Setting Aspirational, Achievable and Management Action Targets Across the Glenelg Hopkins CMA.


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INTRODUCTION

This is the first milestone report on Setting Aspirational, Achievable and Management Action Targets across the Glenelg-Hopkins Catchment Management Authority (GHCMA). The general objective of this project is to assess, spatially re-define and prioritise the aspirational, achievable and management action targets that have been set for the GHCMA region within their Regional Catchment Strategy.

The project integrates and builds on existing data (such as water levels measured in bores, salinity levels measured in rivers, etc) from sub-catchment studies within the GHCMA. There are numerous reports that have synthesized relevant data within the GHCMA for various NAPSWQ strategies and priority settings (such as the Groundwater Flow Systems, GFSs, workshop and report), which will help in setting and prioritising the targets.

This first stage of the project was to collate relevant information from all sources and analyse all existing data required for modelling land use changes within their associated Groundwater Flow System (GFS). Long-term records of groundwater levels and stream salinities were also obtained to determine trends. Salinity trends will be analysed using statistical techniques such as GAM analysis and modelling techniques such as FLOWTUBE will be used to predict the impacts of land management changes.

The specific activities addressed by this first milestone report are to:

1. collate and synthesise all relevant data including GFSs;
2. do a “first pass” review and statistical analysis of stream electrical conductivity (EC) and saltload data, and
3. show how FLOWTUBE modelling can be incorporated to prioritise management actions and then collate existing datasets for selected sub-catchments).

The aim of the modelling exercise is to improve our understanding of the groundwater processes and catchment characteristics along with examining land use change with groundwater behaviour (water balances). The sub-catchments where sufficient data exists will be identified and will be chosen in such a way that it will represent each GFS within the GHCMA. Each sub-catchment chosen will have a fairly close series of networked bores with sufficient data to accurately describe the responsive nature if the
GFS to certain land use changes. Several hypothesis will be tested by the FLOWTUBE modelling:

1. to elucidate the hydrogeological processes operating within the sub-catchments and thereby understand the causes of the salting in affected areas of the GHCMA;
2. to quantify the relationship between these hydrogeological processes by simulating them using a groundwater model of the sub-catchments; and
3. to use this model to test the efficacy of different salinity management strategies.
BACKGROUND

Study Area

The GHCMA is located in southwestern Victoria (Figure 1). The region covers approximately 2.6 million hectares of land, extending from the South Australian border in the west to beyond Warrnambool in the eastern coastal districts and to Ballarat in the Central Highlands. Major provincial centres include Ballarat, Hamilton, Warrnambool, Ararat, Port Fairy and Portland.

![Figure 1. Location of Glenelg-Hopkins Catchment Management Authority (GHCMA).](image)

The region’s climate is typically temperate to Mediterranean. It is characterised by warm, dry summers and cool, wet winters. Annual rainfall ranges from less than 500 mm/yr in the north and east, particularly in parts of the Basalt Plains to more than 850 mm/yr in the Grampians and near Heywood and Portland (Figure 2).
The region’s landforms are quite variable with the north of the region being bound by part of the Great Dividing Range and in the west and south-west of the region, the landform is dominated by the stranded dune systems of the coastal plain.

Figure 3 and Figure 4 show landform units and geomorphology across the GHCMA.
Figure 4. Geomorphology across the GHCMA (after, Dahlhaus, 2002).

The region comprises six main drainage basins – the Upper and Lower Glenelg, Upper and Lower Hopkins, Portland Coast and Millicent Coast basins (Figure 5). The major rivers are the Glenelg and Hopkins, which drain northern uplands to the coast at Nelson and Warrnambool, respectively.

Figure 5. Major drainage basins across the GHCMA.
Surface water quality is variable across the GHCMA with good quality water found in the highlands reaches (typically those sourced form the Grampians), and the poorer water found in the mid to lower reaches of the major rivers (e.g. Hopkins and Wannon). In fact, surface water is some areas already exceeds Murray-Darling Basin Commission benchmarks for salinity (800 and 1,500 EC) (SKM & AV, 2001). It has also been suggested by the Victorian Water Quality Monitoring Network Trend Analysis, undertaken by SKM, (1999) that within the GHCMA, stream salinity is increasing on average by 2 EC units per year.

Almost one third of the region is estimated to be at high risk of salinity, with another half considered to be at moderate risk under the worst-case scenario (SKM & AV, 2001). In recent years, land use across the GHCMA has changed quite substantially. Prior to the collapse of the wool industry in the mid 1990's the region supported mainly grazing enterprises. However, today land use is predominately dryland agriculture (Figure 6) and the area of land under pasture is ever increasing. This along with range of natural resource management issues such as, increasing areas of secondary salinity and a general decline in both surface and groundwater quality (caused by such land use changes) have put at risk the long-term environmental sustainability of the region.

![Figure 6. Land use across the GHCMA (after, Dahlhaus, 2002).](image)

**Addressing the Current Situation**

Within the region, addressing salinity management issues is one of the key challenges in protecting the areas natural resources. Through the GHCMA Salinity Plan (GHCMA a,
2003) and the GHCMA Regional Catchment Strategy (GHCMA b, 2003), priority areas and targets have been identified. However, it is not clear if the management strategies associated with these areas are in fact feasible for the regions controlling bodies to carry out. Therefore, the task ahead is to undertake predictive scenario modelling to assist in determining which management strategies are the most suitable for each priority area.

**Priority areas**
The main goal of setting priority areas is to ensure the most effective and efficient use of community and government resources, as they will be directed to where the most benefit will accrue. The GHCMA Salinity Plan (GHCMA a, 2003) has identified priority areas for 137 base level sub-catchments (Figure 7). These priority areas were based careful consideration of the salinity hazard, distribution of assets and opportunity for intervention. Four key steps were taken in the decision making process.

*Salinity Hazard*
Salinity is widespread across the GHCMA but it is not uniform with some areas more affected than others. Salinity mapping has been completed for the region and along with information on groundwater salinity levels, percent of shallow watertables, stream flow weighted salinity and land management, unit ranking has been used to determine which sub-catchments are threatened by salinity. The salinity hazard was normalised to the sub-catchment area, to ensure that sub-catchments of different sizes were treated equally.

*Asset Identification*
Agricultural land, environmental and infrastructure assets were located within each sub-catchment. It is important that these assets are protected if the regional communities are to maintain their standard of living.

*Asset Risk Assessment*
Each asset type (agricultural land, environmental, infrastructure) was assessed against the appropriate hazard criteria to produce a normalised assessment of the risk of salinity to assets in the sub-catchment. Where discrepancies in the assessment occurred, a Salinity Technical Committee was appointed to qualify the judgement.

*Technical feasibility of control*
Groundwater Flow System characteristics influence the likely effectiveness of available management options, the scale of work required and the timeframe required to accrue benefits. A groundwater characterisation was completed for the region and the flow systems grouped according to their responsiveness to recharge management options. Groundwater Flow System responsiveness
is based on the fundamental assumptions that Local Groundwater Flow Systems are responsive to recharge management, while Intermediate and Regional Groundwater Flow systems are not.

Each of the region’s 137 base level sub-catchments were assessed according to the criteria described above using the Integrated Catchment Salinity Risk and Prioritisation (ICSRP) Framework. This framework developed by the Centre for Land Protection Research uses GIS data sets to interrogate and relate data. From here the sub-catchments were grouped into one of five categories where broad management options were assigned accordingly (Figure 7).

**Priority A1** Salinity hazard, high/moderate value assets, groundwater system responds to recharge control activities

*Options*: Recharge management + Discharge Management + Engineering.

**Priority A2** Salinity hazard, high/moderate value assets, groundwater system does not respond to recharge control

*Options*: Discharge Management + Engineering.

**Priority B1** Salinity hazard, low value assets, groundwater system responds to recharge control activities.

*Options*: Recharge Management + Discharge Management + Engineering.

**Priority B2** Salinity hazard, low value assets, groundwater system does not respond to recharge control.

*Options*: Discharge Management + Engineering.

**Priority C** No salinity hazard.

*Options*: No salinity investment.
Figure 7. Priority areas for 137 base level sub-catchments within the GHCMA.
Targets
Targets have been defined and established within the GHCMA Salinity Plan. Their main aim is to measure the progression toward achievement of their associated goals as required by State government. Three levels of targets will be set: Aspirational, Resource Condition and Management Action.

**Aspirational Targets**
Aspirational targets as defined by the GHCMA Salinity Plan (GHCMAa, 2003), are a statement about the desired condition of the region in relation to salinity in the longer term (50 years +). Actions within the plan have been developed with this long-term goal in mind and will progressively move the region towards achieving this goal.

**Aspirational Goal:** That surface and groundwater salinity levels do not negatively impact on key regional assets.

**Resource Condition Targets**
Resource Condition Targets also often referred to as End of Valley Targets provide specific, time bound, measurable targets for the medium term (10 - 20 years). The National Framework for natural resource management standards and targets identifies a minimum set of eight matters for which targets must be set in the region. Three of these relate to salinity management.

1. Area of land threatened by shallow or rising watertables,
2. Surface water salinity; and
3. Extent of critical assets identified and protected from salinity and degrading water quality.

Establishment of appropriate targets requires prediction of trends, an assessment of risk to assets and values and agreement on the acceptable level of risk. Insufficient data currently exists in the region to enable appropriate targets to be set for all matters except surface water salinity. High priority actions have been identified in the GHCMA Salinity Plan (GHCMAa, 2003) to support development of appropriate targets in consultation with the community by December 2004.

Interim surface water salinity targets have been set for four catchment points by the GHCMA Salinity Plan, (GHCMAa, 2003). Targets indicate the maximum stream salinity level desired for these rivers by 2012.
1. Hopkins River at Wickliffe 15000 EC 90 % of the time
2. Hopkins River at Hopkins Falls 7500 EC 90 % of the time
3. Glenelg River at Sandford 3300 EC 90 % of the time
4. Wannon River at Henty 5840 EC 90 % of the time

These targets will be reviewed and may change dependant on our understanding of impact of the on-ground works in altering the resource condition. Information that will enable us make this assessment will come from modelling land use change and observing the groundwater response (eg the impact of trees or pastures on salinity). Extrapolation to broader catchment scale, and the extended timeframe over which actions may become effective or have an impact, add additional complexity.

Management Action Targets
The GHCMA Salinity Plan (GHCMA a, 2003) identifies practical, achievable actions in five programs, which contribute to achieving the resource condition targets and our Aspirational goal. These programs are:

1. Land Management Program
2. Capacity Building Program
3. Research and Investigation Program
4. Monitoring Program
5. Coordination Program

The on-ground works actions of the Land Management Program have specific targets associated with them. Tree and lucerne programs have been accelerated with 50% of the required works to be implemented in the first 10 years with the remaining 50% to be implemented second 20 year period. Targets are reported in Table 1.
Table 1. Land Management Program on-ground works targets (after GHCMA a, 2003).

<table>
<thead>
<tr>
<th>Land Management Program Actions</th>
<th>Groundwater Flow Systems</th>
<th>Program Action No.</th>
<th>Priority Areas</th>
<th>30yr Target</th>
<th>Annual Target</th>
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<tbody>
<tr>
<td><strong>Discharge Revegetation (ha)</strong></td>
<td>All Systems</td>
<td>1.1.3, 1.1.5</td>
<td>A1</td>
<td>9273</td>
<td>309</td>
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<td></td>
<td></td>
<td>1.1.3, 1.1.5</td>
<td>A2</td>
<td>8785</td>
<td>293</td>
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<tr>
<td></td>
<td></td>
<td>1.1.4, 1.1.6</td>
<td>B1</td>
<td>418</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.4, 1.1.6</td>
<td>B2</td>
<td>737</td>
<td>24</td>
</tr>
<tr>
<td><strong>Fencing Discharge (km)</strong></td>
<td>All Systems</td>
<td>1.1.1</td>
<td>A1</td>
<td>1890</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.1</td>
<td>A2</td>
<td>1245</td>
<td>41</td>
</tr>
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<td></td>
<td></td>
<td>1.1.2</td>
<td>B1</td>
<td>107</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2</td>
<td>B2</td>
<td>125</td>
<td>4</td>
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<td><strong>Perrenial Pasture (ha)</strong></td>
<td>Woorndoo, Fractured Paleozoic, Deeply Weathered Paleozoic</td>
<td>1.3.1</td>
<td>A1</td>
<td>28479</td>
<td>949</td>
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<th>Accelerated Actions</th>
<th>Groundwater Flow Systems</th>
<th>Program Action No.</th>
<th>Priority Areas</th>
<th>30yr Target</th>
<th>Annual Target (yrs 1-10)</th>
<th>Annual Target (yrs 11-30)</th>
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<td>Tree Blocks (ha)</td>
<td>Fractured Paleozoics, Deeply weathered granite, fractured granite, Merino Tablelands, Pliocene Sands</td>
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<td>A1</td>
<td>6310</td>
<td>315</td>
<td>158</td>
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<tr>
<td>Tree Belts (km)</td>
<td>Western Dundas Tablelands, Eastern Dundas Tablelands, Deeply weathered granite, fractured granite, Woorndoo</td>
<td>1.2.1</td>
<td>A1</td>
<td>406</td>
<td>20.3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2.2</td>
<td>B1</td>
<td>22</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>Fencing Tree Belts (km)</td>
<td>Western Dundas Tablelands, Eastern Dundas Tablelands, Deeply weathered granite, fractured granite, Woorndoo</td>
<td>1.3.1</td>
<td>A1</td>
<td>813</td>
<td>41</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2</td>
<td>B1</td>
<td>43</td>
<td>2</td>
<td>1.2</td>
</tr>
<tr>
<td>Lucern (ha)</td>
<td>Woorndoo, Deeply Weathered Paleozoic</td>
<td>1.3.2</td>
<td>A1</td>
<td>1452</td>
<td>73</td>
<td>36</td>
</tr>
</tbody>
</table>
MATERIALS AND METHODS

Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, and Figure 13 show the location of the GHCMA Salinity Sub-Catchments, Groundwater Flow Systems, locations of groundwater bores and other information that will be used in this project.
Figure 8. Location of the GHCMA Salinity Sub-Catchments.
Figure 9. Location of the GHCMA Salinity Sub-Catchments with reference to Groundwater Flow Systems.
Figure 10. Location of all Groundwater bores within the GHCMA Salinity Sub-Catchments.
Figure 11. Salt stores within the GHCMA Salinity Sub-Catchments.
Figure 12. Estimated groundwater recharge within the GHCMA Salinity Sub-Catchments.
Figure 13. Expected groundwater response to land use change within the GHCMA Salinity Sub-Catchments.
Stream Gauging Stations

Figure 14 shows the location of the major stream gauging stations that will be used in this project to help set achievable management strategies across the GHCMA.

![Map of major stream gauging stations within the GHCMA](image)

**Figure 14. Major stream gauging stations within the GHCMA**

Statistical Analysis

Attempts were made to analyse stream salinity trends at each stream gauging stations within the GHCMA however, long term stream salinity monitoring has been infrequent and irregular across most of the CMA, making the establishment of salinity trends difficult in many cases.

The aim of this type of data analysis is to obtain stream salinity trends that are independent of fluctuations in flow and season, and hence are indicative of the impacts of saline groundwater inflows caused by catchment salinisation. A standard approach used in water agencies throughout the world is the non-parametric Seasonal Kendall’s $\tau$ and LOESS smoother techniques (Hirsch et al., 1982; Cleveland, 1994). As highlighted in Jolly et al. (2001), problems arise from the application of the Seasonal Kendall’s $\tau$ technique when the stream salinity data are autocorrelated, as was shown to be the case for many of the stations in the MDB. To overcome this problem a new semi-parametric statistical methodology was employed (Morton, 1997) which uses the Generalised Additive Model (GAM) approach (Hastie and Tibshirani, 1990). While corrections for flow and seasonal effects are implicit in the technique, it is important to note that the analysis does not account for long-term climatic variations *per se.*
In this technique, additive regression terms were fitted to $\log EC$ (log $\mu S/cm$), the explanatory variables being time (months), $\log flow$ (log ML/day) and sinusoidal seasonal terms. This non-linear GAM model represented the response of $\log EC$ to time and $\log flow$ by arbitrary smooth curves using cubic splines with knots at each data point. The mathematical form of the regression was:

$$\log EC = \alpha + S(time; df_t) + S(\log flow; df_f) + \beta \sin(2\pi \text{month}/12) + \gamma \cos(2\pi \text{month}/12) + \varepsilon$$  \hspace{1cm} (1)$$

where $\log EC$ was the natural logarithm of EC, $\log flow$ was the natural logarithm of flow + 1, time was in years, month had values of 1 to 12, $S(t; df)$ was a smoothing spline of $\log EC$ versus time with $df_t$ degrees of freedom, $S(\log flow; df_f)$ was a smoothing spline of $\log EC$ versus $\log flow$ with $df_f$ degrees of freedom; $\alpha$, $\beta$, $\gamma$ were linear regression coefficients and $\varepsilon$ was the residual error. The terms $df_t$ and $df_f$ are smoothing parameters that determine the shape of the splines fitted to the data.

We followed Morton’s (1997) recommendation that values of 4 for $df_t$ and 2 for $df_f$ were adequate for data sets of the length used in this project. The term $S(x; m)$ is the sum of the linear (which is of the form $a+b*x$) and the non-linear (which has mean zero and no linear trend) components of the trend. By separating the linear and non-linear components of the spline function, Equation (1) was rewritten as:

$$\log EC = \alpha + \eta \text{time} + C_{\text{time}} + \chi \log flow + C_{\log flow} + \beta \sin(2\pi \text{month}/12) + \gamma \cos(2\pi \text{month}/12) + \varepsilon$$ \hspace{1cm} (2)$$

where $\eta$ and $\chi$ were linear coefficients of time and $\log flow$ respectively, and $C_{\text{time}}$ and $C_{\log flow}$ were the non-linear components of $S(\text{time}; df_t)$ and $S(\log flow; df_f)$ respectively. The linear coefficient of time, $\eta$, was used to calculate the percentage change in EC per annum using the formula:

$$\{100 \times (e^{\eta} - 1)\}$$ \hspace{1cm} (3)$$

Figure 15 shows the two components of the trend. The significance of the non-linear component cannot be determined and as such is qualitative. The significance of the linear component of the trend can be determined quantitatively.
The model fits were carried out using Ordinary Least Squares (referred to as the OLS approach) regression. If autocorrelation of the residuals of the OLS fits were found to be high (>0.2), then fits were carried out with first order autoregressive parameters (referred to as the TSM approach).

The significance of the linear components of the trends at the 5% probability level was estimated as ±2 standard errors. Standard errors for stations with sufficient data to use the TSM approach were taken directly from the statistical output. However, if the number of missing months was too large (>20%), then the TSM approach failed and it was necessary to use the OLS approach with a multiplier applied to the standard errors. This multiplier was derived from likelihood theory and was adjusted both for the magnitude of the autocorrelation and for the amount of missing data:

\[ \left(1 + 2\, pAR / (1 - AR1) \right)^{1/2} \]  

where \( p \) was the proportion of available data and \( AR1 \) was the first order autocorrelation coefficient. It should be noted that this multiplier is an approximation which assumes that the missing values occur independently and at random.

For each station, all available EC data were used to determine the trends. Obvious outliers, caused by erroneous flow or EC values, were identified by high residual values and were removed from the data set and the trends recalculated. There were never more than six points per station where this was necessary.
Groundwater Modelling

Catchment scale groundwater modelling will be used to examine the effect of different recharge rates on the extent of salinity. This section of the report discusses the model description, calibration, parameterisation, sensitivity and results.

Groundwater heads in sub-catchments in the GHCMA will be simulated using FLOWTUBE (Dawes et al. 1997, Dawes et al. 2000, Dawes et al. 2001). This is a simple numerical one-dimensional groundwater flow model. It is a mass-balance model that solves for a change in hydraulic head induced by recharge and discharge fluxes, and lateral transfers in the direction of flow. The results of FLOWTUBE are considered to be a hydraulic head transect along an aquifer.

The model considers a one or two-layer system. In the case of a single layer, the aquifer is assumed to be unconfined and having variable transmissivity dependent on the saturated thickness of aquifer. In the case of a two-layer system, the lower layer is assumed to contain any lateral transmission of water while the upper layer contributes storage capacity only. In this case the lower layer is usually confined or semi-confined, and how this is conceptualised controls the simulated mechanism for groundwater discharge.

Water sources considered by FLOWTUBE are (i) point sources of runoff at the upstream end of the aquifer, often manifested as recharge beds collecting surface water from a steeper part of the catchment, and (ii) diffuse recharge or discharge spread in an arbitrary spatial and temporal pattern across the aquifer being modelled. The latter source is the recharge component most altered by the replacement of native species with annual cropping and grazing systems in Australia.

FLOWTUBE allows a variety of boundary conditions for the aquifer. At the downstream end there are two options: (i) the flux is controlled by a specified groundwater head at a nominated distance, useful where a permanent water source occurs nearby that controls head build up such as a river or irrigation area, or (ii) the flux is controlled by local aquifer properties and the groundwater surface and drains freely, which can be useful when the groundwater catchment is poorly defined or only the upper part of a catchment is considered.

For diffuse recharge input there are three options: (i) a user-specified pattern of fixed recharge amounts with an evaporation component controlled by an extinction depth, which is the traditional implementation within groundwater models, (ii) recharge calculated by FLOWTUBE internally as the difference between the current head and a reference elevation multiplied by an impedance factor, applicable where definite connection and transfers exists between a surface storage and transmitting aquifer with little outside influence, and (iii) a continuous function of recharge/discharge based on GIS
analysis of depth to water from a DEM, most useful when there are near surface water levels causing discharge controlled by topographic features.

It should be noted that with the current version of FLOWTUBE, the continuous recharge/discharge functions are mutually exclusive with the head-induced and fixed recharge pattern, as are the two-aquifer flux conditions. This means it is not possible to switch between recharge/discharge functions and a sudden flood or drought through a fixed recharge distribution within the one simulation. Spikes of recharge however may be superimposed on head-induced recharge situation.

The aim of the modelling exercise is to improve our understanding of the groundwater processes and catchment characteristics along with examining land use change with groundwater behaviour (water balances). The sub-catchments where sufficient data exists will be identified and will be chosen in such a way that it will represent each GFS within the GHCMA. Each sub-catchment chosen will have a fairly close series of networked bores with sufficient data to accurately describe the responsive nature if the GFS to certain land use changes.

Several hypothesis will be tested by the FLOWTUBE modelling:

1. to elucidate the hydrogeological processes operating within the sub-catchments and thereby understand the causes of the salting in affected areas of the GHCMA;
2. to quantify the relationship between these hydrogeological processes by simulating them using a groundwater model of the sub-catchments;
3. to use this model to test the efficacy of different salinity management strategies.

Sensitivity analysis was also be carried out to demonstrate depth of weathering (aquifer thickness); width of valley/drainage line and aquifer properties (calibrate using rear heads).
RESULTS
In this section we present a summary of the results from the data exploration, stream salinity trend analysis, and the catchment water and salt balance components of the project.

Statistical Analysis
The mean EC and saltload for seasonally corrected linear EC trends for two of the major stream gauging stations (Stations 236202, and 238224) as shown in Figure 14, are shown in Figure 16, Figure 17, Figure 18, and Figure 19 and a summary across the GHCMA is shown in Figure 20.

Figure 16. Statistical analysis of smoothed EC at Hopkins River at Wickliffe.

Figure 17. Statistical analysis of smoothed saltload at Hopkins River at Wickliffe.
Figure 18. Statistical analysis of smoothed EC at Glenelg River at Fulham Bridge.

Figure 19. Statistical analysis of smoothed Saltload at Glenelg River at Fulham Bridge.
Figure 20. Summary of the statistical analysis of smoothed EC at the major gauging stations within the GHCMA.
Groundwater Modelling

Figure 21 is an example of how FLOWTUBE will be used in this study to model the affects of land use change on groundwater response. Sub-catchment H3.2 (Hopkins River/Mustons Creek area) was chosen as a suitable sub-catchment to model as it is believed there are reasonable salt stores within the sub-catchments and it is also believed to respond fairly rapidly to land use change.

Figure 21. Characteristics and bore locality of Sub-catchment H3.2 within the GHCMA.
One “FLOWTUBE” as illustrated in Figure 22 will be utilised to model the area, as the topography and Groundwater Flow System are not all that complex here. A point source of recharge (or flux) will be specified in the upper part of the “tube” along with any regional through-flow.

Figure 22. Discretisation of Sub-catchment H3.2 within the GHCMA for FLOWTUBE modelling.
DISCUSSIONS AND CONCLUSIONS

Preliminary results from analysing all the available data are presented below.

Table 2a. Relationship between sub-catchment and proportion of underlying Groundwater Flow System (Glenelg River region).

<table>
<thead>
<tr>
<th>Subcatchment Name</th>
<th>Area (ha)</th>
<th>% of Groundwater Flow Systems (GFS) in subcatchment</th>
</tr>
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<tr>
<td></td>
<td>Local</td>
<td>Intermediate</td>
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<tr>
<td>G1.1</td>
<td>940</td>
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</tr>
<tr>
<td>G1.2</td>
<td>16756</td>
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<td>G1.3</td>
<td>41313</td>
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<td>8549</td>
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<td>G1.5</td>
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<td>G1.6</td>
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Table 2a. Continued….

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Table 2b. Relationship between sub-catchment and proportion of underlying Groundwater Flow System (Portland region)

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Table 2b. Relationship between sub-catchment and proportion of underlying Groundwater Flow System (Hopkins River region)

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