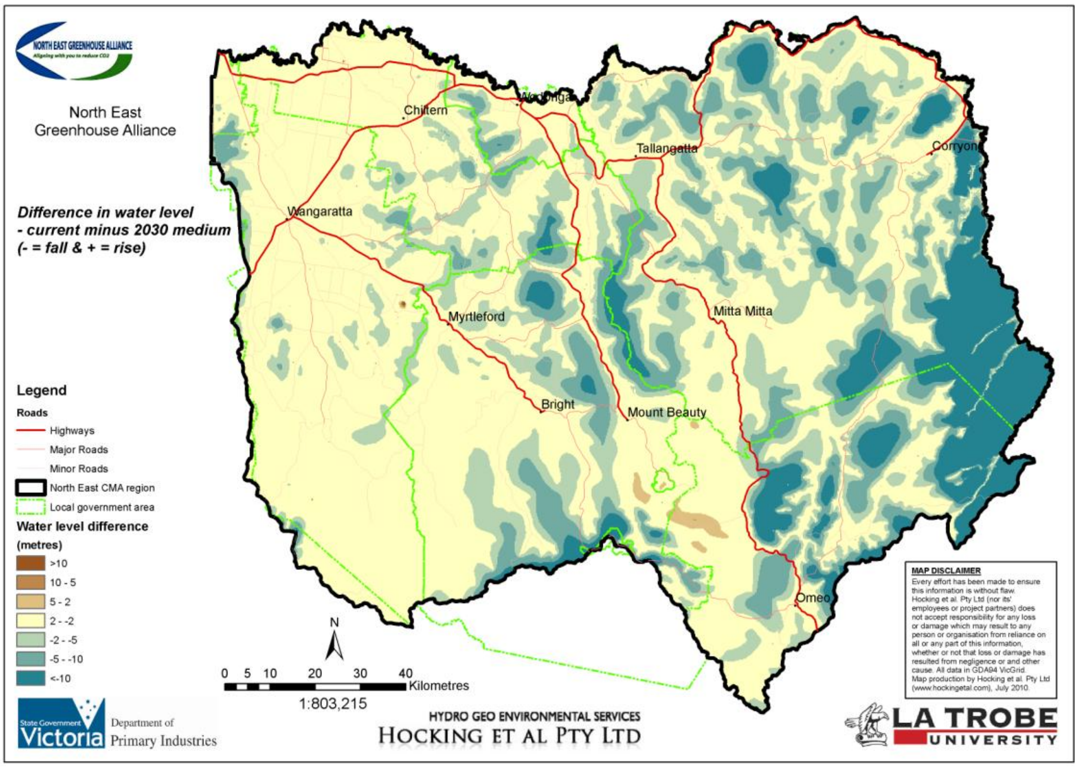



Figure 4.3.32. Change in watertable elevation from current condition under 2030 medium climate scenario

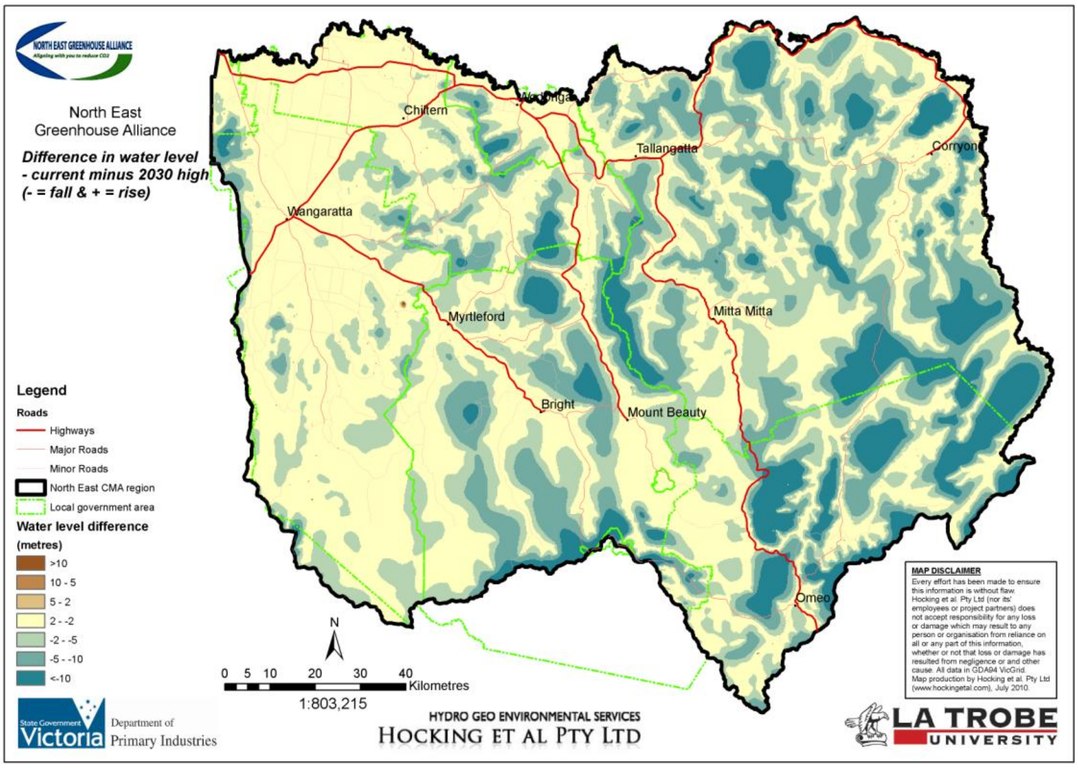



Figure 4.3.33. Change in watertable elevation from current condition under 2030 high climate scenario

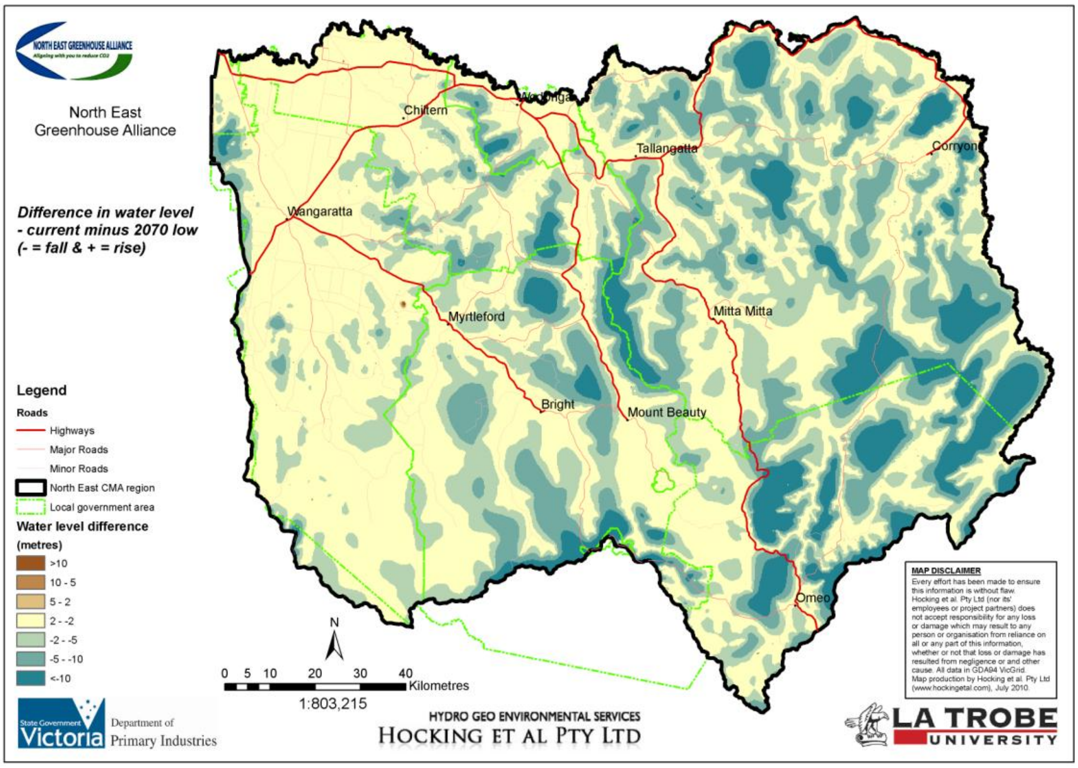



Figure 4.3.34. Change in watertable elevation from current condition under 2070 low climate scenario

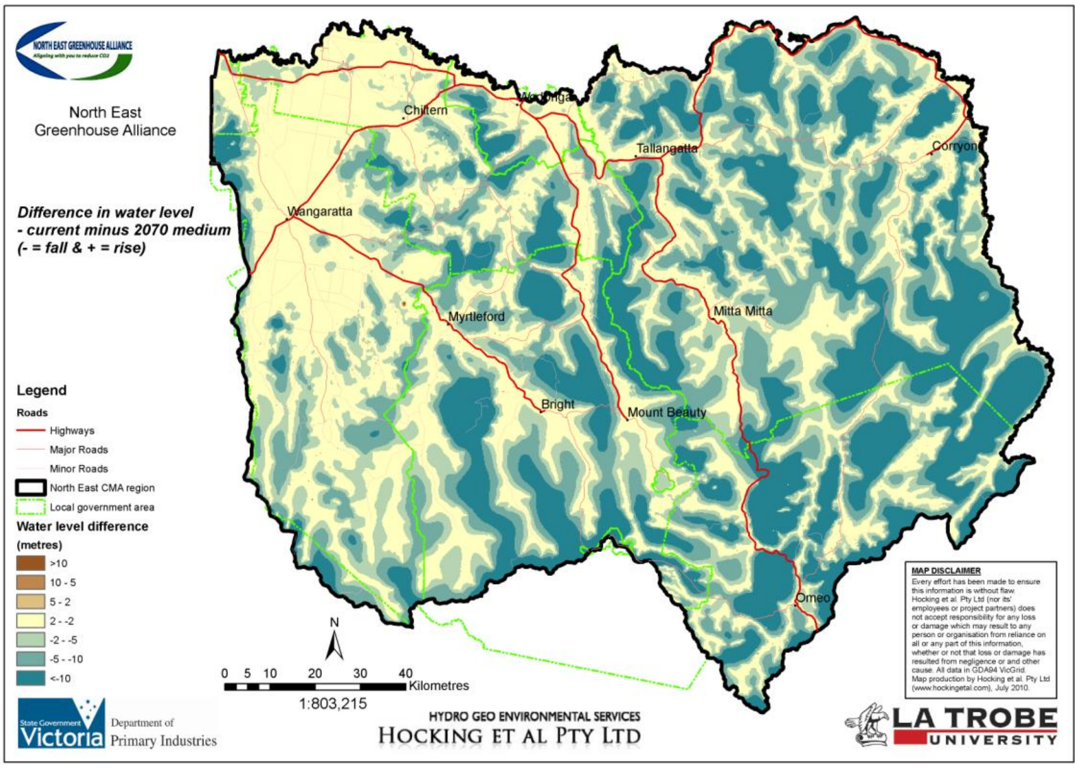



Figure 4.3.35. Change in watertable elevation from current condition under 2070 medium climate scenario

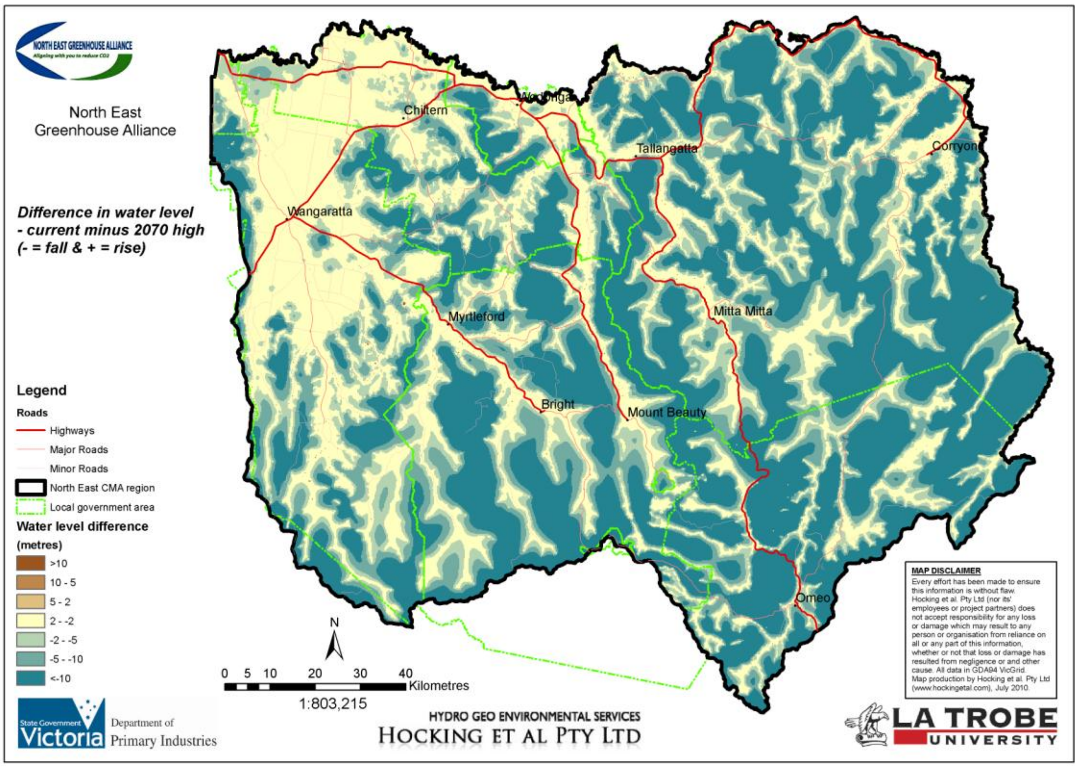



Figure 4.3.36. Change in watertable elevation from current condition under 2070 high climate scenario

# 5 COMPARATIVE RESULTS

This section summarises the predicted impacts of future climate on water resources within the North-East region of Victoria as reported in previous studies. Also summarised are the recently derived results developed by the project partners. In general, previous estimates have been broadly reported for the entire region which has limited the comparison to only consider CMA wide estimates. Table 5.1 summarises the seasonal impacts of future climate scenarios on rainfall and temperature range across the North-East CMA region relative to 1990 condition. This information is consistent with the spatially averaged impacts presented in Section 4.3. The corresponding likely climate change impacts on water balance components for the entire North-East CMA region are summarised in Table 5.2. A comparison of results suggests that the DPI estimates used in this review are within the limits reported by previous studies. However this is not the case when comparing the likely climate change impacts on the Ovens Valley as summarised in Table 5.3. Key observations from comparing the independently derived estimates of the impact of climate change on the water balance in the Ovens Valley are:

1. GHD recharge impacts are significantly greater than those estimated by DPI. The GHD 2050 estimates are approximately two-fold greater than the DPI 2070 estimates.
2. The CSIRO 2030 low water availability estimates are broadly consistent with the DPI predictions. However the CSIRO 2030 medium estimate is approximately two-fold the DPI prediction whereas the CSIRO 2030 high estimate is approximately three-fold the DPI prediction. That is, in general the CSIRO 2030 predictions are significantly greater than the DPI estimates.
3. The CSIRO 2030 high water availability estimate is approximately the same as the GHD 2050 high estimate.
4. The CSIRO 2030 high water availability estimate is approximately the same as the DPI 2070 high estimate.
5. The GHD 2050 high water availability estimate is approximately the same as the DPI 2070 high estimate.
6. In general, the GHD 2050 predictions are the same as the DPI 2070 estimates.
7. CSIRO assumes the greatest impact earlier (2030) with GHD and DPI assuming the same impacts at 2050 and 2070 respectively.

These observations clearly demonstrate the magnitude of variation in climate change impact predictions on water availability. This reinforces the uncertainties associated with the derivation of the hydrological impact of future climate scenarios.

Table 5.1: CSIRO future seasonal climate projections for the North-East region

| | | |
|---|---|---|
| | 2030 | 2070 |
| Spring | Warmer by 0.3 to 1.6°C | Warmer by 0.8 to 5.0°C |
| | Precipitation decrease +3 to -15% | Precipitation decrease +10 to -40% |
| Summer | Warmer by 0.3 to 2.0°C | Warmer by 0.8 to 6.0°C |
| | Precipitation change uncertain +15 to -15% | Precipitation change uncertain +40 to -40% |
| Autumn | Warmer by 0.3 to 1.6°C | Warmer by 0.8 to 5.0°C |
| | Precipitation change uncertain +10 to -10% | Precipitation change uncertain +25 to -25% |
| Winter | Warmer by 0.2 to 1.4°C | Warmer by 0.7 to 4.3°C |
| | Precipitation decrease +3 to -10% | Precipitation decrease +10 to -25% |

Table 5.2: Summary of annual climate change impacts derived from various studies (% deviation from historical)

| Attribute | Report | Benchmark | Scenario | 2030 | 2070 |
|---|---|---|---|---|---|
| Average rainfall | DPI | relative to 1957-2004 | High | -4 | -9 |
| | CSIRO | relative to 1990 | | -3 | -10 |
| Average temperature | CSIRO | relative to 1990 | | 0.9 | 2.9 |
| Potential evaporation | CSIRO | relative to 1990 | | 3 | 9 |
| Wind speed | CSIRO | relative to 1990 | | -1 | -2 |
| Relative humidity | CSIRO | relative to 1990 | | -0.6 | -2 |
| Solar radiation | CSIRO | relative to 1990 | | 0.7 | 2.2 |
| | | | | | |
| Runoff – entire region | DPI | relative to 1957-2004 | High | -8 | -17 |
| | CSIRO | relative to 1990 | | 0 to -20 | 0 to >-20 |
| | | | | | |
| Total quickflow – entire region | DPI | relative to 1957-2004 | High | -8 | -17 |
| Total inflows to Murray system | NRSWS | relative to 1990 | Low | 5 | ~ 8 |
| | NRSWS | relative to 1990 | Medium | -10 | ~-21 |
| | NRSWS | relative to 1990 | High | -20 | ~-40 |

Table 5.3: Summary of annual climate change impacts derived from various studies (% deviation from historical) for the Ovens Valley.

| Attribute | Report | Benchmark | Scenario | 2030 | 2050 | 2070 |
|---|---|---|---|---|---|---|
| Recharge | GHD | relative to historic | Last 12 yrs | | -24 | |
| | GHD | relative to historic | B1 | | -42 | |
| | GHD | relative to historic | A1F1 | | -84 | |
| | DPI | relative to 1957-2005 | Low | -6 | | -12 |
| | DPI | relative to 1957-2005 | Medium | -9 | | -21 |
| | DPI | relative to 1957-2005 | High | -13 | | -31 |
| | DPI | relative to 1957-2005 | Last 10 yrs | -9 | | |
| | | | | | | |
| Total yield | CSIRO | relative to historic | Low | negligible | | |
| | CSIRO | relative to historic | Medium | -13 | | |
| | CSIRO | relative to historic | High | -45 | | |
| | GHD | relative to historic | Last 12 yrs | | -10 | |
| | GHD | relative to historic | B1 | | -30 | |
| | GHD | relative to historic | A1F1 | | -45 | |
| | DPI | relative to 1957-2005 | Low | -2.1±1 | | -11.9±3 |
| | DPI | relative to 1957-2005 | Medium | -6.9±2 | | -27.2±6 |
| | DPI | relative to 1957-2005 | High | -12.8±3 | | -44.1±9 |
| | DPI | relative to 1957-2005 | Last 10 yrs | -17.2±3 | | |

# 6 CONCLUDING COMMENTS

A review of previous climate change studies has identify

ed significant differences in the predicted impacts of climate change on the water resources within the North-East CMA region of Victoria. The discrepancies in estimates are due to:

1. Varying assumptions underpinning the development of climate change scenarios
2. Different modelling techniques used
3. Varying methods used to assign climate change scenarios

It is noteworthy that no previous climate change studies considered the entire North-East CMA region with sufficient spatial resolution to address the project objectives. Typically previous studies focused on key river basins such as the Kiewa and Ovens river systems. Additionally previous studies adopted future projections which did consider both the 2030 and 2070 climate change scenarios. Given these limitations this review deployed a methodology developed by project partners to downscale climate pattern of change estimates and subsequently modelled the impact of climate change on water availability within the CMA region using a suite of physically based farming system models and a fully distributed multi-layered groundwater model. The adopted methodology presented in this report is shown to offer finer scale, CMA wide regional estimates across a range of designated future climate scenarios.

Key findings from this study are broadly aligned to climate change scenarios previously assessed and reported with the general observation that:

1. Under future climate water supplies will be less reliable
2. Groundwater levels are expected to decline due to reduced recharge and increased extractions
3. More frequent and severe water restrictions are likely to be imposed on urban water users
4. River and wetland biodiversity will be stressed and likely to decline
5. Water quality is likely to decline

Specific conclusions from this study are:

1. Large uncertainties are associated with climate change predictions, both at the point scale and catchment scale. These uncertainties are introduced due to variability in the underpinning data, simulation model constructs and assumptions adopted with model applications.
2. Significant variations in climate change impacts on water availability have been previously reported, and in some cases contrast the predictions derived in this study. This reinforces the degree of uncertainties associated with the derivation of the hydrological impact of future climate scenarios.
3. Under the low 2030 climate condition flows would be reduced by between 2% and 14% depending upon landscape position and dynamics. In order of increasing impact, Wangaratta Shire would be least impacted (-2%) followed by the Alpine

Shire (-3%), then Indigo Shire (-9%), Wodonga Shire (-10%) and Towong Shire (-11%). Key river basins would similarly be impacted with reduced flows ranging from 1% to 14%. In order of increasing impact, the Ovens catchment would be least impacted (-2%), followed by the Kiewa (-6%), the Mitta catchment (-9%) and the Upper Murray basin (-12%).

4. Under the dry extreme 2030 climate condition flows would be reduced by between 10% and 25% across the North-East CMA region. In order of increasing impact, Alpine Shire would be least impacted (-12%) followed by the Wangaratta Shire (-13%), then Indigo and Wodonga Shires (-20%) and Towong Shire (-21%). The corresponding reduction in river basin flows range between 10% and 28%. In order of increasing impact, the Ovens catchment would be least impacted (-13%), followed by the Kiewa (-14%), the Mitta catchment (-20%) and the Upper Murray basin (-23%).
5. Under the low 2070 climate condition flows would be reduced to approximately those predicted under the dry extreme 2030 climate conditions with reductions ranging between 9% and 24%. In order of increasing impact, Wangaratta and Alpine Shires would be least impacted (-12%), followed by the Indigo Shire (-19%), then the Wodonga Shire (-20%) and Towong Shire (-21%). Key river basins would also be impacted with reduced flows ranging from 9% to 26%. In order of increasing impact, the Ovens catchment would be least impacted (-12%), followed by the Kiewa (-14%), the Mitta catchment (-19%) and the Upper Murray basin (-22%).
6. Under the dry extreme 2070 climate condition flows would be reduced across the North-East CMA region by between 34% and 61%. In order of increasing impact, the Alpine Shire would be least impacted (-41%), followed by the Wangaratta Shire (44%), Indigo Shire (-48%), then the Wodonga Shire (-50%) and Towong Shire (-52%). Key river basins would similarly be impacted with reduced flows ranging from 33% to 65%. In order of increasing impact, the Kiewa catchment would be least impacted (-41%), followed by the Ovens (-44%), the Mitta catchment (-52%) and the Upper Murray basin (-55%).
7. The groundwater resource within the North-East CMA region is unlikely to be sustainable based on the simulation of groundwater dynamics using the provided groundwater entitlement data under full allocation assumptions.
8. An understanding of landscape dynamics is critical in estimating the impact of climate change on water availability, productivity and groundwater sustainability.

On the basis that the IPCC original climate change projections have been revised, this study recommends undertaking more detailed modelling using the recently updated CCAM Mark 3.6 pattern of change data from CSIRO. Enhancement of the existing groundwater model to better capture temporal groundwater dynamics and sustainable extraction limits has also been identified as a key recommendation.

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# Appendix A – Climate station trends

Table A.1. Variations in mean annual rainfall (mm/yr) for all climate stations within the North-East CMA region under various climate scenarios. Also shown are the corresponding percentage change in mean annual rainfall relative to the 1990 (Null) condition.

| | Null | 2030Low | 2030Med | 2030High | 2070Low | 2070Med | 2070High | Hist 1935-1990 | 2030Low % | 2030Med % | 2030High % | 2070Low % | 2070Med % | 2070High % | Hist% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81004 | 569 | 553 | 544 | 533 | 535 | 504 | 461 | 570 | -2.7 | -4.3 | -6.2 | -5.9 | -11.4 | -18.9 | 0.23 |
| 81055 | 513 | 499 | 491 | 481 | 482 | 454 | 415 | 513 | -2.7 | -4.3 | -6.3 | -5.9 | -11.6 | -19.1 | -0.05 |
| 81057 | 520 | 505 | 497 | 486 | 488 | 458 | 418 | 525 | -2.8 | -4.4 | -6.4 | -6.1 | -11.8 | -19.6 | 1.01 |
| 82000 | 606 | 590 | 581 | 570 | 572 | 540 | 496 | 605 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.1 | -0.15 |
| 82001 | 987 | 963 | 950 | 933 | 936 | 887 | 821 | 994 | -2.4 | -3.8 | -5.6 | -5.2 | -10.2 | -16.9 | 0.63 |
| 82006 | 584 | 568 | 560 | 549 | 550 | 519 | 477 | 584 | -2.6 | -4.1 | -6.0 | -5.7 | -11.0 | -18.3 | 0.13 |
| 82008 | 1004 | 983 | 971 | 956 | 958 | 915 | 857 | 1008 | -2.1 | -3.3 | -4.8 | -4.5 | -8.8 | -14.6 | 0.39 |
| 82009 | 907 | 885 | 872 | 856 | 859 | 813 | 752 | 908 | -2.4 | -3.8 | -5.6 | -5.3 | -10.3 | -17.0 | 0.14 |
| 82010 | 693 | 675 | 665 | 652 | 654 | 618 | 569 | 697 | -2.6 | -4.0 | -5.9 | -5.5 | -10.8 | -17.8 | 0.61 |
| 82011 | 787 | 770 | 760 | 748 | 750 | 715 | 668 | 789 | -2.2 | -3.4 | -5.0 | -4.7 | -9.2 | -15.2 | 0.27 |
| 82015 | 683 | 665 | 654 | 641 | 644 | 607 | 557 | 688 | -2.6 | -4.2 | -6.1 | -5.7 | -11.2 | -18.4 | 0.77 |
| 82017 | 686 | 668 | 658 | 645 | 647 | 611 | 562 | 674 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.1 | -1.72 |
| 82018 | 1012 | 988 | 974 | 956 | 959 | 909 | 842 | 1026 | -2.4 | -3.8 | -5.5 | -5.2 | -10.2 | -16.9 | 1.36 |
| 82021 | 627 | 611 | 602 | 590 | 592 | 559 | 515 | 627 | -2.6 | -4.0 | -5.9 | -5.6 | -10.8 | -17.9 | 0.01 |
| 82022 | 930 | 909 | 897 | 882 | 885 | 843 | 786 | 928 | -2.2 | -3.5 | -5.1 | -4.8 | -9.3 | -15.4 | -0.18 |
| 82024 | 1043 | 1020 | 1007 | 991 | 994 | 947 | 884 | 1057 | -2.2 | -3.4 | -5.0 | -4.7 | -9.2 | -15.2 | 1.34 |
| 82026 | 999 | 978 | 966 | 952 | 954 | 913 | 856 | 1000 | -2.0 | -3.2 | -4.7 | -4.4 | -8.6 | -14.2 | 0.18 |
| 82028 | 790 | 771 | 761 | 747 | 750 | 711 | 660 | 801 | -2.4 | -3.7 | -5.4 | -5.1 | -10.0 | -16.5 | 1.40 |
| 82029 | 668 | 650 | 640 | 628 | 630 | 595 | 547 | 669 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.1 | 0.22 |
| 82032 | 749 | 730 | 719 | 706 | 708 | 669 | 617 | 751 | -2.5 | -4.0 | -5.8 | -5.5 | -10.6 | -17.5 | 0.30 |
| 82034 | 952 | 928 | 914 | 897 | 900 | 852 | 787 | 945 | -2.5 | -3.9 | -5.7 | -5.4 | -10.5 | -17.3 | -0.72 |
| 82035 | 1045 | 1026 | 1015 | 1002 | 1004 | 965 | 913 | 1048 | -1.8 | -2.8 | -4.1 | -3.9 | -7.6 | -12.6 | 0.23 |
| 82038 | 589 | 574 | 565 | 554 | 556 | 524 | 482 | 591 | -2.6 | -4.1 | -6.0 | -5.7 | -11.0 | -18.2 | 0.27 |
| 82039 | 597 | 581 | 572 | 561 | 563 | 531 | 488 | 598 | -2.6 | -4.1 | -6.0 | -5.7 | -11.1 | -18.3 | 0.11 |
| 82040 | 549 | 535 | 526 | 516 | 518 | 488 | 448 | 550 | -2.7 | -4.2 | -6.1 | -5.7 | -11.2 | -18.5 | 0.19 |
| 82041 | 631 | 615 | 605 | 593 | 595 | 561 | 515 | 633 | -2.7 | -4.2 | -6.1 | -5.8 | -11.2 | -18.5 | 0.22 |
| 82044 | 972 | 950 | 937 | 922 | 924 | 880 | 819 | 974 | -2.2 | -3.5 | -5.1 | -4.9 | -9.5 | -15.7 | 0.29 |
| 82045 | 816 | 795 | 783 | 769 | 771 | 729 | 673 | 817 | -2.5 | -3.9 | -5.7 | -5.4 | -10.6 | -17.5 | 0.18 |
| 82046 | 780 | 761 | 751 | 737 | 740 | 702 | 651 | 781 | -2.4 | -3.7 | -5.4 | -5.1 | -10.0 | -16.6 | 0.20 |
| 82047 | 807 | 789 | 779 | 766 | 768 | 731 | 681 | 808 | -2.2 | -3.5 | -5.1 | -4.8 | -9.4 | -15.6 | 0.18 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82051 | 554 | 539 | 531 | 521 | 522 | 493 | 453 | 556 | -2.6 | -4.1 | -6.0 | -5.7 | -11.1 | -18.3 | 0.37 |
| 82052 | 825 | 806 | 796 | 782 | 784 | 746 | 694 | 829 | -2.3 | -3.6 | -5.2 | -4.9 | -9.6 | -15.9 | 0.49 |
| 82053 | 636 | 619 | 610 | 598 | 600 | 567 | 521 | 637 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.0 | 0.23 |
| 82055 | 749 | 730 | 718 | 705 | 707 | 667 | 614 | 748 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.0 | -0.06 |
| 82056 | 721 | 704 | 694 | 681 | 683 | 648 | 600 | 724 | -2.4 | -3.8 | -5.5 | -5.2 | -10.2 | -16.9 | 0.43 |
| 82057 | 824 | 804 | 793 | 778 | 781 | 740 | 685 | 825 | -2.4 | -3.8 | -5.5 | -5.2 | -10.2 | -16.9 | 0.14 |
| 82058 | 937 | 916 | 905 | 890 | 892 | 851 | 794 | 941 | -2.2 | -3.4 | -5.0 | -4.7 | -9.2 | -15.2 | 0.49 |
| 82059 | 1228 | 1202 | 1187 | 1168 | 1171 | 1118 | 1047 | 1256 | -2.1 | -3.3 | -4.8 | -4.6 | -8.9 | -14.7 | 2.29 |
| 82066 | 788 | 771 | 761 | 749 | 751 | 716 | 669 | 791 | -2.2 | -3.4 | -5.0 | -4.7 | -9.2 | -15.1 | 0.29 |
| 82068 | 1029 | 1008 | 996 | 981 | 984 | 942 | 885 | 1022 | -2.0 | -3.2 | -4.6 | -4.4 | -8.5 | -14.0 | -0.61 |
| 82076 | 1029 | 1007 | 995 | 980 | 982 | 938 | 879 | 1016 | -2.1 | -3.3 | -4.8 | -4.5 | -8.8 | -14.5 | -1.24 |
| 82088 | 752 | 734 | 724 | 711 | 713 | 676 | 626 | 750 | -2.4 | -3.8 | -5.5 | -5.2 | -10.1 | -16.7 | -0.30 |
| 82092 | 1127 | 1103 | 1089 | 1071 | 1074 | 1024 | 957 | 1134 | -2.2 | -3.4 | -5.0 | -4.7 | -9.1 | -15.1 | 0.66 |
| 82098 | 873 | 850 | 837 | 821 | 824 | 778 | 716 | 890 | -2.6 | -4.1 | -5.9 | -5.6 | -10.9 | -18.0 | 2.03 |
| 82100 | 715 | 698 | 688 | 675 | 677 | 642 | 594 | 716 | -2.4 | -3.8 | -5.6 | -5.3 | -10.2 | -17.0 | 0.17 |
| 82117 | 808 | 788 | 777 | 763 | 765 | 725 | 671 | 821 | -2.4 | -3.8 | -5.6 | -5.3 | -10.3 | -17.0 | 1.61 |
| 82127 | 532 | 518 | 510 | 500 | 501 | 473 | 434 | 533 | -2.6 | -4.1 | -6.0 | -5.7 | -11.1 | -18.3 | 0.21 |
| 82137 | 814 | 794 | 783 | 769 | 771 | 730 | 676 | 809 | -2.4 | -3.8 | -5.6 | -5.3 | -10.3 | -17.0 | -0.68 |
| 82138 | 637 | 620 | 611 | 599 | 601 | 568 | 523 | 636 | -2.6 | -4.0 | -5.9 | -5.6 | -10.8 | -17.9 | -0.03 |
| 83004 | 1726 | 1691 | 1671 | 1646 | 1650 | 1579 | 1482 | 1752 | -2.0 | -3.2 | -4.7 | -4.4 | -8.6 | -14.2 | 1.47 |
| 83008 | 1233 | 1207 | 1192 | 1173 | 1177 | 1123 | 1052 | 1236 | -2.1 | -3.3 | -4.8 | -4.6 | -8.9 | -14.7 | 0.26 |
| 83010 | 1134 | 1110 | 1096 | 1078 | 1081 | 1031 | 964 | 1137 | -2.2 | -3.4 | -4.9 | -4.7 | -9.1 | -15.0 | 0.20 |
| 83012 | 1403 | 1374 | 1357 | 1336 | 1340 | 1280 | 1199 | 1410 | -2.1 | -3.3 | -4.8 | -4.5 | -8.8 | -14.6 | 0.46 |
| 83013 | 598 | 582 | 572 | 560 | 562 | 529 | 484 | 604 | -2.7 | -4.3 | -6.3 | -5.9 | -11.5 | -19.1 | 0.92 |
| 83014 | 1826 | 1786 | 1763 | 1734 | 1739 | 1657 | 1546 | 1983 | -2.2 | -3.5 | -5.0 | -4.8 | -9.3 | -15.3 | 8.62 |
| 83023 | 1214 | 1187 | 1172 | 1152 | 1156 | 1100 | 1026 | 1213 | -2.2 | -3.5 | -5.1 | -4.8 | -9.4 | -15.5 | -0.10 |
| 83024 | 1442 | 1410 | 1392 | 1369 | 1373 | 1309 | 1222 | 1451 | -2.2 | -3.4 | -5.0 | -4.7 | -9.2 | -15.2 | 0.69 |
| 83025 | 707 | 687 | 676 | 662 | 665 | 625 | 571 | 707 | -2.8 | -4.3 | -6.3 | -6.0 | -11.6 | -19.2 | 0.05 |
| 83029 | 914 | 890 | 877 | 860 | 863 | 814 | 750 | 921 | -2.6 | -4.0 | -5.9 | -5.6 | -10.8 | -17.9 | 0.85 |
| 83031 | 1132 | 1106 | 1091 | 1072 | 1075 | 1021 | 948 | 1134 | -2.3 | -3.7 | -5.4 | -5.1 | -9.8 | -16.3 | 0.16 |
| 83032 | 1414 | 1385 | 1368 | 1347 | 1351 | 1292 | 1212 | 1419 | -2.1 | -3.2 | -4.7 | -4.4 | -8.6 | -14.3 | 0.36 |
| 83037 | 2254 | 2204 | 2175 | 2139 | 2145 | 2042 | 1903 | 2325 | -2.2 | -3.5 | -5.1 | -4.8 | -9.4 | -15.6 | 3.15 |
| 83038 | 1088 | 1064 | 1051 | 1033 | 1036 | 987 | 921 | 1082 | -2.2 | -3.5 | -5.1 | -4.8 | -9.3 | -15.4 | -0.60 |
| 83067 | 1206 | 1179 | 1164 | 1145 | 1148 | 1093 | 1019 | 1197 | -2.2 | -3.5 | -5.1 | -4.8 | -9.4 | -15.5 | -0.80 |
| 83073 | 1895 | 1855 | 1832 | 1804 | 1809 | 1727 | 1617 | 1905 | -2.1 | -3.3 | -4.8 | -4.6 | -8.9 | -14.7 | 0.50 |
| 83083 | 1116 | 1089 | 1074 | 1056 | 1059 | 1005 | 933 | 1117 | -2.3 | -3.7 | -5.4 | -5.1 | -9.9 | -16.4 | 0.13 |
| 83084 | 2030 | 1985 | 1960 | 1928 | 1933 | 1842 | 1718 | 2224 | -2.2 | -3.5 | -5.0 | -4.8 | -9.3 | -15.4 | 9.56 |
| 83085 | 1809 | 1769 | 1746 | 1718 | 1723 | 1641 | 1531 | 1968 | -2.2 | -3.5 | -5.0 | -4.8 | -9.3 | -15.3 | 8.79 |
| 84001 | 642 | 624 | 613 | 600 | 602 | 565 | 514 | 644 | -2.9 | -4.5 | -6.6 | -6.2 | -12.1 | -20.0 | 0.28 |
| 84037 | 645 | 627 | 617 | 604 | 606 | 569 | 520 | 646 | -2.8 | -4.4 | -6.4 | -6.0 | -11.7 | -19.4 | 0.20 |
| 84044 | 746 | 720 | 706 | 688 | 691 | 639 | 569 | 746 | -3.4 | -5.3 | -7.8 | -7.4 | -14.3 | -23.7 | 0.03 |

Table A.2. Variations in average daily temperature ($^{o}$C) for all climate stations within the North-East CMA region under various climate scenarios. Also shown are the corresponding change in average daily temperature relative to the 1990 (Null) condition.

| | Null | 2030Low | 2030Med | 2030High | 2070Low | 2070Med | 2070High | Hist 1935-1990 | 2030Low Delta T | 2030Med Delta T | 2030High Delta T | 2070Low Delta T | 2070Med Delta T | 2070High Delta T | Hist Delta T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 81004 | 14.64 | 15.26 | 15.62 | 16.07 | 15.99 | 17.27 | 18.99 | 14.66 | 0.62 | 0.98 | 1.43 | 1.35 | 2.63 | 4.34 | 0.020 |
| 81055 | 15.54 | 16.20 | 16.58 | 17.05 | 16.97 | 18.33 | 20.14 | 15.56 | 0.66 | 1.04 | 1.51 | 1.43 | 2.78 | 4.60 | 0.016 |
| 81057 | 15.70 | 16.36 | 16.74 | 17.21 | 17.13 | 18.48 | 20.30 | 15.72 | 0.66 | 1.04 | 1.51 | 1.43 | 2.78 | 4.60 | 0.016 |
| 82000 | 15.03 | 15.69 | 16.06 | 16.53 | 16.45 | 17.79 | 19.59 | 15.05 | 0.65 | 1.03 | 1.50 | 1.42 | 2.75 | 4.56 | 0.017 |
| 82001 | 12.99 | 13.61 | 13.97 | 14.42 | 14.34 | 15.61 | 17.32 | 13.02 | 0.62 | 0.98 | 1.43 | 1.35 | 2.62 | 4.33 | 0.032 |
| 82006 | 15.30 | 15.96 | 16.33 | 16.80 | 16.72 | 18.06 | 19.86 | 15.32 | 0.65 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.016 |
| 82008 | 11.56 | 12.14 | 12.48 | 12.90 | 12.82 | 14.02 | 15.63 | 11.64 | 0.58 | 0.92 | 1.34 | 1.26 | 2.46 | 4.08 | 0.080 |
| 82009 | 12.98 | 13.60 | 13.95 | 14.40 | 14.32 | 15.60 | 17.31 | 13.02 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.039 |
| 82010 | 14.81 | 15.47 | 15.84 | 16.31 | 16.23 | 17.57 | 19.37 | 14.83 | 0.65 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.015 |
| 82011 | 13.87 | 14.48 | 14.83 | 15.27 | 15.19 | 16.43 | 18.10 | 13.97 | 0.61 | 0.95 | 1.39 | 1.31 | 2.56 | 4.23 | 0.093 |
| 82015 | 14.73 | 15.35 | 15.71 | 16.15 | 16.08 | 17.35 | 19.07 | 14.75 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.022 |
| 82017 | 14.55 | 15.17 | 15.53 | 15.97 | 15.90 | 17.17 | 18.88 | 14.58 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.33 | 0.027 |
| 82018 | 12.71 | 13.28 | 13.61 | 14.02 | 13.95 | 15.13 | 16.71 | 12.81 | 0.57 | 0.90 | 1.31 | 1.24 | 2.42 | 4.00 | 0.102 |
| 82021 | 14.99 | 15.64 | 16.02 | 16.49 | 16.41 | 17.75 | 19.55 | 15.00 | 0.66 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.014 |
| 82022 | 14.65 | 15.26 | 15.60 | 16.04 | 15.96 | 17.19 | 18.85 | 14.71 | 0.60 | 0.95 | 1.38 | 1.30 | 2.53 | 4.20 | 0.053 |
| 82024 | 12.56 | 13.19 | 13.55 | 14.00 | 13.92 | 15.21 | 16.94 | 12.64 | 0.63 | 0.99 | 1.44 | 1.36 | 2.64 | 4.37 | 0.072 |
| 82026 | 12.94 | 13.52 | 13.86 | 14.28 | 14.21 | 15.40 | 17.02 | 13.03 | 0.58 | 0.92 | 1.34 | 1.27 | 2.46 | 4.08 | 0.091 |
| 82028 | 14.44 | 15.09 | 15.45 | 15.92 | 15.83 | 17.15 | 18.92 | 14.47 | 0.64 | 1.01 | 1.47 | 1.39 | 2.71 | 4.47 | 0.028 |
| 82029 | 14.72 | 15.35 | 15.70 | 16.15 | 16.07 | 17.35 | 19.06 | 14.75 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.029 |
| 82032 | 14.77 | 15.39 | 15.75 | 16.20 | 16.12 | 17.39 | 19.11 | 14.81 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.33 | 0.034 |
| 82034 | 14.45 | 15.07 | 15.42 | 15.87 | 15.79 | 17.07 | 18.78 | 14.48 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.038 |
| 82035 | 13.26 | 13.86 | 14.20 | 14.63 | 14.56 | 15.79 | 17.45 | 13.36 | 0.60 | 0.94 | 1.37 | 1.30 | 2.53 | 4.19 | 0.101 |
| 82038 | 15.17 | 15.82 | 16.20 | 16.67 | 16.59 | 17.93 | 19.73 | 15.18 | 0.65 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.008 |
| 82039 | 14.79 | 15.44 | 15.81 | 16.28 | 16.20 | 17.54 | 19.35 | 14.49 | 0.66 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | -0.298 |
| 82040 | 15.32 | 15.98 | 16.35 | 16.82 | 16.74 | 18.08 | 19.88 | 15.33 | 0.66 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.006 |
| 82041 | 14.88 | 15.54 | 15.91 | 16.38 | 16.30 | 17.64 | 19.45 | 14.90 | 0.65 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.017 |
| 82044 | 14.45 | 15.05 | 15.40 | 15.83 | 15.76 | 16.99 | 18.65 | 14.52 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.19 | 0.065 |
| 82045 | 14.96 | 15.60 | 15.97 | 16.43 | 16.35 | 17.67 | 19.43 | 15.02 | 0.64 | 1.01 | 1.47 | 1.39 | 2.70 | 4.47 | 0.058 |
| 82046 | 15.09 | 15.73 | 16.10 | 16.56 | 16.48 | 17.79 | 19.56 | 15.13 | 0.64 | 1.01 | 1.47 | 1.39 | 2.71 | 4.47 | 0.042 |
| 82047 | 14.51 | 15.14 | 15.50 | 15.95 | 15.87 | 17.15 | 18.89 | 14.59 | 0.63 | 0.99 | 1.44 | 1.36 | 2.64 | 4.38 | 0.079 |
| 82051 | 15.46 | 16.11 | 16.49 | 16.96 | 16.88 | 18.22 | 20.02 | 15.46 | 0.65 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.002 |
| 82052 | 14.54 | 15.17 | 15.53 | 15.98 | 15.90 | 17.19 | 18.92 | 14.63 | 0.63 | 0.99 | 1.44 | 1.36 | 2.64 | 4.38 | 0.088 |
| 82053 | 15.16 | 15.78 | 16.13 | 16.58 | 16.50 | 17.78 | 19.49 | 15.19 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.030 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82055 | 14.64 | 15.26 | 15.62 | 16.07 | 15.99 | 17.26 | 18.98 | 14.67 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.032 |
| 82056 | 15.02 | 15.66 | 16.03 | 16.49 | 16.41 | 17.72 | 19.49 | 15.04 | 0.64 | 1.01 | 1.47 | 1.39 | 2.70 | 4.47 | 0.025 |
| 82057 | 13.86 | 14.48 | 14.84 | 15.28 | 15.21 | 16.48 | 18.19 | 13.89 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.33 | 0.027 |
| 82058 | 14.06 | 14.66 | 15.00 | 15.44 | 15.36 | 16.59 | 18.25 | 14.09 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.19 | 0.030 |
| 82059 | 11.82 | 12.42 | 12.76 | 13.19 | 13.12 | 14.35 | 16.01 | 11.86 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.20 | 0.039 |
| 82066 | 13.86 | 14.47 | 14.82 | 15.25 | 15.17 | 16.42 | 18.09 | 13.95 | 0.61 | 0.96 | 1.39 | 1.31 | 2.56 | 4.23 | 0.092 |
| 82068 | 13.93 | 14.51 | 14.85 | 15.27 | 15.19 | 16.39 | 18.00 | 13.99 | 0.59 | 0.92 | 1.34 | 1.27 | 2.46 | 4.07 | 0.066 |
| 82076 | 13.19 | 13.78 | 14.11 | 14.53 | 14.46 | 15.66 | 17.27 | 13.27 | 0.59 | 0.92 | 1.34 | 1.27 | 2.46 | 4.07 | 0.082 |
| 82088 | 14.44 | 15.08 | 15.45 | 15.91 | 15.83 | 17.15 | 18.92 | 14.47 | 0.64 | 1.01 | 1.47 | 1.39 | 2.70 | 4.47 | 0.026 |
| 82092 | 11.62 | 12.25 | 12.61 | 13.06 | 12.98 | 14.27 | 16.00 | 11.70 | 0.63 | 0.99 | 1.44 | 1.36 | 2.64 | 4.37 | 0.081 |
| 82098 | 14.21 | 14.83 | 15.19 | 15.64 | 15.56 | 16.84 | 18.55 | 14.24 | 0.62 | 0.98 | 1.43 | 1.35 | 2.63 | 4.35 | 0.031 |
| 82100 | 15.31 | 15.95 | 16.31 | 16.78 | 16.70 | 18.01 | 19.78 | 15.34 | 0.64 | 1.01 | 1.47 | 1.39 | 2.70 | 4.47 | 0.031 |
| 82117 | 13.70 | 14.34 | 14.71 | 15.17 | 15.09 | 16.40 | 18.17 | 12.90 | 0.64 | 1.01 | 1.47 | 1.39 | 2.70 | 4.47 | -0.797 |
| 82127 | 15.41 | 16.07 | 16.44 | 16.91 | 16.83 | 18.17 | 19.97 | 15.42 | 0.66 | 1.03 | 1.50 | 1.42 | 2.76 | 4.56 | 0.013 |
| 82137 | 13.87 | 14.49 | 14.85 | 15.30 | 15.22 | 16.49 | 18.21 | 13.90 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.025 |
| 82138 | 15.07 | 15.70 | 16.05 | 16.50 | 16.42 | 17.70 | 19.41 | 15.10 | 0.62 | 0.98 | 1.43 | 1.35 | 2.62 | 4.34 | 0.027 |
| 83004 | 12.23 | 12.80 | 13.12 | 13.53 | 13.46 | 14.62 | 16.19 | 12.30 | 0.57 | 0.89 | 1.30 | 1.23 | 2.40 | 3.96 | 0.072 |
| 83008 | 13.91 | 14.48 | 14.81 | 15.22 | 15.14 | 16.31 | 17.88 | 13.95 | 0.57 | 0.90 | 1.31 | 1.23 | 2.40 | 3.97 | 0.045 |
| 83010 | 14.23 | 14.83 | 15.18 | 15.61 | 15.53 | 16.76 | 18.42 | 14.28 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.19 | 0.047 |
| 83012 | 12.26 | 12.83 | 13.16 | 13.56 | 13.49 | 14.66 | 16.22 | 12.33 | 0.57 | 0.89 | 1.30 | 1.23 | 2.39 | 3.96 | 0.071 |
| 83013 | 11.92 | 12.49 | 12.82 | 13.23 | 13.16 | 14.33 | 15.91 | 12.02 | 0.57 | 0.90 | 1.31 | 1.24 | 2.41 | 3.99 | 0.102 |
| 83014 | 6.11 | 6.68 | 7.01 | 7.41 | 7.34 | 8.51 | 10.07 | 6.22 | 0.57 | 0.90 | 1.30 | 1.23 | 2.40 | 3.96 | 0.112 |
| 83023 | 13.38 | 13.99 | 14.33 | 14.76 | 14.69 | 15.92 | 17.58 | 13.45 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.19 | 0.064 |
| 83024 | 9.22 | 9.79 | 10.11 | 10.52 | 10.45 | 11.62 | 13.19 | 9.31 | 0.57 | 0.90 | 1.30 | 1.23 | 2.40 | 3.97 | 0.093 |
| 83025 | 11.38 | 11.95 | 12.28 | 12.69 | 12.62 | 13.79 | 15.37 | 11.47 | 0.57 | 0.90 | 1.31 | 1.24 | 2.42 | 3.99 | 0.093 |
| 83029 | 12.87 | 13.44 | 13.77 | 14.18 | 14.11 | 15.27 | 16.84 | 12.92 | 0.57 | 0.90 | 1.31 | 1.23 | 2.40 | 3.97 | 0.043 |
| 83031 | 14.33 | 14.96 | 15.31 | 15.76 | 15.68 | 16.95 | 18.67 | 14.37 | 0.62 | 0.98 | 1.43 | 1.35 | 2.62 | 4.33 | 0.037 |
| 83032 | 11.19 | 11.76 | 12.09 | 12.50 | 12.43 | 13.59 | 15.16 | 11.25 | 0.57 | 0.90 | 1.31 | 1.23 | 2.40 | 3.97 | 0.056 |
| 83037 | 6.91 | 7.48 | 7.82 | 8.22 | 8.15 | 9.33 | 10.91 | 7.02 | 0.57 | 0.90 | 1.31 | 1.24 | 2.42 | 4.00 | 0.106 |
| 83038 | 13.92 | 14.52 | 14.87 | 15.30 | 15.23 | 16.46 | 18.12 | 13.98 | 0.60 | 0.95 | 1.38 | 1.31 | 2.54 | 4.20 | 0.062 |
| 83067 | 12.76 | 13.36 | 13.71 | 14.14 | 14.06 | 15.29 | 16.96 | 12.82 | 0.60 | 0.95 | 1.38 | 1.30 | 2.53 | 4.20 | 0.058 |
| 83073 | 8.16 | 8.77 | 9.11 | 9.54 | 9.47 | 10.70 | 12.36 | 8.24 | 0.60 | 0.95 | 1.38 | 1.30 | 2.54 | 4.19 | 0.075 |
| 83083 | 14.20 | 14.82 | 15.17 | 15.62 | 15.54 | 16.82 | 18.53 | 14.24 | 0.62 | 0.98 | 1.42 | 1.35 | 2.62 | 4.34 | 0.039 |
| 83084 | 9.05 | 9.63 | 9.96 | 10.37 | 10.30 | 11.47 | 13.05 | 7.01 | 0.57 | 0.90 | 1.31 | 1.24 | 2.42 | 4.00 | -2.043 |
| 83085 | 6.15 | 6.72 | 7.05 | 7.45 | 7.38 | 8.55 | 10.11 | 6.26 | 0.57 | 0.89 | 1.30 | 1.23 | 2.40 | 3.96 | 0.114 |
| 84001 | 11.96 | 12.59 | 12.95 | 13.40 | 13.33 | 14.62 | 16.35 | 12.07 | 0.63 | 0.99 | 1.45 | 1.37 | 2.66 | 4.40 | 0.110 |
| 84037 | 12.23 | 12.81 | 13.13 | 13.54 | 13.48 | 14.65 | 16.23 | 12.34 | 0.57 | 0.90 | 1.31 | 1.24 | 2.42 | 3.99 | 0.105 |
| 84044 | 10.01 | 10.64 | 11.00 | 11.46 | 11.38 | 12.68 | 14.42 | 10.14 | 0.63 | 1.00 | 1.45 | 1.37 | 2.67 | 4.42 | 0.132 |

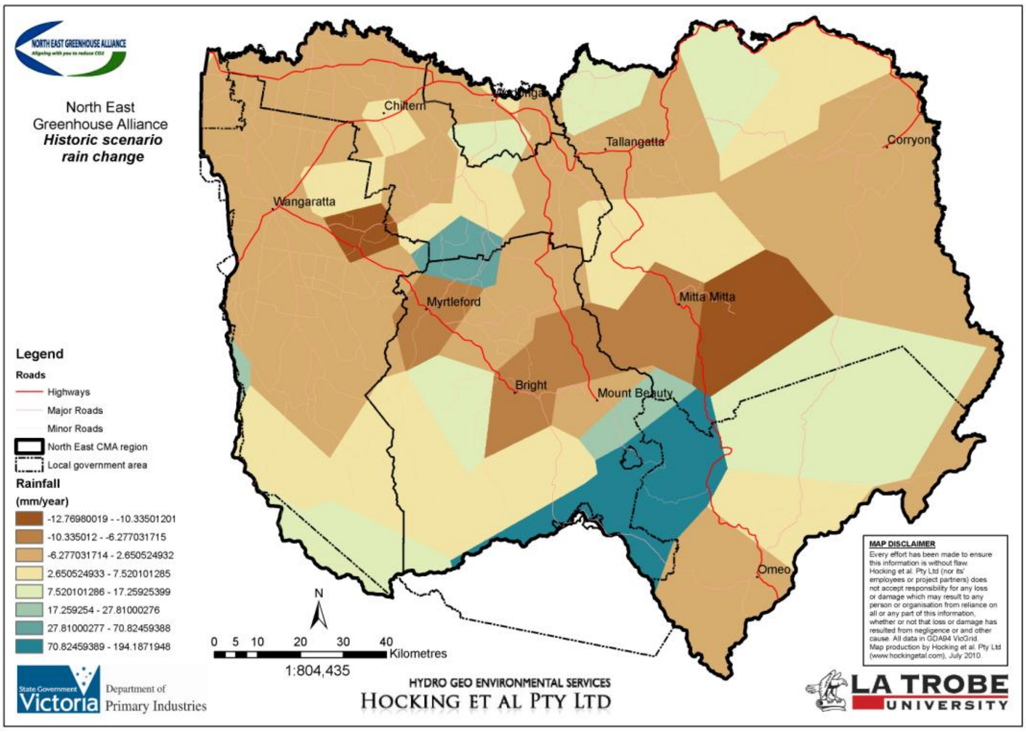


Figure A.1. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region.

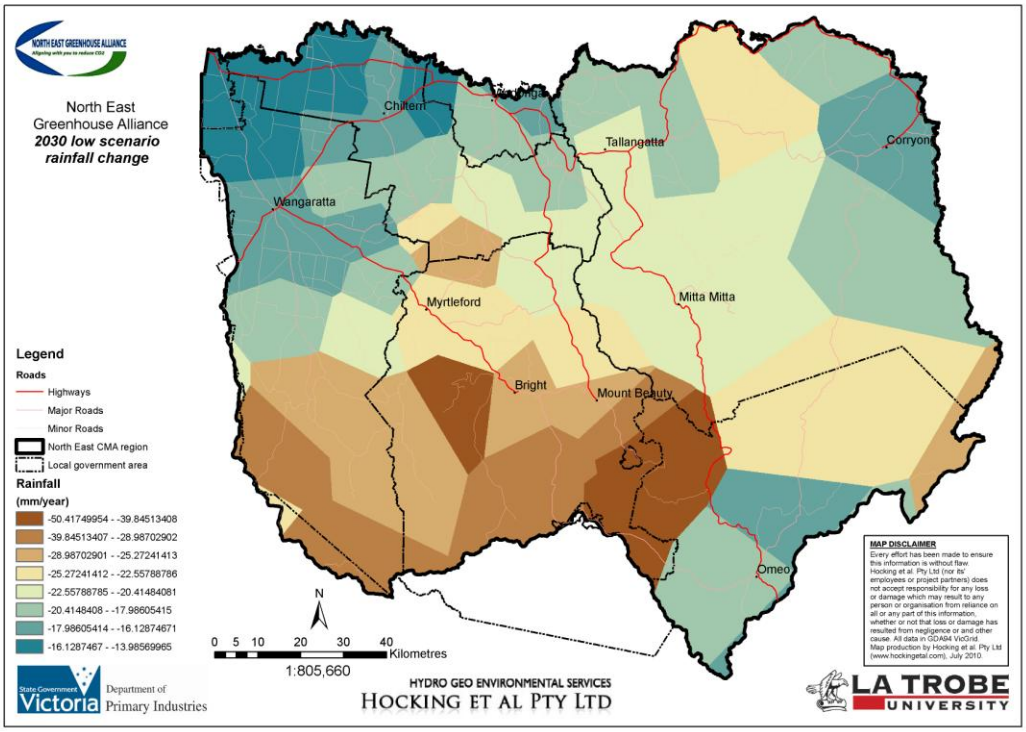


Figure A.2. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2030 low scenario.

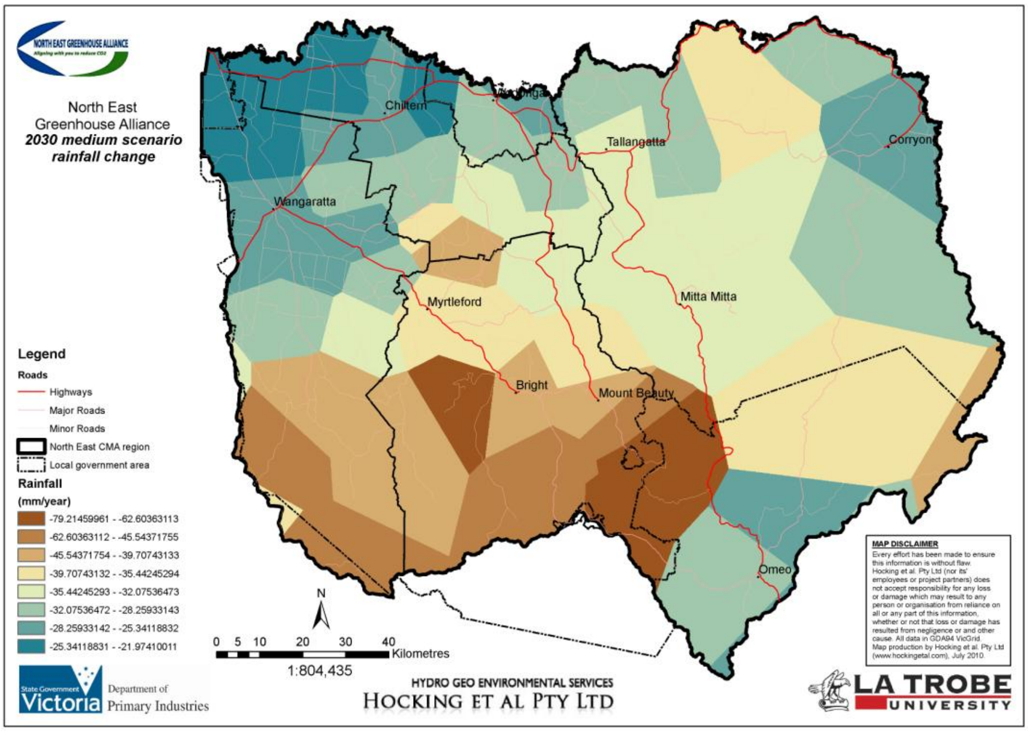


Figure A.3. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2030 medium scenario.

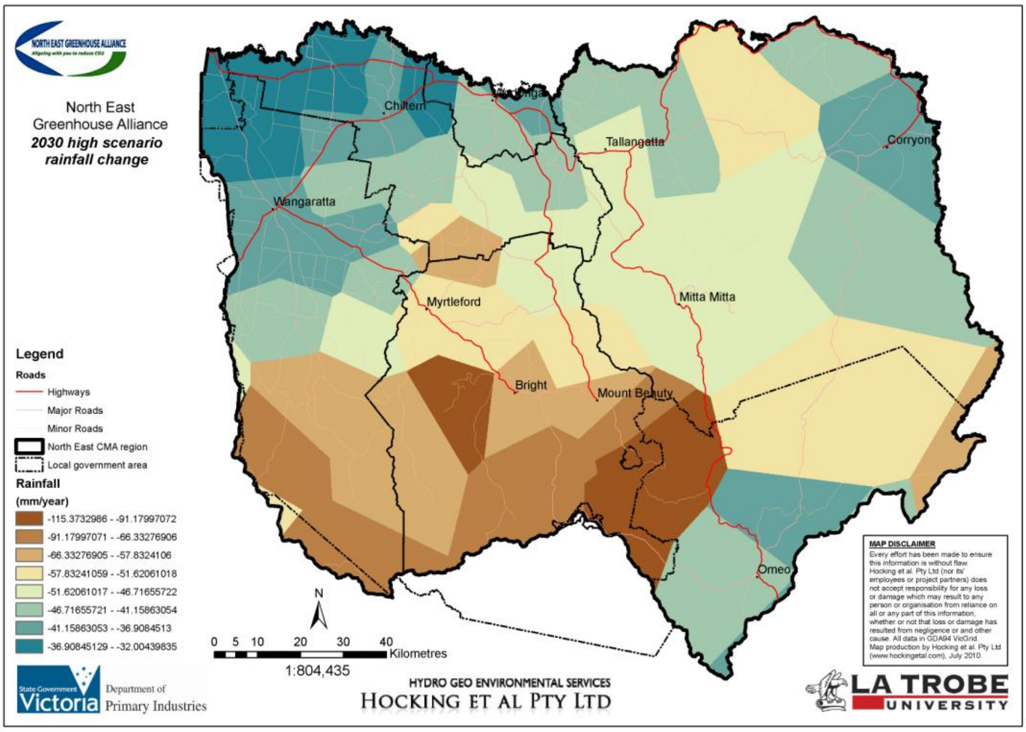


Figure A.4. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2030 high scenario.

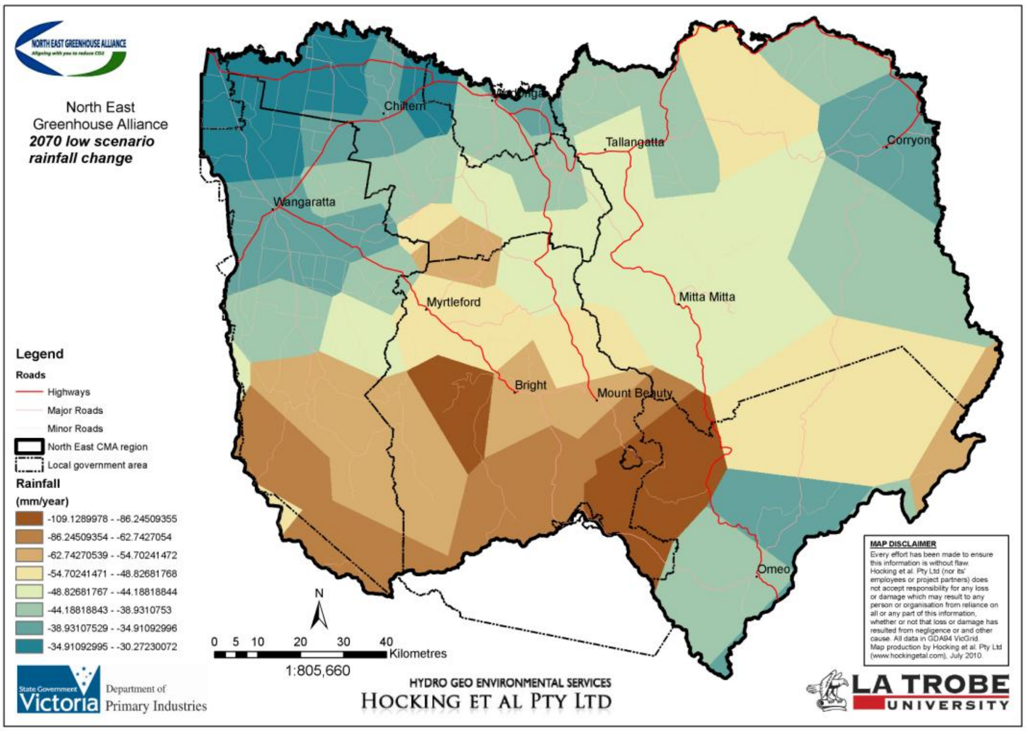


Figure A.5. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2070 low scenario.

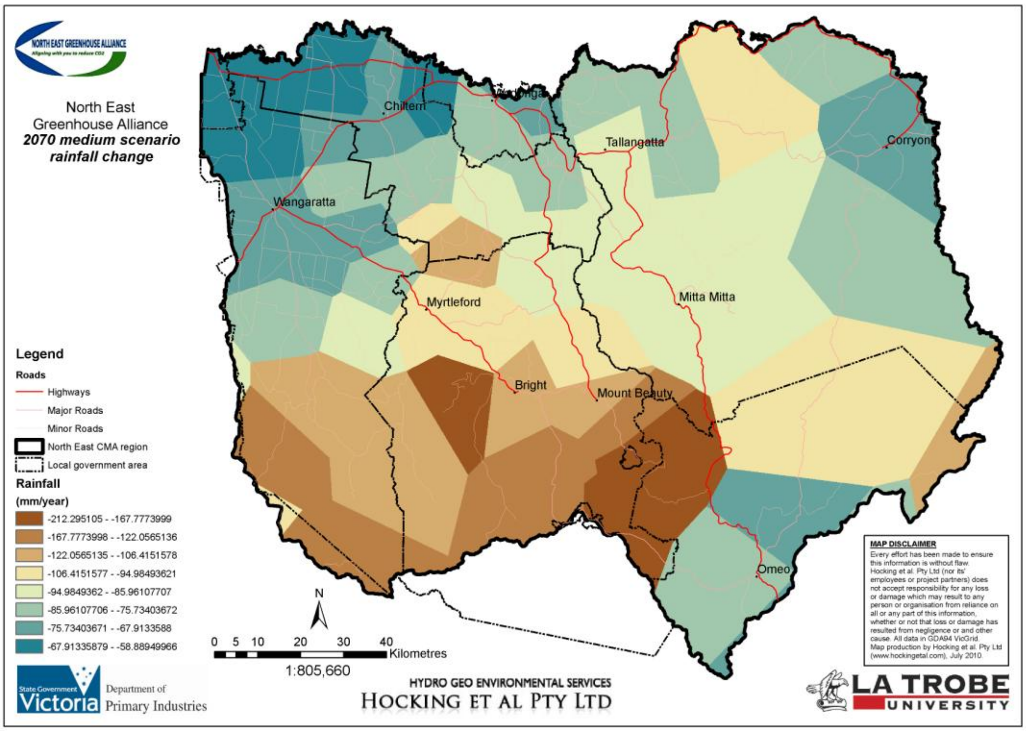


Figure A.6. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2070 medium scenario.

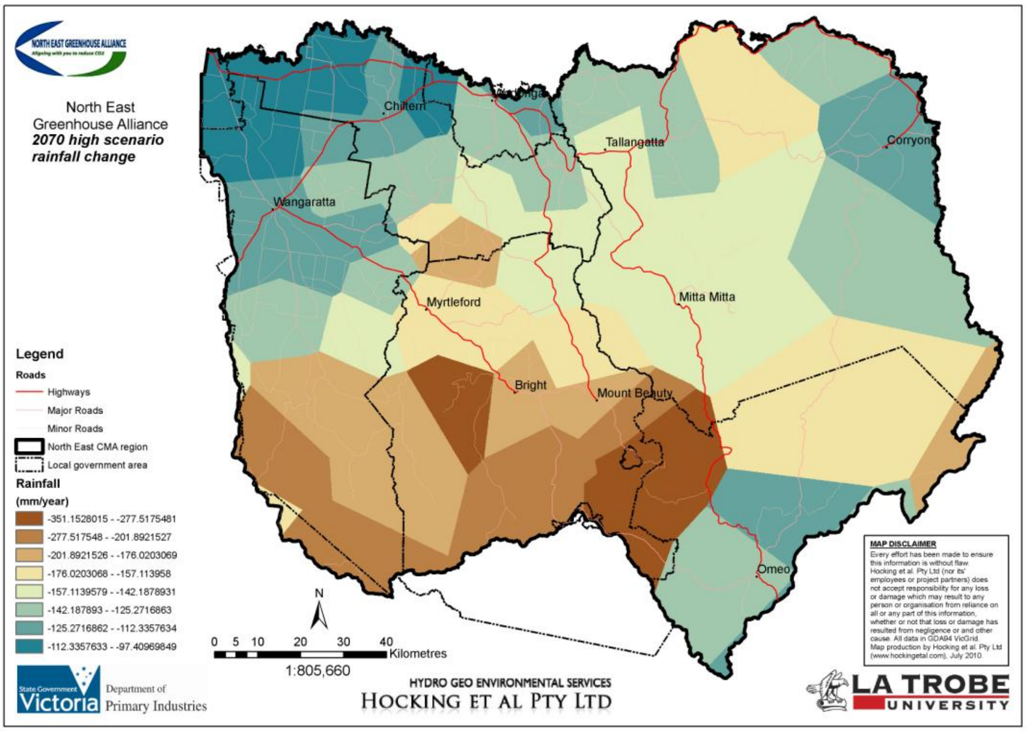


Figure A.7. Change in mean annual rainfall (mm/yr) relative to the 1990 mean annual rainfall for all climate stations within the North-East CMA region assuming the 2070 high scenario.

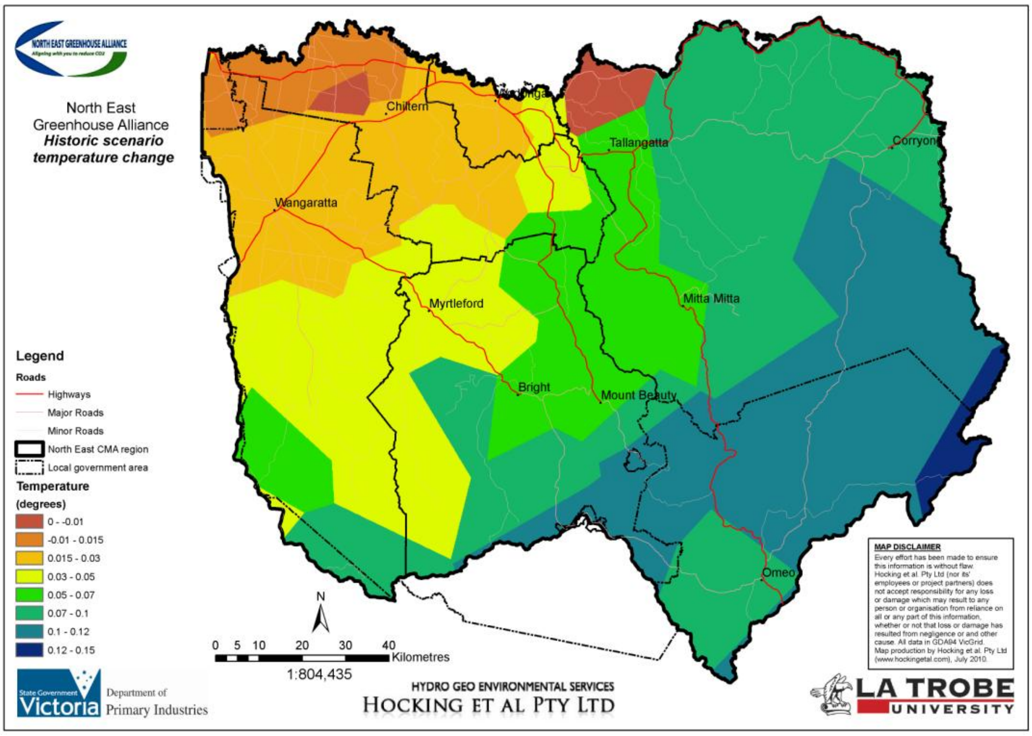


Figure A.8. Change in mean daily temperature ($^{o}$C) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the detrended 1990 scenario.

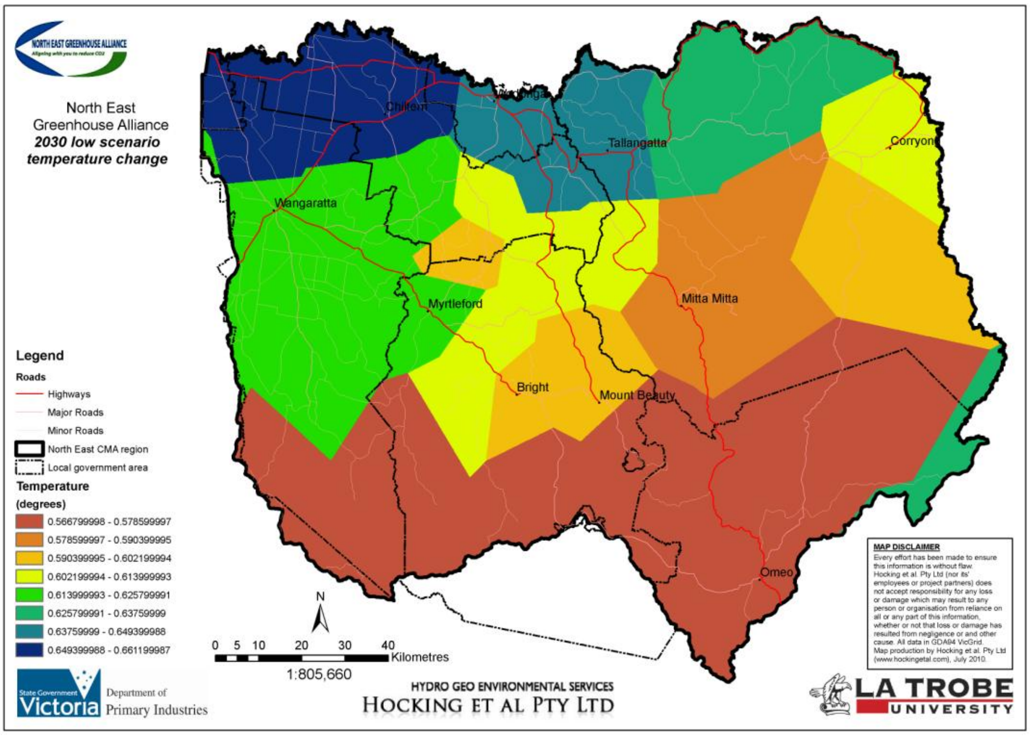


Figure A.9. Change in mean daily temperature ($^{o}C$) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2030 low scenario.

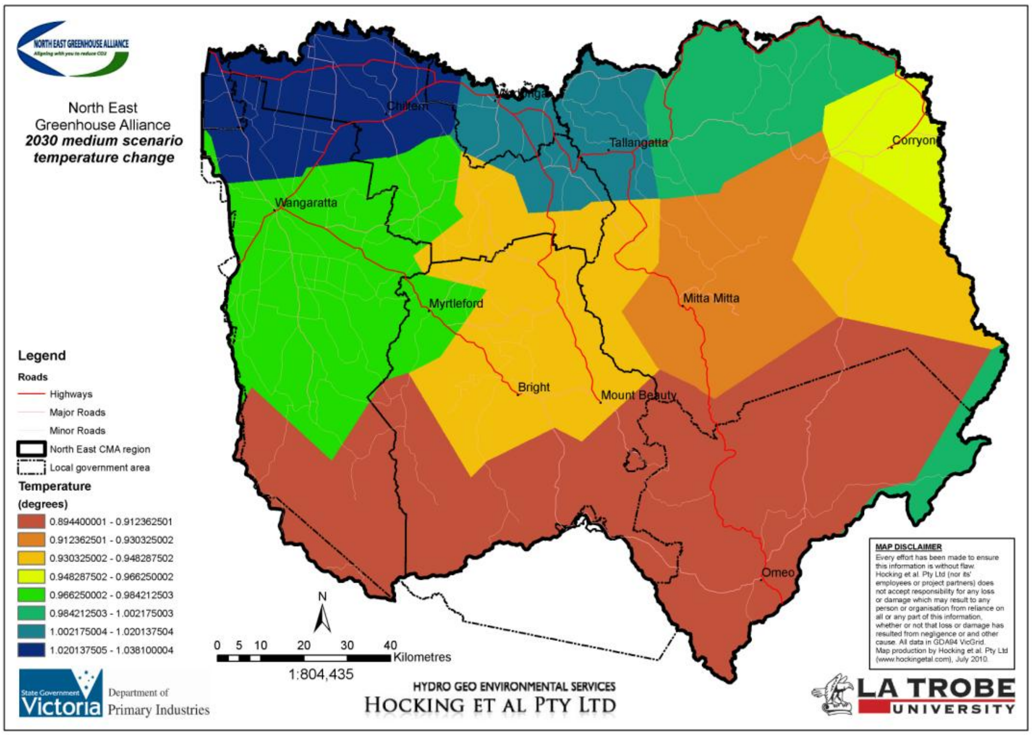


Figure A.10. Change in mean daily temperature ($^{o}C$) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2030 medium scenario.

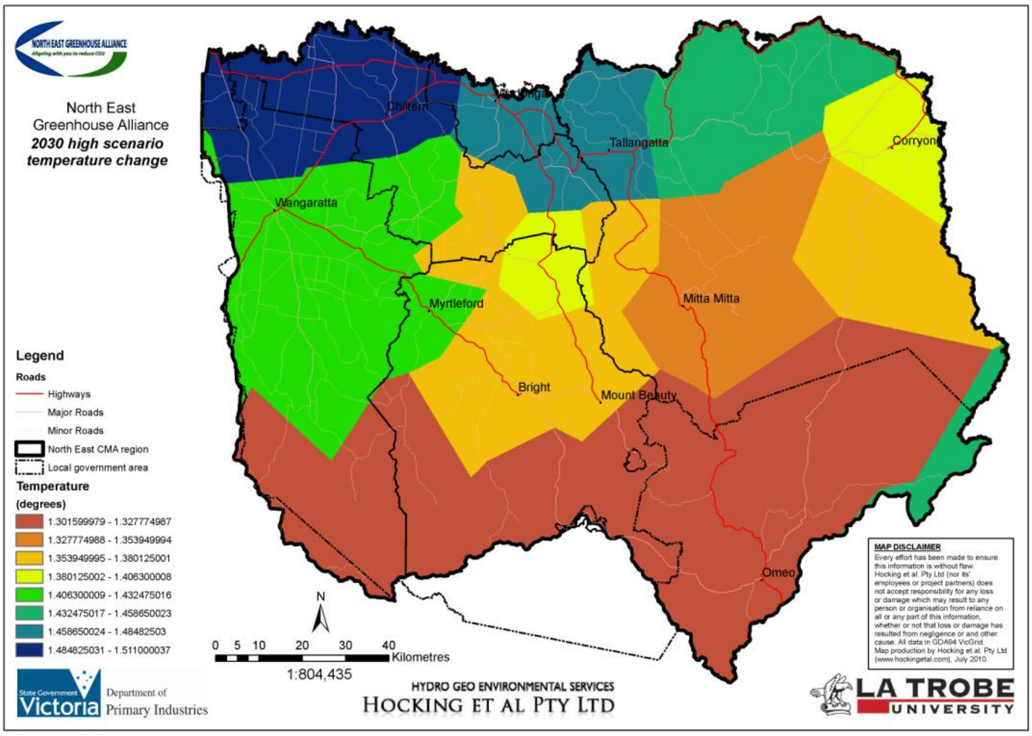


Figure A.11. Change in mean daily temperature ($^{o}$C) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2030 high scenario.

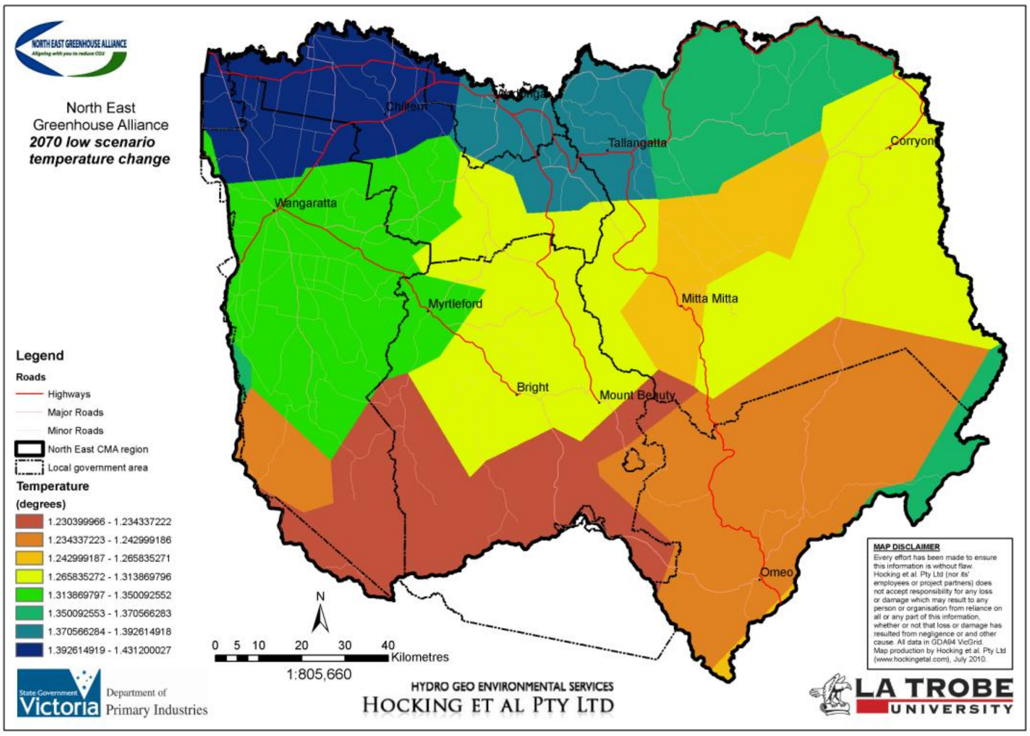


Figure A.12. Change in mean daily temperature ($^{o}$C) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2070 low scenario.

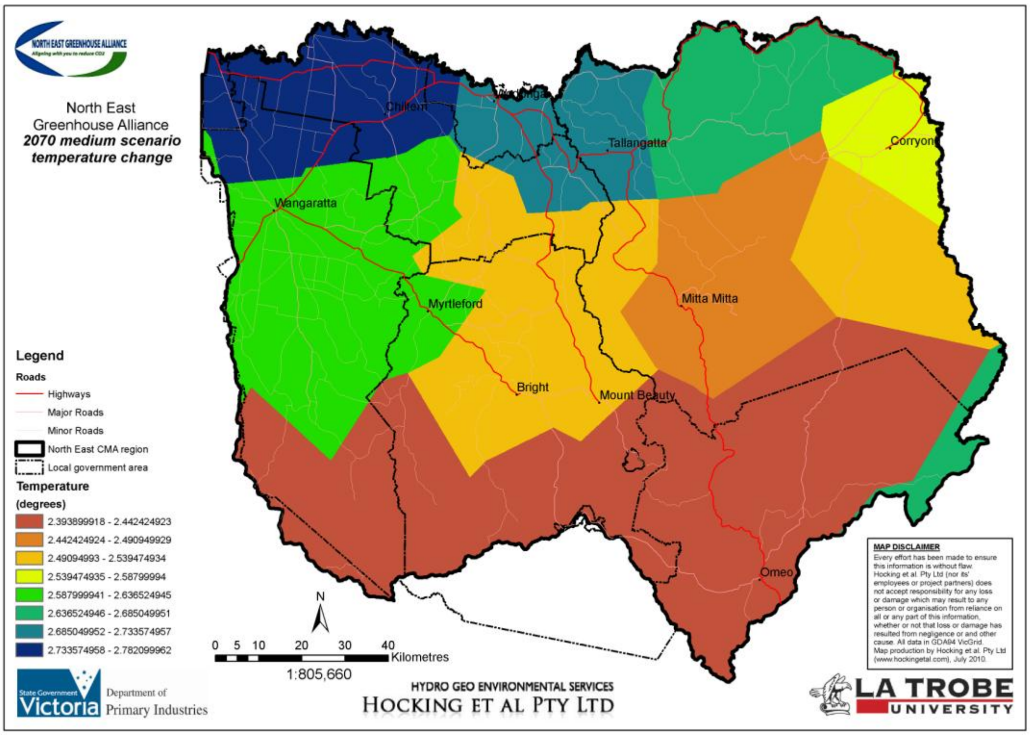


Figure A.13. Change in mean daily temperature ($^{o}$C) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2070 medium scenario.

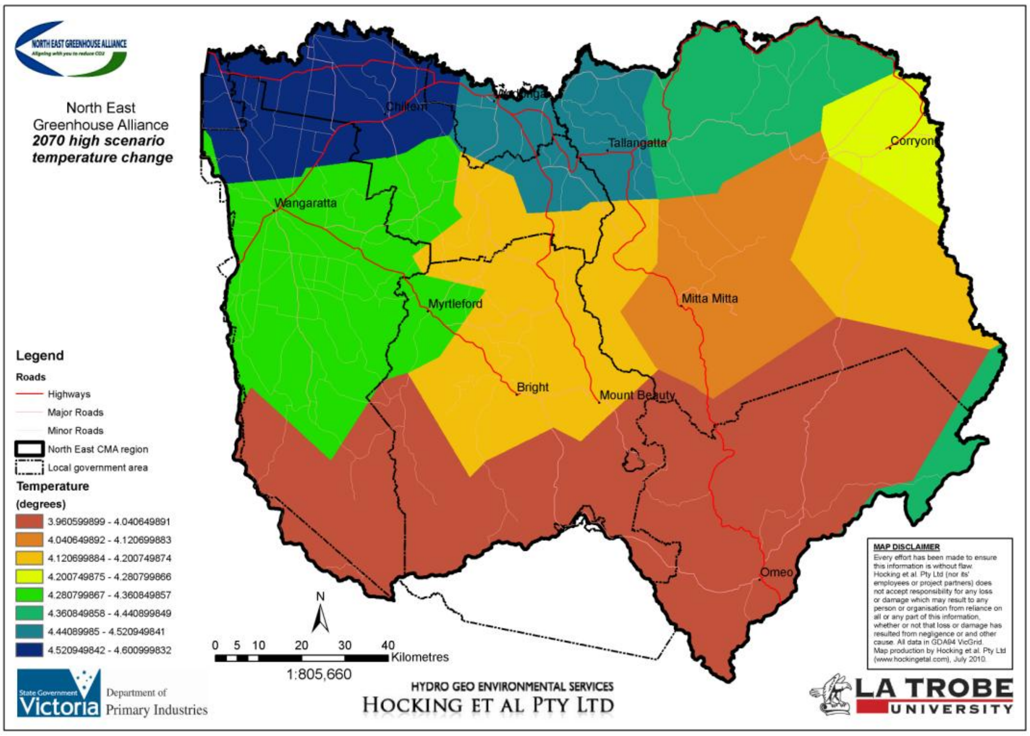


Figure A.14. Change in mean daily temperature ($^{o}$C) relative to the 1990 mean daily temperature for all climate stations within the North-East CMA region assuming the 2070 high scenario.

# Appendix B – Spatial data layers

This Appendix presents key spatial data sets that underpin the analysis used to estimate current and future water resources within the North-East CMA region of Victoria.

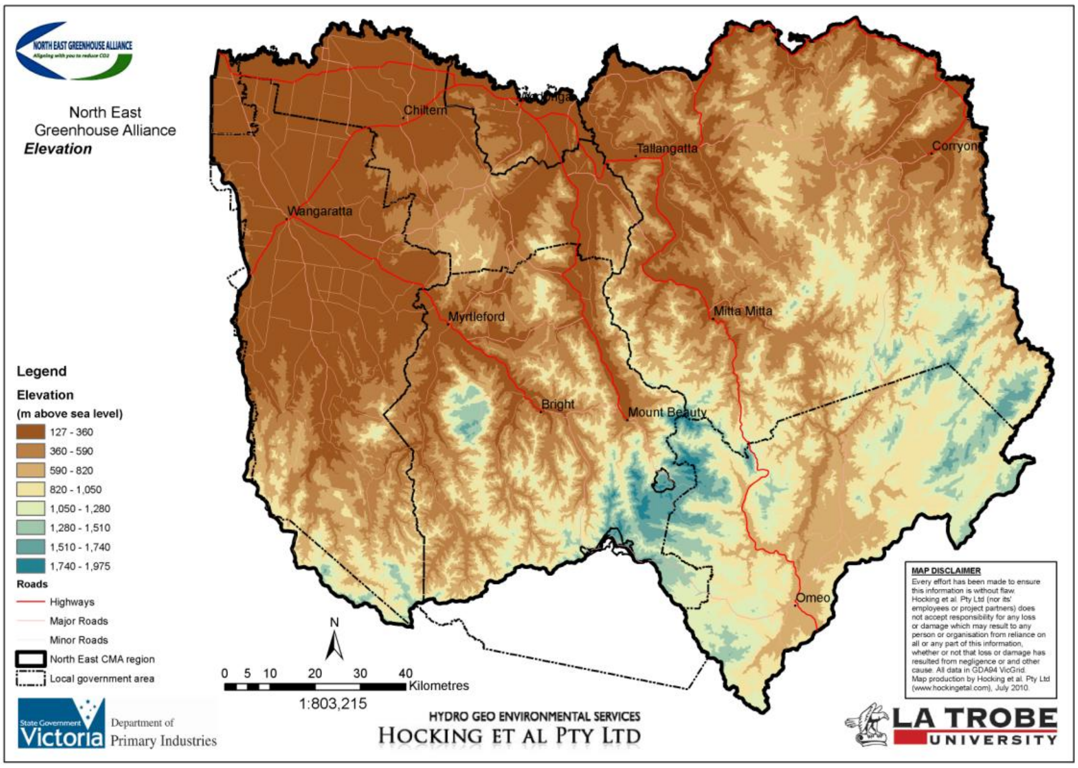


Figure B.1. Elevation (metres above sea level)

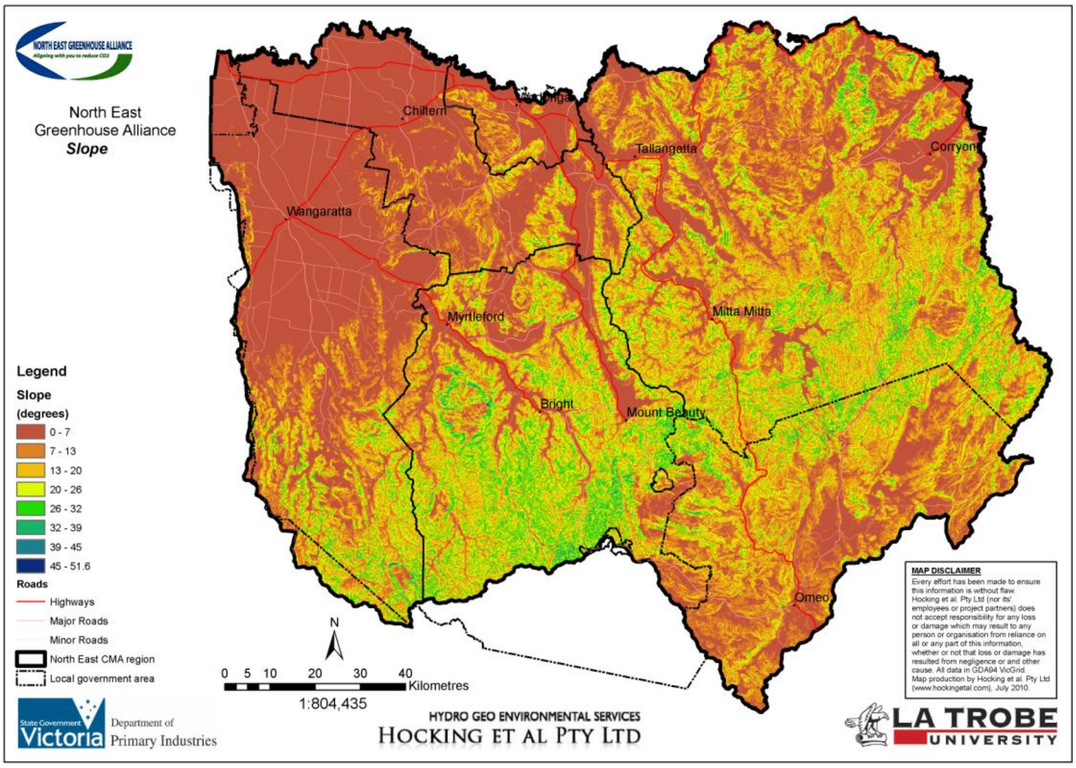


Figure B.2. Slope in degrees.

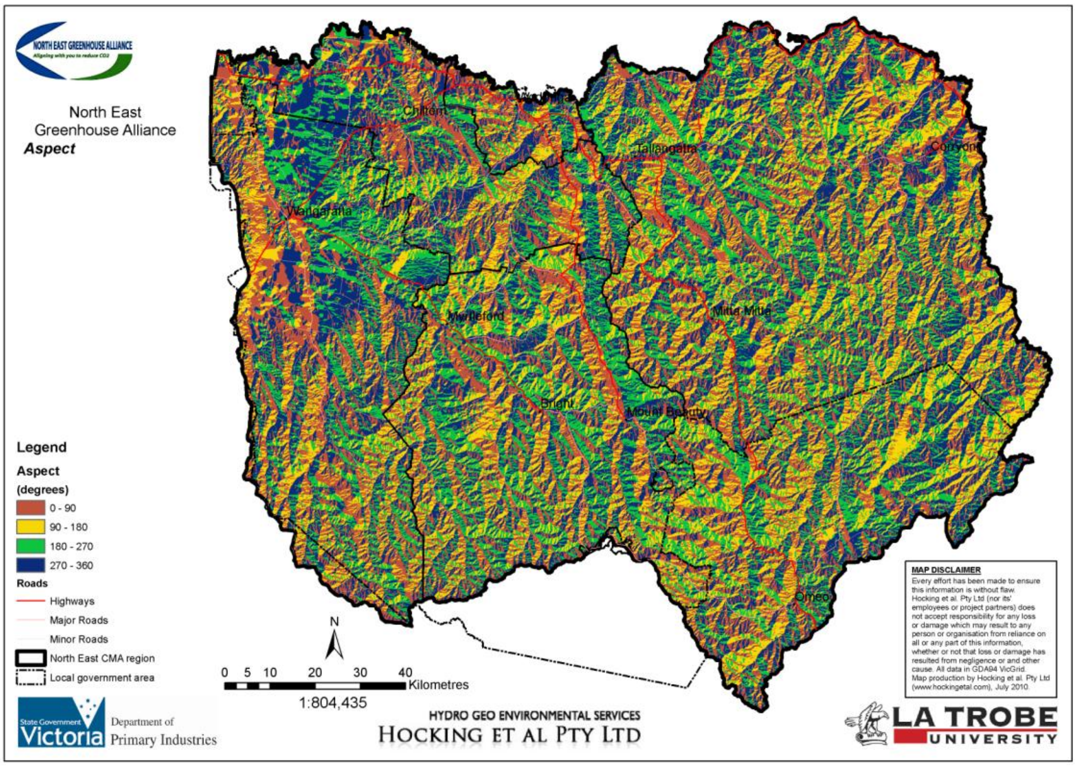


Figure B.3. Aspect in degrees.

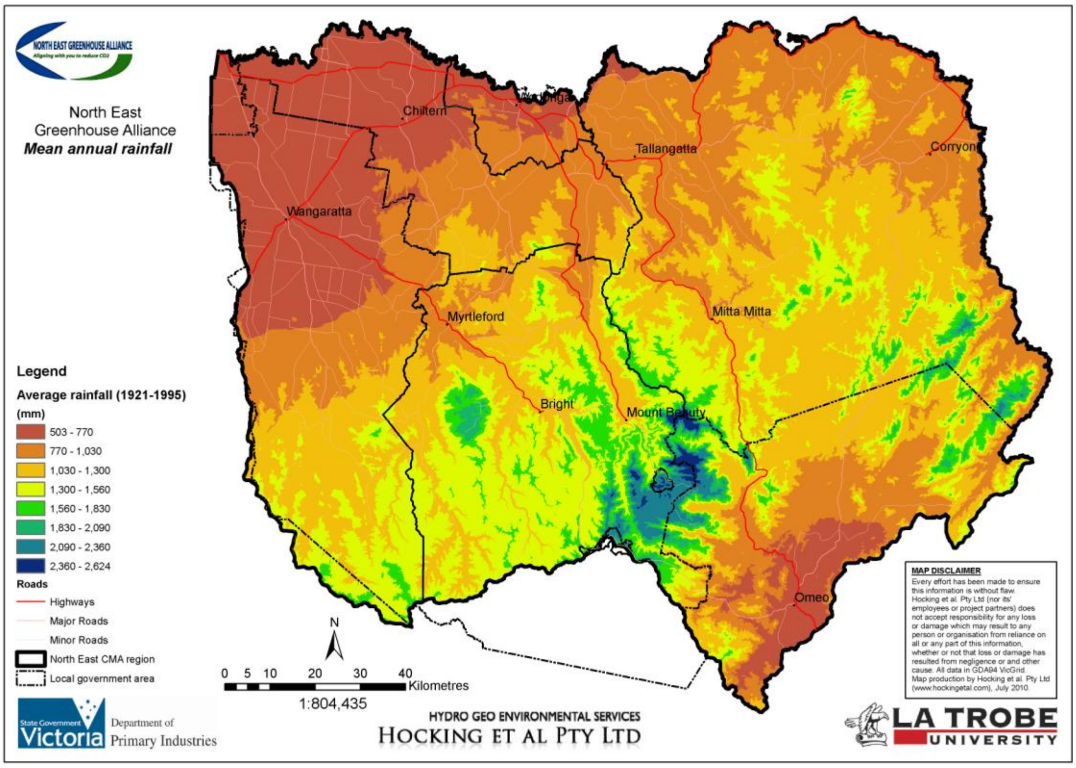


Figure B.4. Mean annual rainfall (mm/yr) for the period 1957-2005.

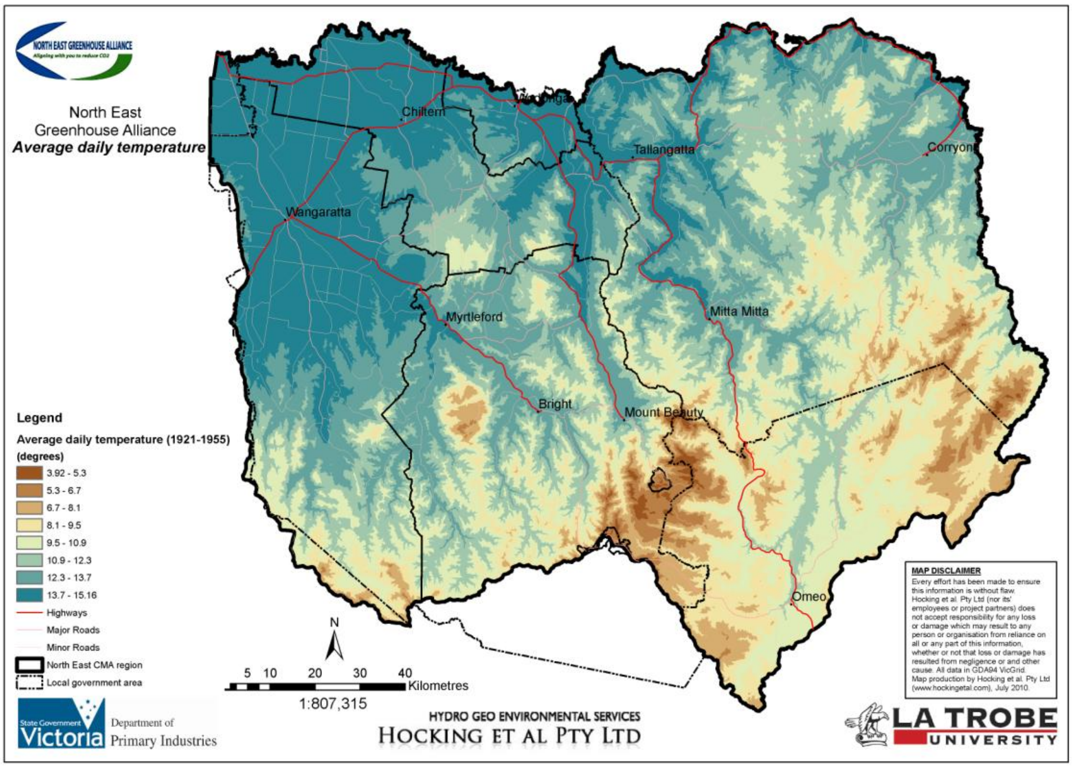


Figure B.5. Average daily temperature (oC) for the period 1957-2005.

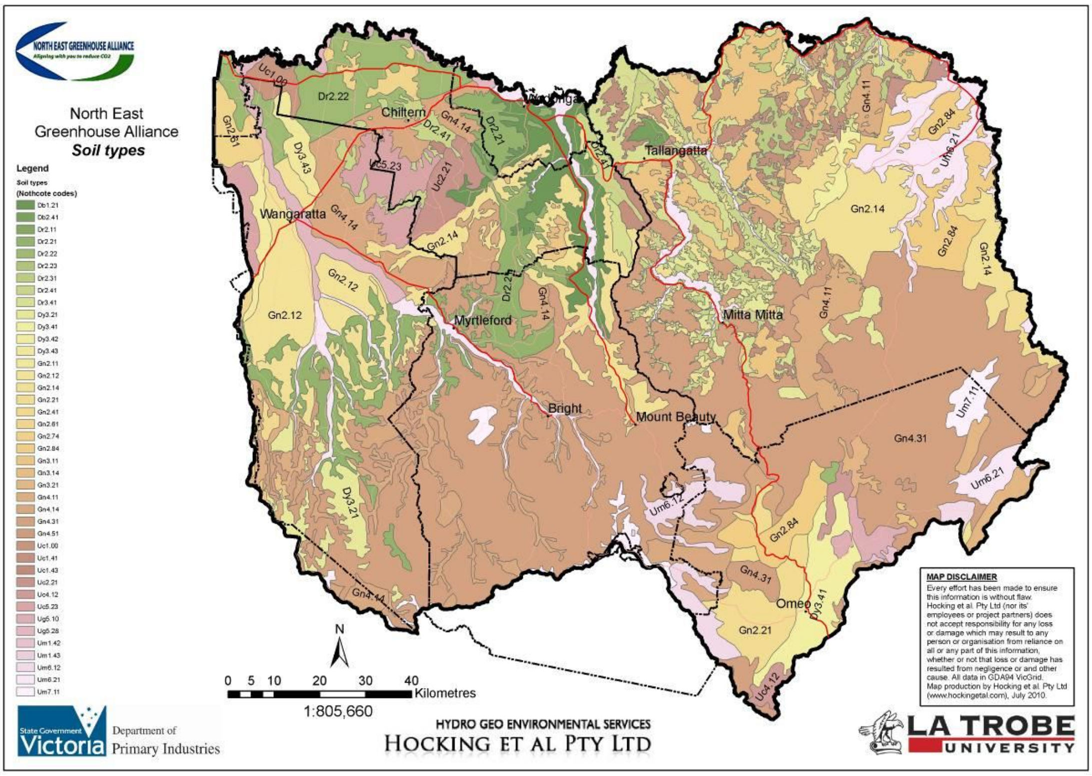


Figure B.6. Soil type classified to Northcote coding.

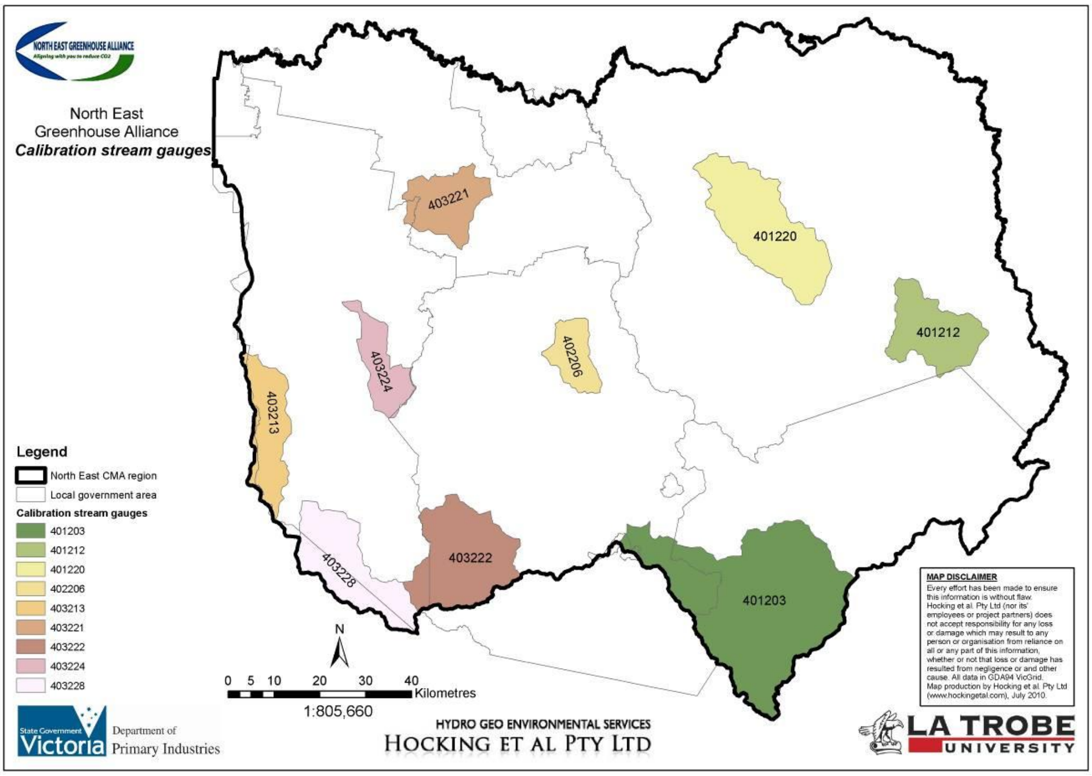


Figure B.7. Calibration surface water flow catchments.

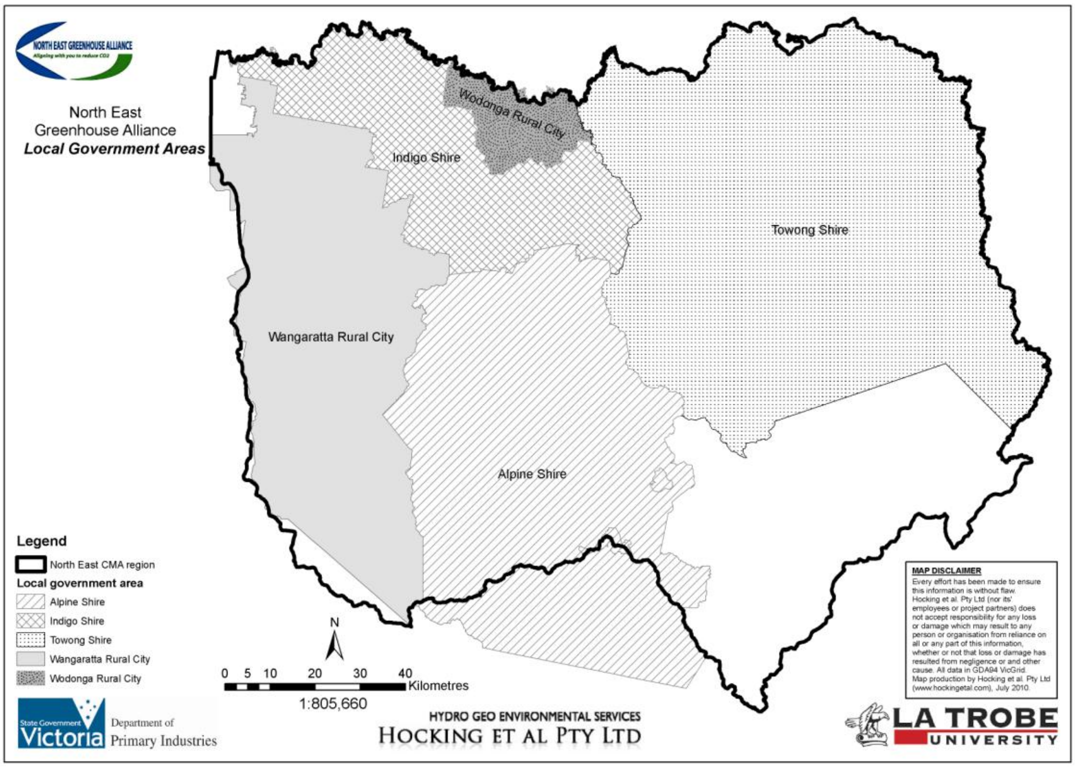


Figure B.8. Local Government Areas (LGA) within the North-East CMA region.

## Appendix C – Groundwater conceptualisation

This Appendix presents key spatial data sets that underpin the analysis used to estimate current and future groundwater resources within the North-East CMA region of Victoria. The conceptualisation of the complex groundwater interactions were developed by Hockingetal Pty Ltd, reviewed by independent consultants and subsequently adopted by the Victorian Department of Sustainability and Environment through the EcoMarkets project.

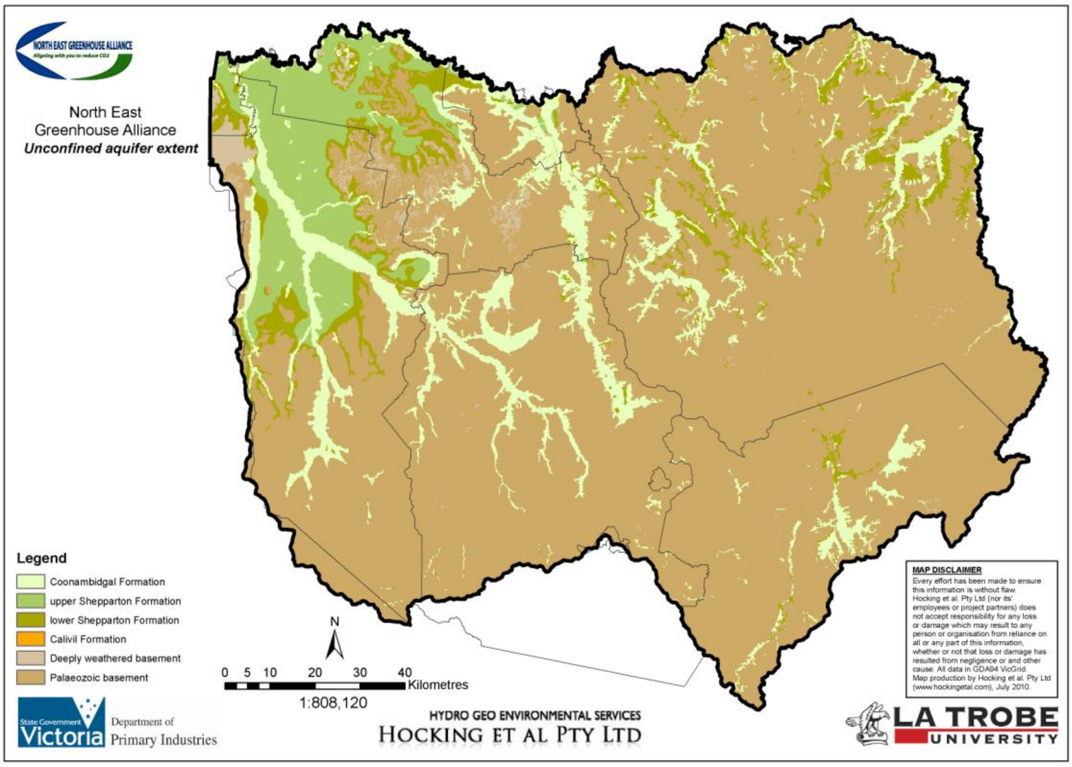


Figure C.1 Spatial extent of unconfined aquifers present in the North-East CMA groundwater model.

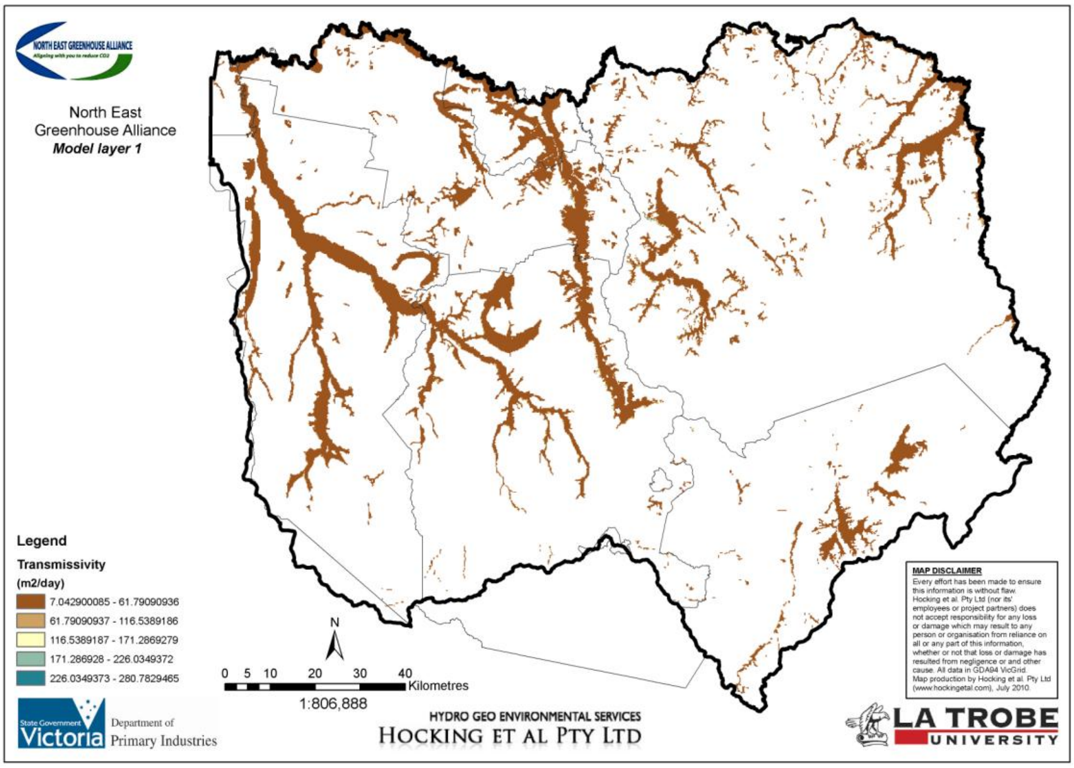


Figure C.2. Spatial extent of layer one adopted by the North-East CMA groundwater model.

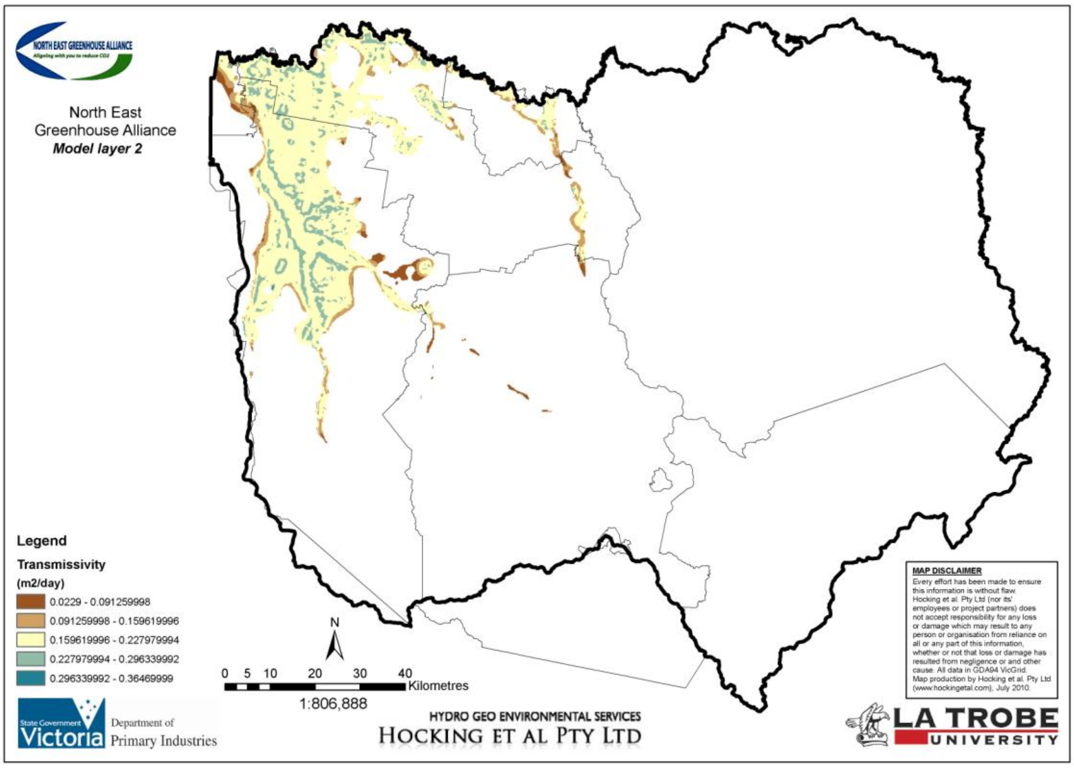


Figure C.3. Spatial extent of layer two adopted by the North-East CMA groundwater model.

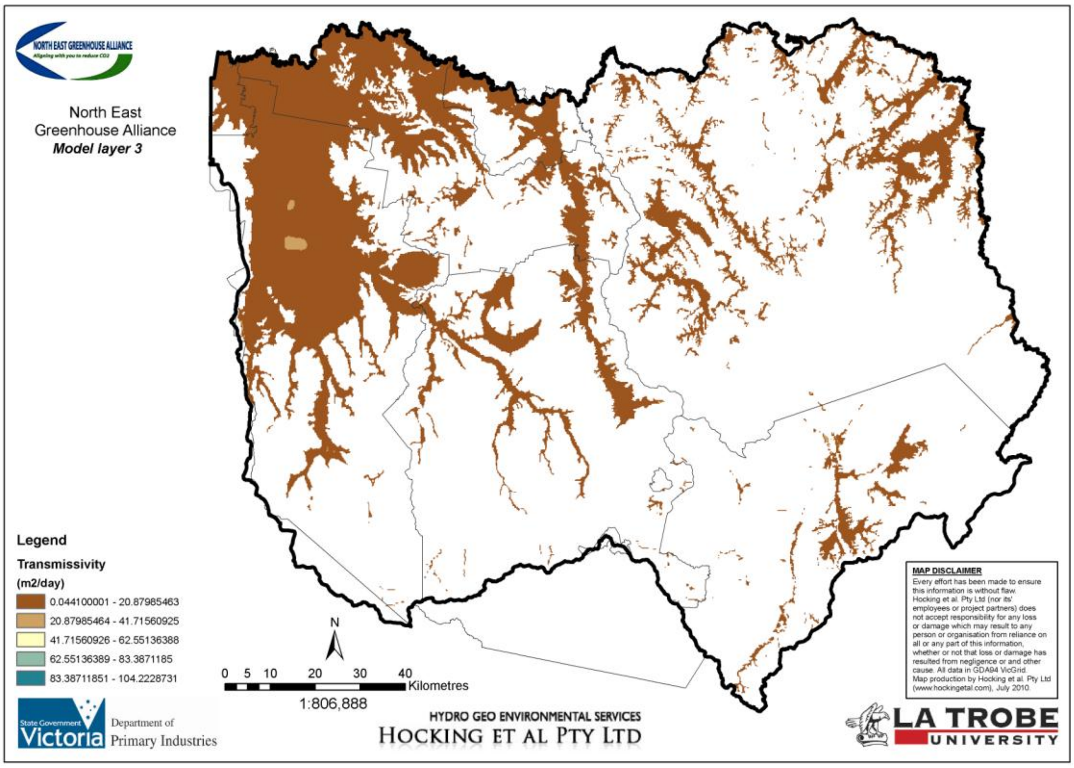


Figure C.4. Spatial extent of layer three adopted by the North-East CMA groundwater model.

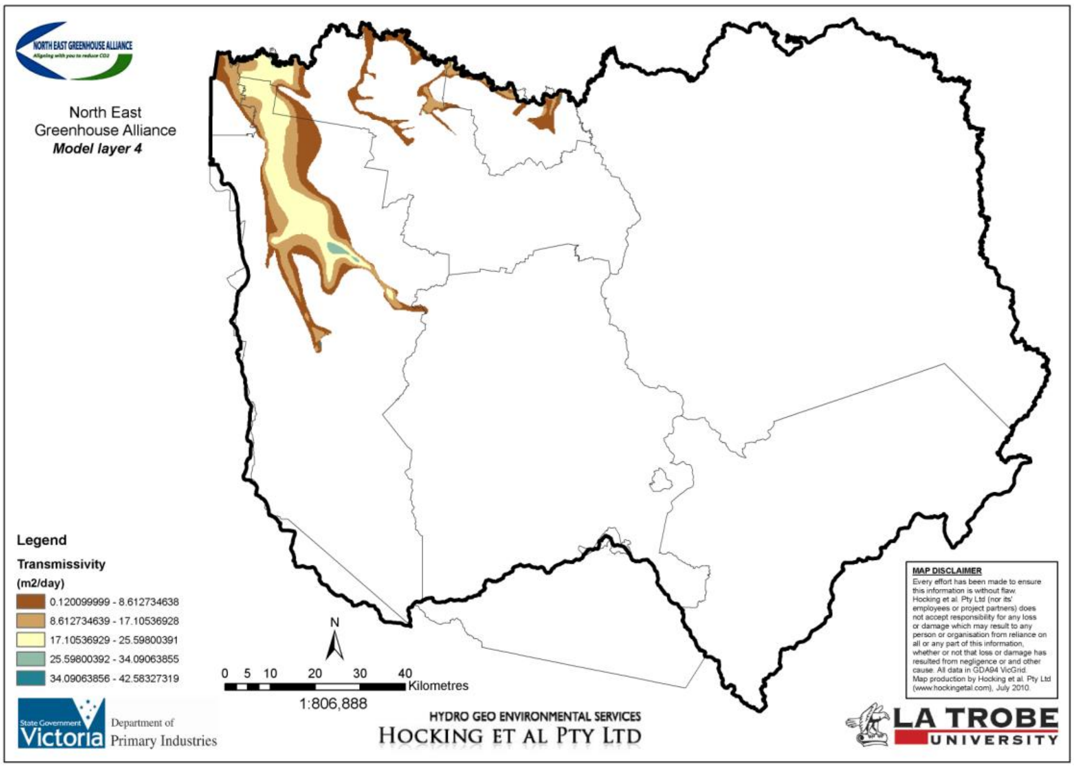


Figure C.5. Spatial extent of layer four adopted by the North-East CMA groundwater model.

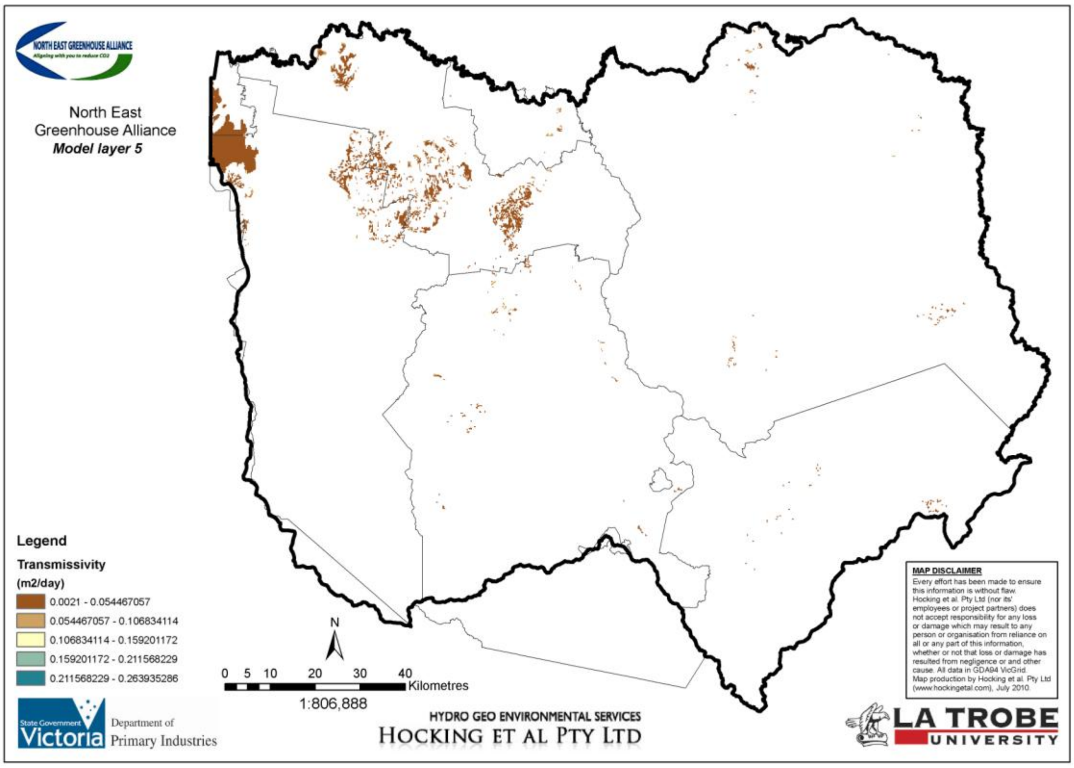


Figure C.6. Spatial extent of layer five adopted by the North-East CMA groundwater model.

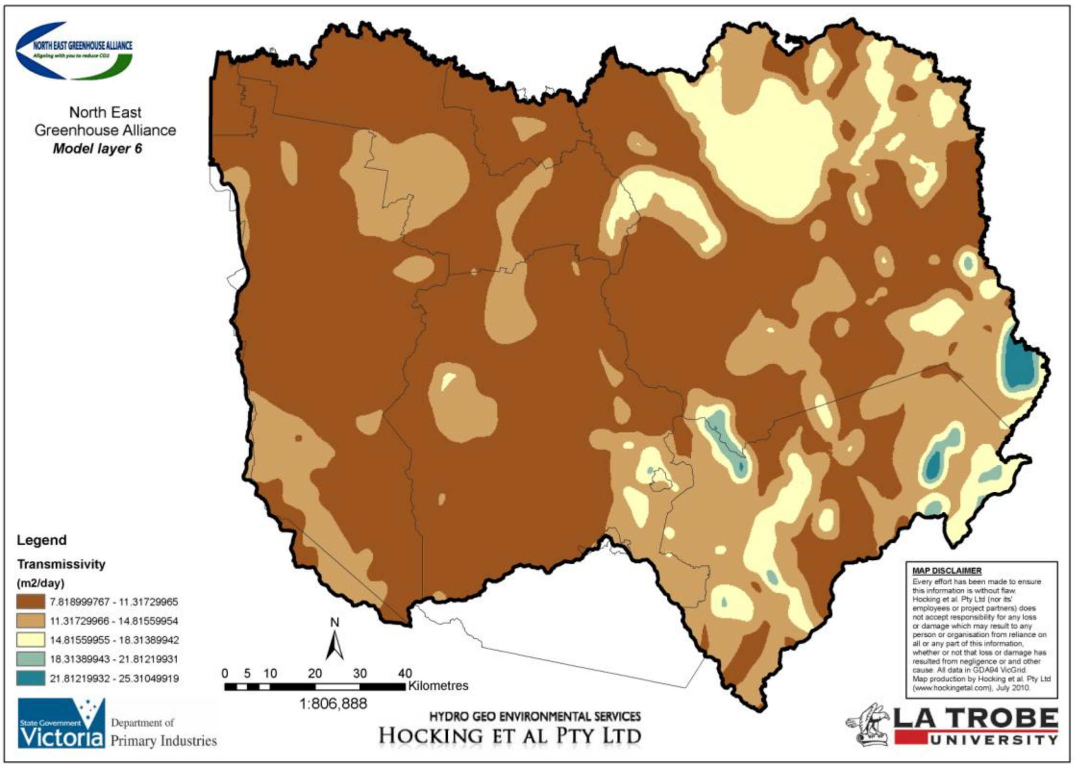


Figure C.7. Spatial extent of layer six adopted by the North-East CMA groundwater model.

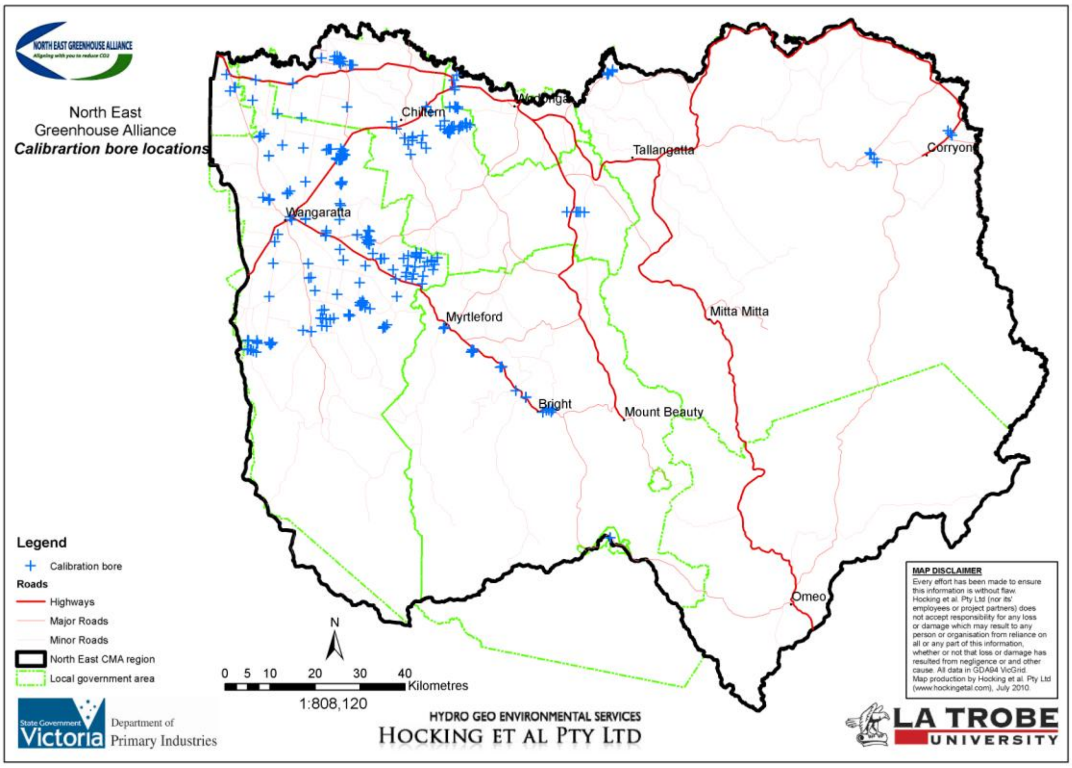


Figure C.8. Location of the groundwater bores used to calibrate by the North-East CMA groundwater model.

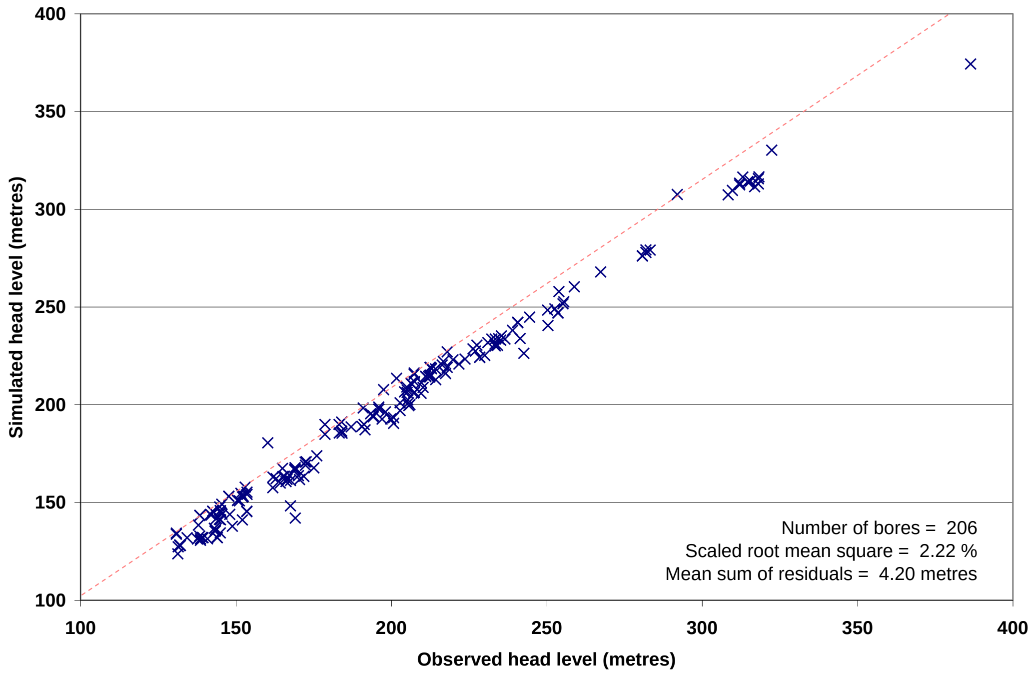


Figure C.8. Observed versus predicted groundwater elevations derived using the North-East CMA groundwater model.

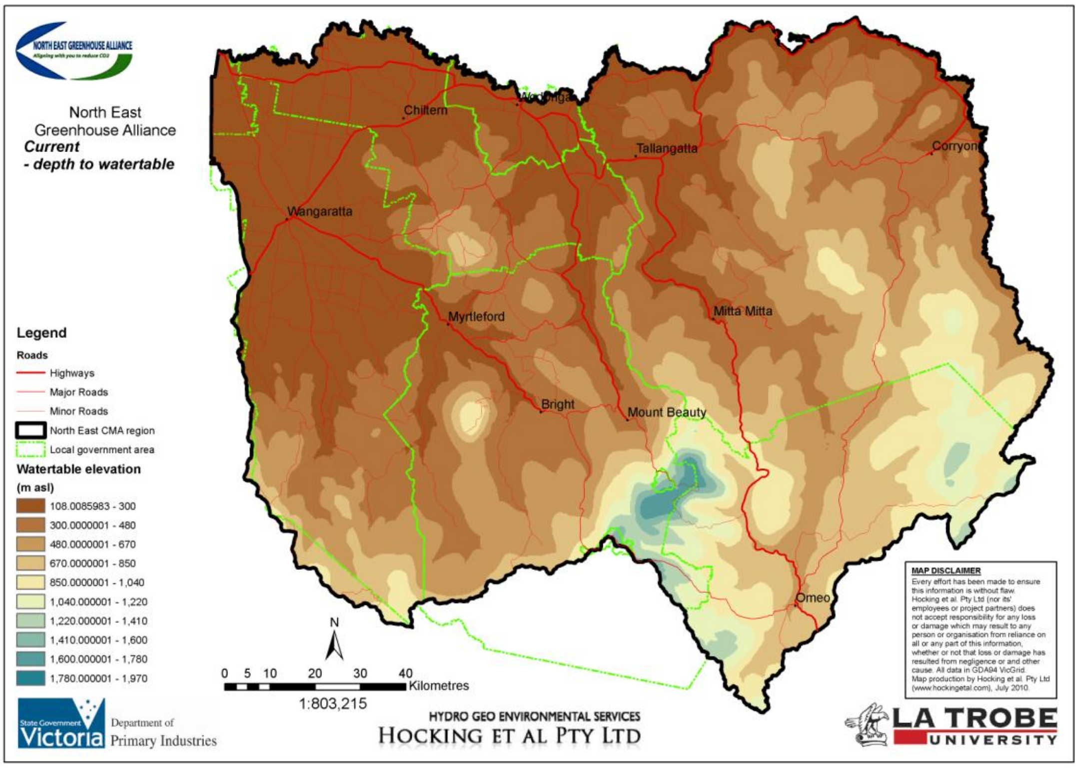


Figure C.9. Predicted watertable elevation (mAHD) derived using the North-East CMA groundwater model.

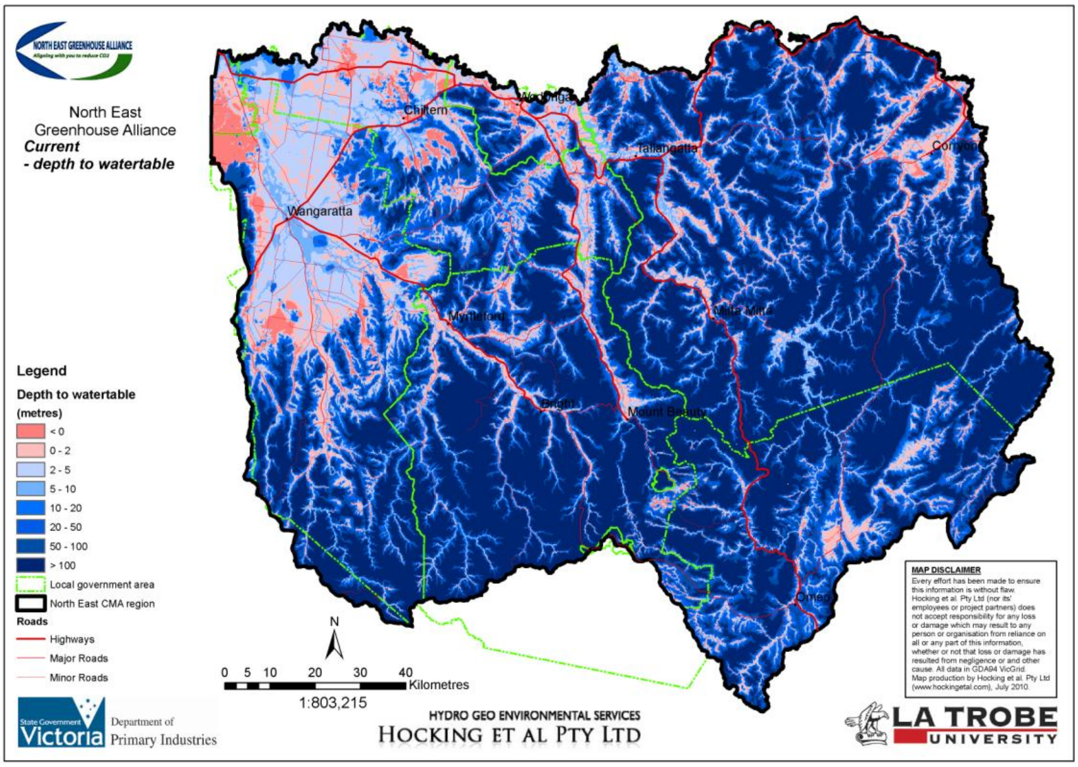


Figure C.10. Predicted depth to watertable (metres) derived using the North-East CMA groundwater model.

North East Greenhouse Alliance

# User Groups, Access to Water and Current Usage Statistics

North East Victoria Adapting to a Low Water Future: Project Context Setting – Deliverable 2

**Acknowledgements**

The North East Greenhouse Alliance project *North East Victoria Adapting to a Low Water Future*, of which this paper is a part, is funded by the Australian Government through *Water for the Future.*

Author Dr Jayanath Ananda

La Trobe University

Regional School of Business

P O Box 821

Wodonga VIC 3689

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# Executive Summary

Understanding how climate variability impacts on the water availability and security is critical in the formulation of regional and local government level policies effectively. The work carried out by this consultancy is part of a three-phase project – 'North East Victoria Adapting to a Low Water Future' implemented by the North East Greenhouse Alliance (NEGHA) under the Commonwealth Government's "Water for the Future' programme. This report reviews water consumption trends, access rights of user groups and the reliability of water supply sources in North East Victoria as part of the context setting for adaptation planning.

North East Victoria enjoys a relatively high security of water supply compared to some other regions of Victoria because of its proximity to regulated river systems and large storage facilities. However, securing the region's water supplies in the medium to long term period involves dealing with significant climate and policy-related constraints. The rural water use is the dominant water use in the region with over three quarter of the total water being allocated for irrigation and domestic & stock. The urban water consumption has been relatively stable although the demand for reticulated water supply has been rising at a steady rate during the last decade. Except for a few communities which are not connected to a reticulated supply, the majority of the residential population in the region has access to a secure water supply. However, challenges remain in securing water supplies for townships without a reticulated supply and also dealing with commercial and industrial expansions. In certain local government areas, such challenges can be amplified by increased population and residential development.

# 1 INTRODUCTION

## 1.1 Background

- Understanding how climate variability impacts on the water availability and security is critical in the formulation of regional and local government level policies. The communities in the North East region are more likely to experience stressed water supply systems along with impacts due to reduced water availability to agriculture, tourism, water-intensive manufacturing, food processing and the like. Adaptation to a low water future is crucial in reducing vulnerability of the communities and to circumvent the unavoidable impacts of climate change.
- North East Greenhouse Alliance (NEGHA) has identified the necessity to develop a regional climate change adaptation strategy for its region of influence. Under the Strengthening the Basin Communities component of the Water for the Future programme, the Australian Government has funded the 'Adapting to a Low Water Future' project proposed by the NEGHA. The objective of the project is to develop a strategy to manage climate change risks and vulnerabilities with respect to water availability. It is envisaged that developing adaptive actions to mitigate the risks and building resilience within communities will enable the region to better respond to a low water future.
- This report is part of a three-phase project examining the challenges of adapting to climate change induced water stress in North East Victoria. The project is funded by the Australian Government under the 'Water for the Future' programme (the 'Strengthening the Basin Communities' component). North East Greenhouse Alliance was commissioned to implement the project on behalf of five local governments – City of Wodonga, Rural City of Wangaratta, Alpine, Indigo and Towong Shires.

## 1.2 Aims of the report

- The Phase 1 of the project aims to provide the necessary contextual details related to adaptation to a low water future. The Phase 1 is divided into four components: climate change and water availability (Deliverable 1), water usage and access rights (Deliverable 2 - this report), water demand and user behaviour (Deliverable 3) and a preliminary vulnerability assessment (Deliverable 4).
- The aim of this report is to provide an understanding of water usage in North East Victoria with a particular reference to user groups and their water consumption patterns, access right configurations and supply sources. The specific objectives are to:
    - identify population demographic trends and provide preliminary population projections for 2030 and 2070;
    - examine the economic base and trends in the region;

  - identify and categorise various water user groups in the North East region;
  - itemise water usage and share by sectors (urban and rural) and subsectors (residential, commercial and industrial);
  - describe water consumption trends and patterns in the region;
  - identify access rights to a range of water sources including groundwater, reticulated supply, stormwater, reclaimed/reuse water, etc.; and
  - analyse the reliability of water supply systems in the region.

- The methodology of the consultancy involved collating and analysing a range of water-related information collected from water agencies in the region including North East Water (NEW), Goulburn-Murray Water (G-MW) and Department of Sustainability and Environment (DSE). Several socio-economic studies undertaken by ABS, ABARE and Department of Agriculture, Forestry and Fisheries (DAFF) were reviewed. The population and demographic information were extracted from the latest ABS databases and Department of Planning and Community Development publications and analysed on a Local Government Area (LGA) basis. Information collected from numerous research publications and personal communications with key stakeholders were also included.
- The remainder of this report is organised as follows. The next section provides a brief overview of the study region and its land use characteristics. Section 2 provides an overview of population and demographic trends including a preliminary forecast for the region. A snapshot of the economic base of the region (analysed at the LGA level) is also presented in section 2.  Section 3 reviews the water access and entitlement configuration for the region and its broad ramifications when adapting to a low water future. Water user groups and consumption trends are reviewed in Section 4. Itemised water usage by sectors and by local government area are also identified.  A brief overview of water sources is provided in section 5. Section 6 analyses the reliability of water supply and the review findings are summarised in section 7.

## 1.3 North East Victoria

- North East Victoria covers an area of about 19,000 square kilometres and is made up of five Local Government Areas (LGAs): Alpine Shire, Indigo Shire, Towong Shire, City of Wodonga and Rural City of Wangaratta and parts of Moira and East Gippsland (see Figure 1 below).

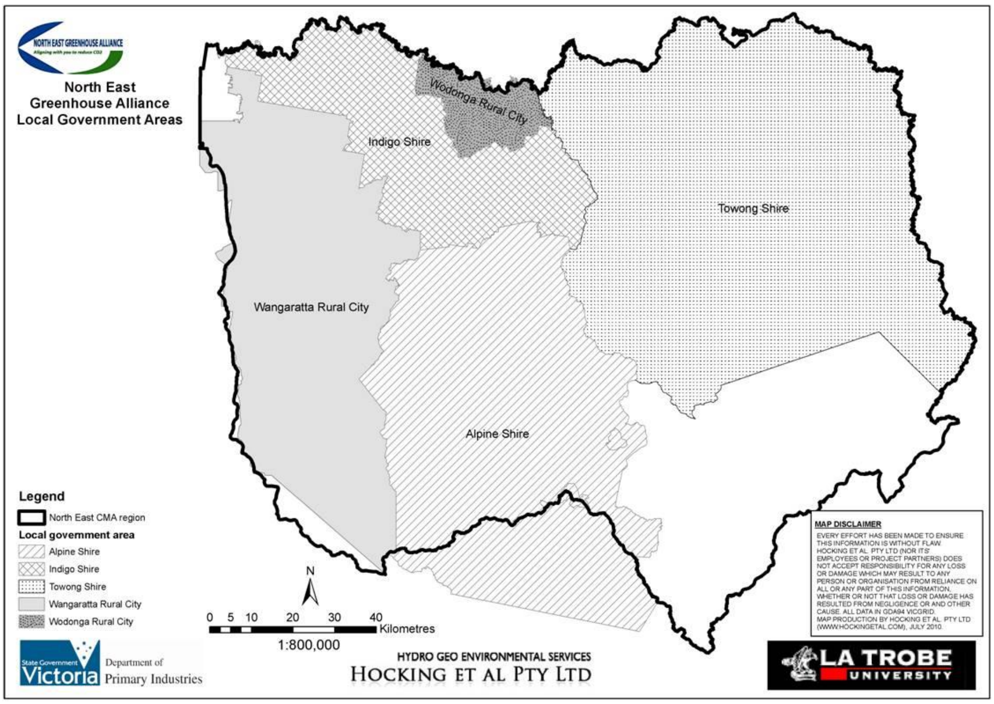



**Figure 1. North East Victoria Local Government Areas**

- North East Victoria[1] also encompasses the Ovens-Murray Statistical Division. Local Government Areas and Statistical Local Area (SLAs) under the Ovens-Murray Statistical Division are given in Table 1. The analysis carried out in subsequent sections of this report uses this classification unless otherwise specified.

**Table 1. LGAs and SLAs in the Ovens-Murray Statistical Division**

| Statistical Division | Local Government Area | Statistical Local Area |
|---|---|---|
| Ovens-Murray | Alpine Shire | Alpine Shire East<br>Alpine Shire West |
| | Indigo Shire | Indigo Shire Pt A<br>Indigo Shire Pt B |
| | Towong Shire | Towong Shire Pt A<br>Towong Shire Pt B |
| | Wangaratta Rural City | Wangaratta RC – Central<br>Wangaratta RC – North<br>Wangaratta RC – South |
| | City of Wodonga | Wodonga Rural City |

[1] North East Victoria can be described by two ways: by geographical features such as catchments, basins, rivers and valleys, or by Statistical Divisions and Local Government Areas.

Source: ASGC, ABS (2009)

## 1.4 Land Use

- North East Catchment encompasses an area of about 1.9 million hectares of North East Victoria (NECMA, 2006) and about 55% of that is designated (see Table 2 below) as nature reserves (BRS, 2009).
- Like many other rural catchments, the land use in North East Victoria has been changing significantly, the most recent being the closure of tobacco industry in 2006.
- Wangaratta and Towong LGAs hold over 60% of the land mass in the region.
- Cereal production is the most dominant cropping activity in the region and almost entirely concentrated in Indigo and Wangaratta LGAs. Non-cereal broadacre crops occupied the second largest category spreading Indigo, Wangaratta and Alpine LGAs. This was followed by orchard trees (including nuts) and grape vines. The total area under various agricultural activities in each LGA is given in Figure A1 in Annex 1.
- Commercial forestry[2] has existed in the region since the 1920's and currently contributes over $213 million to the region's economy (DPI, 2008). Section 2.5 provides an overview of the forestry sector in the region.
- A detailed description of the current land use characteristics of each LGA can be found in DPI (2008).

**Table 2. Land use in the North East CMA region**

| Land Use | Area (Sq Km) | Area (%) |
|---|---|---|
| Nature conservation | 10,920 | 55.1 |
| Minimal use | 841 | 4.2 |
| Forestry (incl. plantations) | 286 | 1.4 |
| Grazing (incl. native pasture) | 5,621 | 28.4 |
| Cropping (incl. irri. pasture) | 685 | 3.5 |
| Urban (incl. residential) | 1113 | 5.6 |
| Water | 339 | 1.7 |
| Total | 19,805 | 100.0 |

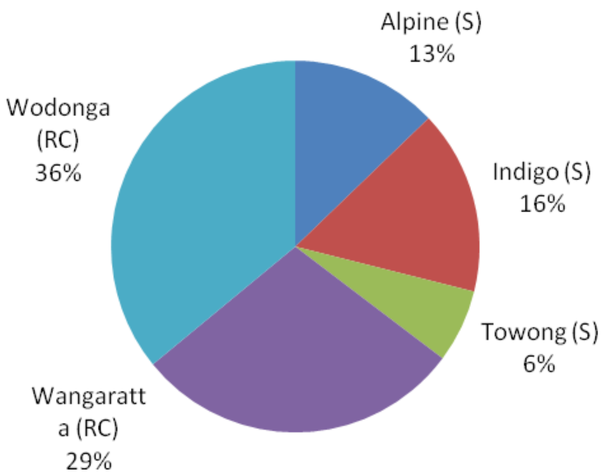
Source: Bureau of Rural Sciences (2009)

[2] The majority of the commercial forestry in the region involves softwood plantations.

# 2 POPULATION AND ECONOMY

## 2.1 Current Population

- Population growth alone is likely to place some additional stress on water supply infrastructure, particularly the urban water supply. This section reviews the current population and demographic trends in the region. It also provides preliminary population projections for the five LGAs.
- There were an estimated 95,715 persons living in the Ovens-Murray region in North East Victoria[3] in 2006, less than 2% of the Victoria's population (ABS, 2010). The Indigo Shire and the City of Wodonga contributed to the bulk of the population growth during recent times.
- According to the latest ABS statistics, Wodonga is the largest centre in North East Victoria with an estimated population of 35,733 persons followed by the Rural City of Wangaratta with an estimated population of 28,663 persons (ABS, 2010). The share of population in each municipality as a proportion of the regional population is shown in Figure 2.




Source: Regional Population Growth, Australia (ABS, 2010)

**Figure 2. Proportion of population by LGA, 2009**

- Wangaratta (1.4%) and Indigo (1.3%) local government areas have experienced the highest average annual population growth rates (2004-2009) in the North East

[3] Only includes the Alpine Shire, Indigo Shire, Towong Shire, Wangaratta and Wodonga. The population figures for the Ovens-Murray Statistical Division in 2006 and 2009 (projected) were 96,111 and 99,872, respectively (ABS, 2010).

region. Wangaratta also ranked the 33rd fastest growing LGA in Victoria while Wodonga ranked the 35th (Table 3) (ABS, 2010).

| **LGA** | **Average annual growth rate (%)** | **State rank (2008-09)** | |
|---|---|---|---|
| | | Fastest growth# | Largest growth |
| Alpine Shire | 0.3 | 70 | 67 |
| Indigo Shire | 1.3 | 51 | 59 |
| Towong Shire | 0.4 | 66 | 71 |
| Wangaratta Rural City | 1.4 | 33 | 49 |
| The City of Wodonga | 0.9 | 35 | 43 |

**Table 3. Population growth rates, North East Victoria, 2004-09**

# Local Government Areas with populations of less than 2,000 people at 30 June 2008 have been excluded from the fastest growth rankings.
Source: ABS Regional Population Growth, Australia, 2008-09 (cat. no. 3218.0)

- It appears that the household size of Regional Victoria has decreased over recent decades. DPCD (2010) attribute this to rising 1 and 2 person households and this has implications for urban water use (see section 4.5 on urban water consumption).

## 2.2 Population Projections

- The Department of Planning and Community Development has estimated population trends up to 2036 as part of Victoria in Future (VIF) 2008 project. These estimates are based largely on current planning and housing trends/policies.
- Latest population projections indicate that both Victoria and Regional Victoria are expected to grow at an average annual growth rate of around 1% between 2006 and 2036 (DPCD, 2010).

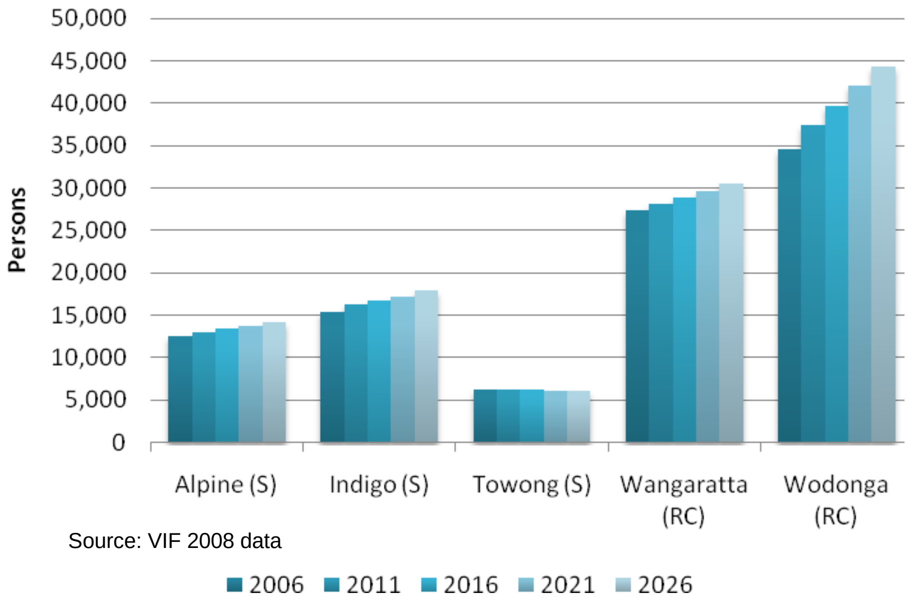



**Figure 3. VIF 2008 population projections**

- The Ovens-Murray region is projected to grow from 96,406 to 119,810 persons between 2006 and 2036 (DPCD, 2010). This represents an average annual growth rate of 0.7% which is lower than the projected growth rate for regional Victoria (1%) (DPCD, 2010). The projected populations for North East Victorian LGAs are shown in Figure 3.
- The LGA-level population projections for the NEV region are available only up to 2026 and projections beyond that are currently not available.
- Beyond 2026, projections are only available for Melbourne and regional Victoria which are based on demographic variables such as fertility rates, mortality rates, migration rates to/from overseas, interstate, within state. For instance, the region attracts people from major cities like Melbourne seeking a change in lifestyle. Wodonga, in particular is likely to attract future growth given its role as a large service centre located adjacent to Albury. It is estimated that as Victoria's population ages, the net movement from Melbourne is projected to increase from 70 per year to 300 per year in the Ovens-Murray Statistical Division (DPCD, 2010).
- An attempt was made to estimate future population trends for the LGAs in North East Victoria. These are only crude estimates and should be interpreted cautiously as they do not take into account demographic variables explicitly and will invariably be subject to long-term policy changes amongst others. For example, the extensive policy debate at the national level around sustainable population will invariably have some impact on these estimates.
- The approach taken to forecast future population trends in North East Victoria draws on:
    - Victoria in Future (VIF) 2008 – First Release, Projected Populations Totals and Components
    - ABS Population Projections, Australia 2006-2101, Cat. No.3222.0 (2008)

- A preliminary population forecast for North East LGAs is shown in Figure 4. The VIF 2008 projections were used as the base population for each LGA. Projections were obtained extrapolating each LGA's share of the growth for regional Victoria (2006-2026). The assumption that each LGA share is likely to increase or decrease, depends on whether the LGA contains large regional centres, or has climate or amenity advantages which would make it an attractor to migrants, mainly families and retirees from Melbourne, have not been taken into consideration.

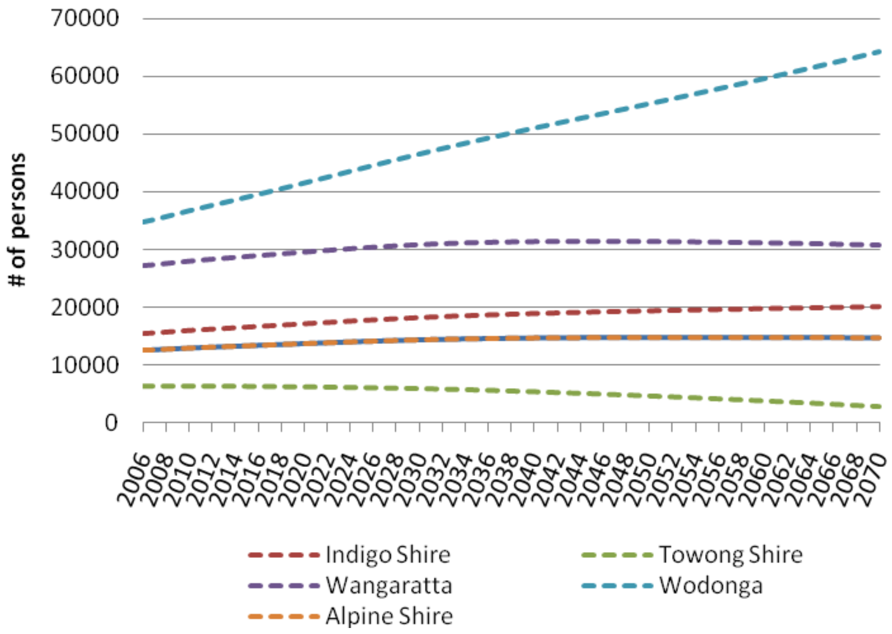
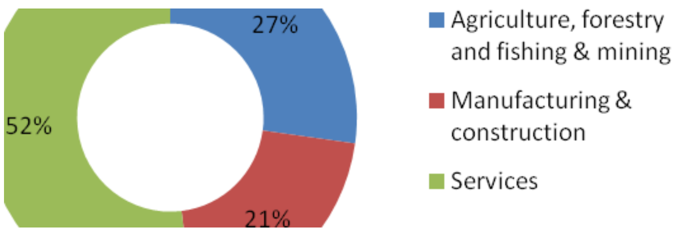



**Figure 4. Projected population, 2030 & 2070**

- The forecasting produced positive population growth rates for 2030 for all LGAs (Alpine 0.36%; Indigo 0.51%; Wangaratta 0.31%; Wodonga 1.01%) in North East Victoria except for Towong Shire (-0.65%). However, only Wangaratta and Wodonga growth rates remained positive in 2070. Note that the VIF 2008 projected figure for regional Victoria in 2026-2036 is 0.8%.
- The projections on population structure indicate that the aged population in North East Victoria is more likely to increase (see Annex 1, Fig. A2 and A3 for details). Although not drastic, such subtle structural changes will have some implications for residential water use.

## 2.3 Overall Economy

- North East Victoria has a diverse economy. Major industries include agriculture, manufacturing, tourism and forest products[4]. Key manufacturers include major food processing facilities, packaging and fabrication facilities. Although agriculture is significant, over 50% of the businesses in the region are engaged in the service sector (Figure 5). The recent boom in property and construction has created a large number of construction and manufacturing businesses in the region. The percentage share of businesses by major industry sector is shown in Figure 5.




Source: ABS (2010)

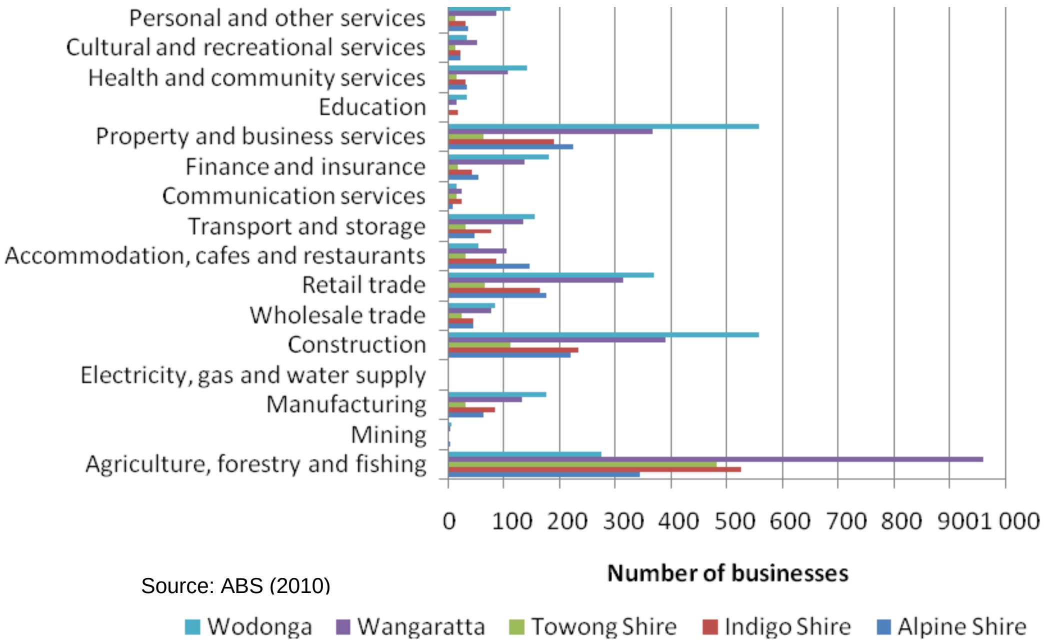
**Figure 5. No. of businesses by major industry sector, 2007**

## 2.4 Manufacturing and services

- The region's residents earned a taxable income of $1895 million (Ovens-Murray SD) in 2007 (ABS, 2010). Labour force statistics indicate that a range of service sectors in the region continued to expand in terms of employment – community services, wholesale and retail services and recreational and personal services (DPCD, 2010). Currently, healthcare, retail trade and manufacturing sectors are the main employment providers in regional Victoria (ABS, 2010b).
- Wangaratta recorded the highest number of business enterprises in the agriculture, forestry and fishing category in 2007 while Wodonga recorded the highest number of property, business services, and construction and retail trade categories (see Figure 6).
- During 2004-2007, a number of businesses in agriculture (-1.3%) and recreational services (-13.2%) contracted in the North East Victoria region whilst education,

[4] The monetary contribution from each industry sector to the overall economy of North East Victoria or to the regional economy is not publicly available.

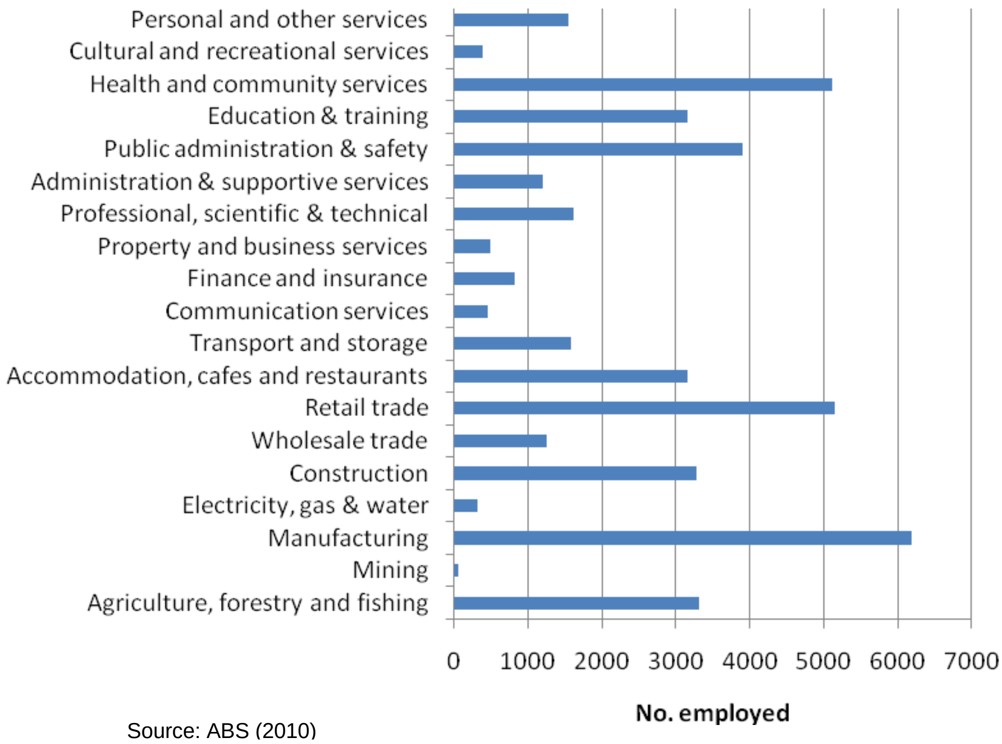
construction, personal services and health sectors recorded expansion (ABS, 2010). There are a variety of plausible explanations including drought and trends towards larger firm size/amalgamations.




Source: ABS (2010)

**Figure 6. No. of Businesses by LGA, 2007**

- Employment by industry for the North East region is shown in Figure 7. Manufacturing is the largest employment provider in the region closely followed by retail trade and healthcare. Industry highlights for the five LGA are given in section 2.7.




Source: ABS (2010)

**Figure 7. Employment by industry in North East Victoria, 2006**

- The region has experienced an expansion of the construction industry in recent times. Often construction activity is seen as a proxy for population growth. However, the relationship between housing growth and dwelling growth is not linear (DPCD, 2010).
- The number of businesses engaged in construction industry grew by over 19% from 2004 to 2007 in the Ovens-Murray Statistical Division (National Regional Profile, O-M, ABS, 2010).

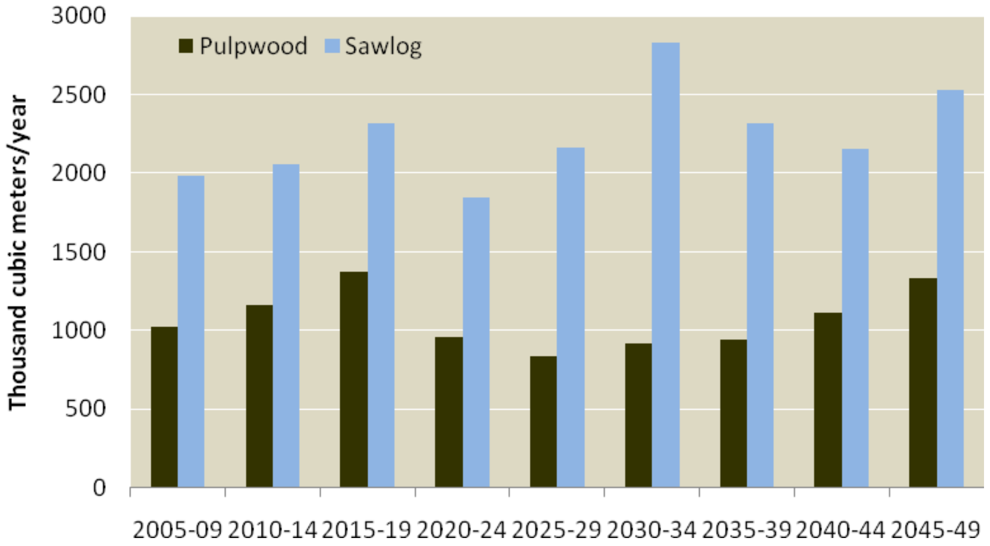
## 2.5 Forestry

- The North East Victoria region has a significant forest industry which supplies sawlogs, veneer and pulpwood to industries dispersed throughout the region; major processing facilities are located in Wangaratta, Myrtleford and Benalla.
- The total plantation area in the Murray Valley Region[5] increased by about 3% from 2000 to 2005 (Commonwealth of Australia, 2006). The softwood area increased by about 2%, partly due to development of new plantations and partly due to more comprehensive reporting of previously established plantations (Commonwealth of Australia, 2006). Forest plantation forecasts indicate that the North East continues to maintain its share of sawlog production and increase pulpwood production in the Murray Valley region throughout the period up to 2049 (see Figure 8). Note that the

[5] Murray Valley region stretches from Gundagai to Melbourne and includes farm forests in North East Victoria.

effects of reduced water availability due to climate change have not been considered in the above forecast.

- There are plans to expand the forest plantation area by a total of 50,000 hectares by 2020 (Commonwealth of Australia, 2007) which will have a significantly impact on the water availability in the catchment. Studies of two catchments in Murray Darling Basin indicate that such forecast forest plantation expansion may reduce stream flow by up to about 1% (Commonwealth of Australia, 2007). At a local government scale, and in particular years, the impact may be significant if new plantations are concentrated in particular sub-catchments.




Source: DAFF (2007)

**Figure 8. Forest plantation log supply, Murray Valley Region**

## 2.6 Agriculture

- Livestock production is the largest contributor to the region's agricultural economy. It contributed $327 m to the region's economy in 2006 (ABS, 2010).
- Wangaratta LGA is the highest contributor to the gross agricultural value of the region producing an output of $107 m in 2006 (see Figure 9).
- The major cropping enterprises include wheat, canola, oats and barley. Horticulture in the region includes grapevines, berries, apples and nuts. Tobacco used to be a major contributor to the gross value of agricultural product in the region until late 2006 (DPI, 2008).

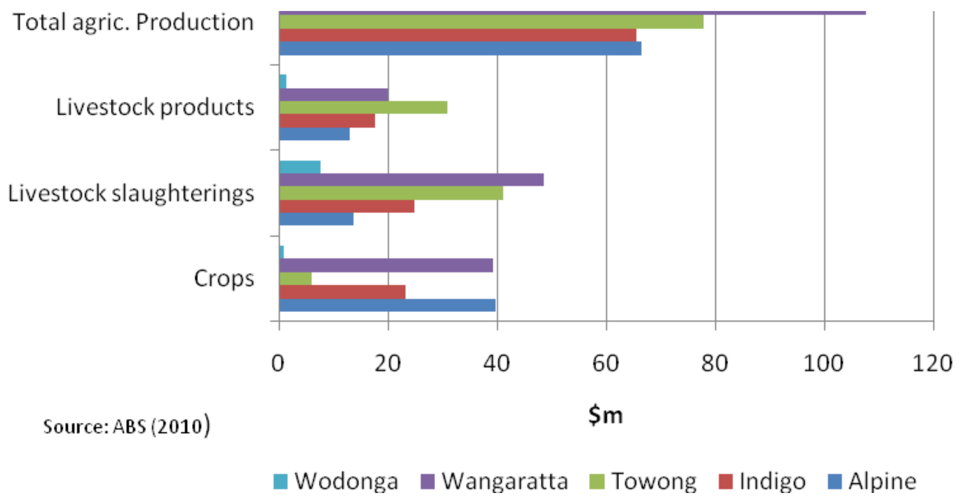
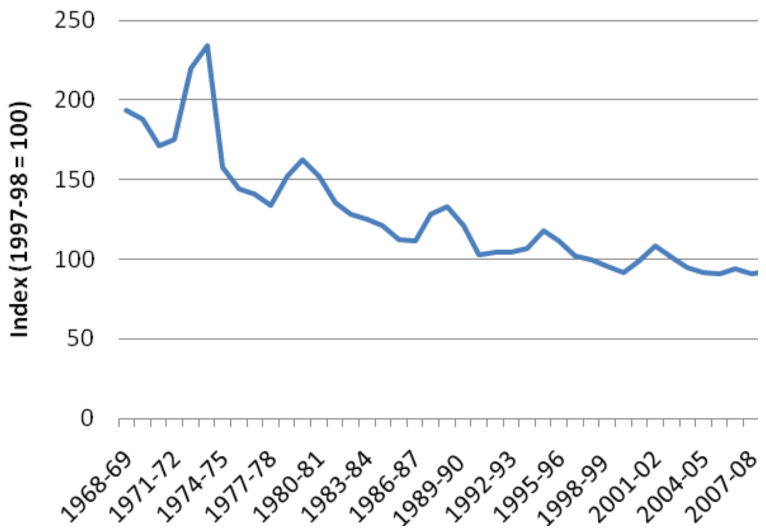



**Figure 9. Gross value of agricultural production (2006) by LGA**

- There has been an overall decline in Australian farmer's terms of trade despite increased commodity prices during last forty years (see Figure 10). Coupled with low water availability, unfavourable terms of trade invariably influences the speed of adjustment and adaptation options for farming communities in the region.




Source: ABARE Commodity Statistics (2009)

**Figure 10. Australian farmers' terms of trade, 1989-69 to 2008-09**

## 2.7 Industry Highlights by Local Government Areas

- This section provides a brief snapshot of each Shire's industry profile. The ABS Census 2006, ABS National Regional Profile (2010) and the community profiles of the Hume Sustainable Communities Project (DPCD, 2008) were used for the analysis.

### 2.7.1 Alpine Shire

- The hospitality industry (accommodation & food industry) is the largest employment provider in the Alpine Shire reflecting the importance of major ski resorts such as Falls Creek, Mount Hotham and Mount Buffalo and valley regions for tourism. Accommodation and food industry accounted for 14.6% of the total employed whereas manufacturing and retail trade sectors accounted for 11.2% and 10.7% of total employment, respectively.
- Overall, there was an average annual decline of 4.2% in total number employed in the Alpine Shire during 1996-2006 (ABS Census 2006).
- Whilst agriculture retains some importance as a regional employer, most employment growth in the last decade has been in the service sector.
- In 2007, the service sector occupied the highest number of businesses (52%) in the Alpine Shire, followed by agriculture (27%) and manufacturing (21%).

### 2.7.2 Indigo Shire

- The Indigo Shire economy comprises more than one thousand business enterprises[6]. The major activities include manufacturing, healthcare and farming (beef, dairy, fruit and viticulture).
- Manufacturing is the largest industry sector in the Indigo Shire employing over 1000 people (15.7% of total employment). Healthcare (12.9%) and agriculture (11%) sectors are also significant employers in Indigo Shire.
- The retail trade sector experienced the largest growth in employment and grew at an average annual growth rate of 5.4% while the construction industry had an average growth rate of 4.6% per year during 1996-2006.

### 2.7.3 Towong Shire

- The economy of Towong Shire is largely based on livestock farming, irrigated agriculture and intensive horticulture. Agriculture accounts for over a quarter of the labour force (26.4%) in the Towong Shire. However, its overall significance in terms of employment has declined over the past decade. For instance, the number employed in the agriculture, forestry & fishing sector declined by 1.5% during 1996-2006.

[6] excluding businesses in the agriculture, fishing and mining sector.

- Employment in the construction and retail sectors has grown by 4.5% and 2.5%, respectively during 1996-2006.

### 2.7.4 Wangaratta Rural City

- Wangaratta supports several major manufacturing facilities including one major textile manufacturing plant, transport and distribution activities. Manufacturing is the largest employment provider (15.6% of total employment) in Wangaratta.
- Health care and retail trade sectors are also significant industries in Wangaratta
- A higher population growth rate (33rd fastest growing LGA in Victoria) has boosted the labour force in Wangaratta at an average of 1.3% per year from 1996-2006.

### 2.7.5 City of Wodonga

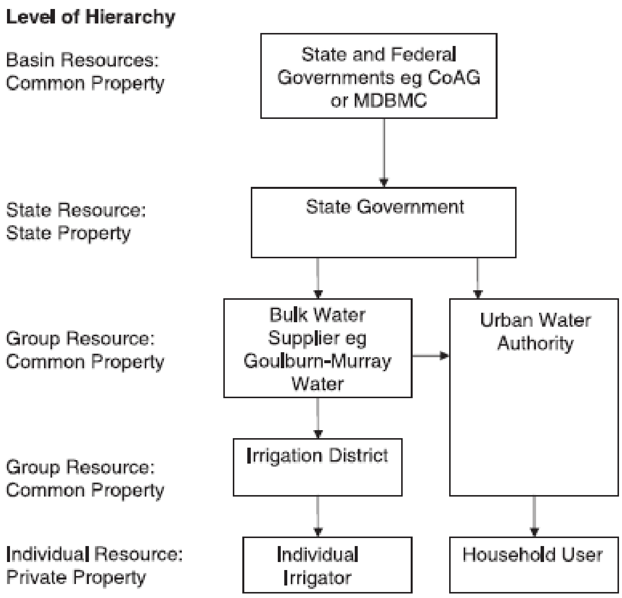
- Albury-Wodonga is the largest regional centre for North East Victoria and supports a large retail sector, healthcare facilities in addition to a significant public administration sector.
- Manufacturing is the main contributor to the economy and also the primary employer in city of Wodonga, providing employment for 15.2% of the total employed in Wodonga.
- The construction sector experienced the largest growth (7.4%) supported by strong population and household growth during the past decade. Wodonga's population growth ranked 43rd largest growth in Victoria (the highest in North East Victoria).
- City of Wodonga also experienced an average labour force growth of 2.4% per year from 1996 to 2006.
- The employment numbers by industry for Alpine Shire, Indigo Shire, Towong Shire, Wangaratta and Wodonga are given in Tables A1-A5, respectively (Annex 2).

# 3 WATER RIGHTS AND ENTITLEMENTS

- This section provides an overview of the water access rights and entitlement framework for the North East region.
- Water rights are specified as water entitlements which are defined in the Water Act 1989.
- A water entitlement is the long-term or perpetual property right to access water under specific conditions.

## 3.1 The structure of water rights

- Water rights often take a hierarchical form (see Figure 11 below) where a superordinate institution (e.g. the state government) may attenuate the rights of a subordinate institution (e.g. the urban water authority).




Source: Adapted from Crase & Dollery, 2006, p.454.

**Figure 11 An institutional hierarchy of water entitlement-holders**

## 3.2 Types of rights and entitlements

### 3.2.1 Bulk entitlements

- Bulk entitlements are held by both urban and rural water corporations with secure tenure in perpetuity. Urban bulk entitlements provide water for urban users whilst rural bulk entitlements provides for irrigation.

- Water corporations hold two types of bulk water entitlements: (a) source bulk entitlements which provide a share of inflows, storage capacity and releases and (b) delivery bulk entitlements which provide a set volume each year, subject to defined restrictions during periods of water shortages[7]. Currently, North East Water has surface water bulk entitlements to 28,000 ML per year (NEW, 2007). Historical bulk water entitlements for urban water are shown in Figure 20 (section 6). Accurate and consistent data on bulk water entitlement on rural water, including groundwater use, are not readily available for the region.

### 3.2.2 Water shares

- Water shares are the perpetual water access rights in regulated systems held by individuals. These water shares can be further differentiated as High-Reliability Water Shares (HRWS) and Low-Reliability Water Shares (LRWS).

### 3.2.3 Domestic and stock water rights (sec 8 rights)

- Section 8 of the Water Act 1989 allows individuals to access surface and groundwater for Domestic and Stock (D&S) purposes without an entitlement and free of charge.
- Although pivotal in influencing the reliability of supplies for other entitlements-holders, information on D&S use is sparse because, until recently, it received little or no scrutiny. The estimated D&S records for the region are only available from 2007/08 season.

### 3.2.4 Environment entitlements

- Environmental entitlements provide for a share of the available resource in order to meet environmental needs including environmental values and health of ecosystems.
- Specifying water rights for the environment recognises the significant benefits for securing environmental flows.
- The current average availability of the environmental entitlement for the Northern Region is about 232 GL/year (DSE, 2009).

## 3.3 Limits on water entitlements

- Limits on water entitlements are imposed to ensure the reliability of supply to other entitlement holders and environmental values.
- The limits are based on three premises: the Murray-Darling Basin Cap, Permissible Consumptive Volumes (PCVs) and Sustainable Diversion Limits (SDLs).

[7] A detailed description of various water rights and entitlements can be found in DSE (2009).

- The Murray-Darling Basin Cap sets the volume of surface water that can be diverted (based on the 1993/93 levels) from each of the Basin's major rivers. Allocations to existing entitlements must remain below the Cap.
- PCVs are the maximum volume of water (surface and groundwater) that can be used for consumptive purposes.
- SDLs limit water use in unregulated systems preventing allocations detrimental to the environment. SDLs have been set for 1584 sub-catchments in Victoria and they are currently under review.

## 3.4 Inadequacy of water rights

- Many scholars have highlighted the inadequacy of the prevailing entitlement framework with respect to 'hydrological integrity' (e.g. issues of return flows) which leads to externalities and economic inefficiency (Randall, 1981; Young and McColl, 2003a; 2003b; Crase and Dollery, 2006).
- Inadequacy of property rights with regard to water storage and capacity sharing (inter-temporal transfer and carry over) has also been noted (Brenan, 2008; Hughes, 2010).
- Land use changes due to plantation forestry are not covered by the current entitlement framework. Such land use changes can undermine the reliability of existing entitlements (DSE, 2009).

## 3.5 Water rights configuration and adaptation

- The water entitlement structure in North East Victoria invariably affects the adaptation possibilities.
- As described in section 2.1, higher order institutions distribute water rights and these rights are attenuated at each level.
- Rights in the regulated water systems are relatively well defined as opposed to rights in unregulated systems, such as Ovens, where a stream flow management plan has not been finalised and therefore the Minister can assign water for environment without monetary compensation. Relative inexperience in water trading also increases vulnerability to a low water future.
- Water rights also specify how the risk is to be borne by various water users:
    a. Rights to authorities (common property) vs. rights to individuals (private property)
    b. Consumptive use vs. environmental needs
    c. Urban use vs. irrigation and domestic & stock use
    d. Regulated system vs. unregulated system
    e. Type of water source

- Sustainable Diversion Levels (SDLs) impinge on users in both regulated and unregulated systems.

## 3.6 Security in water entitlements

- Arguably, the reliability of entitlement is more critical than the level of entitlement or allocation when adapting to a low water future. The water entitlements in Victoria are governed by a set of risk assignment provisions laid down by the National Water Initiative (NWI). They intend to provide certainty over who should bear the risks of future water quantity reductions or reliability of allocations. According to the provisions, the above risks will be borne by (a) entitlement holders, if the reduction is caused by seasonal or long-term changes in climate or natural events such as bushfires; (b) by the government, if the reduction is a result of the government's policy and (c) by both water entitlement holders and governments based on a specified formula, if the reduction results from improvements in knowledge about the environmentally sustainable use of water (Commonwealth of Australia, 2010). The recent announcement by the current Minister for Water indicating an intention to purchase any 'gap' between the SDLs of the new Murray-Darling Basin Plan and the current environmental water reserve, suggests that some changes in these risk sharing principles will occur.
- Bulk water entitlements in the regulated systems have the highest level of security. In case of water stress, the Minister for the Water can intervene and reallocate water from environmental flows in favour of meeting residential water needs. The level of security of various water entitlements for North East Victoria are summarised in Table 4.

**Table 4. Water entitlement security, North East Victoria**

| Level of security | Type of entitlement/right | Entitlement-Holders |
|---|---|---|
| Level 1 | Bulk entitlements (R) | NEW |
| | | G-MW |
| | | Residential users |
| | | Commercial users |
| | | Industrial users |
| | | Irrigators |
| Level 2 | Bulk entitlements (U) | NEW |
| | | G-MW |
| | | Residential users |
| | | Commercial users |
| | | Industrial users |
| | | Irrigators |
| Level 3 | Environmental water entitlements | EWH on behalf of the general public |
| | D&S (sec 51 licenses) | |

*Notes:*

**Water shares** - a share of the available resource in a regulated system

**Water-use licences**- allow an irrigator to use water to irrigate land up to an annual use limit

**Sec 8 rights**- domestic & stock use rights

**Environmental entitlement** - a share of available resource set aside to meet environmental needs

**Sec 51 licences** - allow for diversions from unregulated river systems and extractions of groundwater

**NEW** - North East Water
**G-MW** - Goulburn-Murray Water
**EWR** - Environmental Water Reserve

# 4 WATER USER GROUPS AND CONSUMPTION TRENDS

- This section describes various water user groups in North East Victoria and provides a snapshot of their water consumption trends.
- Broadly, water users can be classified into urban and rural categories. Urban water users can be further subdivided into residential, commercial and industrial users. North East Water is the urban water supplier for the region.
- The rural water uses include irrigation and stock & domestic purposes. Goulburn-Murray Water is the bulk water supplier for rural water users.
- In addition to consumptive use, a legally recognised amount of water is set aside to meet environmental needs. A range of environmental entitlements are specified for the major river systems in the region.

## 4.1 Rural Water Use

- Goulburn-Murray Water provides irrigation water for about 26,000 surface water customers, about 5,000 groundwater customers and over 1,200 domestic and stock customers (G-MW, 2009).
- In 2008-09 season, the total rural water use (regulated, unregulated, groundwater and domestic and stock) for the North East Victoria region was over 64,500 ML[8] (G-MW data). This represents about 77% of total water use in the region[9].
- The breakdown of rural water use in 2008-09 for the region is given in Table 5. Over 58% of the water allocated came from the regulated systems while groundwater account for 14% of the total rural water use in the region. About one fourth of rural water emanates from unregulated systems in North East Victoria. It should be noted that groundwater volumes were based on a combination of metered and estimated use whilst domestic & stock figures were only estimates. It is also worth noting that Deliverable 1 highlights existing problems with the current level of licensed extractions from groundwater – namely the resource appears to be significantly over-allocated.

[8] This figure does not include the groundwater and domestic & stock water use (16,880 and 3032 ML) in the unincorporated area covering the entire G-MW region including North East (G-MW data).
[9] Assuming a 19,000 ML of average total urban water use (2001-2010) per annum.

**Table 5. Rural water use, North East Victoria, 2008-09**

| Category | Source | Volume (ML) | % |
|---|---|---|---|
| **Regulated systems** | Murray (Hume to Nyah) | 24118 | |
| | Mitta | 3037 | |
| | Ovens (including King) | 10492 | |
| | *Total Regulated* | **37647** | 58% |
| **Unregulated Systems** | Upper Murray (above Hume) | 3939 | |
| | Kiewa | 5239 | |
| | Ovens (unregulated) | 7597 | |
| | *Total Unregulated* | **16775** | 26% |
| **Groundwater** | Barnawartha GMA | 381 | |
| | Mullindolingong GMA | 613 | |
| | Upper Ovens GMA | 1463 | |
| | Lower Ovens GMA | 6825 | |
| | *Total Groundwater* | **9282** | 14% |
| **Domestic & Stock** | Barnawartha GMA | 20 | |
| | Mullindolingong GMA | 56 | |
| | Upper Ovens GMA | 133 | |
| | Lower Ovens GMA | 604 | |
| | *Total Domestic & Stock* | **813** | 1% |
| | **GRAND TOTAL** | **64517** | 100% |

Source: G-MW data

## 4.2 Rural Water Use by Activity

- Water consumption by agricultural activity is an important indicator in assessing vulnerability to a low water future. On average, pasture (for grazing and broadacre crops) production in the region recorded the highest water use 4.2 and 4.0 ML per hectare, respectively (pasture for hay & silage 3; vegetables 2.7; fruits 2.5; grapevines 1.5). The per hectare water use figures were considerably lower in Victoria on average. For example, comparative figures for Victoria - pasture for hay & silage 3.2; broadacre crops 2.4) (ABS, 2008).
- Table 6 shows the water use in farms of North East Victoria by Statistical Local Areas. As mentioned earlier (section 1.7), Wangaratta has the highest concentration of farms and the agricultural water use in the region.

**Table 6. Water use in farms in North East Victoria**

| SLA | No. of Agricultural businesses | Irrigation volume applied (ML) | Other agricultural uses (ML) | Total water use (ML) |
|---|---|---|---|---|
| Indigo (S) - Pt A | 418 | 6784 | 1511 | 8295 |
| Indigo (S) - Pt B | 162 | 4629 | 444 | 5073 |
| Towong (S) - Pt A | 135 | 2914 | 715 | 3629 |
| Towong (S) - Pt B | 406 | 12674 | 2530 | 15204 |
| Wangaratta (RC) - Central | 13 | 66 | 12 | 78 |
| Wangaratta (RC) - North | 323 | 1991 | 1514 | 3506 |
| Wangaratta (RC) - South | 599 | 16410 | 2539 | 18948 |
| Alpine (S) - East | 223 | 3781 | 650 | 4430 |
| Alpine (S) - West | 178 | 4668 | 478 | 5146 |

| | | | | |
|---|---|---|---|---|
| Wodonga (RC) | 119 | 574 | 418 | 992 |
| **Total** | **2576** | **54491** | **10811** | **65301** |

Source: ABS (2008)

## 4.3 Water Trading

- Water trading can be an effective tool to tackle the challenges associated with adaptation to a low water future. Through trade, water can be transferred to the most efficient use while meeting the changing needs of the community. The existing water markets are far from fully competitive and there is scope for greater integration of contiguous water supply systems (Garnaut, 2008).
- One of the flexible adaptation options for irrigators in the region is engaging in water trade, in either the temporary or permanent. The introduction of water trading in Victoria's irrigation regions has triggered a relatively rapid change in farming entry and exit patterns including consolidation and associated land use change (DPCD, 2010).
- In 2007-08, high-reliability water share transfers[10] in the Murray and the Ovens systems were 79 GL (7% of the total entitlement) and 0.5 GL (2% of the total entitlement), respectively. For the same period, the allocation transfers[11] for the Murray and Ovens systems were 132 GL (21% of total available) and 1.6 GL (6% of total available), respectively. A noteworthy fact is that temporary trade volumes in unregulated river systems is low (Ovens and King unregulated – 0.4 GL; Kiewa – 0.7 GL) (DSE, 2009).
- There are restrictions on the volume of trade between irrigation regions and there is only limited trade between urban and irrigation water systems.

## 4.4 Urban Water Users

- The urban water supply is a critical enabler of economic activity in North East Victoria. The region has several towns where large industries with high water demand are operating.
- According to North East Water, there were a total of 44,112 water connections in North East Victoria in 2008-09. Out of that, 39,238 were residential customers, 4081 were commercial customers and 235 were industrial customers. The remaining 358 were reported as vacant.
- There has been a steady increase in the total number of urban water connections as shown in Figure 12.

[10] High-reliability water shares were previously known as permanent trade.

[11] Previously known as temporary trade.

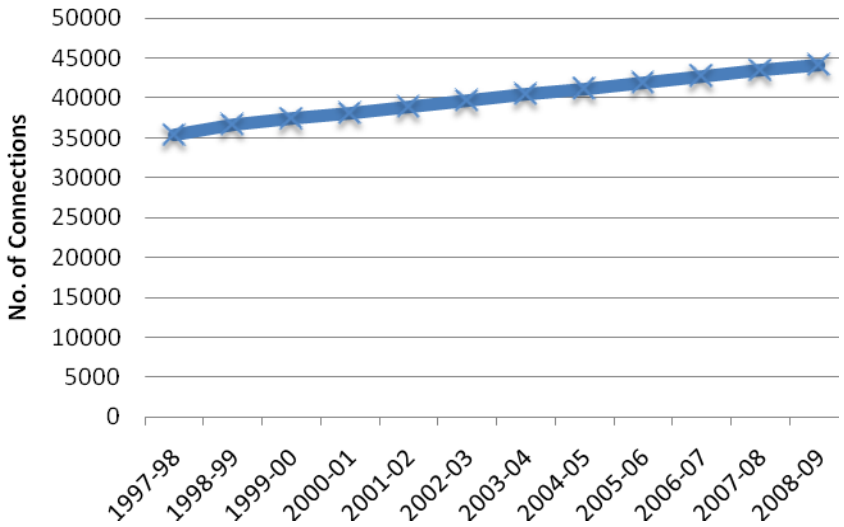



**Figure 12. Total no. of urban water connections**

- The main driver of this growth in recent times appears to be the growth in industrial and commercial customers. The growth in urban water connections by sector is shown in Figure 13.

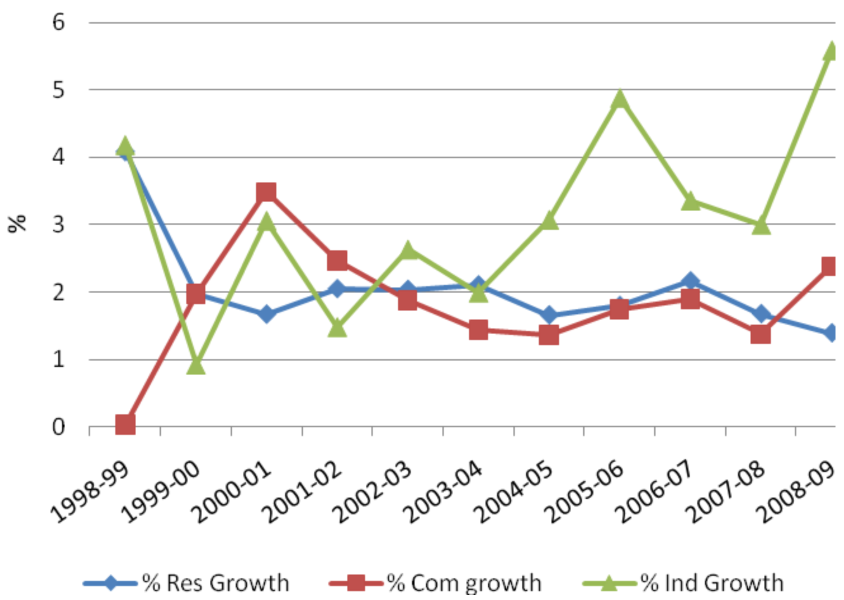
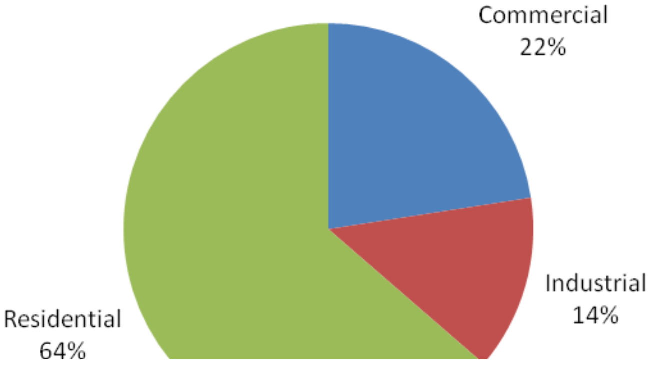



**Figure 13. Growth in urban water connections**

## 4.5 Urban Water Consumption

- The volume of water diverted from regulated rivers for urban use by the North East water is less than 2% of the region's consumptive use. The largest proportion of water use is attributable to irrigated agriculture in the region (NEW, 2007).
- In a typical year, North East Water uses about 21,000 ML of water (NEW, 2007)




Source: NEW data

**Figure 14. Urban water consumption by sectors**

- Urban water consumption (the 10 year average; 1999-00 to 2008-09) in North East Victoria by sectors is shown in Figure 14 above. About 64% of the urban water use in North East can be classified as residential followed by commercial (22%) and industrial (14%). The urban water allocation by water supply source is presented in Annex 1 (Fig A10).
- Although the demand for urban water supply connections has increased, total urban water use has been declining since 2002-03. The historical urban water use by sectors is illustrated in Figure 15.

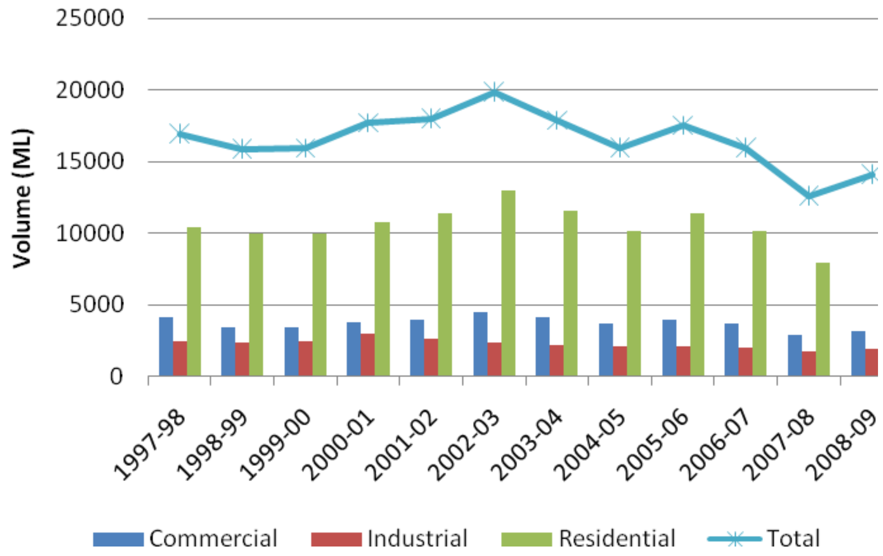
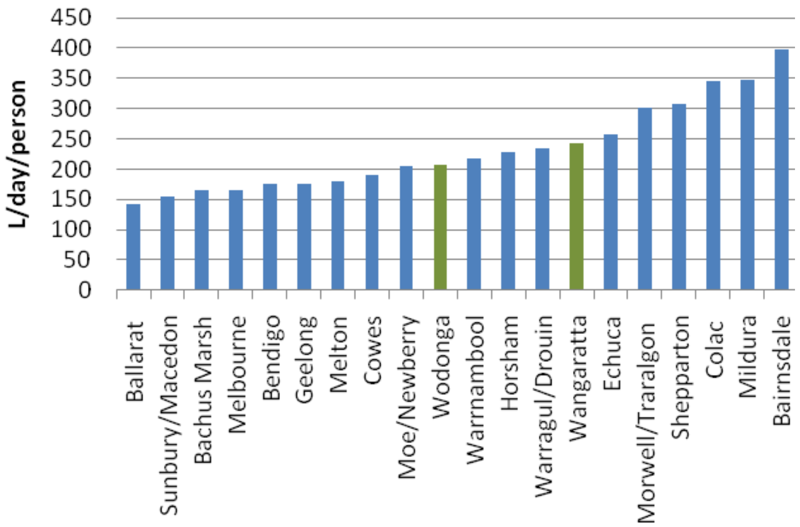



**Figure 15. Urban water use by user category**

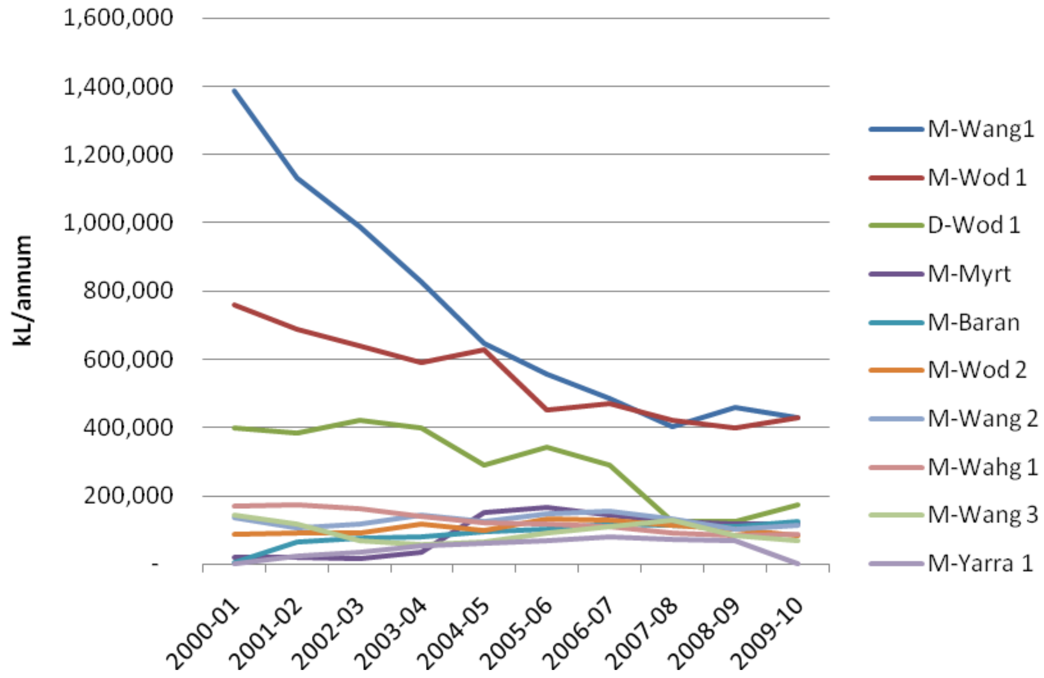
- The Wangaratta LGA has a relatively larger proportion (22%) of industrial water use whereas Towong Shire has the smallest (1%). Historical urban water consumption and number of supply connections for each LGA in North East Victoria are shown in Fig. A4 in Annex 1.
- In 2007-08, the average per capita residential water consumption in Wodonga and Wangaratta were 207 and 243 L/day, respectively (DSE, 2010) (see Figure 16 below). These figures fall on the mid range of the residential water consumption of the top 20 population centres in Victoria. The highest was recorded for Bairnsdale (398 L) while the lowest recorded was in Ballarat (143 L) (DSE, 2010).




Source: Victorian Water Accounts, 2007-08

**Figure 16. Average per capita residential water consumption, 2007-08**

- The top 10 urban water users in the region belong to the manufacturing industry with defence industry (Wodonga) being the only exception. Over time, it appears that the volume of water used has declined. The historical water consumption patterns of the top ten urban water users are shown in Figure 17.




*Key: M- Manufacturing; D- Defence*

**Figure 17. Top 10 urban water users**

## 4.6 Urban Water Demand Forecasts

- North East Water Supply Demand Strategy (WSDS) (2007) provides demand forecasts for their 25 water supply systems incorporating population growth and climate variables. The evidence indicates that there is a strong positive correlation between population growth and residential water demand for Wangaratta and Wodonga (NEW, 2007).
- The projections indicate that Indigo, Alpine and Wodonga LGAs are expected to have a higher urban water demand in the next 40 year period. Summary of water demand growth rates (2004- 2054) as reported by WSDS for each LGA is given in Table 7.

**Table 7. Summary of urban water demand forecast (2004-2054)**

| *LGA* | *Initial Growth* | *50-year* |
|---|---|---|

| | | Nominal Growth |
|---|---|---|
| **Alpine Shire** | | |
| *Bright* | 2.00% | 1.18% |
| *Harrietville* | 0.46% | 0.27% |
| *Mount Beauty* | 0.46% | 0.27% |
| *Myrtleford* | 0.92% | 0.54% |
| **Indigo Shire** | | |
| *Barnawartha* | 4.00% | 2.35% |
| *Beechworth* | 0.68% | 0.40% |
| *Wahgunyah* | 0.68% | 0.40% |
| *Yackandandah* | 1.50% | 0.88% |
| **Towong Shire** | | |
| *Bellbridge* | 3.00% | 1.77% |
| *Corryong* | 0.30% | 0.17% |
| *Dartmouth* | 0.30% | 0.17% |
| *Tallangatta* | 0.30% | 0.18% |
| *Walwa* | 0.30% | 0.21% |
| **Wangaratta** | | |
| *Glenrowan* | 0.92% | 0.54% |
| *Oxley* | 0.92% | 0.54% |
| *Moyhu* | 0.35% | 0.20% |
| *Springhurst* | 0.35% | 0.21% |
| *Wangaratta* | 0.92% | 0.54% |
| *Whitfield* | 0.35% | 0.20% |
| **Wodonga** | | |
| *Wodonga* | 1.90% | 1.12% |

Source: NEW (2007)

## 4.7 Carryover

- As an emergency response measure, carryover was introduced in Northern Victoria in 2006/07 which is mainly relevant to the Murray System. This allows both the urban and rural water entitlement-holders to keep their unused water in storages for use in the following season.
- Carryover is an important tool in low allocations years and current rules specify that the entitlement-holder's carryover plus allocations cannot exceed 100% of the entitlement (DSE, 2009).
- The carryover volumes for the Murray system were 23,450, 59,670, 66,480 and 262,500 ML for 2006-07, 2007-08, 2008-09 and 2009-10, respectively (G-MW data)[12].
- Table 8 summarises the carryover trends in urban water for five water delivery systems with Wodonga system carrying the largest volume.

**Table 8. Total urban carry over water (ML)**

| System | 2007-08 | 2008-09 | 2009-10 | 2010-11 |
|---|---|---|---|---|

[12] Note that carryover for the Murray System is only representative of the carryover held by G-MW customers (to Nyah) and excludes carryover against environmental entitlements.

| | | | | |
|---|---|---|---|---|
| Bellbridge | 58 | 39 | 27 | 66 |
| Tallangatta | 193 | 180 | 211 | 435 |
| Wodonga | 1305 | 1878 | 3275 | 3610 |
| Rutherglen | 239 | 138 | 0 | 480 |
| Yarrawonga | 449 | 199 | 0 | 426 |
| Total | 2244 | 2434 | 3513 | 5017 |

Source: NEW data

## 4.8 Environmental water

- Environmental entitlements are created through relevant State/Commonwealth legislation for environmental purposes.
- Whilst the need to define environmental entitlements in a similar manner to consumptive entitlements is recognised, this invariably affects the reliability of other entitlement-holders. Therefore, creating more localised rule-based entitlements' that reflect the characteristics of the environmental water is urged.
- The existing environmental entitlements extracted from the Northern Region Sustainable Water Strategy are given below.

**Table 9. Existing environmental entitlements in the Murray system**

| High-reliability entitlement (GL) | Low-reliability entitlement (GL) | Rule-based entitlement (GL)* | Average availability (GL/year) | Comment |
|---|---|---|---|---|
| | 99.0 | | 37.0 | Murray Environmental Entitlement (from Living Murray conversion of sales water) |
| 27.6 | | | 27.5 | Flora & Fauna Bulk Entitlement |
| | | 50.0 | 49.8 | Barmah Environmental Water Allocations |
| | | 25.0 | 19.0 | |

Source: DSE (2009)
*Rule-based water may be actively used for environmental purposes, but are not environmental entitlements.

- Often environmental water is available only when other commitments have been met and instances where there is insufficient storage capacity.

# 5 WATER SOURCES

- This section categorises various water sources available to North East Victoria.
- North East Victoria sources its water predominantly from regulated rivers such as Upper Murray, Kiewa and Ovens[13] rivers which provide a high level of reliability. These river systems also have major reservoirs including Dartmouth Dam, Lake Hume, Lake Buffalo, Lake William Hovell, Lake Nillacootie and Lake Mulwala. In addition, groundwater, rainwater, stormwater and recycling contribute to the total supplies.
- North East Victoria region covers five Groundwater Management Areas (GMAs): Barnawartha GMA in the Ovens Basin, Goorambat in the Broken Basin, Mullindolingong GMA in the Kiewa Basin, Murmungee GMA, Upper Ovens and Lower Ovens GMA.

## 5.1 Total water availability

- Estimating the total water (surface and groundwater) use and availability for North East Victoria is problematic because different water agencies use different boundaries in reporting. Both the G-MW and NEW cover different geographical areas to what is regarded as the North East Catchment area.
- On average, over 85% of total rural water use in the North East region is surface water and 14% is groundwater (ABS, 2008).
- Over 90% of the urban water for the North East Victoria region comes from rivers and reservoirs. In addition, groundwater (bores and springs), recycled water (treated wastewater), rainwater (from household roofs) and stormwater (urban run off) add to the total supply[14].
- Table 10, compiled from the Northern Region Sustainable Water Strategy (DSE, 2009), outlines the average availability of surface water under historical inflows for the North East Victoria river basins.

[13] Note that the Ovens system has smaller capacity for regulation.

[14] Actual rainwater capture and usage is unknown while stormwater run off constitutes a minor usage currently (NEW, 2007).

**Table 10 Average surface water based on historic inflows (GL/year)**

| System | Total resource | Water that can be taken under entitlements | | | | | Average Environmental water[6] |
|---|---|---|---|---|---|---|---|
| | Average annual streamflows[1] | Regulated rivers: Urban use[2] | Regulated rivers: Rural and D&S[3] | Unregulated rivers[4] | Unlicensed dams[5] | Total | |
| Murray | 7,618 | 58 | 1,549 | 21 | 8 | 1,636 | 4,089* |
| Kiewa | 689 | 1 | 0 | 14 | 5 | 21 | 674 |
| Ovens | 1,718 | 11 | 26 | 20 | 20 | 78 | 1695 |
| Total | 10025? | 70 | 1575 | 55 | 33 | 1735 | |

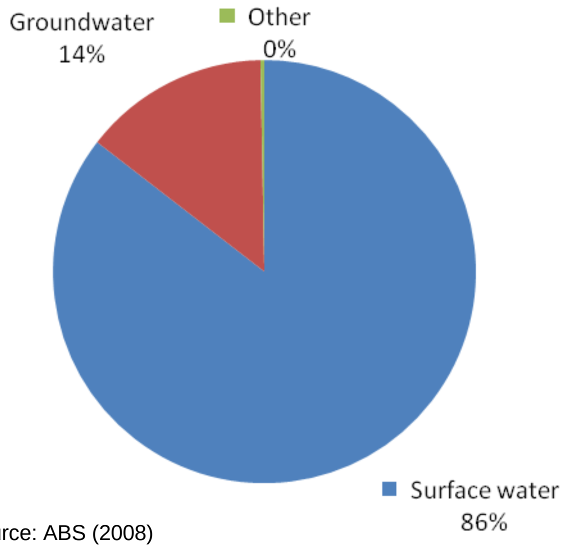
Notes:

1. Except for Kiewa Basin, estimates from long-term inputs to resource allocation models of basins plus estimated usage of unregulated rivers and small dams (State Water Report 2004/05).
2. Urban bulk entitlement volumes
3. Estimated as bulk entitlement volumes from regulated rivers except for Murray.
4. State Water Report 2005/06.
5. State Water Report 2005/06.
6. Estimated as end of valley flows.

*Estimated as River Murray flow at South Australian border.
Source: DSE (2009)

## 5.2 Sources of rural water supply

- As shown below, 86% of the rural water is sourced from surface water and 14% of the total supply is sourced from groundwater.




Source: ABS (2008)

**Figure 18 Rural water supply sources**

## 5.3 Sources of urban water supply

- Each water source is typically associated with different water quality and reliability characteristics which are discussed in section 5. The sectoral contribution to the total urban water supply in the region is depicted in Figure 19 below.

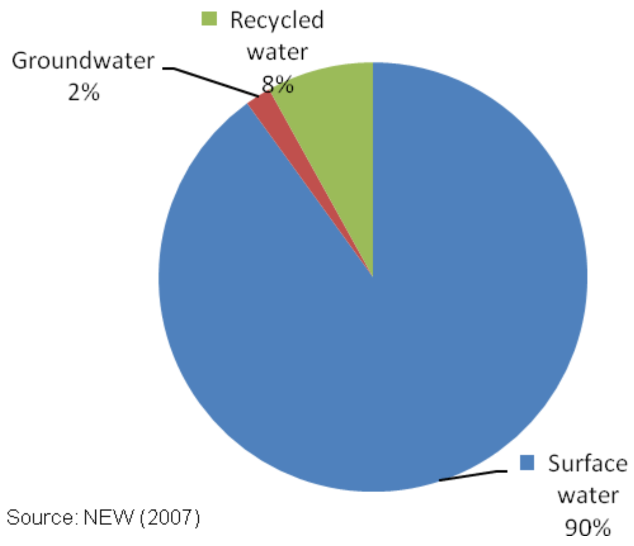



**Figure 19 Urban water supply sources**

- North East Water currently holds groundwater licenses for over 600 ML.
- Groundwater is used as the main or only supply for towns such as Goorambat (shallow bore), Barnawartha (deep bore) and Chiltern[15] (springs and deep bore) (NEW, 2007).
- Recycled water use is significant as NEW currently operates eighteen wastewater treatment plants and one trade waste plant (Wangaratta)[16]. North East Water produces approximately 9,000 ML of reclaimed water per annum through their wastewater treatments plants (NEW, 2010). Reclaimed water use opportunities for each LGA are briefly reviewed in section 6.
- Currently, there are no direct records on rainwater tank usage for the region. The WSDS estimates the rainwater use to be over 2000 ML per year assuming that on average each household has a storage tank of 2000-litre capacity and intercepting 80% of the rainfall that lands on 100 $m^2$ roof (NEW, 2007).
- The ABS statistics indicate that households in regional Victoria use a higher proportion (66%) of self-extracted water[17] when compared to metropolitan Melbourne (45%) (ABS, 2010). A greater proportion of households in regional Victoria (46%) had rainwater tanks than Melbourne (22%). Also noteworthy is the positive correlation between the household income and the self-water extraction. For example, in regional Victoria, fewer households had self-extracted water if household income was less than $25,000 per year (59%) compared to households with household income $110,000 or more per year (72%) (ABS, 2010c).
- Unlike rainwater, stormwater picks up oils and greases from roadways, litter and other pollutants such as nutrients from domestic gardens. Accordingly, it needs to be treated for fit-for-purpose applications. The current rainwater usage in the region is minimal (NEW, 2007).

[15] Chiltern, since then, has switched to the pipeline that feeds from the Murray System.

[16] Fifteen wastewater treatment plants (out of a total of 19) are located in the LGAs covered by this study.

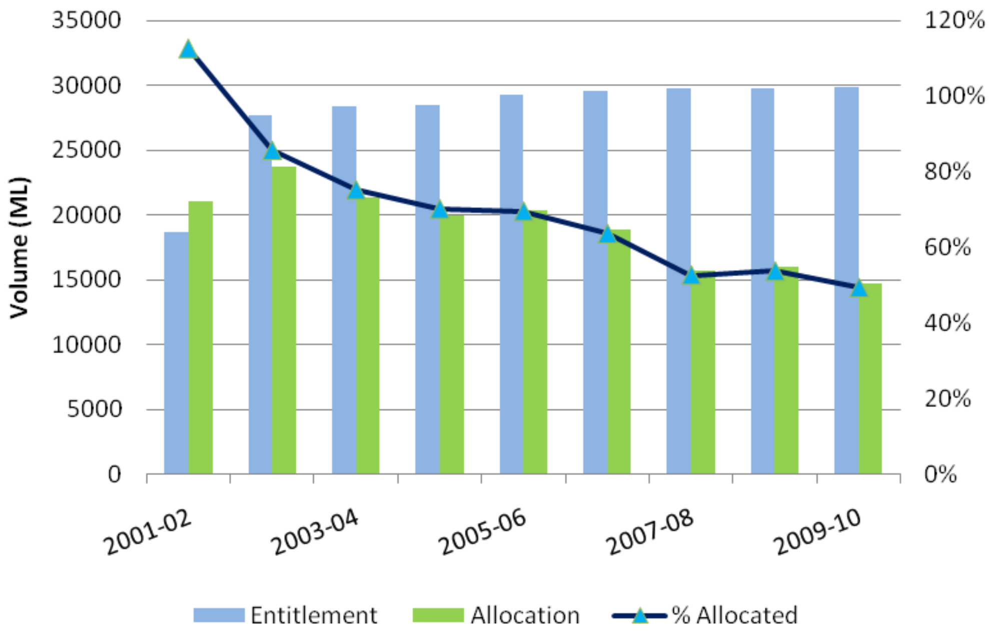
[17] Self-extracted water is water extracted directly from the environment for use (including rivers, lakes, groundwater and other water bodies).

# 6 WATER SUPPLY RELIABILITY

- Water supply reliability for a user in a town is a function of number of related factors including supply system reliability, reliability of the entitlement, access to alternative water sources and broader policy considerations.

## 6.1 Reliability of supply sources

- The core variables that affect supply reliability include reduced water availability, increased stream flow variability and consumer demand.
- Figure 20 shows the historical allocation and entitlement from all surface water sources of North East Water. The volume of water received has been progressively reduced during the last decade. In 2001-02, the allocation was 113% compared to 49% allocation in 2009-10.




Source: NEW data

**Figure 20 Surface water allocations (urban)**

- The reliability of individual urban water supply systems varies considerably between towns. The towns served by regulated systems such as the Murray River and the Ovens River generally have a higher reliability (95%) compared to the towns supplied with unregulated water supply systems[18].
- The supply reliability of an urban water system is the proportion of time that a supply system is able to meet demand. The North East Water Supply Demand Strategy

[18] It is worth noting that Wangaratta is reliant on Lake Buffalo and Lake William-Hovell – both relatively small storages, so inter-year reliability differs from the Murray system.

(NEW, 2007) provides the supply reliability of its delivery systems expressed as the probability that restrictions of any severity will not be imposed any given year or month. For example, a 95% reliability implies that water restrictions are likely to impose only once in every 20 years on average.

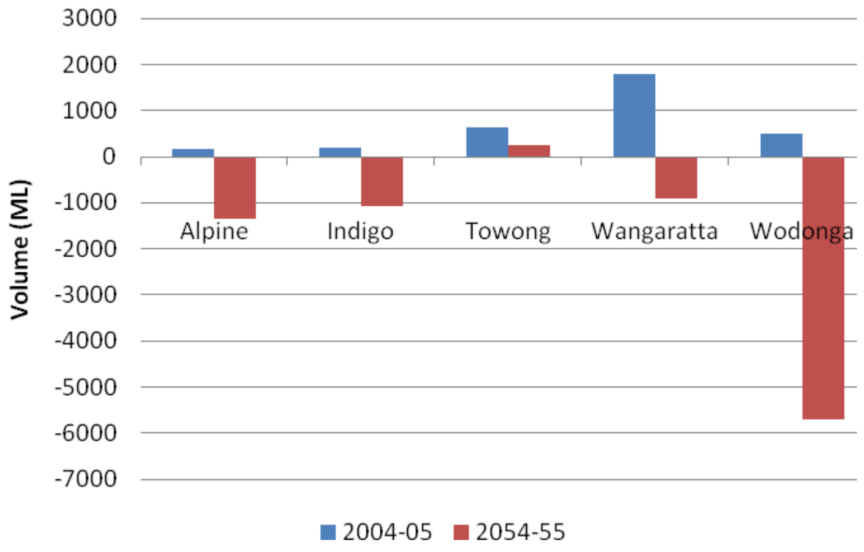
- Out of the 25 water delivery systems, the vast majority (69%) of the population is served by 9 regulated systems which generally have a higher reliability (NEW, 2007). The towns that are most susceptible to supply system variability are Springhurst, Harrietville and Bright (See Table 11).

**Table 11. Water supply system reliability by LGA**

| LGA | Supply System | Town | System reliability |
|---|---|---|---|
| Alpine Shire | Ovens | Bright | 65% |
| | Ovens | Harrietville | 65% |
| | Kiewa | Mount Beauty | 95% |
| | Ovens | Myrtleford | 95% |
| Indigo Shire | Groundwater | Barnawartha | Bore |
| | Kiewa | Beechworth | 93% |
| | Murray | Chiltern | Spring & Bore |
| | Kiewa | Yackandandah | 93% |
| Towong Shire | Murray | Bellbridge | 95% |
| | Upper Murray | Corryong | 95% |
| | Mitta Mitta | Dartmouth | 95% |
| | Murray | Tallangatta | 95% |
| | Upper Murray | Walwa | 95% |
| Wangaratta RC | Ovens | Glenrowan | ND |
| | King | Moyhu | 95% |
| | King | Oxley | 95% |
| | King | Whitfield | 95% |
| | Ovens | Springhurst | 63% |
| | Ovens | Wangaratta | 95% |
| Wodonga | Murray | Wodonga | 95% |
| | Murray | Baranduda | 95% |
| | Murray | Bonegilla | 95% |
| | Murray | Ebden | 95% |
| | Murray | Killara | 95% |

ND – Not determined.

- The Water Supply Demand Strategy prepared by the North East Water analysed their 25 water systems incorporating population and demand changes and supply factors including climate in their assessment. Figure 21 depicts the urban water supply demand imbalance for the municipalities in the North East region (Yarrawonga, Benalla, Goorambat and Bundalong excluded). However, the above assessment did not take into account the water demand emanating from future industrial growth and was based on very early predictions of climate change.
- According to NEW (2007), Towong Shire is the only municipality with surplus water or a positive net balance by 2054-55. The Wodonga LGA is expected to have the largest supply demand imbalance by 2054-55 unless of course additional water is secured, say by purchasing entitlements from other users.




**Source: NEW (2007) data**

**Figure 21 Urban water supply demand imbalance**

## 6.2 Reclaimed water use opportunities

- Reclaimed water provides substitution possibilities for adaptation. The recently concluded Wastewater Strategy of North East Water identified reclaimed water use opportunities for its nineteen wastewater systems considering a 50-year forward planning period. The wastewater systems located within the five LGA areas and the potential to use reclaimed water for drinking[19], residential 3rd pipeline, industrial use, watering open public spaces and agricultural and horticultural use are summarised in Table 12.

**Table 12. Wastewater systems and opportunities for reclaimed water use**

| LGA | Wastewater system | Inflows 2010 (ML/yr) | Drinking supply | 3rd pipe system | Industrial reuse | Open spaces | Agric/ Horti. |
|---|---|---|---|---|---|---|---|
| Alpine Shire (Total - 905 ML) | Bright | 300 | 2 | 1 | 1 | 3* | 3 |
| | Mount Beauty | 197 | 1 | 1 | 1 | 2 | 1 |
| | Myrtleford | 408 | 1 | 1 | 1 | 2 | 2 |
| Indigo Shire (Total - 495 ML) | Beechworth | 326 | 2 | 2 | 1 | 2 | 3* |
| | Chiltern | 89 | 1 | 1 | 2 | 2 | 3* |
| | Yackandandah | 80 | 2 | 1 | 1 | 2 | 3* |
| Towong Shire (Total - 322 ML) | Bellbridge | 27 | 1 | 2 | 1 | 3 | 3* |
| | Corryong | 161 | 1 | 1 | 1 | 2 | 3* |
| | Dartmouth | 15 | 1 | 1 | 1 | 1 | 1 |
| | Tallangatta | 119 | 1 | 1 | 1 | 2 | 3* |
| Wangaratta RC (Total -2819 ML) | Wangaratta | 2333 | 1 | 2 | 2 | 2 | 3 |
| | Wangaratta (Trade Waste) | 486 | 1 | 1 | 2* | 2* | 2 |
| City of Wodonga (Total - 4459 ML) | Wodonga | 4178 | 1 | 2 | 3 | 3 | 1 |
| | Barandudа | 240 | 1 | 1 | 1 | 2 | 1 |
| | Barnawartha | 41 | 1 | 1 | 1 | 2 | 2* |

Source: NEW (2010) data
Legend:
1 – Not likely that reclaimed water opportunity will be adopted
2 – Possible that reclaimed water opportunity will be adopted
3 – Recommended reclaimed water opportunity
* Current use of reclaimed water

[19] The Wastewater strategy emphasises that it is not the current government policy to use reclaimed water directly in drinking water supply.

- The basis of determining opportunities for each wastewater system included existing infrastructure, ability to meet current obligations, security and reliability of alternative supply options and cost considerations (NEW, 2010).

- The Wastewater Strategy recommends reclaimed water for urban public open spaces for all five LGAs except the township of Dartmouth. Both the Indigo and Towong Shires currently use reclaimed water for agricultural or horticultural use.

- Within the time horizon considered (50 years), there is a possibility of towns such as Wodonga, Wangaratta, Bellbridge and Beechworth adopting 3$^{rd}$ pipe systems (residential). Overall, it appears that Indigo Shire and Wangaratta have the most opportunities to use reclaimed water. The wastewater inflow analysis revealed a seasonal variation (spring spike) and Wodonga and Wangaratta municipalities have significantly large volumes of inflows compared to other LGAs.

# 7 FINDINGS OF THE REVIEW

- North East Victoria has a diverse economy. Service and manufacturing sectors in the region make major contributions whilst the agricultural sector still plays an important role. Significant restructuring in certain sectors have also taken place due to changing economic and social needs in the region and elsewhere.
- Forest industry projections indicate that there may be an expansion of plantation forestry in the study area. At a local government scale, such expansions can potentially reduce the stream flow in particular sub-catchments in certain years. These projections also fail to account for the impacts of climate change in the region.
- Population demographics analysis reveals that the North East region is expected to grow at an average annual rate of 0.7% in the medium term. However, it is noteworthy that this rate of growth is lower than the projected growth rate for Regional Victoria (1%).
- Population growth among different LGAs in the North East region is asymmetrical. Some LGAs such as Wodonga are likely to grow at a faster rate than the regional growth rate whilst others, such as Towong Shire, may experience a negative growth rate in the long run.
- The water entitlement configuration for the region represents a hierarchical structure with different degrees of attenuation at each level. This means adaptation options depend not only on the decisions made at the lowest levels of the hierarchy but also by the decisions made at superordinate levels.
- A myriad of entitlement and access rights have been defined for various water uses and user groups. Implicit in this specification is the reliability of entitlement which is different to water supply reliability.
- Limitations of the current water entitlement framework, particularly maintaining the ‘hydrological integrity’ and better articulation of environmental entitlements contribute towards a better understanding of adaptation options for the region.
- North East Victoria enjoys a relatively high security of water supply compared to other regions in Victoria because of its proximity to regulated river systems and large storage facilities.
- The data on water consumption analysis for the North East region is complicated by the fact that different water agencies have different reporting boundaries and the estimates provided should be treated as preliminary estimates.
- The sectoral water consumption in the region is overwhelmingly skewed towards rural water use (irrigation and D&S) which represents about 77% of the total water use in the region.
- Over half of the rural water supplied in North East Victoria comes from regulated systems and one fourth from unregulated systems. Wangaratta and Towong LGAs were the highest rural water users in the region which is consistent with their relatively large agricultural sector (section 2.5). Also noteworthy is that the region’s average per hectare water use is considerably higher than the Victorian average.

- Water trading can be an efficient tool to redistribute water in accordance with changing community, economic and environmental needs. Currently, the potential benefits of trade is largely limited to those who are part of a regulated system as trading in unregulated systems is less common.
- Urban water demand growth has been growing steadily during the last decade. It appears that, in addition to residential growth, a recent spike in industrial growth in water consumption has contributed to the overall demand. However, demand for reticulated water supply is not reflected in volumes of urban water consumed over time. This can be largely attributed to urban water restrictions imposed in recent times and adaptation measures at the household and firm level in part as a rational response to rising water prices.
- The residential sector accounts for about 64% of the total urban water use while commercial and industrial sectors account for about 22% and 14%, respectively.
- In certain localities, decreasing household size coupled with an ageing population and water efficient urban design may offset part of the demand growth.
- The projections in urban water demand indicate that certain towns such as Barnawartha, Wodonga, Chiltern, Bright, Bellbridge and Bundalong will experience higher demand growth than other towns in the region.
- To date, residential water supplies have been given priority over the other users when there are very low allocations to Bulk Entitlements. Commercial and industrial users may be vulnerable to reduced water availability if alternative supply options are not available. However, the vulnerability of ecological assets is probably most at risk under the current arrangements.

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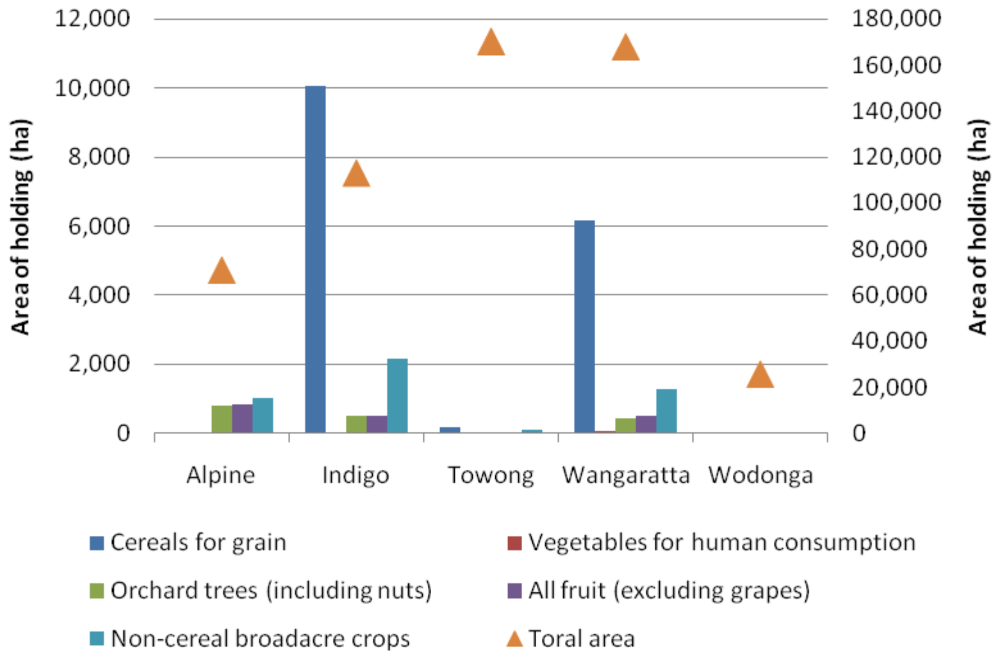
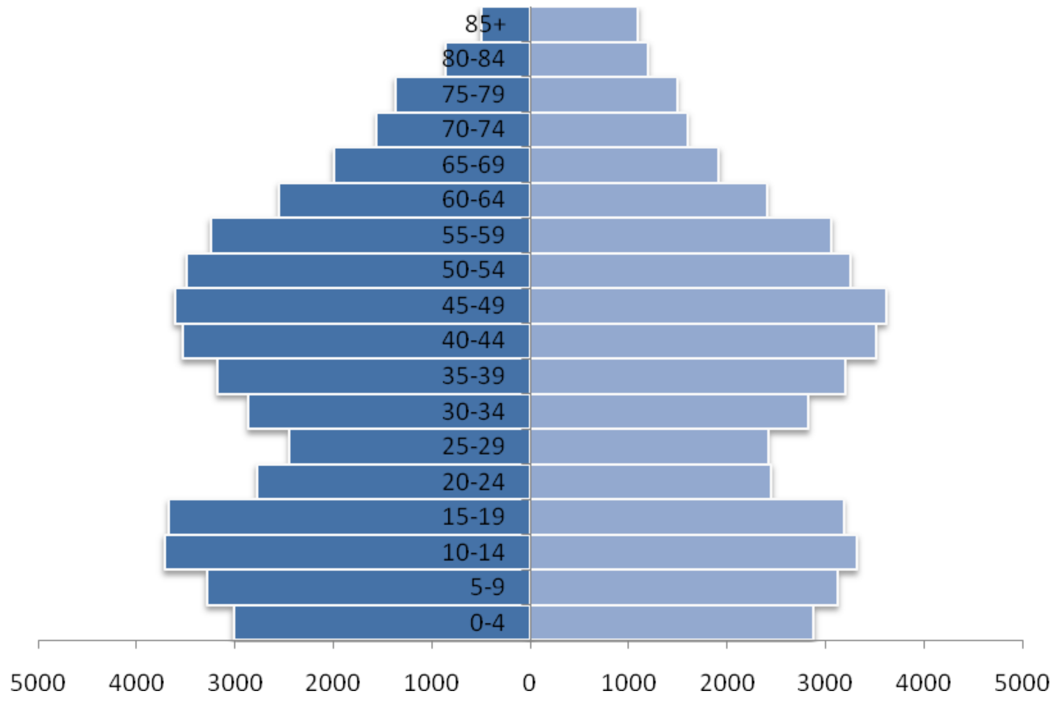
# 9 Annex 1




Source: ABS (2010)

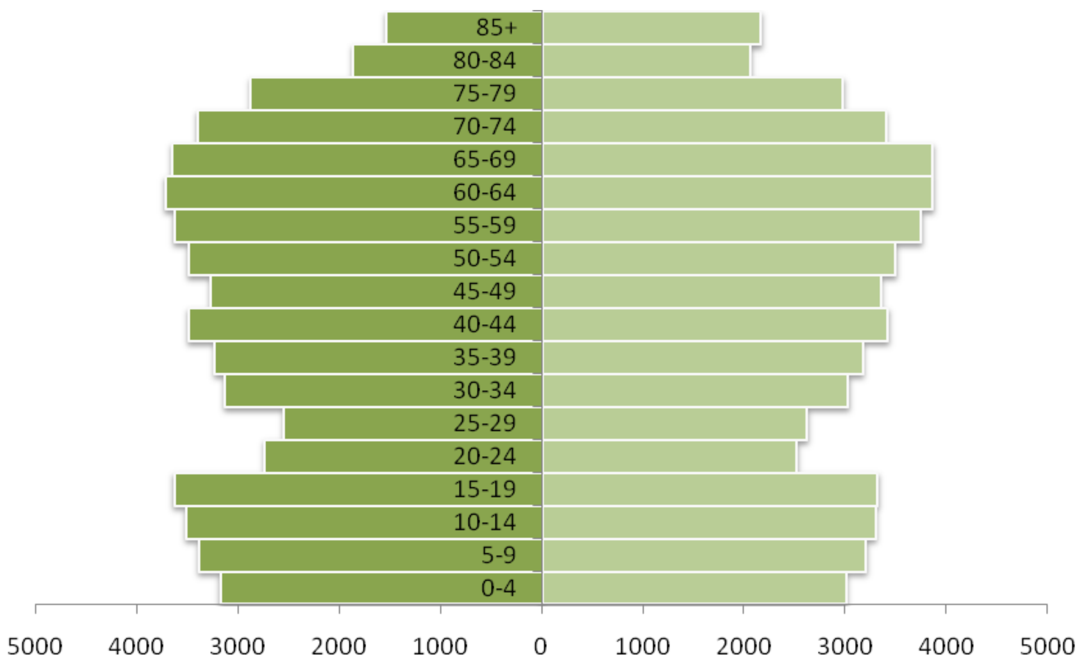
**Figure A1. Areas of holdings in 2006 – North East Victoria**

## Population and demographics




Source: Victoria in Future 2008

**Figure A2: Age structure, North East Victoria, 2006**




Source: Victoria in Future 2008

**Figure A3: Projected age structure, North East Victoria, 2026**

**Urban water use**

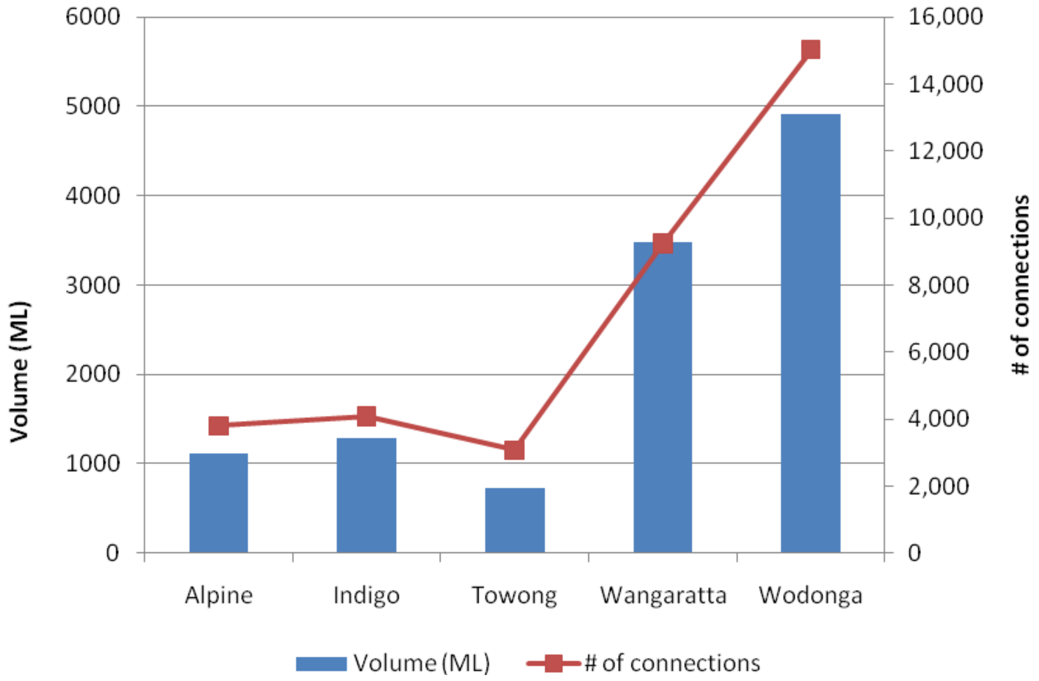



**Fig A4. Total urban water consumption in North East Victoria, 2008-09**

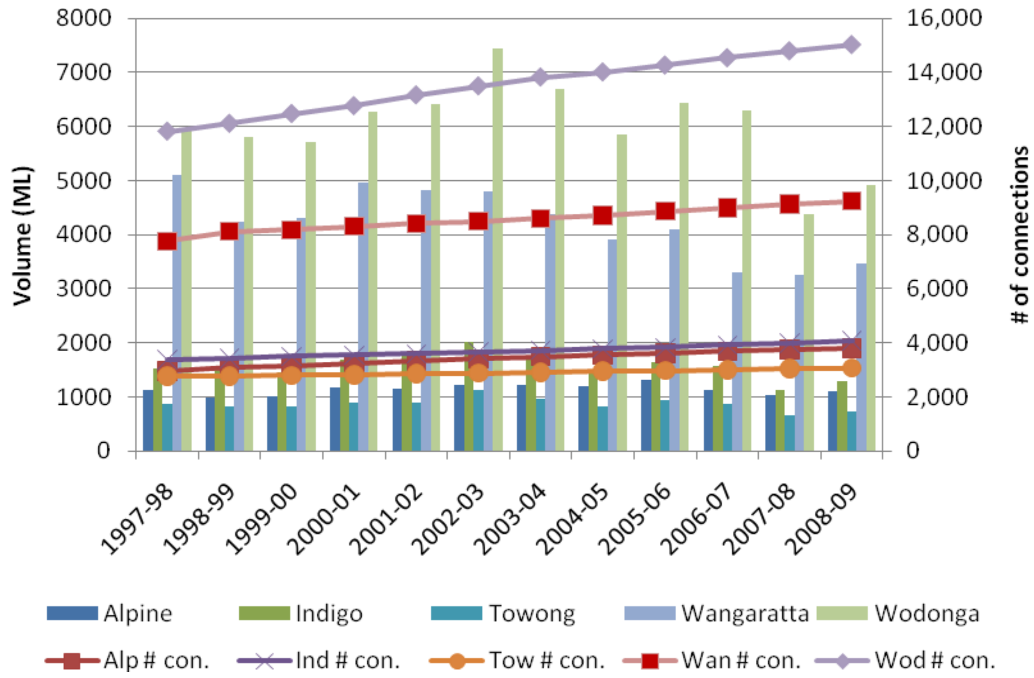



**Fig A5.Total urban water consumption by LGAs, 1997-98 to 2008-09**

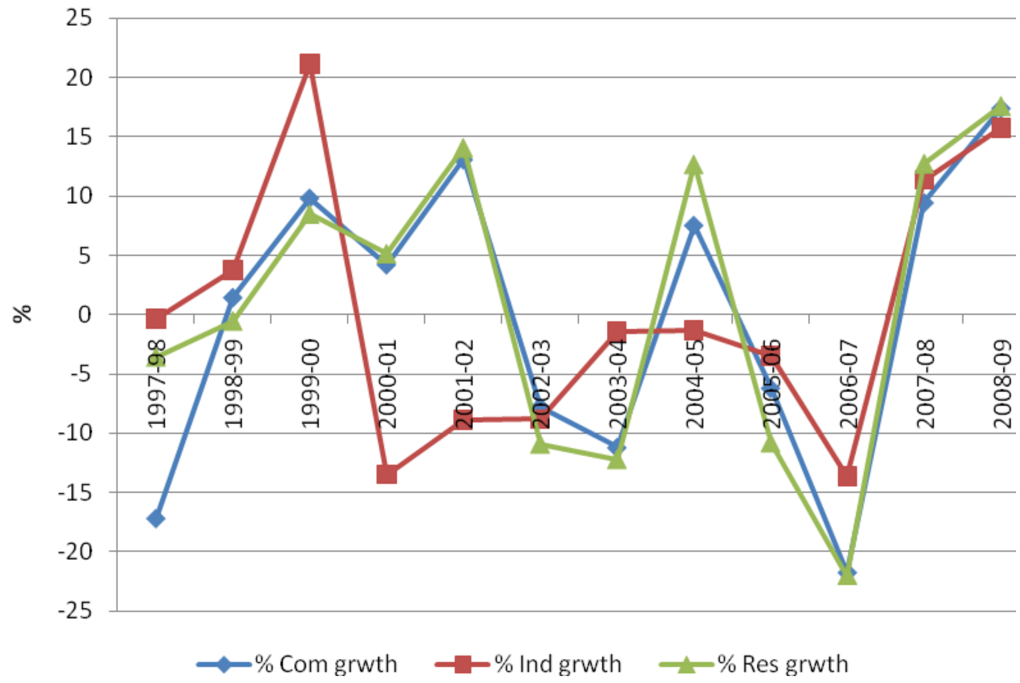



**Figure A6. Sectoral growth in urban water consumption**

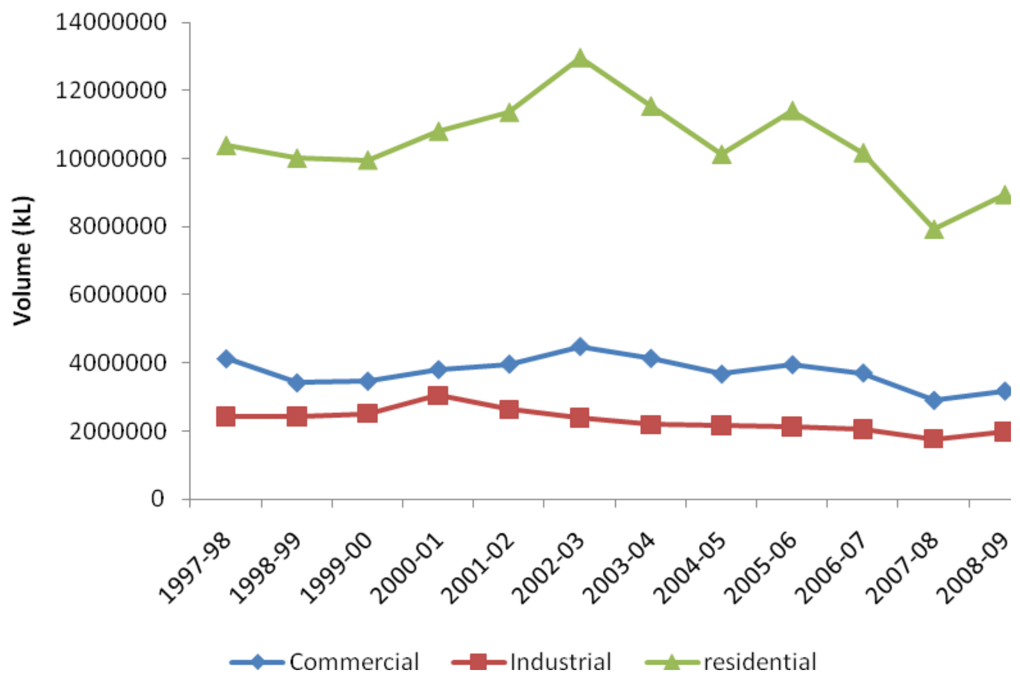
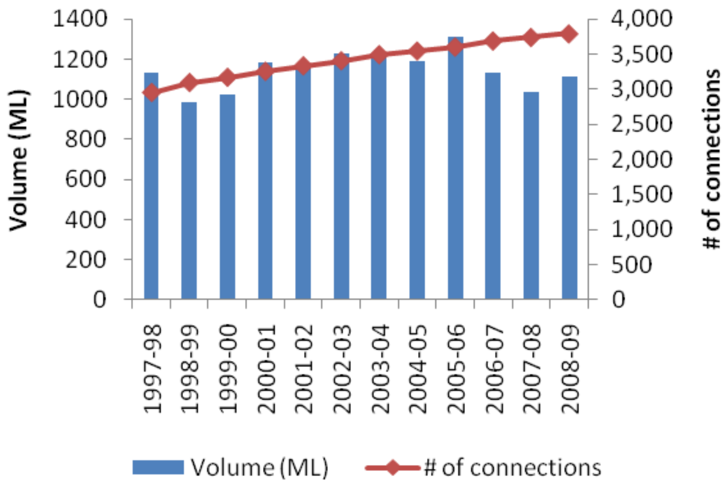
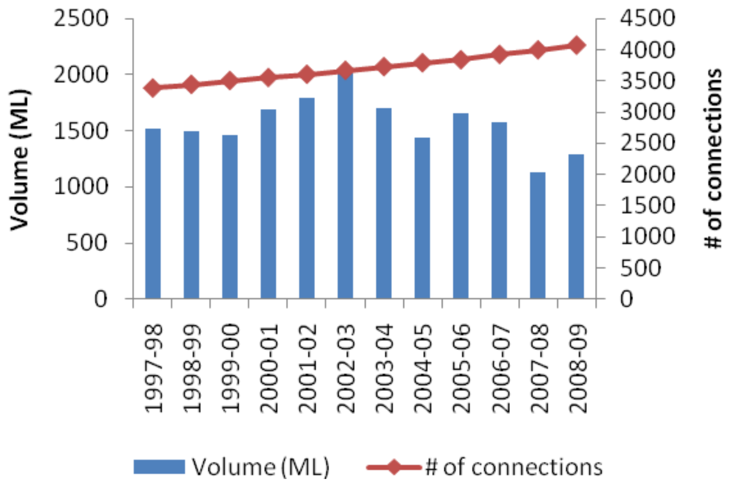



**Figure A7. North East Victoria urban water consumption**

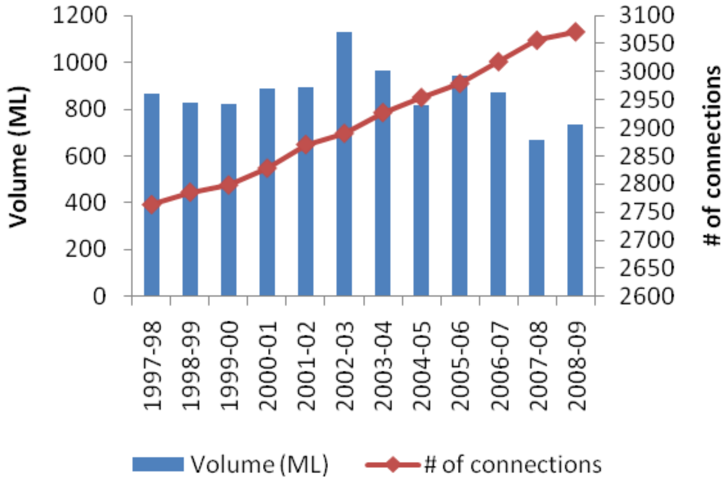
**Figure A8. Total urban water consumption (ML) by LGA**



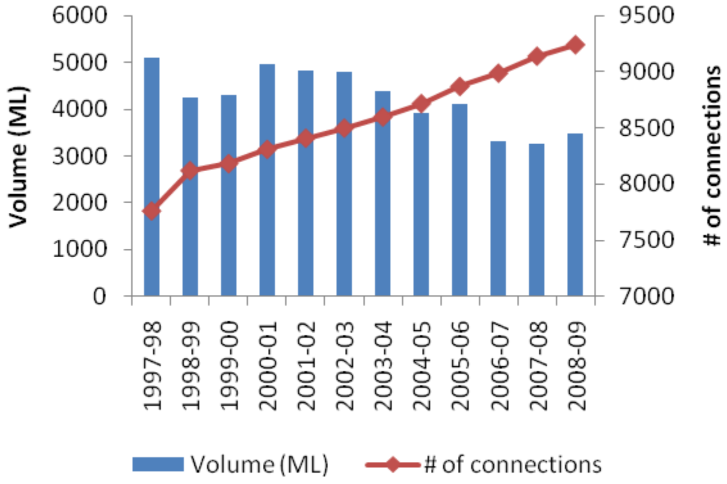

a. Alpine Shire



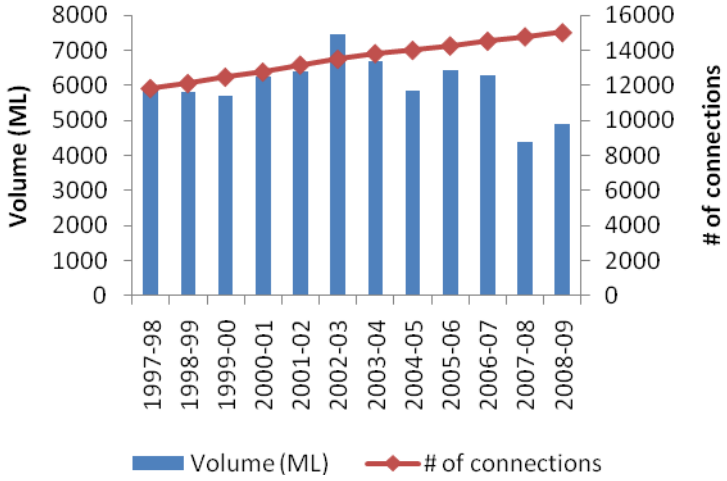

b. Indigo Shire




c. Towong Shire




d. The Rural City of Wangaratta




e. The City of Wodonga

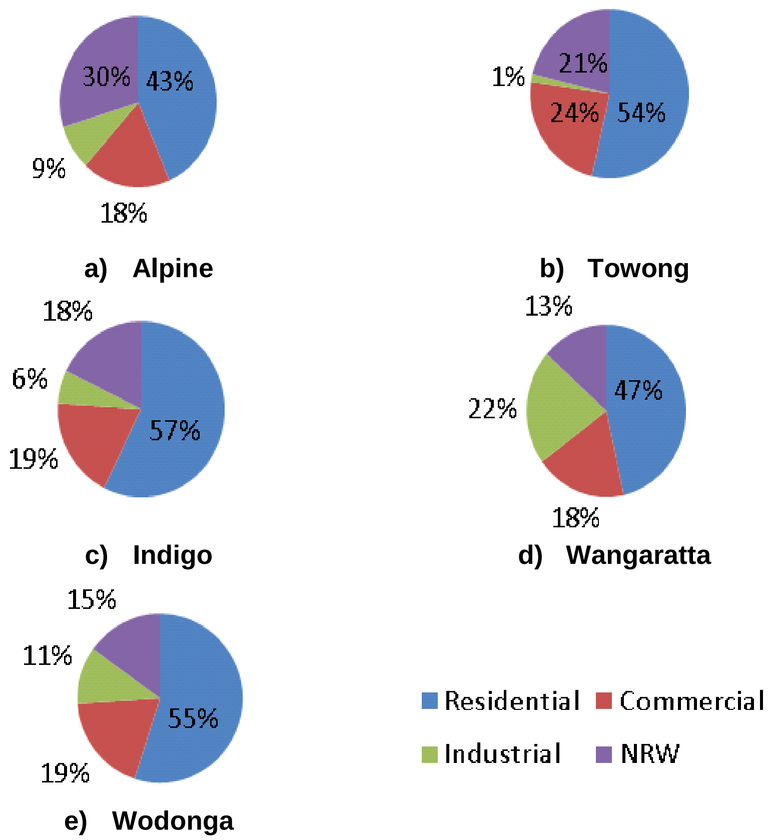
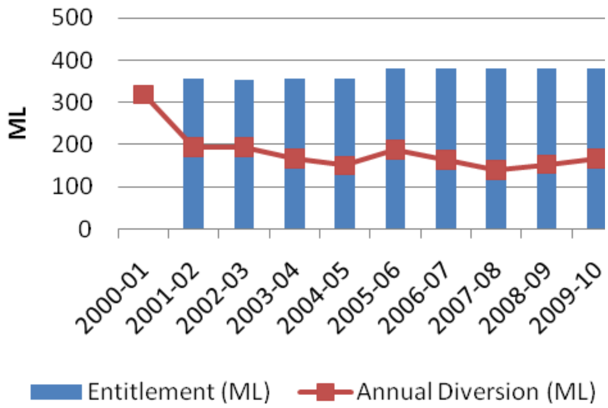
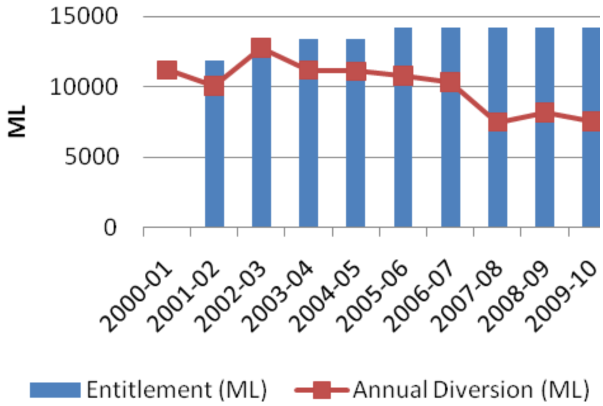


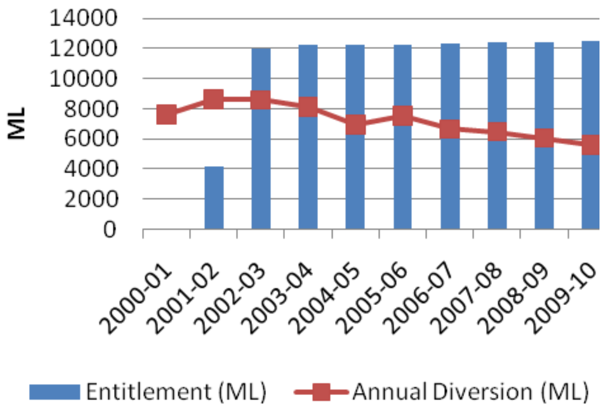

**Figure A9. Urban water use by sectors in North East Victoria**




**Kiewa system**




**Murray**




**system** **Ovens system**

**Figure A10. Urban water entitlements and allocations by supply system, 2000-10**

## Wastewater inflows

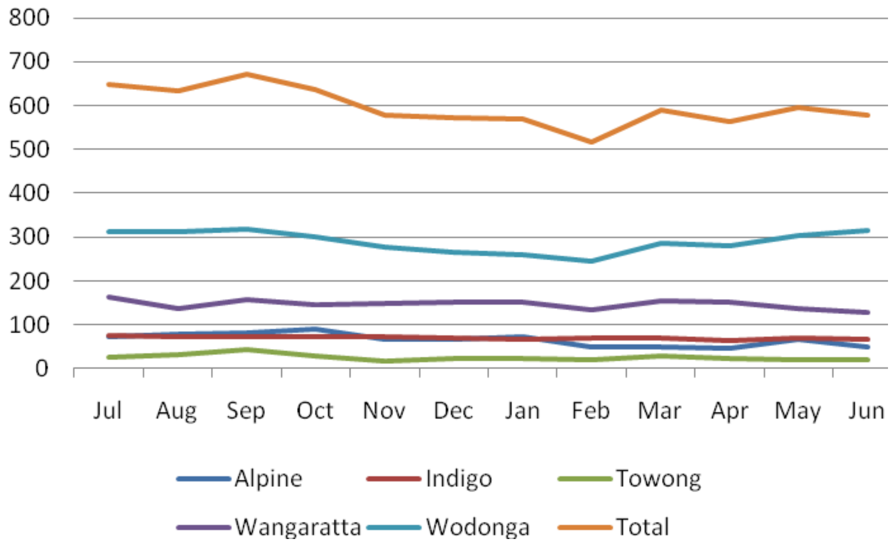



**Figure A11. Seasonal wastewater inflows, 2009-10**

# 10 Annex 2

### Table A1. Employment by industry for Alpine Shire, 2006

| Industry | No. employed | % total employed | Avg. Ann. Ch. 1996-2006 |
|---|---|---|---|
| Agriculture, forestry & fishing | 592 | 10.1% | -2.8% |
| Mining | 15 | 0.3% | -7.3% |
| Manufacturing | 656 | 11.2% | -3.9% |
| Electricity, gas & water | 88 | 1.5% | -5.3% |
| Construction | 453 | 7.7% | -0.4% |
| Wholesale trade | 101 | 1.7% | -10.8% |
| Retail trade | 628 | 10.7% | -2.1% |
| Accommodation & food services | 856 | 14.6% | -3.5% |
| Transport, postal & warehousing | 173 | 2.9% | -5.1% |
| Information Media & telecommunications | 56 | 1.0% | -12.1% |
| Financial & insurance services | 98 | 1.7% | -11.1% |
| Rental, hiring & real estate services | 140 | 2.4% | -0.9% |
| Professional scientific & technical services | 259 | 4.4% | -7.7% |
| Administrative & support services | 153 | 2.6% | -6.9% |
| Public administration & safety | 314 | 5.4% | -4.6% |
| Education & training | 446 | 7.6% | -4.2% |
| Health care & social assistance | 582 | 9.9% | -3.4% |
| Arts & recreation services | 86 | 1.5% | -4.6% |
| Other services | 170 | 2.9% | -5.3% |
| **TOTAL** | **5866** | **100.0%** | **-4.2%** |

Source: ABS Census 2006

### Table A2. Employment by industry for Indigo Shire, 2006

| Industry | No. employed | % total employed | Av. Ann. Change 1996-2006 |
|---|---|---|---|
| Agriculture, forestry & fishing | 737 | 11.0% | 0.1% |
| Mining | 19 | 0.3% | 3.9% |
| Manufacturing | 1051 | 15.7% | 0.5% |
| Electricity, gas & water | 30 | 0.4% | -4.4% |
| Construction | 502 | 7.5% | 4.6% |
| Wholesale trade | 163 | 2.4% | -0.7% |
| Retail trade | 701 | 10.5% | 5.4% |
| Accommodation & food services | 439 | 6.6% | 3.6% |
| Transport, postal & warehousing | 256 | 3.8% | 3.8% |
| Information Media & telecommunications | 48 | 0.7% | -0.4% |
| Financial & insurance services | 73 | 1.1% | -2.4% |
| Rental, hiring & real estate services | 51 | 0.8% | 3.8% |
| Professional scientific & technical services | 249 | 3.7% | 3.2% |
| Administrative & support services | 141 | 2.1% | 1.9% |
| Public administration & safety | 523 | 7.8% | 3.6% |
| Education & training | 577 | 8.6% | 2.3% |
| Health care & social assistance | 864 | 12.9% | 1.9% |
| Arts & recreation services | 56 | 0.8% | 2.0% |
| Other services | 219 | 3.3% | 1.8% |
| **TOTAL** | **6699** | **100.0%** | **2.0%** |

Source: ABS Census 2006

### Table A3. Employment by industry for Towong Shire, 2006

| Industry | No. employed | % total employed | Av. Ann. Change 1996-2006 |
|---|---|---|---|
| Agriculture, forestry & fishing | 679 | 26.4% | -1.5% |
| Mining | 0 | 0.0% | 0.0% |
| Manufacturing | 196 | 7.6% | 0.3% |
| Electricity, gas & water | 31 | 1.2% | -6.8% |
| Construction | 207 | 8.0% | 4.5% |
| Wholesale trade | 72 | 2.8% | -3.5% |
| Retail trade | 207 | 8.0% | 2.5% |
| Accommodation & food services | 142 | 5.5% | 0.1% |
| Transport, postal & warehousing | 105 | 4.1% | 1.6% |
| Information Media & telecommunications | 20 | 0.8% | -8.0% |
| Financial & insurance services | 39 | 1.5% | -1.6% |
| Rental, hiring & real estate services | 13 | 0.5% | 3.7% |
| Professional scientific & technical services | 73 | 2.8% | 3.3% |
| Administrative & support services | 42 | 1.6% | 1.3% |
| Public administration & safety | 140 | 5.4% | 1.8% |
| Education & training | 198 | 7.7% | -0.3% |
| Health care & social assistance | 293 | 11.4% | 2.3% |
| Arts & recreation services | 19 | 0.7% | 6.6% |
| Other services | 96 | 3.7% | 0.0% |
| **TOTAL** | **2572** | **100.0%** | **0.2%** |

Source: ABS Census 2006

### Table A3. Employment by industry for Wangaratta Rural City, 2006

| Industry | No. employed | % total employed | Av. Ann. Change 1996-2006 |
|---|---|---|---|
| Agriculture, forestry & fishing | 1110 | 9.2% | 0.5% |
| Mining | 15 | 0.1% | 0.0% |
| Manufacturing | 1879 | 15.6% | -2.1% |
| Electricity, gas & water | 75 | 0.6% | -0.4% |
| Construction | 872 | 7.2% | 4.4% |
| Wholesale trade | 351 | 2.9% | -1.1% |
| Retail trade | 1539 | 12.8% | 3.2% |
| Accommodation & food services | 768 | 6.4% | 2.6% |
| Transport, postal & warehousing | 410 | 3.4% | 1.9% |
| Information Media & telecommunications | 147 | 1.2% | -2.6% |
| Financial & insurance services | 220 | 1.8% | 0.4% |
| Rental, hiring & real estate services | 99 | 0.8% | 2.8% |
| Professional scientific & technical services | 345 | 2.9% | 1.7% |
| Administrative & support services | 313 | 2.6% | 6.8% |
| Public administration & safety | 744 | 6.2% | 3.2% |
| Education & training | 851 | 7.1% | 1.5% |
| Health care & social assistance | 1718 | 14.3% | 2.7% |
| Arts & recreation services | 112 | 0.9% | 2.0% |
| Other services | 462 | 3.8% | 0.9% |
| **TOTAL** | **12030** | **100.0%** | **1.3%** |

Source: ABS Census 2006

### Table A4. Employment by industry for City of Wodonga, 2006

| Industry | No. employed | % total employed | Av. Ann. Change 1996-2006 |
|---|---|---|---|
| Agriculture, forestry & fishing | 188 | 1.2% | 1.4% |
| Mining | 16 | 0.1% | 0.6% |
| Manufacturing | 2405 | 15.2% | 2.7% |
| Electricity, gas & water | 88 | 0.6% | -2.0% |
| Construction | 1240 | 7.8% | 7.4% |
| Wholesale trade | 563 | 3.6% | -0.2% |
| Retail trade | 2071 | 13.1% | 2.9% |
| Accommodation & food services | 953 | 6.0% | 1.1% |
| Transport, postal & warehousing | 639 | 4.0% | 3.2% |
| Information Media & telecommunications | 188 | 1.2% | 1.3% |
| Financial & insurance services | 392 | 2.5% | 2.3% |
| Rental, hiring & real estate services | 189 | 1.2% | 2.5% |
| Professional scientific & technical services | 683 | 4.3% | 6.3% |
| Administrative & support services | 548 | 3.5% | 5.0% |
| Public administration & safety | 2179 | 13.8% | -0.2% |
| Education & training | 1093 | 6.9% | 2.6% |
| Health care & social assistance | 1654 | 10.5% | 4.3% |
| Arts & recreation services | 113 | 0.7% | 0.2% |
| Other services | 599 | 3.8% | 0.2% |
| **TOTAL** | **15801** | **100.0%** | **2.4%** |

Source: ABS Census 2006

North East Greenhouse Alliance

# Water Demand, Drivers, Trends and Related Behaviour

North East Victoria Adapting to a Low Water Future: Project Context Setting – Deliverable 3

**Acknowledgements**
The North East Greenhouse Alliance project *North East Victoria Adapting to a Low Water Future*, of which this paper is a part, is funded by the Australian Government through *Water for the Future.*

Author Dr Alistair Watson

403/147 Beach Street
Port Melbourne
Victoria
Australia 3207

Telephone: + 61 3 9646 1719

Facsimile: + 61 3 9645 1174

E-mail: aswatson@bigpond.net.au

# Contents

# 1 INTRODUCTION AND AIMS

The purpose of this project is to help local government in North East Victoria adapt to a lower water future caused by climate change. This part of the report concentrates on factors affecting water supply and demand. Somewhat ironically, given the stimulus for this project, it turns out that the demand for reticulated water by town dwellers, and for water for stock and domestic purposes by local dryland farmers, is far more important than future limitations in the aggregate supply of water, as affected by climate change-induced declines in rainfall and runoff.

Local government in Victoria is not directly responsible for providing urban water to ratepayers but satisfactory water services are crucial for household amenity, and commercial and industrial development. Investment in urban water infrastructure and associated pricing policies will be important for local government planning of the new housing developments that are required for the expanding population of North East Victoria.

The obvious reason that the emphasis will be on urban water in this report is that unlike other parts of Northern Victoria, North East Victoria has relatively little irrigation apart from floodplains of the Ovens and King Rivers and a few river pumpers along the Murray. However, there are several major water storages located in North East Victoria such as Dartmouth Dam and Lake Hume that were built to support extensive irrigation in the Murray-Darling Basin (National Water Commission 2010, pages 57 and 126). The volumes stored for irrigation, and associated flows, are multiple orders of magnitude greater than the amounts required for urban use and stock and domestic use on farms in the region, now and in the conceivable future[20].

## 1.1 Consumption Patterns and Trends

Readily available data put water issues in Australia and North East Victoria in proper perspective (Cooper 2010, page 279). Agriculture is the biggest user of water abstracted from rivers, streams and groundwater accounting for two-thirds of all water use in Australia. Most agricultural output in Australia is produced from natural rainfall, with farmers taking advantage of when and where rainfall occurs. As elaborated elsewhere in the report, dryland farmers are experienced in adapting production plans to a range of contingencies – (short-term) weather, markets and technical change. It can be anticipated that dryland farmers will exhibit similar flexibility in response to (long-term) climate change. Deliverable 4 also provides evidence supporting this view. Not just much more vulnerable to the effects of climate change on water supply, irrigation farmers are far less adaptable because of the rigidity imposed by capital invested in on-farm and off-farm irrigation infrastructure (Kingwell 2006).

[20] The amount required to meet environmental demands is addressed elsewhere.

There are major forestry industries in North East Victoria – both softwood and harvesting of native forests. Forestry has been under pressure in recent years because of bushfires and more stringent environmental obligations. Expected declines in runoff with climate change will force further rationalisation of forestry, especially if the Basin Plan now being developed for the Murray-Darling Basin requires forestry industries to purchase water to offset the effects of forestry on Murray-Darling Basin hydrology.

Use by households accounts for only 11 per cent of Australia’s water resources, with around half used inside the dwelling and a half used outside. Data for North East Victoria *per se* are even starker (North East Water 2007, page 21). North East Water (NEW) has a surface water entitlement to 28,000 ML/year, which is 2 per cent of the 1,400,000 ML high security water entitlement for irrigation in the Victorian and New South Wales Murray System. NEW also holds entitlements for around 2 per cent of the total (around 30,000 ML) groundwater resource of the region.

It follows that water shortages and concomitant water restrictions in North East Victoria are either an artefact of existing institutional arrangements for water sharing between irrigation and urban use or reflect deficiencies in the delivery infrastructure available to supply urban water or stock and domestic water. Arguably, the former is much more important and the water restrictions in North East Victoria of the last few years with all their costs and inconvenience to consumers have been excessive – although this is not the way that official or public opinion would have it, and nor is it the focus of the remainder of this report.

## 1.2 Demand Drivers

While the task of analysing ‘drivers’ of water policy could be interpreted at first glance as pulling together data on water supply and demand, to proceed solely in this fashion would neglect an important determinant of the past, present and future for water in North East Victoria; which is government policy itself. This part of the report begins with some remarks on irrigation policy in Victoria and why it has taken so much effort to break down, and so far only partially, the longstanding separation of the irrigated and urban sectors. This is important because water resources in the study region are not just available to local residents.

Existing institutional arrangements are a hangover from the traditional dominant role of irrigation in Victoria, going back for a century or more. The interests of residents of provincial cities and country towns in urban water availability and cost are still under-represented in political arrangements. Farmers dominate the Water Services Committees of irrigation authorities like Goulburn-Murray Water (G-MW) responsible for storing and delivering bulk water to rural water authorities. This was clearly demonstrated in the summer of 2006/07 when irrigators in the Ovens Valley pumped too much water with consequent water shortages in Wangaratta (Watson 2007). There are also inconsistencies in charging practices for irrigation and urban water.

The remainder of the section concentrates on government policy regarding urban water and characteristics of urban water consumers, their attitudes and behaviour in response to water restrictions, as unnecessary as most of those restrictions have been in North East Victoria.

In addition, since current water policy for both irrigation and urban sectors is now driven by greater ‘concern for the environment’, we need to consider carefully what concern for the environment actually means, and how such concern is interpreted in practice. It turns out that there are major differences of opinion in understanding and interpreting the multi-faceted notion of environment, and its application to both regulated river systems and urban water. These matters are above and beyond obvious political differences based on particular interests in water policy. Unravelling these philosophical differences helps explain the political and empirical difficulties now encountered in designing and implementing Australian water and environmental policy.

***The meaning of water demand for each sector is not the same. There are major differences of opinion in understanding and interpreting the multi-faceted notion of environment.***

# 2 HISTORICAL BACKGROUND TO WATER POLICY

As emphasised above, irrigation is the dominant use of water abstracted from Australian rivers. Much of Australia’s present approach to water policy stems from political alliances and persistent attitudes associated with the earlier dominance of irrigation in Australia. While there is little doubt that the policy of wholesale river regulation and encouragement of irrigation was superficially attractive and certainly popular, there were initial professional doubts and warnings as to its efficacy.

Two early irrigation specialists, Gordon and Black (1882, page 11) concluded their report to the Victorian Parliament on irrigation in Northern Victoria as follows:

> The preceding remarks are not put forward by us as conveying anything new on the subject of irrigation. The facts and figures referring to the experience of other countries may, however, prove interesting to many who have not had the opportunity of becoming conversant with the subject, and we think their publication would tend to elicit criticism and suggestions that might be of value in dealing with the question in its application to this colony. We believe that too sanguine views of its profitableness are often entertained from an under-estimate of the cost and an over-estimate of the results, arising from a want of information or due consideration of the conditions essential for success, and in the public interest we should be glad to see some of the questions we have touched upon thoroughly discussed.

As is often the case, nineteenth century rejection of professional advice on irrigation was an amalgam of conceptual misunderstandings by politicians and what they perceived to be political necessity. And not much has changed to the present day. Rational analysis is still hard to come by in Australian water and irrigation policy. The conceptual misunderstanding, as so elegantly demonstrated by Davidson (1969), backed up by an entire intellectual tradition that his work encouraged, was that large-scale publicly-funded irrigation is unsuited to Australia's resource endowments and potential markets. In short, when land is abundant, and capital and labour scarce, it makes no sense to apply limited, and variable, supplies of water to a small area of land. By definition, irrigation has high capital and operating costs in Australia because water supplies are variable. Especially for fresh produce, irrigated horticulture has high unit labour costs in Australia and is always vulnerable to competition from countries with lower wage costs in production and marketing. These endowment realities have not changed and local governments need to be careful when seeking long term economic development along these lines.

Randall (1981) pointed out that irrigation was pushed way past the point of diminishing returns in the 1960s and 70s long after the best sites for water storage were developed; this was encapsulated in the phrase 'mature water economy' with demand for irrigation water pressing against available supplies and increasing evidence of environmental damage. Some later-developed irrigation areas like the Campaspe have recently fallen over, ostensibly due to drought but drought is not the full story. Unfortunately, many of those who thought they were benefiting from government support for irrigation are still on the scene doggedly resisting the message that a new approach is called for.

The stimulus to widespread government enthusiasm for irrigation, based as it was on flawed analysis of Australian resources and trade opportunities, was compounded by widespread public and political attraction to irrigation developments as part of closer settlement schemes, in pursuit of so-called nation building. Prospects for irrigation were therefore further handicapped by small farm sizes in government-sponsored irrigation areas, condemning settlers to a frugal existence in pursuit of carelessly thought through egalitarian ideals. Low farm sizes in the old irrigation districts persist until the present-day with consequent low incomes, often resulting in serious poverty problems during commodity downturns. This is happening right now in the Sunraysia and the Riverland of South Australia with the severe slump in the wine industry. To a lesser extent, similar trends can be witnessed with the decline in tobacco production in the Ovens Valley.

Such regular occurrences of depressed economic conditions in irrigated industries and the old irrigation districts give claims about the economic benefits of irrigation an extremely hollow ring.

***The current benefits of irrigation are certainly insufficient for residents of country towns and provincial cities outside irrigation areas and their representatives to have any qualms about requesting a reasonable water supply for their domestic, commercial and industrial needs, given that their requirements are so modest in relation to the amount of water now devoted to irrigation. Only minor changes in government policy and institutional arrangements would make this possible.***

Yet the story is still about that Australia suffers from acute water shortages. Governments are queuing up for a new round of expenditure on irrigation infrastructure, this time supposedly directed at water saving despite evidence and advice from reputable authorities (Productivity Commission 2010, Crase and O'Keefe 2009). The burden of their criticisms is that claimed water savings are mostly illusory because water is being shifted in the landscape rather than saved as usually understood. In any case, the economic and administrative case for government supply of specialised off-farm and on-farm infrastructure for irrigators when other farmers and businesses pay for capital equipment themselves is weak, even on the most charitable assessment. As persuasively argued by Kingwell (2006, page 1), investment in long-lived climate-dependent assets like irrigation infrastructure will become even more problematic with climate change. The existing and proposed program of government investment in irrigation infrastructure is bizarre given that the Commonwealth is now actively engaged in a program of buyback of irrigation entitlements, implying the judgement that current environmental costs of irrigation are greater than the economic benefits.

Water trade among irrigators and between irrigation districts has been on the agenda for almost twenty years. Liberalisation of trade to allow freer exchange of water between irrigators and other water users would solve water shortages for provincial cities and rural towns at the stroke of a pen. This is because the value of household, commercial and industrial uses of water will always trump the value of water used for irrigation. The interesting problem then is not solving water shortages as such but deciding the schedule of engineering projects – operating, maintenance and new investments – necessary to supply the local (and expanding) population of North East Victoria. These decisions are subject to environmental and financial constraints and need to account for consumer attitudes and behaviour.

***Current investments in long-lived climate-dependent assets such as irrigation infrastructure can be problematic given the confusing policy signals and their impacts on the community to adapt to a low water future. Many of the existing shortages of water in towns and cities in the North East could be easily addressed through expanded water trade. It also seems likely that future demands could be sensible addressed through the water market.***

# 3 WATER, INSTITUTIONAL ARRANGEMENTS AND THE ENVIRONMENT

Severe drought in much of Australia is the main cause of widespread public and political concern about water policy over the last decade or so. Although the extent of the drought is not completely outside the bounds of past experience, the severity of the drought has heightened fears of climate change. While there are at last a few signs of relief from the drought especially in the northern parts of the Murray-Darling Basin, it will take a long time for irrigation storages to be replenished and for (previously) normal water allocations to be restored to irrigators in Northern Victoria, even if this drought were not a harbinger of climate change.

Following from data and arguments presented in the previous two parts of the report, the drought need not have had the same drastic effects on urban water users as irrigators (see text box below). As pointed out above, water shortages for urban users occur essentially because of rigidities in institutional arrangements for water, in Victoria's case a bulk entitlement system that favours irrigators. Nevertheless, as subsequent discussion will elaborate, many urban consumers were more than willing to share in the discomfort of household water restrictions because they were persuaded by public attention given to the drought to think that rationing of water across the board was equitable.

Hence, widespread interest by urban households in augmenting personal water supplies with rainwater tanks, and public agitation and official support for greater recycling of treated wastewater and harvesting of storm water by water authorities.

***These issues are also taken up briefly later in this section of the report. Suffice to say at this stage; the take home message from these analyses is that these sorts of solutions to water shortage are very location-specific. In addition, there is a vast difference between optimal configurations of water collection and distribution networks before and after the event of their establishment. Put slightly differently, some infrastructure investments and water-saving practices make good sense in new urban developments but are not worth retrofitting in existing networks.***

Before the drought, water policy had been inevitably caught up in the fashion for microeconomic reform of the 1980s and 90s. There were wholesale changes in institutional arrangements for both irrigation and urban water. Obviously, irrigation was a candidate for reform – at least among officials – because of the tradition of substantial government subsidies to irrigators and protection of irrigated industries. In the past, prices charged to irrigators often did not even recover the operating costs of irrigation authorities let alone make a contribution to essential maintenance and capital costs.

Urban water was a different matter; payment of public authority dividends by water utilities that were embodied in consumer prices was the norm rather than the subsidies paid to irrigators. Nevertheless, there was plenty of evidence of overmanning and cost padding in major metropolitan water utilities. From the outset, urban water was regarded differently to other state-owned utilities where a stated aim was to reduce consumer prices by increasing operational efficiency. For urban water, it was widely thought that prices needed to be raised. An impression of concessional pricing for urban water was carried over from the reality of concessional pricing in irrigation.

Reflecting their different histories in Victoria, the application of the microeconomic reform agenda to water resulted in the amalgamation of numerous small-scale and high cost rural urban water authorities into larger units and the disaggregation of previously statewide irrigation authorities into smaller units, although these units were much bigger than the aggregated rural urban water authorities, especially in the geographical sense. Metropolitan, rural urban and irrigation water authorities were all subjected to price regulation by the Essential Services Commission (ESC). More stringent criteria were applied to pricing rules for metropolitan consumers.

Notably, the largest irrigation authority, G-MW, operating over all of Northern Victoria except for the far North West, retained control of headworks and reservoir operations with responsibility for the delivery of bulk entitlements to independent rural urban water authorities. In contrast, wholesale operations and retail distribution of water were separated in metropolitan Melbourne. Water authorities share the common characteristic of natural monopoly because it does not make sense to duplicate distribution networks. Water authorities thus have to be regulated and/or government owned if monopoly pricing is to be avoided.

In New South Wales, retail distribution of irrigation water was handed over to private irrigation companies that are in effect more like irrigator-owned cooperatives than private companies in the usual sense. However, all Victorian water authorities – urban, rural urban and irrigation remain in government ownership. Although government ownership does provide the opportunity for coordinated management, it is an open question whether having several government-owned entities that serve competing interests are harder or easier to manage than having private firms subject to government regulation. In managing irrigation, the opposite may be the case once entrenched industry and local political interests come into play in organizations supposed to be under government control.

A defining difference between urban water authorities and irrigation authorities is the importance of public health in the management of urban water, for both drinking water and wastewater. Urban water systems must be managed at an extremely low level of risk of contamination for drinking water and to control external effects of wastewater. The Department of Health and Community Services administers drinking water standards and the Environment Protection Agency is responsible for regulating the quality of wastewater discharges. Urban water services are also non-interruptible services like electricity. To all intents and purposes, most water used inside the home is the essential service sine qua non.

While they have their own set of tricky problems given the political background to irrigation, organisations like G-MW do not confront the same exacting operational difficulties as urban water authorities. In one important respect though, life is more difficult for irrigation authorities. The microbiological and chemical standards applied to drinking water and wastewater are measureable and objective. Once the standards are established, an urban water authority can employ professional staff and put in place processes to meet the required standards. The organizations regulating water quality are professional and objective. No such clarity applies to the environmental expectations placed on irrigation water authorities, conceptually and technically. Nor are the political issues surrounding the environment any less convoluted than the politics of irrigation as participants apply fixed political positions to questions that are essentially empirical, dependent on the facts and circumstances of the case, not ideological predispositions.

***One important aspect of the water demand analysis is the quality dimension. Whilst well specified water quality standards apply to drinking water, such clarity is absent in the provision of environmental water by rural water authorities. This also raises interesting challenges for smaller communities where an urban water utility is absent.***

The riverine environment has multiple dimensions – waterbirds, riparian vegetation and associated birdlife, floodplains, wetlands, native fish, introduced fish, macro-invertebrates in the river, water quality and more. Extraction of large amounts of irrigation water has some effects on all these attributes, how much depends on the quantum and timing of the extractions; in common parlance, some environmental attributes are flow-related and others are non-flow-related. Against the potential ill effects of irrigation, river regulation provides positive benefits – flood control and the amenity provided by water storages and weir pools, for example. The most difficult issue in environmental policy is deciding what should be the starting point or reference point for the analysis. It is just as unrealistic to suggest, like a few environmentalists, that restoring some original state of nature is possible or even desirable as it is to assert, like a few irrigators, that taking so much water out of the river system has had no deleterious effects on the environment.

Just as in economic policy making, the key question for environmental policy is, now what is the best thing to do? This requires carefully establishing where we are, and then deciding what, when, and how environmental improvements can be made. This will require evaluation of the costs of environmental changes (including costs to irrigators), their technical feasibility and estimation of the value of the environmental benefits received. It is important to recognise that most statements about environmental preferences reflect implicit valuations or weightings of the preferred environmental attribute. Moreover, some environmental changes following river regulation and extensive irrigation are irreversible and are no longer worth bothering about.

Urban water in rural areas does not contribute much to either flow-related or non-flow (timing) related environmental issues because the amount of water diverted from rivers is minuscule compared to irrigation. This is not the same in metropolitan areas where the environmental condition of rivers and catchments may be compromised by extraction of water for household, commercial and industrial use.

***The clue to environmental management for urban water in North East Victoria is to recognise that many of the proposals for water saving, and diminishing the environmental stress on rivers in populous parts of the state, including recycling, rainwater tanks and stormwater harvesting are not applicable to the North East. This is not just a question of the relative quantities involved; there is a vast difference in the economic and environmental logic of urban water management for towns and cities on inland rivers and towns and cities on the coast.***

Unreasonable costs would be imposed on consumers and business in rural areas if water costs were inflated by mandated water saving practices thought suitable for capital cities. In this context, local government in the North East should be cognisant of the impost on residents if state-wide or nation-wide responses to water shortage are markedly at odds with the realities of their region.

# 4 INVESTMENT IN URBAN WATER INFRASTRUCTURE IN NORTH EAST VICTORIA

This section of the report can be dealt with in two sub-sections: actions taken within the household or by businesses operating on their own account (rainwater tanks, dual flush toilets and watering behaviour) and actions taken by the water supply authority, in this case NEW (pipelines, reuse/re-cycle schemes and stormwater capture). Fortunately, the second part of the exercise is straightforward because it has been done already by NEW in their 2007 Water Supply Demand Strategy. In addition, NEW has to have its investment plans approved by the ESC as part of the process of price regulation. Consequently, updated material is readily available to assess the wisdom of so-called 'water efficiency measures and best practice in water management'.

As professional and interesting as their Strategy document is, NEW are compromised in what they say by their status as a state-owned entity. In effect, NEW assume the economic policy problem away with their statements at pages 14 and 17 respectively:

> The majority of water used is sourced from surface water. The [Victorian] Government allocates bulk entitlements to provide water for agriculture, urban consumers and the environment. Bulk entitlements issued by the Government determine the volume of surface water that can be extracted for use.
>
> However, the available water resource in northern Victoria is fixed. There is a regulatory limit on the volume of water that can be diverted from streams and rivers

in any one year. This limit is applied under the Murray-Darling Basin Cap on further extraction of water from the Basin.

The Cap is an agreement between Commonwealth and the states on total water use that has existed for fifteen years or so. The Cap is soon to be superseded by a Murray-Darling Basin Plan in advanced state of development that will reduce the amount of water abstracted from rivers for irrigation in favour of environmental use. The Cap and presumably the Basin Plan may set absolute limits on the total amount of water used in northern Victoria but the distribution of entitlements between urban water, irrigation and environment is a matter that can be determined by the Victorian Government.

***While the modus operandi of the Commonwealth Environmental Water Holder in managing the buyback component of the Commonwealth Water for the Future strategy and the environmental program to be pursued under the Basin Plan are both unknown at this stage, it is obvious that any extra water for the environment would result in more water being stored in upstream dams. It follows that there will be even less reason for urban water shortages in North East Victoria.***

Water will only be short if the Victorian Government chooses not to increase bulk entitlements for urban water, at the modest expense of irrigation, or does not allow trade between urban water authorities and irrigators, so that a similar result could be achieved through market forces, no more no less. The latter approach based on freeing up trade would be more politically acceptable, and in most opinions more equitable, because the property rights of irrigators who have been trading among themselves for around twenty years are taken into account.

Decisions by a water authority like NEW to purchase water rights to augment the supply of 'new' water should be based on the opportunity costs of alternatives like recycling of wastewater and stormwater capture. For consumers, costs, convenience and individual preferences will determine whether to reduce existing water use with rainwater tanks, dual flush toilets or by reconfiguring gardens with more hardy plants.  Salient features of these options are discussed below.

Key to the incentives confronting NEW and its customers in making these decisions will be the way water prices are structured between fixed charges and volumetric charges to recover capital and annual operating costs. Volumetric charges can also be stepped to reflect 'essential' (inside the house) and 'non-essential' (garden watering, swimming pools) uses, although a volumetric charge for so-called essential water is effectively the same as a fixed charge, except very occasionally for small households living in apartments.

In essence, the emphasis given to fixed or volumetric charges is arbitrary, a matter of choice according to the policy objectives being pursued. In many parts of the world water use is not metered and all revenue is then collected from fixed charges. Fixed charges are sometimes based on the value of land so that water charges become a tax on property and wealth. Aspects of this approach have also seen in Australia, even though urban water has been metered for a long time in most parts of the country. The wealth or property tax component of charges has diminished in recent years with more uniform fixed charges for households assigned to the provision of specific services – connection fees, drainage charges, wastewater charges and the like. In Victoria, an environmental/amenity levy to support expenditure on metropolitan parks and waterways is collected as part of water bills. The same logic is not applied to support analogous services provided by catchment management authorities in country Victoria.

Increasing volumetric charges relative to fixed charges encourages investment in water saving techniques by both water authorities and their customers: (annualised) capital and operating costs of the water saving investment will be compared with the value of the water saved.

***Less obviously, once water trade is allowed, higher volumetric charges encourage water purchases from the market. This is because the authorities can recoup expenditure by charging consumers for the additional costs of the water purchased, provided the volumetric charge is higher than the traded price.***

The counterpoint of higher volumetric charges is that revenue received by water authorities is more variable. This is inconvenient to management in an industry characterised by long-lived capital assets that have to be financed and maintained, and low annual operating costs.

Water pricing is not straightforward. Fortunately, the procedures of the ESC are thorough and transparent. The hardest decisions are with respect to charging for capital. Unlike irrigators, urban water consumers pay an interest charge on the sunk capital in water infrastructure, some of which may have been paid for a long time ago. This is invalid. Water available because of past investment in storage and other capital assets has a range of uses, but these uses are independent of costs incurred in the past. From an economic perspective, there is much to be said for considering the demand side in the allocation of water because of the pervasive existence of fixed costs in water infrastructure – for urban and irrigated uses. Rather than have a rigid bulk entitlement system, it would be better for bodies like G-MW to reserve a small amount of water that could be sold by auction or tender. Along with freeing up trade between irrigators and urban water authorities, this would assist the process of price discovery in a situation where so-called ‘cost recovery’ is problematic because of the influence of sunk costs.

## 4.1 Recycling[21]

[21] These notes are based on a review of Australian recycling literature done by the author for John Lind and Gary Stoneham of the Victorian Department of Sustainability and Environment in 2005-6. The full paper is available on request.

Unfortunately, recycling of wastewater is promoted as an objective without thinking much about the process by which ‘how’ and ‘how much’, ‘when’ and ‘where’ recycling is justified. A fundamental insight is that retrofitting capital embodied in sewerage and household plumbing is very costly. There are more opportunities in new subdivisions but new subdivisions are likely to be remote from treatment plants. Almost by definition, sewage treatment will take place at low points in the landscape for convenient discharge to waterways – or the sea in the case of Australian capital cities – and because gravity will be exploited in transporting sewage. It follows that treated wastewater will have to be (expensively) pumped uphill if it is to be used by households. There are some suitable uses for recycled water on playing fields and agricultural land in rural areas if small-scale recycling is possible (sewer mining).

In short, recycled water of potable standard is expensive compared to first use water in almost every circumstance. It is more costly to create and expensive to deliver. Not only that, potable recycled water faces consumer resistance and is vulnerable to scare campaigns despite the fact that recycled water has been consumed for aeons by large populations living in major cities on the inland river systems of many countries, developed and developing. When treated wastewater is already used downstream, it makes little sense to go to the expense of having third pipe systems and so on in the areas where the wastewater was produced.

Cost-based pricing has little to offer as a criterion for pricing recycled water. Recycled water is dearer than first use water and can only be used effectively if the effluent is damaging highly valued environmental assets and/or the recycled water can be used close to its point of treatment. What are often called impediments to the use of recycled water are the result of economic and engineering circumstances. The implication seems to be that anything that gets in the way of recycling is a bad thing, an unnecessary and unwelcome obstacle to a desirable and pre-determined state of affairs, in the eyes of advocates for recycling. Recycled water will most often require subsidies from governments or subsidies from other water users if water authorities hide its costs in prices charged to all water consumers. The case for government subsidies is weak, or non-existent. Fiddling with urban water charges to fund recycling projects would not only be dishonest, it is inequitable. In the case of very small communities, the same principles apply – benefits and costs need close scrutiny.

Even if the health risks of recycling are exaggerated in the public mind, this can be understood by the fact that individuals have not much to gain from using recycled water but a lot to lose if official confidence and scientific evidence based on the measured risks of recycling turns out to be unjustified. Similar risk averse behaviour by consumers has so far encouraged governments to be tentative in their approach to genetically modified plants, despite the scientific consensus that the health risks from using genetically modified plants are minuscule. It remains to be seen if a different risk assessment will be applied to smaller water-scarce communities.

## 4.2 Stormwater capture

NEW (2007, page 21) estimate that potentially 50,000 ML per year is available in their area of operation from urban runoff. Urban runoff ends up in stormwater drains and creeks. Many of the same comments that were made with respect to recycling apply to stormwater. Water quality is an issue for stormwater because urban runoff picks up pollutants and litter from roadways and households.

The point about the costs of retrofitting, this time to established drainage networks, also applies to stormwater. Making use of stormwater is easier in new urban developments that are designed to slow down the flow and filter stormwater for use in public open space and artificial wetlands. The process is described as water sensitive urban design (WSUD). NEW (2007, page 24) also point out that capturing stormwater does not create more water. Water is merely transferred in the landscape.

***Investment in stormwater capture should be predicated not on water saving, but on control of pollution in creeks and flood control in urban areas.***

Capture of stormwater at a small, local scale may have intuitive appeal but should nevertheless pass the same tests described above.

## 4.3 Expansion of the urban water network in North East Victoria

Plans for expansion of the urban water network in North East Victoria by NEW are set out in their 2007 Water Supply Demand Strategy. The plans are based on population estimates and their knowledge of the existing state of the network. The amalgamations of small-scale water authorities that occurred a couple of decades ago were designed to give the reconstituted authorities the skills base and financial strength to plan water supply in their respective areas, and so it has turned out. New areas are being gradually connected to the established network financed from revenue collected across the existing system. This is appropriate. Some cross subsidisation in space and over time is inevitable for network infrastructure. The State Government is supporting extensions to very small communities to provide safe drinking and wastewater services where incremental costs would place a burden on existing customers (NEW 2007, page 43). This is also appropriate, up to a point at least and on the proviso that the incentives for urban development are not excessively distorted.

## 4.4 Rainwater tanks and household water saving devices

Rainwater tanks were once an inconvenient feature of Australian country life, and even before that urban life. The network of lanes in the inner suburbs of Melbourne and other capital cities are a reminder of earlier methods for the collection and disposal of night soil.

Nowadays residents of cities and all but the smallest towns throughout Australia have the advantages of a reticulated water supply and sewerage system. A substantial proportion of Australian farms are connected to stock and domestic water systems, and when they are not, have often made their own arrangements for unlimited personal water supplies by pumping from creeks and groundwater.

So renewed public and private enthusiasm for rainwater tanks, as a supplementary source of water for urban dwellers would strike some as outlandish. Rainwater tanks are a most expensive source of water. There are also health issues with water collected from suburban roofs due to avian excrement and metallic contamination that limit use to gardens, washing machines and toilets inside the home. Crase (2007, pages 2-3) sets out the financial ramifications of private investment in household water provision succinctly.

> An additional mechanism used by urban water managers is to subsidise purportedly 'water efficient' devices. Water-saving dishwashers and rainwater tanks are obvious examples. In the case of the former a 'back of envelope' calculation suggests that it would take $33,000 of government subsidy to save 1 megalitre of water. By way of contrast the capital cost of the latter has been estimated to run to about $300,000 for each megalitre 'saved' – and that assumes there is sufficient rain for the device to fill and adequate enthusiasm on the part of the owner to manage the storage. All of this needs to be compared with the current price of water entitlements in agriculture which can be purchased for around $1200 per megalitre. [Say, in 2010 around $2400 per megalitre.] Paying 30 to 300 times the value for water does not just distort market signals – it also wasted a lot of money garnered from ill-informed taxpayers. This is not to say that private investments in such devices may not be warranted in particular circumstances. The danger lies in the application of a one-size-fits all approach in the North East.

And it might be added, government subsidies waste a lot of money out of the pockets of those water consumers who are encouraged by advertising and so-called consumer education schemes to invest in water saving. Research by Cooper (2010) established that when consumers were informed of the real facts of water use in Australia they were less inclined to accept urban water restrictions (see next section). The Productivity Commission (2008, page xviii) put the cost comparison between household water storage and collective supply slightly differently stating "a common 2000 litre household rainwater tank costing around $1500 holds around $3 worth of water at current mains prices." From a distributional perspective, poorer citizens are less able to avoid the effects of under provision of water from usual sources by investing in high cost options like rainwater tanks, backyard bores and greywater systems within households. Rather than invest in small-scale solutions with government subsidies, it would make better sense to access water from lower unit cost supplies, most obviously rural-urban trades. This applies a fortiori for North East Victoria.

***Whilst there is a renewed public and private enthusiasm for saving water, subsidising 'water efficient' devices such as water-saving dishwashers and rainwater tanks is unlikely to yield desired outcomes. Both the potential deleterious health effects due to contamination and distributional effects can be significant. A one size-fits all should be discouraged.***

## 4.5 Water use in gardens

Almost half the water used by households happens outside the dwelling. Gardening is a popular pastime with both aesthetic and non-aesthetic features. Transpiration from plants moderates summer temperatures. Plants and trees provide habitats for bird life. The amenity of attractive gardens is enjoyed widely and adds value to real estate. People grow fruit and vegetables for their own use.

Yet gardeners and their gardens are the principal targets of water restrictions. This is a function of official attitudes and pragmatism. Domestic gardening in all its variations and manifestations is not essential to immediate survival, however much it is enjoyed by a substantial proportion of the population. Pointedly, water restrictions can be easily applied to gardening by restricting watering times and the equipment used. Even more pointedly, the restrictions can be readily monitored by visual inspection coupled with neighbourly reinforcement. Crase (2009) has referred to “the social cost of having neighbours acting as water vigilantes.”

In contrast, water use inside the home is not restricted because washing, cooking and cleaning are deemed essential and, in any case, inside water use could not be monitored without resorting to costly metering devices, or extraordinarily invasive intrusion. Instead, as discussed above, water use inside houses is officially discouraged by exhortation with tasteless advertising and wasteful subsidies to water-saving devices.

The general point about asset fixity and water saving also applies to garden watering. Over time and at a cost, gardens can be reconfigured to include a higher proportion of hardy native plants and drought-resistant grasses for lawns. While the end result is acceptable to most consumers, rationing by restrictions imposes costs vis-à-vis decisions that would reflect individual circumstances and preferences. Unfortunately, water providers do not consider taste differences under the systems of rationing now usually applied.

Some consumers might prefer to use more water outside and less inside, or vice versa, if water use were rationed by other means (for example, stepped water tariffs, quotas based on household size). Such approaches to rationing are usually criticised for being biased in favour of richer consumers. On closer examination, the costs of adjustment to rationing are far more onerous to less affluent consumers. Well-off consumers avoid water restrictions by installing bores and so on (Crase 2009). Most of the burden of water restrictions falls on gardening enthusiasts, who are well represented among the elderly, and on the young and active, whom are denied recreational and sporting activities in public open space.

***Assigning water restrictions between discretionary and non-discretionary water use has been problematic due to asset fixity. Although gardens can be reconfigured to include a higher proportion of hardy native plants and drought-resistant lawns, the water use inside houses cannot be monitored without resorting to costly monitoring devices.***

Exactly the same remarks apply to water rationing and water use on parks and gardens as were made in the context of costly taxpayer subsidies encouraging consumers to invest in water saving devices.

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| ***A more sensible approach would see water authorities actively involved in the water market purchasing entitlements and allocations, and entering into leases and long-term contracts with irrigators.*** |

# 5 ATTITUDES OF URBAN WATER CONSUMERS

The preceding remarks were prefaced on a mainstream economic view of consumer behaviour and public policy with respect to urban water. Put simply, economists believe that rationing reduces economic efficiency and that consumers find restrictions irksome. The way water restrictions are designed – concentrating on external use does not limit the total amount of water used, and restricts household choices about how they would prefer to respond to water shortages. In addition, economists would advocate that supply augmentation be undertaken using an order of economic merit, regardless of whether the community is connected to a reticulated potable supply.

Nevertheless, differentiation and segmentation of community attitudes to water restrictions and the need for a more subtle approach is increasingly recognized. Water restrictions are politically popular with a substantial proportion of the population. Recently, for example, there was an adverse response to the relaxation of water restrictions in Melbourne (Fyfe 2010). Some consumers support water restrictions to the extent that they are prepared to report on non-compliance by others. Over the long-term, such behaviour could reduce the extent of social cohesion that has made water restrictions more or less acceptable to date.

Fortunately, consumer attitudes to water restrictions have been extensively researched including locally (Cooper 2010 and extensive literature cited therein). Cooper investigated consumers' willingness to pay (WTP) to avoid urban water restrictions using a large sample of households in Victoria and New South Wales, including water rich and water poor communities, and metropolitan areas and provincial cities.

The sample was also partitioned to test how knowledge of the national distribution of water affected consumer reactions. There is plenty of evidence from the press and elsewhere that consumer knowledge of water and water policy is deficient – the most obvious evidence is the near total confusion over water measurement with journalists and politicians shifting carelessly and randomly between kilolitres, megalitres, billions of litres, Olympic swimming pools and Sydney Harbour. Dry country rhetoric is bandied about without any understanding that Australia is well endowed with water in terms of its population compared with most other countries.

Dr Cooper's study explored economic, sociological and psychological aspects of choice behaviour with respect to water use and rationing. Social acceptability is important. The message that excessive water consumption is unacceptable is widespread in the population as indicated in the following quotation (Cooper, Crase and Burton 2010, page 14).

> 18% of the sample reported that they would "definitely not" be prepared to pay any monetary amount to avoid restrictions i.e. this group gave the same response irrespective of the bid amount. This implies a form of protest, or at least a perception that restrictions are not welfare reducing per se.

The statistical analysis conducted by Dr Cooper indicated that households with a lawn, being in a water poor city, having tertiary education, with higher number of residents in the house and higher incomes had higher WTP. An interesting result was that being better informed about water restrictions reduces the predictability of the individual's response to specific questions, suggesting that greater knowledge disturbed the underlying assumptions held by respondents.

Although there is a group that are unwilling to buy their way out of water restrictions, there is another group of around the same size who value not being subject to water restrictions. There is some evidence from the research that this group is growing over time, that is to say some consumers gradually become tired of restrictions.

***An important take-home message about attitudes is that one-size does not fit all when it comes to water policy. Cooper (2010, page 267) "suggests there is scope to develop pricing structures that reflect more closely the value particular segments place on discretionary water use." Clearly, there are also other policy measures that could influence some, but not all, consumers – like information campaigns. However, given the divergence of attitudes, these need to be considered on a case-by-case basis.***

# 6 CONCLUDING COMMENTS

This discursive account of water-related issues in North East Victoria has drawn several broad conclusions. First, the urban water sector of the North East has been unreasonably constrained by the favoured position given of the irrigation sector. However, the adverse effects on the supply of urban water in the North East could be easily redressed by purchases of small amounts of water from irrigators. Second, too much emphasis has been given to costly engineering solutions to water shortages. Third, urban water management for cities and towns on inland rivers is different from cities and towns on the coast. Logical errors associated with misuse of the concept of water saving are even more obvious, since it follows that most water ostensibly saved by improved recycling and the like would have finished up in the river anyway. Fourth, current water policies relying on water restrictions have adverse effects on poorer households who are unable to circumvent their effects by costly investments in rainwater tanks and backyard bores. When considering the options and opportunities for a range of communities in the North East, it would be a pity to replicate these mistakes.

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North East Greenhouse Alliance

# Preliminary Vulnerability Assessment

North East Victoria Adapting to a Low Water Future: Project Context Setting – Deliverable 4

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Authors Professor Lin Crase[1]

Professor Harry Clarke[2]

[1]La Trobe University

Albury-Wodonga Campus

P O Box 821

Wodonga VIC 3689

Tel: (02) 6024 9834

Fax: (02) 6024 9777

e-mail: l.crase@latrobe.edu.au

[2]La Trobe University

Department of Economics and Finance

Bundoora VIC 3086

Tel: (03) 9479 1732

Fax (03) 9479 1654

e-mail: h.clarke@latrobe.edu.au.

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# 1 INTRODUCTION

This component of the project builds on the earlier analysis of the impacts of climate change on water availability by considering the economic, social and institutional fabric of communities in the North East. The intention is to hone in on particular sensitivities and to do so in a manner that will guide further work.

The vulnerability analysis is preliminary and relatively broad. It is developed on a council-by-council basis, since it is this level of government that is expected to make most use of this report. In maintaining a broad perspective several important caveats need to be acknowledged:

- Vulnerability is considered from the perspective of the methodology described in part three of this report;
- We focus primarily on the impacts of reduced water availability – there are potentially other consequences of climate change (e.g. increased incidence and intensity of bushfires, changed commodity prices) that, while important, are not specifically addressed, unless there is a clear link with water availability.
- The focus of attention is on the likely reduction in annual water availability which is inherently uncertain – it needs to be understood that the increased variability of rainfall as well as reduced availability will be the major challenge for some.

The report itself is divided into five additional parts. In Section 2 we summarise the character of each council jurisdiction in order to identify potentially vulnerable economic activities and assets. Section 3 is used to outline a methodology for assessing vulnerability to reduced water availability and this approach is then applied in Section 4 to provide a region-by-region assessment. A comment on the severity of some of the consequences of reduced water availability is offered in Section 5, drawing on particular cases to illustrate the diversity of problems and potential responses. The final section presents some brief concluding remarks.

# 2 A Preliminary Analysis of 'Hot Spots'

This section comprises a brief snapshot of each council jurisdiction, primarily from an economic perspective. Data are drawn from several sources but primarily ABS (2006; 2001) and DPCD (2008). This section also draws together some of the information available in Deliverable 2 and readers may find it helpful to refer to maps provided in Deliverables 1 and 2 . The focus is on understanding the makeup of communities and their dependence on water as an input and the opportunities for adaptation.

## 2.1 Alpine Shire

Economic drivers

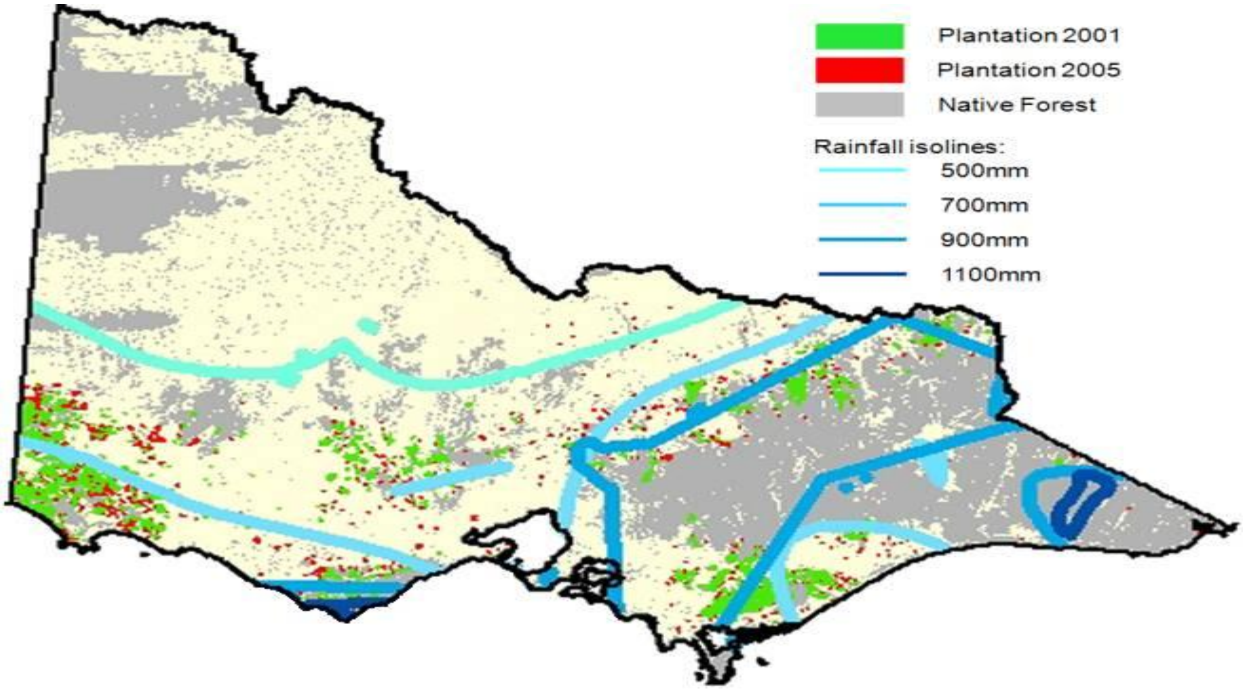
- Relative to the other LGAs, the Alpine Shire has a larger reliance on Accommodation and Food Services as a source of employment (14.6% of employment).
- This can be traced to the significance of the snow industry in the cooler months and the development of attractions and festivals in other seasons.
- The niche food and wine activities are integral to the tourism industry in the shire.
- The combination of natural and agricultural landscapes is an important attractor. Thus, while agriculture is less important to the economy, it has significant synergies with other successful industries.
- Timber and forestry are also important employers, although the distribution of this activity is not even across the shire.
- The three main urban centres are Bright, Myrtleford and Mt Beauty.
- Peri-urban development with a strong influence of Melbournians seeking a 'tree-change' can be found in the shire.
- The shire also contains large areas of valuable natural habitat and refuges.

Water dependency of economy

- The snow industry is partly dependent on sufficient precipitation in winter.

- Rainfall is predicted to fall by as much as 4.1% in the shire by 2030 and 14.3% by 2070, potentially limiting the availability of natural snow. This represents the worst case in the modelling and does not capture increased variability or uncertainty.
- Agriculture remains the largest extractive water user in the shire, with around 400 agricultural businesses consuming about 9000 Megalitres per year. Historically, the tobacco industry was a large user in the shire, but other activities now dominate (e.g. vegetables, fruit and grape production).
- The influx of tourists puts some pressure on the delivery of water and wastewater services to urban areas during peak loads. The water demands of each community are nevertheless largely assured thanks to current and planned capital investments by NEW.
- The fact that many streams are unregulated reduces the scope for trade, although not entirely.
- Peri-urban development may place some localised stress on water resources although the overall predicted change in population is modest by state standards and likely to be manageable.
- The extent and form of forestry is premised, in part, on adequate and relatively high rainfall, as illustrated in Figure 4.1. The processing of timber products is also reliant on water as an input but this component of production is shored up by urban water access.

<u>Table 4.1: Victorian Forestry and its Relationship to Rainfall Isolines</u>




*Source: ACIL Tasman (2010)*

Substitution opportunities and asset specificity

- Snow making has been common place for many seasons and locations (see, for instance, Lee, Cook and Cook 2010). Any contraction of the snow fields attributable to climate change can be expected to apply to all snow locations, so the Alpine shire will be no more disadvantaged by a reduction in snow than any other domestic resort based on this activity. Committed domestic skiers seem likely to continue using the fields, albeit potentially constrained to a smaller area and possibly for a shorter season.
- The opportunity for maintaining tourism income will be premised on the ability to develop alternative attractors. Operators of the resorts have already shown a penchant in this regard be endeavouring to smooth the peaks in demand and offer a wider suite of attractions in the warmer months. One of the effects of climate change will be to accentuate this approach.
- With the exception of grape production, there is already a trend towards annual cropping to substitute for the defunct tobacco industry. This is important because annual cropping can cease during fry periods to limit economic losses.

- Grape production in the region offers synergies with tourism but its economic prosperity will ultimately be determined by successful business strategies and choices – for example, by selecting the varieties that are coming into demand and adequate marketing. Water availability and thus water prices (as reflected in the use of more elaborate technologies to draw water) will have less impact than other factors (see Box 4.1).
- Forestry is highly asset specific and requires long decision timeframes. The predicted decline in rainfall may see some contraction of the forested area, although this is unlikely to be strictly proportional as technological innovations are developed.
- Downstream pressures for water resources may also see increased effort to account for the water used by forests, further constraining the industry (see, for example, ACIL Tasman 2010).
- Ongoing water access for the value-adding timber industry is unlikely to be problematic given substitution and water purchase options for NEW.
- Some natural assets in the shire are isolated remnants with few substitution opportunities.

## 2.2 Indigo

<u>Economic drivers</u>

- Relative to other economies in the region, Indigo has a balanced employment pattern. Manufacturing, Healthcare and Social Assistance, Retail Trade and Agriculture, Forestry and Fishing each account for about 10% of employment.
- The shire is also an active tourist destination, in part with strong linkages to particular agricultural pursuits (e.g. wine). Localised attractions, like the Chiltern Mt Pilot National Park, also draw visitors to the shire (See Box 4.5).
- The shire produces more dryland agricultural output than the other jurisdictions in this study, with around 10,000 ha reported under cereal production in 2006.
- Significant manufacturing businesses are primarily based on processing agricultural outputs. For instance, Uncle Toby's is based in Wahgunyah and produces a variety of processed breakfast cereals.
- Beechworth, Rutherglen and Chiltern are the main urban centres and prove attractive to some because of their historical character.
- The shire surrounds Wodonga and Wangaratta with many residents commuting to these centres for employment.

<u>Water dependency of economy</u>

- Despite the extent of dryland production, irrigated agriculture is the largest water user in the shire consuming around 13,000 Megalitres per year.
- Wine grape production is a prominent water user in the shire, along with pasture production for dairying, especially in the east of the shire.
- Rainfall in the shire is predicted to fall by as much as 6.6% by 2030 and 17.8% by 2070.
- Rutherglen and Chiltern urban centres draw their water supply from the Murray River. The other major settlement of Beechworth is serviced by a designated water storage and NEW has forecast that some self-reliant household measures will need to be considered in the future.
- Some pressures on peri-urban water supplies are already evident (e.g. Yackandandah) and consumers are increasingly being asked to employ self-reliant technologies.

- The food processing plant at Wahgunyah is amongst the top ten potable water users in the north east.

Substitution opportunities and asset specificity

- Perennial activities are generally more exposed to water shortages than annual agricultural pursuits (see, Connor et al. 2009). Grape production faces some challenges, although producers have also developed adaptation strategies (see Box 4.1). Dairying is often regarded as a perennial activity, although it is feasible for producers to substitute other inputs for water, at least in the short and medium term (see, Box 4.2).
- Urban water supplies for towns connected to the Murray are largely assured by trade, provided water can be purchased without constraints and prices are acceptable.
- Some towns in Indigo are not connected to the Murray and in some instances the water utility predicts that households will need to individually carry the responsibility for dealing with shortage. The extent to which 'self-reliant households' constitutes an adequate adaptive response from NEW in these circumstances is a moot point (see, Deliverable 3) and technological solutions of a wider scale are unlikely to be feasible for some communities.
- Water trade offers substitution opportunities for the major water-dependent manufacturer in the shire, subject to the price being acceptable.
- Isolated natural assets face risks.

**Box 4.1 The case of adaptive wine grape producers in the North East**

The review of the economic makeup of the region shows that wine production is both an important activity in its own right and plays a part in defining the character of several jurisdictions. Wine is also, to some extent, water dependent, although this is determined by the form of production, the age of the vineyard and the objectives of the producer.

The recent drought has illustrated the capacity of wine growers to adapt. Several novel strategies have emerged, along with more predictable outcomes. Such measures include:

- Use of the water market to maintain production

- Sale of water allocations and/or entitlements to adjust to new varieties
- Implementation of regulated deficit irrigation in order to maintain production with lower water use.

An important driver of the profitability of wine grape production is the price received for outputs, and thus the relative attractiveness of different varieties (see, Watson and Cummins 2009). The recent decline in the popularity of varieties like Chardonnay has resulted in some vines being abandoned, especially in the Sunraysia district. The varieties in the North East tend to be more varied and often are produced in a manner that takes advantages of the quality rather than the quantity of grapes. This limits exposure to irrigation.

A notable example of adaptation occurred with the introduction of urban water trade by NEW in 2007-08. The ongoing drought and resultant urban water restrictions had led to the deterioration of water-dependent assets in many communities. Given that the prospect for individual urban water users to access the market was limited, NEW established a relatively straightforward mechanism for individuals and groups to access additional water without the expense associated with carting water or installing bores etc. In simple terms, this amounted to a consumer purchasing a volume of water on the water market (usually small) and then using NEW infrastructure to deliver the water. The scheme was limited to organisations providing a community asset (e.g. sporting fields) and businesses that were deemed to be water-dependent. The cost of participating included the purchase of the allocation on the market by the individual, processing and administration fees of $200 and the standard metered water price at the time ($683 per Megalitre) (See, O'Keefe and Henier 2008 for more details).

Notably, a winery located adjacent to an urban water supply used the scheme to maintain wine production during that year. Clearly, were such innovative institutional arrangements not developed, the alternatives for the wine producer would have been more constrained. This is not to say that potable water will always be a profitable choice in all cases but the example highlights that adaptation strategies are taking place. Moreover, intransigent institutional arrangements, for instance in the form of limits to trade, can hinder adaptation rather than assist change.

## 2.3 Towong

Economic drivers

- Towong is the most dependent on primary production of all LGAs in this study. Over 26% of all employment was reported as being related to agriculture, forestry and fishing. The second largest employer is health care and social assistance (11%).
- Although somewhat dated, the data indicate that cattle production and dairying are the major agricultural pursuits and anecdotally this appears to be the case.
- Agriculture is generally less intensive in the shire with average landholdings exceeding 300 hectares.
- The largest urban centres are Corryong and Tallangatta.
- Some tourism activity attends the shire (e.g. foreshores of Lake Hume; high country) although visitor numbers are less than neighbouring shires.
- Manufacturing is generally small scale and the number of businesses in manufacturing is the lowest of the LGAs in the study area.
- There are several smaller villages in the shire, with about 10% having access to reticulated water supplies provided by NEW. The remainder are self-reliant households.
- Towong is responsible for maintaining a large number of roads and bridges relative to the population of the shire and the population is both smaller and older than surrounding LGAs.
- Like many other rural shires in the North East, Towong also hosts important natural habitats and remnant bush.

Water dependency of economy

- Irrigated agriculture uses about 19,000 Melgalitres per year in the shire, mostly from the eastern portion of the jurisdiction (Part B). Much of this is withdrawn to grow pasture for dairy and beef cattle.
- The major urban centres (Corryong and Tallangatta) are predicted by NEW to have adequate water supplies for the medium term.
- Village communities relying on self-reliant technologies face some exposure to water shortage with rainfall in the shire expected to fall by as much as 6.2% by 2030 and 16.1% by 2070 (see Box 4.4).

- Population growth is expected to be negative in the longer term, at least on the basis of recent trends.

Substitution opportunities and asset specificity

- Substitution opportunities for dairying are on offer and assets are adaptable, at least in the medium term (see Box 4.2).
- Most of the forestry activity in the region is native forests and adaptation measures in this context may be important.
- Natural assets appear at risk should the worst case prediction be realised.

**Box 4.2 Dairying drought responses and adaptation**

The cost associated with feeding dairy cattle varies substantially between locations and management regimes (Ho et al. 2010). Historically, much of the nutritional requirements of dairy cattle in northern Victoria have been met by irrigating perennial pasture. The recent advent of drought and high water prices has resulted in new strategies for many adaptive farmers.

Considerable research effort is already underway in this context. For instance, Griffith (2010) provides detailed analysis of the profitability of dairying enterprises under a range of scenarios. In simple terms, these scenarios involve the substitution of fodder and grain for irrigated pasture. Other adaptations involve the transition to annual pastures with harvesting for silage or hay, since under some circumstances hay prices will be heavily correlated to water availability.

The upshot is that some dairy farmers are in a position to sell their water allocation and use the proceeds to purchase input substitutes, while still maintaining production. This may not prove profitable in all cases, especially if grain and fodder prices make substitution unprofitable. Nevertheless, adaptation at the farm level is already taking place in many instances. The public sector continues to play some part in this through research and dissemination activities, although a role for local government or regional intervention is unclear.

## 2.4 Wangaratta

Economic drivers

- Wangaratta Rural City is a major retail and service centre with manufacturing (15.6%), health care and social assistance (14.3%) and retail trade (12.8%) being the three main employment groups.
- The city also has about 9% employment in agriculture, forestry and fishery. The number of agricultural businesses in the LGA is notably higher than the number in other jurisdictions in this study.
- The agricultural productive base is generally broad and includes relatively large tracts of dryland agriculture (around 6,000 hectares of cereals and 1,200 hectares of non-cereals in 2006), substantive areas of orchard (wine) production and the largest area of vegetable production of the locales in this study.
- Important manufacturers include a textile mill based in Wangaratta.
- Tourism is also prominent in the LGA with notable festivals and visitors drawn to the complementary attractions in neighbouring shires and hinterland activities.
- The major urban centres in Wangaratta and there are some smaller villages in the hinterland (e.g. Oxley) that are subject to a reticulated water supply managed by NEW.

Water dependency of economy

- Wangaratta city has a relatively reliable water source from the Ovens River although the regulated capacity of the stream is modest in comparison to the Murray. There have also been some historical water management issues stemming from the institutional arrangements around water management (see Deliverable 3 of this project).
- Agriculture uses about 25,000 Megalitres of water per year and this is mostly located in the south of the LGA.
- The higher value and more successful water using activities (such as Brown's winery) are substantive water users but most water in agriculture is used to produce pasture.
- Some of the manufacturing activity is heavily reliant on water inputs. Two manufacturers in Wangaratta are amongst NEW's top ten water users.
- Rainfall is predicted to fall by as much as 4.5% by 2030 and 15.7% by 2030. Given the importance of groundwater and the prominence of this resource in council planning

documentation, it is worth noting that groundwater recharge is predicted to fall by as much as 11.3% by 2030 and 32.7% by 2070.

Substitution opportunities and asset specificity

- Urban water availability has been expanded in the immediate term by the development of bores that tap the deep aquifer that lies below the Ovens Valley. Although subject to further measurement, the aquifer is predicted to represent a substantive resource. This needs to be considered in the context of predicted changes to recharge, at least for long term investments.
- Substitution for the dairying industry is similar to that described in Box 4.2.
- Peri-urban development in villages and communities without a reticulated supply could prove contentious with the LGA population predicted to grow, at least till 2030. Again, NEW describes the most appropriate strategy in these communities as 'self-reliant households'.
- Water-intensive manufactures in the region have some scope for water trade and are shielded directly from water shortage to the extent that NEW is obliged to adopt appropriate strategies. Nevertheless, some limits to substitution may exist (see Box 4.3).

**Box 4.3: The case of a water-reliant manufacturer in the North East**

In order to gain insights into the preparedness of private manufacturing firms with a dependence on water, a structured interview was undertaken with a senior executive of a local firm. The outcome of that interview is reported here. It is important to emphasise that this is not presented as a definitive empirical analysis of vulnerability. Rather, it is offered in order to provide additional context to that offered in other parts of this project.

The firm is a well-established manufacturing plant in a highly competitive industry. In order to examine the salience of climate change and water scarcity, some production information was sourced. These data revealed that, while water is an important input, utilities (including water, waste water, electricity) comprise less than 10% of the total costs of production. Other more substantive costs relate to raw materials and labour.

This is not to say that the firm could sustain very substantial increases in water prices, especially given the competitiveness of the output market. Rather, it needs to be understood that even though the firm uses several Megalitres per day, water is a modest proportional component of production costs at current prices.

Perhaps not surprisingly, the firm relies heavily on its relationship with the water supplier (NEW) to deal with the risk associated with water supply. In this context, there is a significant effort to maintain communication with the utility (NEW). For instance, the firm has representation on the Water and Wastewater Advisory Committee that advises the Board of NEW about local issues on an annual basis.

The utility would appear to be responsive to the potential needs of the manufacturer, at least to the extent that an emergency supply has been located in close proximity to the plant. If short term interruptions to water supply were to occur the plant would be forced to cease operation immediately and clearly this is not in the interest of the manufacturer or the utility.

Longer-term planning decisions are made against a background of competition for market share. The interviewee saw this is probably the most pressing concern to date.

Some thinking has gone into water supply security, including making more expansive use of reclaimed water. However, the firm clearly has faith in the capability of the utility to manage the risks that attend climate change.

## 2.5 Wodonga

Economic drivers

- Wodonga is the most substantive manufacturing base in the study region with 15% of all employment in the City of Wodonga attributed to this activity.
- The city also acts as a service and administrative hub with almost 14% of the workforce categorised as ‘public administration and safety’ and a similar number in retailing.
- Significant defence force and logistics facilities are also located within the city boundaries.
- Tourism is significant in number but of less importance proportionately than in neighbouring LGAs.
- Wodonga is the major urban centre and smaller communities tend to lie in the neighbouring jurisdictions.
- Of the sites in this study, Wodonga is predicted to experience the most substantive changes in population and thus potential increase in urban water demand.

Water dependency of economy

- Three of NEW’s top ten water users are located in Wodonga. A data anomaly shows one of these relates to the defence force. This presumably occurs because this is treated as a single activity in NEW accounts, regardless of the fact that there are numerous dwellings and other facilities on the base.
- The remaining significant water users are manufacturers, both providing sunstantial local employment.
- The urban community is subject to water restrictions (see Deliverable 3 of this report) in line with the policies of NEW. Notably, these have tended to be shorter and less severe than those imposed in the neighbouring city of Albury.
- Rainfall is predicted to fall by as much as 7.2% by 2030 and 18.3% by 2070. Water inflows into the upper catchment are probably more pertinent insomuch as the regulation structures (dams) upstream of Wodonga are the main driver of water availability.

Substitution opportunities and asset specificity

- Located on a regulated stream with expansive upstream storage offers considerable scope for water trade to meet most demands in the city.

- Other substitution alternatives include recycling and third pipe schemes but these are generally not viable when compared against the costs associated with water trade (see Deliverable 3).
- Major manufacturing users have access to the potable supply as well as other options (e.g. direct pumping from Murray River).

# 3 A Methodology for Considering Vulnerability to Water Supply Uncertainty Due to Climate Change

## 3.1 Background

The impact of climate change on rainfall and streamflow is highly uncertain. This uncertainty is substantial at the national level, and even for broad regions, but becomes even more acute when attention focuses on specific, more narrowly-defined regions such as North-East Victoria (see Deliverable 1). Specific local physical, hydrologic and meteorological factors complicate the assessment of general trends.

Dealing with the uncertainties that circumscribe climate changes and its impact on water supply rather than planning to adapt to a certain anticipated change in water supply is the primary task for those seeking to promote adaptation to changed availability. What is sought is adaptability and flexibility in a range of circumstances – not a specific response based on a highly uncertain forecast.

The impact of water supply uncertainty on a specific economic sector or activity (urban, business, tourism, agricultural, biodiversity conservation) revolves around the dependence of this sector or activity on water and the extent to which a restriction in supply will have an impact. For economic sectors this impact will depend primarily on the availability of substitute low water dependence activities or alternative water sources that firms and consumers can switch to at low cost. It also depends on the time available to make such adjustments.

If there are few substitution options, with high water dependence and if there is substantial short-term and sustained water supply reduction and not much time to adapt, then impacts - and hence climate change vulnerability - will be high. If activity can readily switch to a low water use alternatives or alternative supplies or if there is plenty of time available to make a switch towards activities that involve much less water use then there is lower vulnerability to climate change.

In many situations economic agents, such as farmers, will make adaptations to changed climate and hence to changed water supply availability, without the need for any public policy response. Farmers have altered their production plans to reflect changed agricultural prices and altered climatic circumstances from the commencement of organized agriculture 10,000 years ago[22]. Citizens will similarly make residential locational and technological choices that seek to avoid unnecessary flood damage or forest fire risks that will partly at least reflect climatic and water supply risk.

Public policy actions to mitigate the greenhouse gas emission issues that cause climate change are subject to market failure issues since the action by one party to mitigate emissions will typically create benefits for others - such externalities create the need for a coordinated, negotiated public policy response. Importantly, this is generally not true for adaptive responses since actions to adapt to climate change will primarily benefit the party effecting the adaptation measures. Accordingly the case for public policy responses is far less obvious.

Indeed assigning public agencies to take responsibility for adaptation may have the moral hazard implications of reducing the incentives for individuals to take adaptive measures to assist themselves[23]. Indeed, a response characterized by inappropriate adaptation policies involving subsidies and the like might invoke ‘rent seeking’ behaviour rather than genuine adaptation.

There are four main classes of sensible policy action that can potentially lower vulnerability:

1. Anticipatory investments in long-term infrastructure;
2. Providing economic and climatic information to those affected by changed water supply availability;
3. Providing an expanded range of technological menu items for addressing new water supply situations and finally;
4. Putting into place a water supply policy regime that encourages rather than discourages adaptation.

[22] Perhaps ironically, this event is traced by many to the stabilisation of the world’s climate.

[23] In simple terms, moral hazard of this form would see private agents holding back on adaptation investments in the hope of gaining a subsidy or similar to undertake investments that make sense in their own right.

## 3.2 Long-lived Infrastructure investments

A widely-discussed policy option involves providing anticipatory, long-lived infrastructure investments that offer the opportunity or capacity to adapt to climate change, should this prove necessary. An example that is often cited is to provide extra water supply pipeline capacity to deal with extra water demands in areas that cannot rely on local supplies. Some examples of this approach are already evident in the North East – say in the form of the pipeline developed by NEW to shift water south from the Murray to towns like Chiltern. Such infrastructure is often publicly-provided because of economies of scale or natural monopoly characteristics of the technology. However, often such types of investments are more likely to be shorter-term responses that do not call for long-term lead times in planning. Projects that do require longer lead times might include dam construction, desalination plants or stormwater systems in large cities.

It is not clear whether widespread deployment of such projects has any potential role in North-East Victoria although they might in other parts of the state. Arguably, in some of the more unbanized areas this requires scrutiny, although more detailed analysis would appear to lie outside the scope of this project.

If projects do not have long lead times then it is better, given substantial uncertainty, to 'wait to see' what climate and water supply outcomes do eventuate before committing to expensive infrastructure projects. Such projects will likely have substantive unfavourable economics if water supply outcomes appear less adverse that initially expected. The real test for taking anticipatory infrastructure investment is whether making allowance for changed water supply availability well in advance provides significant cost economies. If it does not, it may be better to wait and see. The local evidence is that the lead time required to deliver projects of this nature is not so great as to require an immediate response (see Box 4.4).

It is important to remember that the extent of climate change is likely to be of the order of 0.1$^{o}$C to 0.2$^{o}$C per decade for the next few decades. Trends will be gradual. While 'trend' experience is unlikely to be observed, extreme climatic events, such as the recent extended drought, are difficult to attribute to climate change and it will not be clear, even if they do occur, that specific longer-term infrastructure investments are sought. Governments should proceed cautiously, including local governments that may not be spending their own money.

## 3.3 Information and Forecasts

Providing information to community members (firms, consumers) that will improve their ability to forecast future climatic and or economic trends and hence to make better water supply and other forecasts is an important class of policies.

| |
|---|
| This is a policy local government and regional agencies might encourage and provide as an extension service. This type of policy helps citizens and firms take care of their own vulnerabilities. |

Climate and water supply information has the character of a public good and will plausibly be under-provided by free markets. For agricultural producers this information might compromise temperature and rainfall forecasts and the effect of climate change on the El Niño/La Niña-Southern Oscillation (ENSO) as well as forecast commodity price trends that might change given the impacts of climate change.

This information is currently provided by various agencies in Australia, such as the CSIRO and by the IPCC. There are three types of information provided:

(a) short-term rainfall forecasts for a period of up to one year based on interpretations of the likely course of ENSO;
(b) medium-term forecasts from of up to 20 years;
(c) longer-term forecasts of up to 50 years and beyond.

Provision of these types of information is hardly likely to be of concern to local governments in a region such as North East Victoria, but the role of these institutions in improving resident access to such forecasts is important. It would be interesting to know, for example, how many residents in the North East are presently aware of this information and make use of it. The issues associated with promoting use of such information may also be worthy of investigation.

### 3.3.1 Short-term forecasts

These are highly conditional forecasts that have almost no relevance for longer-term water resource planning, although they might bear on short-term production planning decisions by farmers. Forecasts otherwise are just too short-term and too conditional. The Department of Meteorology forecast at 21 July 2010 for the remainder of 2010 is typical:

> “Tropical Pacific Ocean temperatures continued to cool over the past fortnight, and are now approaching levels typical of a La Niña. Similarly, other ENSO indicators are also at or exceeding La Niña thresholds. As computer models predict the central Pacific will continue to cool over the coming months, it is now highly likely that the Pacific is in the early stages of a La Niña event, and that 2010 will be considered a La Niña year.
>
> Signs of an emerging La Niña event have been apparent in the equatorial Pacific for several months. Pacific Ocean temperatures have cooled steadily throughout the year and are now more than 1°C cooler than average in some areas on the equator. The Southern Oscillation Index (SOI) has increased in value and is currently around +14, trade winds continue to be stronger than average and cloudiness has remained suppressed over the central Pacific. All of these key indicators are at levels typical of the early stages of a La Niña event.
>
> La Niña periods are usually, but not always, associated with above normal rainfall during the second half of the year across large parts of Australia, most notably eastern and northern regions. Night time temperatures are typically warmer than average and Tropical Cyclone risk for northern Australia increases during the cyclone season (November-April)”.

Whatever their agricultural sector uses, these types of forecasts are clearly not helpful for making longer-term decisions about water supply availability. This information is to a limited extent useful for short-term production planning, but has much more limited significance for longer-term adaptation planning. Specific information for NE Victoria is provided by DPI Victoria in its ‘The Break’ newsletter.

### 3.3.2 Medium term forecasts

These forecasts seek to ascertain longer-term (up to 10 year) impacts of climate change on the El Niño/La Niña-Southern Oscillation (ENSO) and on such things as drought frequencies. Are ENSO events becoming more frequent and are droughts becoming both more frequent and intense? This is an active area of research, although not yet one that can be used in an applied way to guide farmers and other water users in adapting to climate change.

It seems difficult as yet to come up with firm conclusions here. Droughts have occurred around large parts of Australia for about 3 years in 10 since almost the time the first white settlers arrived at Sydney Cove. On this basis moderate drought cannot even be regarded as an extreme climatic event. For instance, in the terrible drought of 1895-1903 about 40 per cent of the cattle in Australia perished. There have also been major prolonged droughts in Australia from 1911-16, 1939-45, 1963-68 and 1991-95 all prior to the current severe drought. There have been specific regional droughts on a much more frequent basis than this.

Over the longer-term we might expect a gradual trend increase in temperature, changed rainfall levels that differ regionally and possibly an increased frequency of extreme climatic events, including drought. There is, however, no basis for interpreting the recent drought event as being attributable to climate change.

The difficulty with perpetuating the claim that climate change caused the current drought is that, if people are persuaded that the current drought is due to climate change, they will come to disbelieve that climate change is a serious threat if the drought breaks and we have good rains for a number of years. Moreover, there are suggestions from some that ocean temperature changes might cause a temporary easing of warming over the next decade or so before temperatures resume their upward trend (see, for example, Pearce, 2009).

### 3.3.4 Longer-Term Forecasts

The IPPC have prepared longer-term climate forecasts for the globe and the CSIRO have prepared longer-term climate forecasts for various Australian regions. In the IPPC's *Fourth Assessment Report* (FAR) average surface global temperatures increases up to the year 2100 are provided though the range of such forecasts covers a range of 2-4.5$^{o}$C. The range of these forecasts has not narrowed over those articulated in the *Third Assessment Report.* Thus, while climate science has advanced so too has the knowledge of what is not known. The FAR also provides evidence on the possibility of catastrophically large temperature increases that go well beyond the upper limit of the indicated range.

It would be futile to plan long-lived investments in long-lived assets by making a particular point forecast of temperature and rainfall. Such investors can however assume that the trend in temperatures will be to increase and that often this will be associated with reduced water supply availability and increased costs. The general message is that if such projects offer returns that are only marginally above those that do not involve longer-term commitments then a shift to options offering greater flexibility will make sense.

## 3.4 Expanding Technical Menu Options

This approach involves providing knowledge of a wider range of technical menu options for adapting to climate change. This information again has the character of a public good and its derivation and provision by means of extension services helps correct a market failure. Even if farmers and others are skillful in adapting to changed climate and water supply availability, increasing the range and quality of the technological options available to them will reduce the adjustment costs they face. Kingwell (2006) summarizes what seem to be on the current menu of agricultural adaptation options:

- development of varietal portfolios suited to greater weather-year variation. In particular, developing varieties with greater drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions, resistance to new or more virulent pests and diseases.

- reduction of downside risk of crop production (e.g. staggered planting times, erosion control infrastructure, minimum soil disturbance crop establishment, crop residue retention, varietal portfolios)
- further facilitation of crop operations (e.g. seeding, spraying, swathing and harvesting) by improvement in skill of weather forecasting
- further facilitation of decisions about crop type, variety selection and crop input levels by improvement in skill of seasonal forecasting
- greater opportunism in planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers)
- improved pasture and crop management decision support systems based on satellite imagery technology and advisory services drawing on expert systems
- further facilitation of decisions about stocking and de-stocking through improved climate prediction systems that more accurately forecast the extent and duration of drought
- alteration of mating time or mating populations based on seasonal conditions and forecasts
- development of water use efficiency strategies to manage potentially lower irrigation water availabilities
- assessment of genetic variation across and within livestock breeds regarding their production response to extreme heat, so that more productive animal systems can be developed
- development of low cost surface sealants on farm dam catchments to allow run-off from small rainfall events
- development of low cost desalination plants to use saline groundwater to supply water to stock or irrigated crops
- utilization of R&D findings on the effect of prolonged dry conditions and extreme heat on weed and pest ecology, especially weed seed survival
- re-design of farm housing, building, machinery and outdoor clothing to accommodate extreme heat

- development of profitable crops or tree species that include returns as renewable energy or carbon sinks

It is not difficult to see how some of these alternatives might apply to non-agricultural pursuits. Staggering investments in forestry or manufacturing or tourism has an obvious parallel with the agricultural checklist above.

There is an on-going need for R&D and innovation that ensures all producers have a capacity to profitably engage in production in the face of changed water supply availability. If climate change is rapid, then the value of knowledge from climate-related regionally-specific R&D will change, since the uncertainty surrounding decisions will also increase.

Some R&D may need to be anticipatory whereby the R&D is assessed for an environment that is likely to unfold, rather than for present climatic conditions. Those businesses and regions most at risk are likely to be those at the edge of the zone of their climate tolerance and where that tolerance will be further eroded; those regions already stressed by economic, social or biophysical condition and those regions where large and long lived investments are being made such as in forestry or on farm fixed investments such as dedicated irrigation systems.

## 3.5 Choosing a Sound Policy Framework

For the most part the preceding analysis has emphasised the role of individual agents in adapting to climate change. The more rational and efficient are water pricing frameworks the more individual firms and consumers will react efficiently to changes in the availability/price of water.

Water utilities themselves become more vulnerable to water supply shocks if they are compelled to cross subsidise supplies to particular groups of consumers by charging higher prices to firms[24]. Firms which then become vulnerable if water availability decreases and prices increase,

[24] This issue is addressed in greater detail later in this report. For example, see Box 4.4.

then will be forced to transfer cost increases to vulnerable protected groups. Heterogeneity in pricing can threaten the viability of all consumers.

Particularly important are interest subsidies and cash transfers to farmers who face 'Exceptional Circumstances' with respect to drought. As the Productivity Commission has pointed out (PC, 2009) the EC drought relief measures are 'ineffective, can perversely encourage poor management practices and should be terminated.' As anti-poverty devices alternative measures should be introduced which address poverty. The current measures induce moral hazard towards planning for drought and for adapting to climate change since the policies reduce the costs of such adverse effects.

The same conclusion could be drawn around urban and peri-urban water users if the extent of cross-subsidisation shields communities from the real costs of their water choices.

It is important that readers understand that some government intervention already limits the adaptive capacity of communities in the study region. Additional intervention may well worsen the problem (see Deliverable 3) and it seems likely that a sound response would be to lobby for a reduction in perverse policies that attend the status quo. This may well be the best thing that local government could do to promote greater adaptation, albeit politically challenging.

# 4 Application of the Vulnerability Methodology to NE Victoria

The key question we consider in this section is 'How vulnerable are consumers, firms and the environment to water supply reductions and water supply uncertainty as a response to climate change in NE Victoria?'. Overall, our assessment is that the north east is reasonably well-placed to handle water supply variability. The region lies at the top of a significant water catchment area and substitution possibilities are feasible for many industries, farmers and residential users[25].

There are however particular issues in specific sectors – in agriculture, industry, tourism, urban and environmental management. This taxonomy is set out below. It is also interesting to analyse issues by local government jurisdiction which brings to the surface particular concerns.

Based on the methodology described in the previous section, vulnerability depends on the extent:

- of water supply dependence;
- of anticipated water availability changes in different jurisdictions;
- to which substitutions to changed water availability can be made short-term.

From the perspective of local government planning, it may also be worth considering the relative economic contribution of the activity to the region, although the extent to which it is desirable or feasible to make decisions solely on this basis is questionable.

Our assessment of vulnerability is developed qualitatively below and, for convenience, presented in line with the different jurisdictions that were described in section 2 of this

[25] We discuss some of the caveats to this in more detail in the final section of this report.

Deliverable. The qualitative scale has been developed in consultation with various water users and with reference to the published literature in this domain. Column 3 (Water dependency) is rated from 1-3 with 3 indicating a high dependence on water given current technologies. Column 5 (Substitution opportunities) is negatively rated 1-3 with 3 indicating few substitution opportunities and 1 indicating many, at least relative to current demands and patterns of consumption. Lead time (column 6) is designed around the decision-making time frame for important investment decisions. A score of 1 suggests that a ‘wait and see’ approach is not too costly and 3 indicates that decisions are relatively pressing in the present context.

The data on declining streamflow is presented only for 2030 and draws from Deliverable 1. To reiterate, these are point estimates and should be treated with great caution. The full range of estimates and the underlying methodology for generating these data should be considered along with the information presented here.

It is important to note that these vulnerability assessments are:

1. Qualitative only;
2. Are not measured in a common metric, and;
3. Should not, under any circumstances, be summed to produce some measure of importance.

In simple terms, the exercise is designed to illustrate the pertinence of the methodology to the North East and to help guide future work but should not be used to prioritise investments or policy choices.

**Table 4.13. Preliminary vulnerability assessment – Alpine Shire**

| Activity | Water Dependency | Predicted Decline in Streamflow by 2030 | | Substitution Opportunities | Lead time requirements | Other comments |
|---|---|---|---|---|---|---|
| | | Low | High | | | |
| Tourism | 2 | 2.0% | 9.7% | 1 | 1 | Snow making technologies may be required. Attention to development of off-season attractions at discretion of private sector. |
| Forestry | 3 | | | 3 | 3 | Processing unlikely to be directly at risk but contraction of forested area probable. |
| Agriculture | 2 | | | 2 | 2 | Varies depending on mix of perennial and annual activity. |
| Manufacturing | 3 | | | 1 | 1 | Almost all manufacturing has access to potable supplies with accompanying planning. |
| Urban reticulated | 3 | | | 1 | 1 | Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Peri-urban | 3 | | | 2 | 2 | Categorisation of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Environmental assets | 3 | | | 3 | 3 | Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least. |

**Table 4.14. Preliminary vulnerability assessment – Indigo Shire**

| Activity | Water Dependency | Predicted Decline in Streamflow by 2030 | | Substitution Opportunities | Lead time requirements | Other comments |
|---|---|---|---|---|---|---|
| | | Low | High | | | |
| Tourism | 2 | 7.6% | 15.7% | 1 | 1 | |
| Forestry | | | | | | Limited activity in LGA |
| Agriculture | 2 | | | 2 | 2 | Varies depending on mix of perennial and annual activity. |
| Manufacturing | 3 | | | 1 | 1 | Almost all manufacturing has access to potable supplies with accompanying planning. |
| Urban reticulated | 3 | | | 2 | 1 | Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Peri-urban | 3 | | | 2 | 2 | Categorisation of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Environmental assets | 3 | | | 3 | 3 | Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least. |

**Table 4.15. Preliminary vulnerability assessment – Towong Shire**

| Activity | Water Dependency | Predicted Decline in Streamflow by 2030 | | Substitution Opportunities | Lead time requirements | Other comments |
|---|---|---|---|---|---|---|
| | | Low | High | | | |
| Tourism | 1 | 8.7% | 17.3% | 1 | 1 | |
| Forestry | 3 | | | 3 | 3 | Processing unlikely to be directly at risk but contraction of forested area probable. Some forward planning appears warranted |
| Agriculture | 2 | | | 2 | 2 | Varies depending on mix of perennial and annual activity. |
| Manufacturing | | | | | | Few water-dependent manufacturers |
| Urban reticulated | 3 | | | 2 | 1 | Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Peri-urban | 3 | | | 2 | 2 | Categorisation of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Environmental assets | 3 | | | 3 | 3 | Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least. |

**Table 4.16. Preliminary vulnerability assessment - Wangaratta**

| Activity | Water Dependency | Predicted Decline in Streamflow by 2030 | | Substitution Opportunities | Lead time requirements | Other comments |
|---|---|---|---|---|---|---|
| | | Low | High | | | |
| Tourism | 2 | 0.7% | 9.6% | 1 | 1 | Some reliance on management of storages. |
| Forestry | | | | | | Limited activity in LGA |
| Agriculture | 2 | | | 2 | 2 | Varies depending on mix of perennial and annual activity. |
| Manufacturing | 3 | | | 1 | 1 | Reliant on adequate forward planning by state agencies like NEW. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Urban reticulated | 3 | | | 1 | 1 | Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Peri-urban | 3 | | | 2 | 2 | Categorisation of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Environmental assets | 3 | | | 3 | 3 | Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least. |

**Table 4.17. Preliminary vulnerability assessment - Wodonga**

| Activity | Water Dependency | Predicted Decline in Streamflow by 2030 | | Substitution Opportunities | Lead time requirements | Other comments |
|---|---|---|---|---|---|---|
| | | Low | High | | | |
| Tourism | 2 | 7.6% | 16.1% | 1 | 1 | Some reliance on management of storages. |
| Forestry | | | | | | Limited activity in LGA |
| Agriculture | 2 | | | 2 | 2 | Varies depending on mix of perennial and annual activity. |
| Manufacturing | 3 | | | 1 | 1 | Planning and consideration of alternatives generally sufficiently advanced. |
| Urban reticulated | 3 | | | 1 | 1 | Planning and consideration of alternatives generally sufficiently advanced. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Peri-urban | 3 | | | 2 | 2 | Categorisation of 'self-reliant households' requires additional policy and planning consideration. Reliance on groundwater as an emergency supply also warrants review give current over-allocation identified in Deliverable 1. |
| Environmental assets | 3 | | | 3 | 3 | Refuge and biodiversity aspects appear vulnerable. Integration with tourism and other activities suggest advocacy role by local government, at least. |

# 5 Social and Economic Consequences of Vulnerability

Water supply variability will affect the consumption plans of consumers, the production plans of firms (including farmers) and the sustainability of natural environments. The extent of these costs depends on:

- the extent of water dependence,
- the magnitude of the actual water supply changes,
- the possibilities for taking actions over a reasonable time frame that will offset the effects of changed water availability – for example, accessing alternative supplies, successfully utilising less water, relocating and so on, and
- the extent to which such changes are anticipated and therefore able to be dealt with on the basis of forward-looking plans.

In the table in the previous section we have attempted to operationalise this approach by providing an, albeit crude, assessment of these issues in particular contexts. This has been done primarily to help guide future research and thinking, since planning and research is an expensive activity in its own right and narrowing the scope may be of use, at least initially.

| |
|---|
| However, what needs to be emphasised is that the basis of forward planning is problematic – the variability of the models used to estimate water availability should not be understated (see, Deliverable 1 for caveats). In addition, there are numerous other factors for which modelling is not feasible. |

For activities such as agriculture the global effects of climate change on output prices are also important (and unpredictable) – farmers may be forced, for example, to access more expensive water supplies if conventional supplies become unavailable or but this will have little effect on their financial viability if the global agricultural product price rises sufficiently so that profit margins can be maintained (see Box 4.1for example).

A key issue is that climate change can be forecast on the basis of trends to average around 0.2$^{o}$C per decade over the next few decades. There is a substantial range around such point forecasts, and an even greater range of forecasts for water availability, because increased temperatures increase evaporation thereby reducing the effectiveness of rainfall but also by adding more water vapour to the atmosphere increasing rainfall itself. The highly non-linear relation between stream-flows and rainfall compounds this uncertainty – small changes in rainfall can be expected to have greatly magnified impacts on stream-flow.

With quite high probabilities the effects of climate change on water supplies will be moderate, and even perhaps in some cases benign. Nevertheless, there are risks of catastrophic changes particularly if, as is currently the case, several large $CO_2$ emitting countries refuse to take determined action to mitigate their carbon emissions. The modelling undertaken in Deliverable 1 has attempted to incorporate these factors as best as possible given the inherent uncertainty. That said, we recommend a cautious approach when contemplating potential responses.

Severe water supply changes will only be concentrated among industries and activities with high water dependence and where substitution possibilities are low.

In our view, forestry and the preservation of biodiversity are important instances. Climate change resulting in reduced water availability will reduce the biological productivity and growth potential of standing forests and increase the extent to which they are exposed to forest fire risks. The latter is particularly important since forests that are harvested over long rotations can be devastated by forest fires. It is well known that fire risks do not substantially affect management practices on forests in terms of selecting harvesting schedules – increased risk increases discount rates and only marginally reduces desired rotations. But such risks greatly reduce the present value of forests providing a strong cost-benefit case for increasing fire detection and fire prevention efforts (Reed, 1984) or even withdrawal from the industry entirely.

In addition, there is at least some evidence that the water used by forests in the upper parts of the catchment will come under increased scrutiny (see, for example, ACIL Tasman 2010 and Deliverable 3). Presently, such water use has proven too difficult to monitor, at least to the extent that the forestry industry has not yet been required to purchase extant water entitlements or allocations. It is unclear whether the present approach of government will continue, particularly in light of wider considerations, like the Basin plan and its successors.

These types of investments need to be anticipatory and relate to optimising the value of long-lived assets. The importance of such investments in forestry is emphasised in the case of the North East by the externalities they create for the region's role as a tourism destination and forestry's function in providing a biodiversity conservation zone, in some instances.

Forestry would prima facie be an industry warranting closer scrutiny in the context of climate change and reduced water availability in the North East. That said, this should not be taken as a recommendation for enhanced government intervention or support.

Notwithstanding the present dependence of urban water users, our assessment is that this group should not be severely affected. This assessment arises from the observation that urban users' water needs are modest compared to agricultural and industrial uses so that shortfalls here can be met by charging increased prices somewhat and shifting consumption from other extensive low-value uses to urban communities. There is also evidence that the needs of urban users are systematically reviewed by the urban water utility, as noted in Deliverable 3. Notwithstanding these advantages, there may also be scope for additional work in this field. For example, it is not at all clear how NEW is contemplating notions like 'self-reliant households' and the measures they have in place to ensure that such self-reliance materialises in a timely manner, should the need arise.

In addition, the outputs from Deliverable 1 indicate that the groundwater resources in the region are already over-allocated to the tune of 40%. Thus, where contingencies have been planned around groundwater access additional planning may be required.

The implied price changes arising from meeting urban demand might adversely impact on low income, high water use households but in policy terms this is not an intractable problem. There are significant potential social impacts here but these can be offset by charging the necessary higher marginal costs of water delivery beyond some subsistence thresholds. Other alternatives including discounting the fixed charges to deal with equity concerns so that consumers still face the marginal cost for each volumetric component of consumption (see, for example, O'Keefe, Crase, and Paul 2010). This will yield approximately efficient outcomes with some measure of distributional justice.

The more severe prospect of small peri-urban communities being cut off from water supplies is a catastrophic outcome for those involved. However, the case for presumptive offsetting investments by water utilities is probably weak, at least for reasonable probability assessments given that shorter term relief programs can typically be engineered (e.g. carting water). However, such vulnerabilities need to be set out for communities to understand so that private adaptive measures can, in addition, be taken. Emergency contingency plans might also be prepared by water utilities and local governments. We note that there are examples of such adaptive responses already in the North East (see, Box 4.4) but there is some doubt as to whether this is the optimal approach and questions about the extent to which the current arrangement would limit rent seeking in a more water scarce environment.

More specifically, as it stands there is at least some incentive for households to locate in smaller non-reticulated communities, in part because of the lower cost of land that attends the lower level of service provided by utilities.

Such households also face relatively weak incentives to undertake additional investments in their own water infrastructure (what NEW presently calls self-reliant households) insomuch as they can be assured that the state will intervene and shore up water supplies in severe times. Moreover, such interventions, to date, have not been undertaken on a cost recovery basis, effectively shifting the cost and risk of water scarcity to other urban water users in the more populous locations. It is not at all clear that these arrangements are consistent with the standard view on redistribution of income or constitute a sensible policy stance.

More specifically, there is no guarantee that a water user in a more populous town like Wodonga is better placed to pay for water infrastructure in small towns than the residents of those towns. It is our view that this issue warrants closer scrutiny since it may have the perverse impact of exposing smaller communities to even greater water risk as a result of climate change.

Commercial impacts on firms/households will be costly to the extent only that anticipatable changes were ignored. Unanticipatable changes that create adjustment costs for firms and households are socially relevant only to the extent that they create extreme social disadvantage such as poverty.

| |
|---|
| Public policy should not seek to guarantee immunity from extreme climatic events – it should articulate the general possibility of such events and encourage commercial and private entities to make appropriate adjustments in adaptive anticipation. Policy should not seek to insulate such entities from the effects of water supply changes since this will have the moral hazard implication of discouraging sought-after adaptation. |

Apart from providing information and seeking to expand the range of adaptation options, the main task for public policy is to provide a social safety net for vulnerable households who fall into severe economic disadvantage. This assistance should not be provided because of these events alone but because there is disadvantage that provides outcomes that fall below generally accepted social norms. It is also folly to endeavour to insulate against disadvantage by shielding groups from the direct costs of change. Put simply, if water becomes more scarce and thus more costly the price faced by all water users should rise, including the poor. Poverty measures should be dealt with separately else we run the risk that water users will not respond to scarcity.

**Box 4.4 Responding to the failure of the Eskdale community water supply**

Eskdale is a small community comprising around 90 residents located in Towong Shire. A community water supply had served the township for around 60 years, having originally been developed by the local timber mill. The reticulated supply was managed by the Eskdale Water trust since 1975 and the system was not required to meet the more stringent standards of potable water imposed on urban water utilities. Prior to 2009 some work had been done considering the feasibility of water supply modifications, primarily in response to concerns about water quality. In February 2009 the Little Snowy Creek ran dry thus limiting the raw water supply to the township.

NEW (the local water utility) was not required to act, insomuch as Eskdale is not part of the designated urban water network. Nevertheless, NEW is a state government entity required to undertake its activities in a socially responsible manner. NEW responded immediately by carting water to shore up supplies for residents.

There was some resistance from residence to upgrade the water supply permanently, largely in response to concerns about cost. Subsequently, NEW surveyed residences and, given the positive response, set about developing and installing a new water supply scheme. This comprised an off-take form the more reliable Mitta Mitta River, a water treatment plant, a clear water storage and a new reticulation network. Approval for the project was received by May 2009 with the system was commissioned in November 2009.

The total cost of the project was approximately $1.1 million. About $475,000 was supplied by different state government agencies with $65,000 provided by local government and $140,000 contributed by local residents. The remaining $400,000 was contributed by the regional water utility (NEW) that services larger towns in the region (NEW 2009; Bird, Ryan and Laauli 2010). In simple terms the residents of these larger towns and the industrial water users in them are now subsidising Eskdale water users.

While the core potential difficulties in relation to water supply vulnerability lie in water intensive agriculture and industry there are also major challenges in the management of biodiversity resources. It is our view that these challenges are non-trivial in the case of the North East.

Biodiversity resources tend to be neglected by many who consider climate change outcomes in NE Victoria. But there are good reasons for maintaining such an emphasis. There are intrinsic reasons for conserving the types of nationally endangered flora and fauna that exists in the NE of Victoria but also instrumental reasons given the aesthetic and tourism value of such resources in the region. Undertaking current measures to expand conservation areas should increase the resilience of natural assets and thus provide expanded adaptive capacity. In addition, a policy along these lines, in our view, approaches a 'no-regrets' option worth considering. In simple terms, should the predictions of climate change ultimately prove less costly than thought, the expanded conservation areas will still retain considerable value, adding to tourism, for instance. This will especially be the case where biodiversity is expanded at the expense of marginal agricultural land.

> Preservation of the regions biodiversity assets needs to become a focus since there are no market-driven pressures for such issues to be addressed.

The rich biodiversity resources of NE Victoria are severely threatened by climate change. This is true, for example, in the box-ironbark forests of Chiltern and in parts of the Warby Range State Park. While the extent of parkland has stabilized in recent years due to government actions, measures of species abundance continue to show a decline. Mac Nally et al. (2009) show that the sustainability of such efforts is threatened by the reduced rainfall consequences of climate change by examining trends in species numbers during the recent extreme drought period that impacted on the NE. This drought lasted long enough to mimic the reduced rainfall scenario that climate change planners fear.

Reduced rainfall reduced food supplies, particularly blossom in flowering trees, and hence the breeding success of the ultra-rare nectar-dependent bird species that reside seasonally in these areas. Severe declines in abundance were described by these authors as a 'collapse' and investment options were suggested to address these issues. None specifically relate to improved water supply options, but are nevertheless noteworthy:

> 'There are several options for enhancing resilience of birds in the box and ironbark system in the face of altered climate. First, measures to restore habitat quality in

existing forested blocks will facilitate breeding if and when more favourable seasons occur. Practices related to fire and extractive industries can be managed to promote structural complexity by retaining large old trees, thinning overly dense stands of regrowth to engender more rapid tree growth of retained stems …protecting fallen timber from firewood harvesting and recreating spatial patchiness in ground layers ….'. (Mac Nally, 2009, p. 727).

Clarke (2008) provides a comprehensive analysis of adaptation investment options for improving the resilience of biodiversity in the face of climate change. These include establishing wildlife corridors and, in critical situations, utilizing captive breeding approaches. These are investments that require long lead times.

**Box 4.5 Case Studies: The Chiltern-Mt Pilot National Park & the Warby Ranges State Park**

**Chiltern.** This recently expanded, 21,600 ha national park is located between Beechworth and the low hills surrounding Chiltern and includes the striking Mt Pilot Range and Woolshed Falls. Chiltern-Mt Pilot National Park protects box-ironbark forest that once covered much of north-east Victoria. It is now less than 25 per cent of its original habitat area and is often a degraded landscape existing as isolated pockets mainly in central Victoria rather than the North East.

The park is the habitat of several rare or threatened species - the Regent Honeyeater (pictured) is one of Australia's rarest birds. Also present are Turquoise and Swift Parrot, Peregrine Falcon, the Brush-tailed phascogale and Squirrel Glider. The Park is one of the most important nature reserves in Southern Australia - it contains more birds, mammals and reptile species than any Box Ironbark site in Victoria. More than 150 bird species have been recorded in the area. Eastern Grey Kangaroos are often seen grazing in the late afternoon and smaller tree-dwelling creatures - Feathertail and Sugar Gliders, Brushtail and Ring-tail Possums - live in tree hollows in the southern areas. Many reptiles, including the Lace Monitor, also reside in the park.

The effects of climate change on the ecology of the park will stem from reduced rainfall and runoff, changed flowering patterns that impact on flowering intensity and flowering commencement which will also affect nectarivorous bird species and on invertebrates dependent on eucalypt species (Tzaros, 2005). There will also be changed bushfire risks.

**Warby Range.** This important state park at 14,460 hectares is the closest neighboring park containing significant box-ironbark forest to Chiltern-Pilot. This is an important areas in Victoria for the Carpet Python, the Northern Sandlewood, Regent and Painted Honeyeaters as well as Swift and Turquoise Parrot. This park is subject to high fire risks that are accentuated by reduced rainfall.

# 6 Concluding Remarks

To sum up, it is most effective and efficient for the pervasive impacts of climate change on the community generally being addressed by all members of the community and not being seen as solely a responsibility of government. This argument applies to many issues in the water supply sector. Major tasks for higher levels of government are to provide forecasts that will help households and firms make informed judgements about climate change. Such judgements are not easy to make, given the substantial uncertainties of climate science. The general message that climate change is occurring and that longer-term water supply provision at current prices may be infeasible is important.

Local governments have a role in providing extension services thus imparting information gathered by other levels of government on these issues. We also argue that local government can play a role in ensuring that some of the present anomalies around risk sharing for smaller communities are addressed, since these may result in deleterious outcomes, especially if water availability is severely reduced.

It is wrong to instinctively rush to the judgement that because water supply variability will almost certainly occur that there is a pressing case for widespread public adaptation investments. Rather, the opposite is the case for North east Victoria and hasty intervention may undermine individual adaptation effort. Exceptions to this statement centre on activities which involve longer-term investments and where failure to act now creates potentially serious avoidable costs. These problems attend the forestry and biodiversity sectors. These sectors have intrinsic values and provide spill-over benefits to tourism and other sectors. The biodiversity conservation sector provides outputs of value to the state and nationally and call for a commitment of resources at these levels.

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North East Greenhouse Alliance

# Summary and Synthesis

North East Victoria Adapting to a Low Water Future: Project Context Setting – Deliverable 5

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Author Professor Lin Crase

La Trobe University

Albury-Wodonga Campus

P O Box 821

Wodonga VIC 3689

Tel: (02) 6024 9834

Fax: (02) 6024 9777

e-mail: l.crase@latrobe.edu.au

# Contents



# Table

# 1 INTRODUCTION

This project has sought to better understand the potential impacts of climate change on water resources in North East Victoria. The ambition was to provide an overview of the region of interest; enhance the climate modelling for the region and increase the modelling resolution; examine pertinent institutional and behavioural characteristics of individuals and organisations in the study area; and provide a preliminary assessment of vulnerabilities.

The purpose of this brief report is to provide a summary of the major findings and to synthesise the different components of the work. Ultimately, this will provide the backdrop for more detailed analysis in subsequent phases of the project.

## 1.1 Main points

- The data pertaining to climate change in the North East are dispersed across many agencies and circumscribed by uncertainty. Modelling approaches are continually being refined and the production of consistent results from this type of analysis remains a challenge.
- Few models have been developed at the level of resolution required for this project.
- The modelling presented here is unequivocally cutting-edge and incorporates important hydrological interactions that have hitherto been either ignored or grossly simplified.
- The modelling indicates that, at a regional scale, there are already serious water management dilemmas. For instance, the data point to the groundwater resources in the study region already being 40% over-allocated.
- Notwithstanding the difficulty of modelling highly unpredictable events at such a fine scale and over such an extended period, these data provide some indication of the potential changes to water availability in the future.
- Using point estimates of such changes is inherently misleading but, regrettably, it is also the most accessible means for many to gain an appreciation of some of the potential effects. The IPCC forecasts for temperature and rainfall are at a global level and have huge ranges without probability information. The rainfall effects are even more uncertain because warming can have ambiguous effects on water supply. This makes national or sub-regional forecasts exceedingly difficult. It is against this background that data on the modelled changes need to be considered. Thus, while reflecting on table 5.1, it is important to appreciate the magnitude of variation embodied in these results.

**Table 5.18 NE CMA LGA future climate percentage change in water balance from historical (1957-2005)**

| | 1995- | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | 2005 | Low | Medium | High | Low | Medium | High |
| Alpine Shire | | | | | | | |
| Rainfall | -5.8 | -1.2 | -2.5 | -4.1 | -3.8 | -8.3 | -14.3 |
| Runoff | -3.0 | -21.8 | -26.1 | -31.2 | -29.4 | -41.6 | -51.6 |
| Evapotranspiration | 2.1 | 0.1 | 0.7 | 1.3 | 1.3 | 2.6 | 2.4 |
| Recharge | -11.1 | -4.0 | -6.8 | -10.3 | -9.8 | -19.0 | -30.1 |
| Streamflow | -14.8 | -2.0 | -5.5 | -9.7 | -9.1 | -20.5 | -33.7 |
| Total flow | -17.6±3 | -3.1±1 | -7.2±2 | -12.3±3 | -11.6±2 | -25.3±5 | -41.2±8 |
| Indigo Shire | | | | | | | |
| Rainfall | -1.4 | -3.5 | -4.9 | -6.6 | -6.3 | -11.2 | -17.8 |
| Runoff | 2.6 | -11.6 | -15.5 | -20.0 | -18.8 | -29.9 | -40.3 |
| Evapotranspiration | 2.3 | -1.3 | -1.6 | -2.1 | -2.0 | -3.9 | -7.8 |
| Recharge | -8.3 | -7.3 | -10.8 | -15.1 | -14.3 | -25.3 | -37.3 |
| Streamflow | -8.6 | -7.6 | -11.3 | -15.7 | -15.0 | -26.2 | -38.2 |
| Total flow | -10.7±2 | -9.4±2 | -14.1±3 | -19.5±4 | -18.6±4 | -32.5±6 | -47.5±9 |
| Towong Shire | | | | | | | |
| Rainfall | -2.0 | -3.5 | -4.7 | -6.2 | -6.0 | -10.3 | -16.1 |
| Runoff | -2.5 | -29.4 | -34.3 | -39.9 | -37.8 | -50.9 | -60.9 |
| Evapotranspiration | 2.5 | -0.2 | 0.1 | 0.3 | 0.4 | 0.4 | -1.4 |
| Recharge | -8.0 | -8.8 | -12.1 | -16.1 | -15.5 | -25.9 | -37.2 |
| Streamflow | -9.4 | -8.7 | -12.6 | -17.3 | -16.7 | -29.0 | -42.6 |
| Total flow | -11.4±2 | -10.9±2 | -15.6±3 | -21.3±4 | -20.6±4 | -35.5±6 | -51.9±9 |
| Wangaratta Shire | | | | | | | |
| Rainfall | -4.5 | -1.4 | -2.8 | -4.5 | -4.2 | -9.1 | -15.7 |
| Runoff | -1.5 | -20.0 | -24.9 | -30.4 | -28.1 | -41.0 | -50.0 |
| Evapotranspiration | 1.8 | -1.0 | -1.1 | -1.2 | -1.1 | -2.1 | -5.0 |
| Recharge | -13.6 | -4.2 | -8.0 | -12.5 | -11.8 | -23.8 | -37.3 |
| Streamflow | -16.8 | -0.7 | -4.7 | -9.6 | -8.9 | -21.4 | -35.1 |
| Total flow | -20.2±3 | -1.8±1 | -6.8±2 | -12.7±3 | -11.9±3 | -27.4±6 | -44.4±9 |
| Wodonga Shire | | | | | | | |
| Rainfall | -1.2 | -4.1 | -5.5 | -7.2 | -6.9 | -11.7 | -18.3 |
| Runoff | -5.1 | -6.4 | -11.0 | -16.5 | -15.4 | -28.8 | -41.1 |
| Evapotranspiration | 2.3 | -2.5 | -2.9 | -3.4 | -3.4 | -5.5 | -9.8 |
| Recharge | -9.1 | -7.5 | -11.2 | -15.7 | -15.0 | -26.2 | -38.2 |
| Streamflow | -9.4 | -7.6 | -11.6 | -16.5 | -15.7 | -27.9 | -40.5 |
| Total flow | -11.7±2 | -9.5±2 | -14.4±3 | -20.4±4 | -19.5±4 | -34.5±7 | -50.1±10 |

- Spatially, the hydrological impacts of climate change in the North East are likely to differ, as indicated by Table 5.1.
- Transposing hydrological changes into impacts on communities, firms and individuals requires some understanding of the socio-economic makeup of different jurisdictions.
- The data presented in Deliverable 2 show the breadth of economic and social activity and connection in the region. Much of the land mass is occupied by agriculture and an even greater area is natural landscapes, with varying levels of ecological value. Collectively, the natural and agricultural landscapes define the aesthetics of the region.
- Aesthetics can be misleading to the extent that agriculture makes a relatively minor direct contribution to the regional economy and its terms of trade continue to decline. However, it does offer important synergies to other

economic drivers in the region. It is also the major water-using sector in the region.

- The services sector is particularly important in some LGAs and this can directly and indirectly be impacted by changes in water availability.
- Some manufacturing activities in the region are heavy water users and rely primarily on the urban water utility to manage the risks associates with reduced water availability.
- The water demands of urban residents are modest relative to the call on water by local agriculturalists. The relative demands of urban users are even more modest when compared with the use by downstream irrigators.
- Institutional impediments to moving water rights between different users remain one of the most significant obstacles to adaptation, although some useful progress is evident.
- The plan to increase environmental water entitlements should increase the surety of water supplies for many in the North East since this will invariably be stored upstream of major urban centres.
- Water pricing is critical because it sends signals to consumers and encourages adaptation to scarcity. This applies to both urban water users and others. The split between volumetric and fixed tariffs is also a component of adaptation – heavier weight on volumetric tariffs encourages greater inter-sectoral trade.
- Augmentation of urban water supplies is best undertaken by considering the economic merit of all alternatives.
- There is a risk that the comparative advantage of the North East will be undermined if expensive retrofitted technologies are imposed on water users, without reference to other low-cost options.
- Augmentation choices based on notions of 'water saving' are particularly dangerous in this context since the North East lies at the top of the catchment and water purportedly saved is simply shifted in time and space thereby affecting other users.
- The ongoing water restrictions imposed on some urban communities is illustrative of the institutional failures that already exist. Such failures seem likely to make adaptation more problematic than it ought to be.

- Increased water scarcity will impose costs but they will not be uniform. The extent of these costs depends on:
    - the extent of water dependence,
    - the magnitude of the actual water supply changes,
    - the possibilities for taking actions over a reasonable time frame that will offset the effects of changed water availability – for example, accessing alternative supplies, successfully utilising less water, relocating and so on, and
    - the extent to which such changes are anticipated and therefore able to be dealt with on the basis of forward-looking plans.

- Taken together and considered on a council-by-council basis these criteria point to several vulnerabilities. However, overall there is a strong case for limiting the extent of policy intervention.

- There is a serious risk that ill-considered intervention will give rise to a moral hazard problem. In simple terms, most adaptations will be undertaken by individuals and firms because they make sense in their own right. Once governments commence offering subsidies and the like to pursue rational adaptation strategies then the private sector will hold back on adapting in order to secure assistance from the state.

- One area requiring additional consideration is forestry, which is a significant contributor on several fronts in the region. Forestry is reliant on relatively high rainfall, requires long-term investment timeframes and has few substitution opportunities. It also produces some spillover biodiversity benefits, depending on management practices.

- Whilst not advocating intervention, we recommend that this sector be treated as being vulnerable in the current context.

- Peri-urban water users also require greater attention. The current institutional arrangement gives rise to perverse incentives for growth in such towns. Dealing with these anomalies now would both increase efficiency in the immediate term and provide clearer adaptation incentives for the future.

- The clearest case for intervention attends the biodiversity assets of the region. There are no market-driven pressures to deal with the vulnerabilities of these sites. There is also a case for arguing that expansion of natural reserves now approaches a ‘no regrets’ solution. If climate change turns out to be less severe than predicted, the conservation and related values of expanded natural areas will still largely justify this course of action.