H11 & H12 Catchment Health Report

Lake Bolac, Fiery & Salt Creeks

Review of existing information on assets, current condition, threats, management options and information gaps.
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1 Executive Summary

This document is a review of the current and historical information relating to the H11 and H12 sub-catchments associated with Lake Bolac including Fiery and Salt Creeks. Information has been collected from a variety of sources such as the community, government agencies, expert opinion, reports and anecdotal evidence.

The catchment has experienced many changes in the past. Historical records indicate that Lake Bolac and Fiery Creek have previously dried out and the name Salt Creek suggests that historically the creek may have had elevated salinity levels. More recent evidence indicates that levels of rainfall are decreasing whilst water use is increasing.

Licensed extractions from the catchment are around 1,220 ML per annum when water quality is acceptable; these figures do not include the capacity of natural wetlands and farm dams which is estimated to be in the order of 59,650 ML and 9,895ML respectively. Water use across the sub catchments is estimated to account for more than 11,000 mega litres per annum. Under current conditions, this equates to lower water quantity and quality in the lakes and waterways. If the predicted change in rainfall patterns occurs the current water quality problems could become worse.

Salinity patterns within the Fiery Creek (Streatham) do not appear to have changed significantly between 1990-98. However the combined effect of changed rainfall patterns, decreased runoff and salinity has had a dramatic impact on Lake Bolac. Peak flows greater than 100ML/day have not occurred in the Fiery Creek since 1997. Decreased flows have corresponded with a dramatic increase in salinity levels in Lake Bolac. The loss of the large flow events has resulted in the saline water in Lake Bolac not being flushed out of the system via Salt Creek, which reportedly has not flowed for seven years.

Ultimately the predicted change in the climate and rainfall patterns will necessitate a cooperative approach to the management of the catchments water resources. In an attempt to achieve this, a number of recommendations have been formulated which include:

1. Investigate ways to optimise flows in the Fiery and Salt Creek system that would not have a detrimental impact on Lake Bolac (high salt water would be a concern) or the agricultural productivity of the region.

2. Consider alternate weir option for the outlet to Lake Bolac

3. Ensure all low flow diversions are in place on in-stream weirs and dams

4. Identify salinity sources in the catchment and take remedial action where appropriate.

5. Undertake a salt budget and water budget, leading to a water management plan.

6. Conduct further research into water quality, stream flow, salinity and cultural heritage for Fiery and Salt Creek catchments.

7. Hold community workshops to convey the findings of this report.

8. Develop a communication plan outlining processes and methods to keep the community informed of the progress of report recommendations.

9. Obtain further information and research relating to water use in the catchment.

10. Establish a community group to assist in the implementation of key recommendations. Include government agency representatives where appropriate.

11. Audit and identify sites of indigenous cultural significance.

12. Continue to revegetate the catchment to combat salinity and restore ecological vegetation classes.

13. Continue to collect and collate existing and new research and information pertaining to H11 and H12 sub catchments.

2 Introduction

2.1 Aims

The primary objective of this report is to review all of the information relating to waterway health, land use and management within the Fiery and Salt Creeks and Lake Bolac sub-catchment area known as H11 & H12, and to identify knowledge gaps. This will enable the community and government departments to coordinate activities that will lead to the improved health of the H11 and H12 sub-catchments.

Information has been obtained from government agencies, universities and community groups. A broad range of information types has been collected including historical raw data, consultants' reports, government agency reports, university theses and research documents.

The primary outcome of this report will be the formulation of a number of key recommendations that will contribute to an improvement in water quality in the H11 and H12 sub-catchments. Recommendations will be subject to a cost benefit analysis to ensure that the best returns are achieved for the expenditure.

2.2 Catchment background

The H11 and H12 sub-catchments are located in the Hopkins River Basin in Western Victoria. The H11 sub-catchment includes; the lower Fiery Creek from the confluence with Wongan Creek, Lake Bolac and Salt Creek (Figure 1). The H12 sub-catchment stretches from the Mt Cole Range to the confluence of the Fiery Creek and Wongan Creek (Figure 1). The major waterways in the catchment are Fiery Creek and Salt Creek. Lake Bolac is a major lake within the catchment, there are also many other lakes and wetlands within the catchment including the nationally significant Nerrin Nerrin Wetlands.

Lake Bolac is situated approximately 100 km west of Ballarat within the H11 sub-catchment (GHCMA 2004). Lake Bolac has a catchment area of approximately 1680km^2 (168,000ha). The climate of the area is best described as Mediterranean, with hot summers and cool winters. The average rainfall ranges from 538 mm/year at Lake Bolac up to 600-700 mm/year in the upper catchment around the headwaters of Fiery Creek between Ararat and Beaufort. The lake is primarily fed by flows from Fiery Creek which discharge into the lake on the southeast shore.

The geological history of Lake Bolac area is best described as volcanic in origin. Further details and information relating to the geology of the site is covered elsewhere, eg. Stuart-Smith and Black (1999). The remainder of the H11 and H12 catchment may be described as ranging from volcanic to sedimentary in origin. Additional details can be sourced from the draft soil management plan (GHCMA 2006c).

The lake itself is formed in a natural depression. Historical records indicate that in the past the lake has dried out (Robinson 1840). Robinson's records indicate that the lake was dry and there were many dead eels present. It was also noted that the lake area was utilised by the local Aboriginal tribes for fishing. This historical information suggests that Lake Bolac was ephemeral in nature and would have dried out completely during extreme dry periods.

Historically it is believed that the mouth of the outlet to Lake Bolac was blocked by sand, which under certain conditions was breached and would allow part of the water from the wetlands to flood downstream (Povey, 1999). Due to local concerns that the sand bar could be washed away and a valuable water resource lost, the outlet was blocked with rock (~1926) (Povey, 1999). Various stages of construction, upgrades and decommissioning have resulted in the current situation with the outlet being a concrete spillway with no water level control device. The artificial weir is likely to be responsible for significant changes to the natural hydrology and water quality of the lake. When full, the lake has a maximum depth of 2.37m and covers an area of approximately 13.6 km^2 (Lake Bolac Dev. Assoc. Inc. 2002). This equates to a total volume of 27,200,000m^3 (27,200 ML) (assuming an average depth of 2m). Additional works in and around Lake Bolac include erosion control and the construction of a number of ablutions facilities over a number of years to service visitors to the lake.

Fiery Creek is approximately 100km long from the headwaters to Lake Bolac (GHCMA 2004). The headwaters are located between Beaufort and Ararat on the southern slopes of the Great Dividing Range in the H12 sub-catchment. Fiery Creek has a number of smaller tributaries of which Wongan Creek is the largest (GHCMA 2004). There are a number of water extraction licences along Fiery Creek, Wongan Creek and Lake Bolac. However, actual extraction from these sources is dependent on water quality and flow. Historically water quality in Lake Bolac was reportedly fresh, however in recent times could be considered brackish (Bostock 2000). Salinity levels in September 2006 reached approximately EC 27,000, half that of seawater. Evaporation of the summer months is likely to cause continued increases in salinity levels as the salts are concentrated.

Land use within the two catchments is dominated by broadacre agriculture and cropping. In addition to the traditional forms of land use small areas of agro forestry and plantation forestry (35.2km^2 based on Australian Bureau of Statistics 2003) (WatLUC 2005) have appeared in the upper catchment of H12.

Salt Creek now begins at the outlet of Lake Bolac and its flow path through the landscape has been modified in the past (~1928). Salt Creek passes through low-lying land that appears to have been modified with improved drainage for pasture and crops. The land around Salt Creek is dotted with a large number of wetlands, the majority of which have been drained although some of the wetlands persist. This change in land use may also be contributing to the low flows in Salt Creek. Historically the wetland areas retained water in the catchment during the wetter periods and allowed water to leave the catchment throughout the year.

The Glenelg Hopkins River Health Strategy (GHCMA, 2004) has classified the river health in all of the sub-catchments in the region primarily based on Index of Stream Condition (ISC) data collected in 1999. None of the waterways in H11 or H12 was classified as ecologically healthy based on this information. However it is worth noting that there are many reaches on Fiery Creek, its tributaries and wetlands that provide habitat for a wide variety of wildlife. During a recent walk (2006 hEELing Walk) from the headwaters of Fiery Creek to Lake Bolac participants observed many areas where the creek appeared to have a high value, (good riparian vegetation, good water quality etc.), although many degraded areas were also noted along the creek.

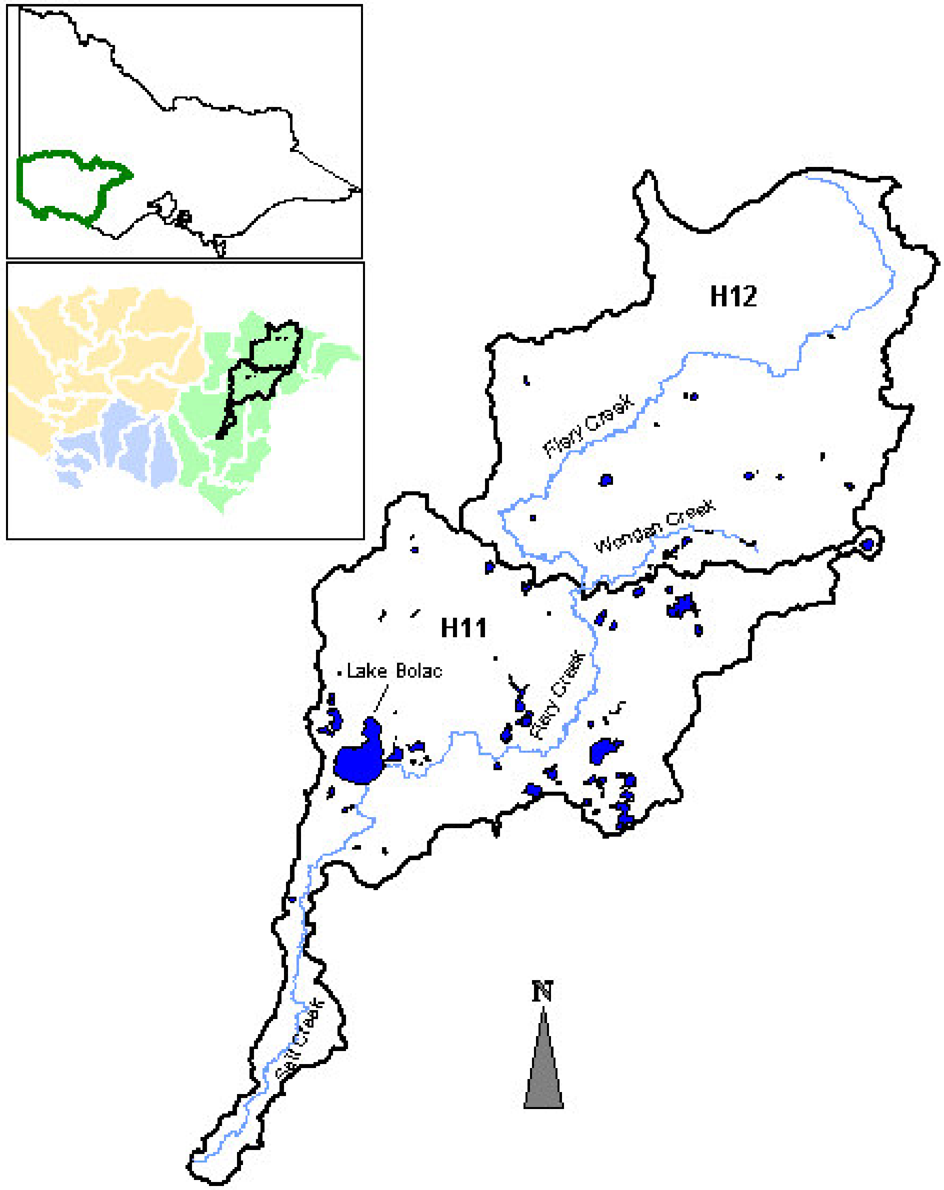

Figure 1: The Glenelg Hopkins CMA region, southwest Victoria with the H11 and H12 sub-catchments highlighted.

2.3 Anecdotal Catchment Information

Landholders and community members from the catchment have provided information covered in this section. Reports suggest that Fiery Creek stopped flowing in 1944, 1967 and 1982. Since 1993 flows have been sporadic down the Fiery. Extreme weather events have resulted in flooding over the years. In 1944, 1946 and 1956 there were a number of heavy rainfall events over several months that resulted in flooding throughout the Western District of Victoria including Fiery Creek, Lake Bolac and Salt Creek. By 1980 many of the springs appear to have dried up. In April/May 2006 the creek had flows at certain points along its course, however flows were intermittent and there was only seasonal discharge to Lake Bolac. Overall there is a wide range of information available from the community and any future actions should draw on this resource.

2.4 Planning & Management Responsibilities

In the past there has been a great deal of confusion regarding the responsibilities of the many government agencies and stakeholders with respect to the management of Lake Bolac and the catchment. It is imperative that these responsibilities are clearly stated and outlined so that the community has a clear understanding. Provided below is a brief description of the agency responsibilities with respect to the Lake Bolac, Fiery Creek, and Salt Creek catchments.

2.4.1 Legislative Responsibilities

There are six government agencies, an indigenous group and a community group that have legislative responsibilities for the management of Lake Bolac and its associated waterways. They are the Department of Primary Industries (DPI), the Department of Sustainability and Environment (DSE), Parks Victoria (Parks Vic), Southern Rural Water (SRW) the Environmental Protection Agency (EPA), Glenelg Hopkins CMA, Framlingham Aboriginal Trust and The Lake Bolac Foreshore Committee of Management.

Department of Primary Industries (DPI) consists of eight divisions**;** Agriculture Development, Biosecurity Victoria, Business and Corporate Services, Catchment and Agricultural Services, Fisheries Victoria, Minerals and Petroleum, Primary Industries Research Victoria and Policy Group. See www.dpi.vic.gov.au for detailed information regarding the key responsibilities of each of theses divisions.

In relation to H11 and H12, Fisheries Victoria has the following responsibilities:

- Management of Aquaculture License activities and recreational fisheries. (Sub catchments H11 and H12 are located within the South West Region of Fisheries Victoria)
- Authorisation for all stock enhancement, translocation and harvest under provisions of the Fisheries Act 1995 and the Fisheries Regulations 1998. Since December 2003, the translocation or deliberate movement of aquatic organisms has required approval under the Fisheries Act 1995. The Guidelines for the Translocation of Aquatic Organisms in Victoria provide a structured basis for the assessment of any translocation proposals within a risk-based framework, whether on a one-off or an ongoing basis. (Available at www.dpi.vic.gov.au/fishing)
- Managing the recreational fish stocking program through an annual consultative process. (Lake Bolac has a history of recreational fish stocking.)
- Implementation of the Glenelg Hopkins Fishery Management Plan, declared on 16 November 2006 and available at www.dpi.vic.gov.au/fishing. (The water bodies covered in this report occur within the planning area.)

Catchment and Agricultural Services division provides technical land management and salinity management advice.

The Agriculture Development division has the follow responsibilities (DPI website March 2007):

- Integrating farming systems into landscapes
- Research and development to sustainably increase on-farm productivity of grain and horticultural industries

- Developing more productive and sustainable livestock and pasture management systems and products that accurately meet consumer requirements
- Contributing to a more competitive and sustainable agri-food sector by delivering additional customer value and market access
- Empowering rural communities to more effectively manage change

Department of Sustainability and Environment (DSE)

"The Department of Sustainability and Environment is Victoria's leading government agency responsible for promoting and managing the sustainability of the natural and built environments." (DSE website February 2007)

DSE has five divisions, Built Environment, Strategic Policy and Projects, Water Sector Group, Land Stewardship and Biodiversity and Resources and Regional Services. See www.dse.vic.gov.au for detailed information regarding the key responsibilities of each of theses divisions.

DSE responsibilities relevant to the H11 and H12 sub catchments include:

- Provision of expert advice on issues associated with the delivery of the Government's new water agenda
- Ensuring all public land resource utilisation is consistent with sustainability policy and represents best practice in environmental management; this includes forests, parks, coastal management and crown land functions.
- Fire management and other emergency management issues.
- Integration of legislative and regulatory arrangements, institutional arrangements and service delivery arrangements across the public lands spectrum.
- Development of policies for the use of land and other natural resources on public land, in particular consistent and effective pricing policies.
- Ensuring there is effective research, data assembly, monitoring and reporting on biodiversity across the State - within available resources.
- Directing programs to protect biodiversity and manage nuisance flora and fauna.

DSE land management responsibilities for Lake Bolac are enacted through the Lake Bolac Foreshore Committee of Management (see below).

Southern Rural Water is responsible for implementing the Government's regulations and policy for surface and groundwater in accordance with the Water Act (1989).

Southern Rural Water:

- Assesses licence applications for the construction of new farm dams and bores
- Manages new and existing groundwater and surface water licences and monitors the use of this water according to licence conditions
- Assesses and manages temporary and permanent water transfers.

SRW staff provides advice on licensing issues and ensure that licence holders operate within their licence conditions.

SRW also supports the development and implementation of groundwater and streamflow management plans and the installation of meters.

Environment Protection Agency is responsible for investigating pollution events. The EPA helps to protect Victoria's land and water resources through mechanisms including environmental laws, policies and regulatory controls, and by working in partnership with Victorian communities, including businesses, government, individuals and groups. EPA undertakes monitoring of particular areas of concern when the need arises but is better placed to assist agencies in their research.

EPA is working with other relevant agencies to better manage their collective response to fish kills and develop a state-wide response memorandum of understanding. EPAs role in managing fish kills is to:

- Receive notification of fish kills from agencies or the public.
- Notify other relevant agencies and stakeholders so that they may respond.
- As necessary, direct other agencies to clean up (remove dead fish from waterways) in order to protect the environment.
- Investigate fish kill incidents and determine, if possible, the cause of the fish kill. Report findings to relevant agencies and the community.
- As appropriate, undertake enforcement action consistent with EPA Enforcement Policy, and recover costs.
- Coordinate media releases.
- As necessary, run a debrief session.

Parks Victoria is responsible for the management of Crown Land. The extent of management is as described in the Land Conservation Council recommendations for the Ballarat study area in April 1982.

Recommendation K 18, Highway Park, is 9 ha in size and is located between the Glenelg Highway, the cemetery, and Lake Bolac in Section A of the Parish of Parupa. Recommendation M 3, Lake Bolac Lake Reserve, consists of Lake Bolac (1340 ha) and is also in the Parish of Parupa. Both K 18 and M3 are in the Parks Victoria computer system as reserves to be managed by Parks Victoria but recommendation K 18 has not been separately reserved and implemented.

Glenelg Hopkins Catchment Management Authority (CMA) has a Board of 9 Directors appointed by the Victorian Minister for Environment under the provisions of the Catchment and Land Protection Act 1994.

Glenelg Hopkins CMA is the caretaker of river health and has a set of functions under both the *Catchment and Land Protection Act 1994* and the *Water Act 1989*.

These functions include but are not limited to:

- Development and coordination of the implementation of a Regional Catchment Strategy (RCS)
- Development of waterway management plans for designated waterways,
- Licensing and regulation of works on designated waterways
- Floodplains and drainage functions

The full suite of waterways functions can be viewed in the *Statement of Obligations* available at www.glenelg-hopkins.vic.gov.au. Lake Bolac, Fiery and Salt Creeks are designated Waterways and therefore Glenelg Hopkins CMA has responsibility for the development of waterway management plans and the assessment of applications to carry out works on the waterway, which includes the bed and banks.

The State and Federal Governments utilise the CMA for administration of funding including the National Heritage Trust (NHT) and National Action Plan for Salinity and Water Quality (NAP) both due to end June 2008.

Glenelg Hopkins CMA supports the community in accessing natural resource management information and resources via the Community Landcare Facilitator team. The Upper Hopkins Community Landcare Facilitator will support the H11 and H12 catchment communities.

Framlingham Aboriginal Trust currently (March 2007) has legislative responsibilities for
matters under part IIA of the Aboriginal & Torres Straight Islander Heritage Protection Act 1984, and manages indigenous cultural heritage with the assistance of the South West Wimmera Cultural Heritage Program (Mr Herbie Harradine, Cultural Heritage Officer).

From 28 May 2007 Aboriginal cultural heritage will be covered by one Act of Victorian law, the Aboriginal Heritage Act 2006 (yet to be proclaimed at time of writing). On the day the Aboriginal Heritage Act 2006 is proclaimed, part IIA of the Aboriginal and Torres Straight Islander Heritage Protection Act 1984 will also be repealed. New "registered Aboriginal parties" for the purposes of the Aboriginal Heritage Act 2006 will have legislative responsibility for protection of indigenous cultural heritage. Applications for registration are currently (March 2007) being received by the Aboriginal Heritage Council.

The Lake Bolac Foreshore Committee of Management is appointed by DSE/ Parks Victoria to manage specific areas of Crown Land as described below.

Figure 2 shows the areas of responsibility for Lake Bolac. Lake Bolac Foreshore Committee Incorporated is appointed over “portion of the land in the Parish of Parupa temporarily reserved for Public Purposes by Order in Council of 24 August 1880. The majority of the lake is a reserve for “Water Supply Purposes Reserve”.

The powers of committees of management are from the Crown Land (Reserves) Act 1978. Relevant passages from Section 15 are as follows.

A committee of management of any land appointed under section 14:
(a) Shall manage improve maintain and control the land for the purposes for which it is reserved and for that purpose may employ officers servants and workmen;
(b) May exercise all such powers functions and authorities and shall carry out all duties as are conferred or imposed on it by any regulations made pursuant to section 13 and shall have authority to do all such acts matters and things as are necessary for or incidental to carrying into effect and enforcing such regulations in respect of the land;
(c) May carry out works and improvements on the land;
(d) May expend any revenue from the land or any other moneys for any of the purposes aforesaid.

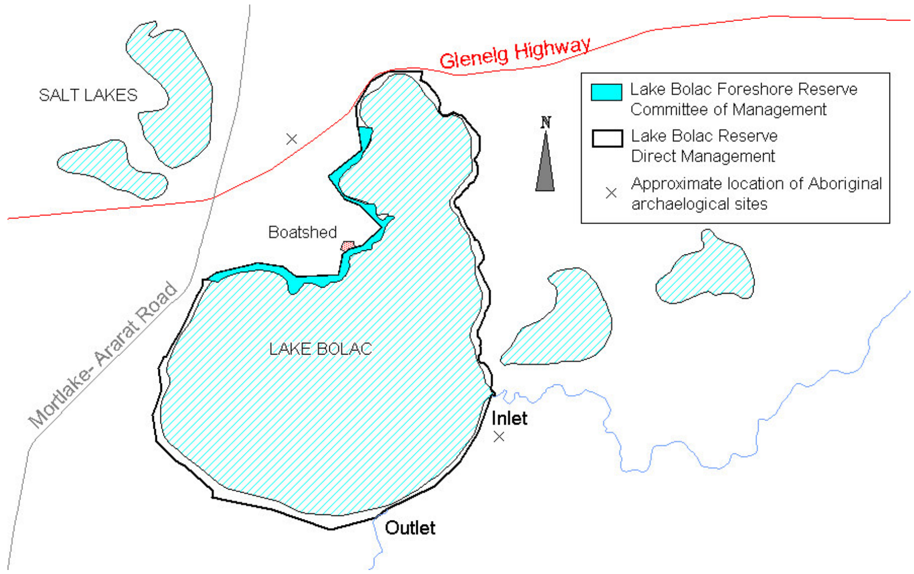

Figure 2: Lake Bolac and areas of management and Aboriginal Archaeological sites in the area.

2.5 Community Organisations

There are 52 community groups (Appendix 1) involved with Lake Bolac and the associated sub-catchments. The Lake Bolac Development Association, Landcare groups, and other community groups have an interest in maintaining and improving the H11 and H12 sub catchments.

Landcare Groups in the sub-catchments are, Buangor, Raglan & district, Lake Goldsmith, Broken Creek, Fiery Creek, Woorndoo and Lake Bolac.

2.6 Future Consultation

As outlined above there are a wide range of stakeholders with an interest in Lake Bolac, Fiery and Salt Creeks. These include the indigenous community, adjoining landowners who may have either water licences or free-of-right access to water from the system, government agencies and a wide range of community groups. Any proposed activities or actions should consider all of the above-mentioned community stakeholders, government agencies and the indigenous community as outlined in section 2.4 and 2.5. Individual landholders should also be consulted where appropriate.

2.7 Local Economy

The local economy of H11 and H12 consists primarily of tourism, agriculture and aquaculture. When valuing the regions assets, consideration must be given to the social, environmental and economic aspects. This section is primarily concerned with valuing the economy of H11 and H12.

2.7.1 Tourism

The local and regional community views Lake Bolac as an important social asset. It has been used for camping, water sports, fishing, and passive recreational activities including walking and bird watching.

Financial benefits to the region as a direct result of Lake Bolac cannot be underestimated. Campers, day-trippers and recreational fishers contribute to the local economy. When the lake is full, up to 20,000 visitors including day trippers and campers may visit the lake annually, primarily over the school holiday periods. The 1998 figures indicate that there were 7,500 camping nights and 9,000 visitors to the lake between Christmas 1997 and 24 March 1998 (LBFCM 1998). More recent figures from 2004 – 2005 indicate that there were 9,250 camping days and 20 – 40,000 visitors to Lake Bolac (LBFCM records). The 2004-2005 figures indicate that visitors to Lake Bolac may inject between $462,500 (campers only) and $2,000,000 (assuming 40,000 visitors) annually to the local economy, assuming visitors and campers spend $50/person. This is a conservative estimate as Tourism Victoria figures put the spending at $66/person for the Grampians region. Lake Bolac is a great financial asset to the local community. The recent downturn in visitors to the Lake (2005/2006) since the 2006 eel deaths and as a result of low water levels is an obvious concern.

2.7.2 Agriculture

Agricultural returns from the catchment are an important part of the economy. Detailed statistics and information relating to farm income can be found in the Farm Monitor Project (Quinn *et al* 2005), summary report 2004-2005. In an attempt to estimate total agricultural income in the catchment land use figures from the catchment in 2003 (WatLUC 2005) have been used in conjunction with gross income figures from the Farm Monitor Project (Quinn *et al* 2005) (Table 1). It is estimated that the agricultural activities in the H11 and H12 catchment generate a gross income ranging between $66.58 million and $78.45 million per year.

Table 1: Agricultural value for the H11 and H12 catchment (Quinn *et al* 2005, WatLUC 2005)

	Land Use	Area of Catchment	Yield/ha ($)	Annual value Million ($)
H12 (880km2)	Cropping	24.9% (21912ha)	740-850	16.2-18.6
	Livestock	59.6% (52448ha)	341-414	17.88-21.71
			Total	34.08-40.31
H11 (859 km2)	Cropping	31% (26629ha)	740-850	19.7-22.6
	Livestock	43.7% (37538ha)	341-414	12.80-15.54
			Total	32.5-38.14

Decreasing water quality in Lake Bolac means that it is unsuitable for irrigation and this has resulted in the loss of food crop (vegetables) production in the area. The area of production lost is unknown and the loss in income cannot be confirmed, however it was reported that a number of different crops were grown and additional employment opportunities existed as a result of these activities.

2.7.3 Aquaculture

88 Golden Eels Aust Pty Ltd based at Colac holds a commercial Aquaculture licence (licence no. CLE 1) for short finned eel farming issued by Fisheries Victoria for Lake Bolac and associated waters. The licence is annually renewably and can only be withdrawn by the relevant Victorian Government Minister. The licence requires catch and effort data to be provided to Fisheries Victoria and places restrictions on the type and quantity of fishing gear that can be used. These restrictions may be relaxed under special circumstances such as drought, to enable harvest of fish that may otherwise be lost.

The current proprietors have operated on Lake Bolac for nine years and base their management plan on a sustainable average harvest of 20 -30 tonnes per annum from Lake Bolac and associated waters (Bill Allan, *pers. com.*, 2007). Actual catch figures are dependent on a range of factors including climatic conditions. The proprietors view this business as a farming enterprise requiring significant effort to develop and maintain a sustainable fishery by capture and release, capture for growing on and capture for harvest.

The proprietors hold similar licenses for Lake Colac and Lake Merdiduke and interests in a number of other commercial eel fishing licences in western Victoria. Lake Bolac is key to the success of this business. It is the only stock enhanced waters currently able to be fished by this business (Bill Allan, *pers. com.*, Jan 2007) due to the drought conditions being experienced across southern Australia.

Until 2004-05 100% of 1kg fish catch was processed for export to European markets. Currently due to drought conditions, 100% of the catch is processed for the domestic market. With the support of a federal government grant, market focus is changing to achieve 50% of high quality, value added product going to the domestic market by the end of 2007 (Bill Allan, *pers. com.*, 2007).

The proprietors of 88 Golden Eels Aust Pty Ltd unofficially monitor the lake environment and alert EPA and Fisheries Victoria as necessary (Bill Allan, *pers. com.*, 2007).

3 Cultural Heritage

There were a number of Aboriginal clans inhabiting the H11 & H12 catchments at the time of European settlement; details can be found in Clark (1990), Lake Bolac was a particularly important site because of the eels. During eel migrations from the wetlands to the ocean, the local clans gathered along Salt Creek. Each clan was allotted a portion of the creek between the wetlands and as far down stream as the junction with the Hopkins River. A fish trap was constructed and the clans fished and stayed in the areas for up to two months. The region around Lake Bolac and down both sides of Salt Creek is claimed by the *Bulug bura*, a clan of the *Dab wurrung*. The *Bulug bura* clan permitted most other clans to fish the eel migration. Permission was rarely denied except from unfriendly clans. In 1841 Robinson reported that there were between 800-1000 Aboriginals gathered at the lake (Clark 1990).

There are a number of significant archaeological sites around Lake Bolac. The approximate location of these sites can be seen in Figure 2. As outlined by Godfrey (2000) the first site is located on the south-eastern shore of the lake in a dune complex. The site extends south from Fiery Creek for 1060m and is 100m wide. Animal bones, stone tools and charcoal have been found at the site and there are reports referencing the site as far back as 1841. Dating of some of the remains confirms that the site dates back to at least 12,480±560 before present. The site is highly significant and the details of the archaeological survey are well documented by Coutts (1982) and Godfrey *et al*. (1996). There are erosion problems at the site and stabilisation has included the construction of a rock wall along the base of the sand dune. Any activities in the region and major changes to the water level in Lake Bolac may impact the site and the appropriate authorities should be consulted about future actions that may impact the site (see section 2.4.)

The stone arrangement to the north is also an important site in the catchment (Long & Schell 1999). The proximity of these two sites to Lake Bolac highlights the significance of the area to the traditional landholders. During the hEELing walk (2006) many signs of the indigenous presence in the landscape were observed including rock fish traps and scar trees. These sites have not been surveyed or formally identified.

4 River Health

4.1 Stream Flow

The Flow Stress Ranking project (Nathan *et al* 2005) establishes a relative threat to river health based on the level of water extractions by rural, urban and industry users. The impact water extractions are having on stream flow is determined by comparing predicted natural stream flows to current stream flows. Flow Stress Ranking data for Fiery Creek and Salt Creek indicates that both are under significant flow stress.

Both Fiery and Salt Creeks were among the lowest ranking streams in the state, i.e. current flows have been substantially modified. In particular, flows over summer have been reduced with both low flows and cease to flow periods being the flow components most affected. Winter flows have been less affected between natural and current. Methods used to determine flow stress are located in Appendix 4 and detailed information is located in the primary source. Assessments of the Sustainable Diversion Limits (SDLs) through the winterfill period (July to October) indicate that allocations exceed sustainable limits. Farm dams are also reported as the dominant demand in this assessment.

In light of the findings of this report it must also be noted that anecdotal evidence suggests that in the recent past the creek has stopped flowing, which is supported by the historical reports of Fiery Creek being dry.

4.1.1 Fiery Creek

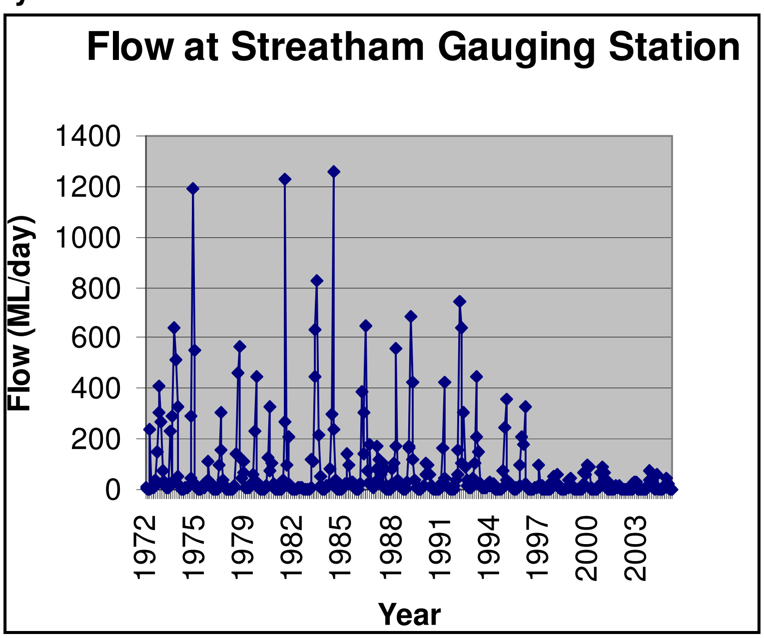

Figure 3: Monthly stream flow in Fiery Creek at Streatham (ML/day) (www.vicwaterdata.net)

Figure 3 illustrates the decreased flows in Fiery Creek at Streatham since 1972. It is clear that there has been a decreased flow in Fiery Creek since 1997; significantly there have been no high flow events greater than 100ML/day. The decreased flow in Fiery Creek does not directly correlate to rainfall data (Figure 4). Figure 4 illustrates the variability in rainfall across the catchment; a further look at the annual rainfall totals suggests that there has been a slight decrease in annual rainfall totals. However, the annual rainfall data alone does not explain the change in flow patterns in Fiery Creek. It is important to remember that a direct correlation may not be expected from this data as it is monthly data and does not illustrate the changes in rain fall pattern which impact runoff events. For example there may be the same amount of rainfall which occurs in many small rainfall events (low runoff) rather than a lower number of intense rainfall events (high runoff).

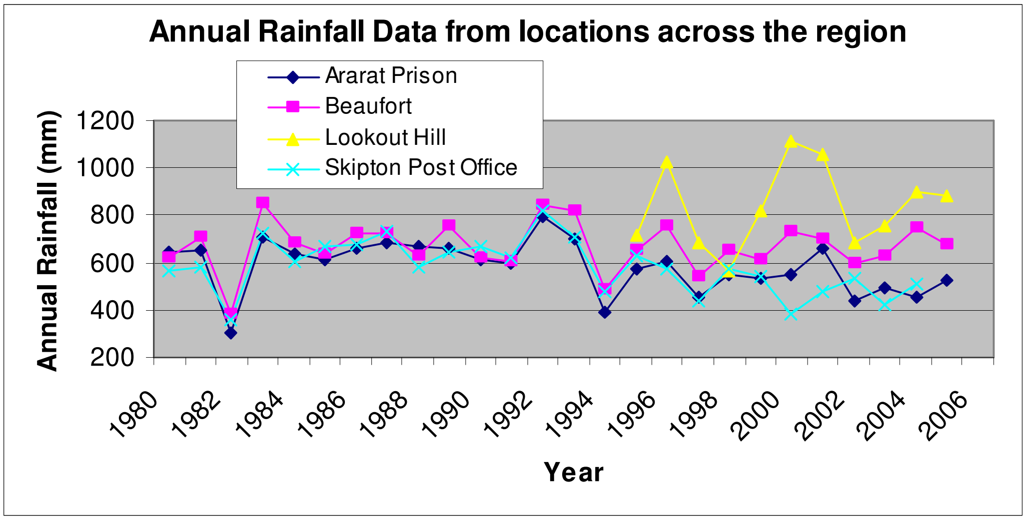

Figure 4: Annual rainfall totals from various locations in the region.

Other causes that may account for the low flows include increased extractions directly from the waterways, land use change and an increase in the number of dams within the catchment.

No data was found regarding the flow patterns in Salt Creek, as there is no gauging station on the creek. Anecdotal evidence indicates that the creek flow has been low for at least the last 7 years. Summer flows are dependent on spring inputs and there will be a small contribution from the immediate catchment area, which is small. Contributions to flow from the catchment may occur over winter and summer but are most probably restricted to winter.

4.1.2 Barriers/Weirs

There is one official gauging station in the H11 sub-catchment on Fiery Creek at Streatham. In addition to this, there are an unconfirmed number (up to 13) of smaller weirs, dams and structures in the catchment above Lake Bolac. It is presumed most of these have been constructed legally to facilitate water extraction. There is an historical diversion on Middle Creek at Listons Road, which was constructed in the 1870-80's for stock and domestic use by several landholders. Approximately a third of the water is diverted from this point into Charleycombe Creek, which flows into Fiery Creek via Billy Billy Creek further downstream than the Fiery Ck - Middle Creek confluence. Some of this water may also be used for irrigation purposes. The diversion may reduce the amount of water reaching Fiery Creek by making it available for agriculture in the upper catchment, however the volume would be difficult to quantify.

Middle Creek is one of the first creeks to run each year as its catchment has granite geology and infiltration rates are low and runoff rates high. It is fair to say that it may also be one of the first to dry and may have prompted the diversion in the first instance to overcome the erratic water supply. Central Highlands Water services the town of Beaufort using a water supply diverted from headwaters in the upper catchment of the Fiery Creek in the Mount Cole State Forest. The off-takes consist of three weirs with a combined catchment size of around 8 sq. kilometres. Central Highlands Water has an entitlement (Bulk Water Entitlement) through DSE to harvest about 415 ML per year from the Fiery Creek Catchment. Annual water consumption by the town varies greatly but the average annual consumption is 206 ML (pers comm. Geoff Wright Central Highlands Water).

There are no barriers or weirs on Salt Creek; however the outlet weir from Lake Bolac is a significant barrier. Throughout both the H11 and H12 catchments there are areas where the stream channel has been colonised by either macrophytes (*Phragmities australis* and Typha *spp*) or willow species, which may be considered a barrier. It is important to note that while these formations may impede flow, they are unlikely to stop the stream flow. Further investigation into alterations to the outlet structure is required.

4.2 Water Management

4.2.1 Use by vegetation

Table 2 refers to the amount of water that is available for uses other than for growing vegetation, i.e., surface water runoff and drainage below the root zone (typically groundwater recharge), less evaporation. Rates are dependant on the soil type and water table depth and are averaged within the two sub-catchments. This data was calculated by SKM for the Water and Landuse Change Study (WatLUC 2005).

Table 2- Runoff amounts for different land uses in the H11 and H12 sub-catchments.

Land-use	H12 (mm/year)	H11 (mm/year)
Annual pasture	114.33	68.49
Perennial pasture –short growing	78.34	36.66
Perennial pasture- long growing	61.27	24.54
Cropping	92.91	48.76
Grapes	43.36	13.37
Plantation	1.60	1.66
Woodland	21.85	4.90
Native Grass	31.65	9.03
Low Rainfall Farm Forestry (eg, sugar gum)	13.34	2.51
Grapevine- irrigation	44.52	13.88
Perennial pasture- irrigation	195.83	149.66
Urban	253.57	232.42
Commercial	380.35	348.63

4.2.2 Extractions

Significant investment in infrastructure to extract water exists on waterways in the study area.

Southern Rural Water has provided all information and detail below unless otherwise stated. Table 3 details all of the licensed extractions from the Lake Bolac catchment as of June 2006. No water was pumped in the 2004–05 financial year and it is unlikely that water will be pumped in the 2005-06 financial year (G. Willis, SRW *pers. com.*, 2006). The primary reason for no pumping occurring in the last two years is poor water quality. Only the irrigation licences for Lake Bolac are metered, all other licences are un-metered. In addition to these licences, most landowners have 'free-of-right' to obtain water from the waterways of the catchment for stock and domestic use. Access to water under free of right includes direct stock watering, windmill pumping to stock troughs and tanks and motorised pumping. The total licensed extraction from Lake Bolac and its catchments amounts to 1220.2 ML per annum.

Table 3: Licensed water extraction from the Lake Bolac Catchment. All details supplied by Southern Rural Water.

Location	Licence Type	No of Licences	Quota (ML)
Lake Bolac	Irrigation	7	897.8
	Stock and domestic	10	27.8
Fiery Creek	Irrigation direct pump	1	25
	Irrigation off stream winter fill	1	30
	Stock and domestic direct pump	3 x 2.2ML	6.6
Wongan Creek	Irrigation direct pump winter fill	1	20
	Off stream dam winter fill	1	56
	On stream dam winter fill	1	155
	Pyrenees shire road maintenance	1	2
Total			**1,220.2**

4.2.3 Additional Extraction Data obtained since September 2006

One of the actions outlined in this document is to continue to collect and collate information pertaining to the H11 and H12 sub catchments. Since the steering committee last met (September 2006) additional information has been located and included in this section of the document as an addendum. This information relates to the storage capacity of farm dams and natural wetlands in the catchments. Licensed extractions and diversions have already been discussed in section 4.2.2 and 4.1.2. However the capacity of other storages in the catchments has not been fully addressed. Additional data from the Flow Stress Ranking project (Nathan *et al* 2005) provides some estimate on the storage capacity of farm dams in the catchment and some basic calculations based on the area of wetlands in the catchment provide an insight into the water storage capacity of the catchment.

Details relating to the Flow Stress Ranking project are located in Appendix 4. It is important to note that the Flow Stress Ranking report was prepared from topographical maps for the entire state and the data was not confirmed by aerial photographs or ground truthing in the H11 and H12 sub catchments. While every effort was made to separate natural wetlands and lakes from the farm dams there will be some error in designating the type of water body. An estimate for wetland holding capacity has been determined using the data (area) from section 5.4 an assumption that the wetlands were on average 0.5m deep. In light of the assumptions the data has been presented in Table 4.

Table 4: Estimated water storage capacity of natural wetlands and farm dams in the H11 and H12 sub catchments.

	Holding Capacity of Different Water Bodies (ML)		
	H11	**H12**	**Total (ML)**
Farm Dams	7,020	2,875	9,895
Wetlands	48,195	11,465	59,650
Sub-catchment Total (ML)	55,215	14,340	
Total (ML)			**69,545**

The total capacity of Lake Bolac is 27,000ML and the storage capacity of farm dams and wetlands in the catchments is 2.5 times greater. While there will be some error associated with the estimated water storage capacity in Table 4 it does highlight that there is a huge potential storage capacity within the catchment above Lake Bolac.

A more detailed water budget has been highlighted as a key recommendation and may eliminate some of the error associated with the above calculations. However the aims and targets of any future action would need to be clearly defined to ensure that new and valuable information was being obtained. This will require the methodology from which this data has been obtained to be critically reviewed prior to any future works of this type being undertaken. The research conducted by Raiber will also need to be reviewed prior to beginning any proposed works of this nature. Ongoing research may include a salt budget and water budget for Lake Bolac (see section 4.3.)

4.2.4 Ground Water

Ground water is a significant water resource in both catchments with an estimated 102 bores in the H11 catchment and 90 bores in the H12 catchment (Interactive Maps- Catchment and Water Mapper, www.dse.vic.gov.au). The source of this data could not be verified as the resource states that the data provided is derived from a number of sources. Additionally there are many uncounted bores including unregistered bores, old bores constructed before records were kept and new bores not yet listed.

It can be assumed that there are more bores located in both sub-catchments and that there will be increased numbers of bores in the future if surface water quality decreases. No detailed data or information relating to extractions from bores and the impact this is having on the catchments waterways was located.

4.3 Lake Modelling

Preliminary modelling has been carried out by Raiber (unpublished data) to assess the response of Lake Bolac to a number of different scenarios. The modelling conducted by Raiber indicated that if the recent rainfall patterns (2000-05) were to continue then the Lake Bolac water levels would continue to fall (Figure 5). Although not modelled it may be concluded that under this scenario water quality would continue to decline with lake water level. In light of these predictions, additional modelling indicates that a change in weather patterns to a slightly wetter climate and or additional flows in Fiery Creek would result in Lake Bolac filling. More detailed modelling data will be available when this research has been completed.

Mattias Raiber is carrying out ongoing research and will model the effects of land use change in the next stage of his PhD project. It is intended that further modelling of stream flows in Fiery Creek will be conducted and the lake water budget developed that inturn will be used to prepare a salt budget for the lake. The outcomes of this research should be considered before future actions are carried out, as this data will be extremely valuable. The proposed modelling will provide more detailed insight into the effect of land use change on stream flows in Fiery Creek and the impacts that this might have on lake level and water quality, particularly conductivity.

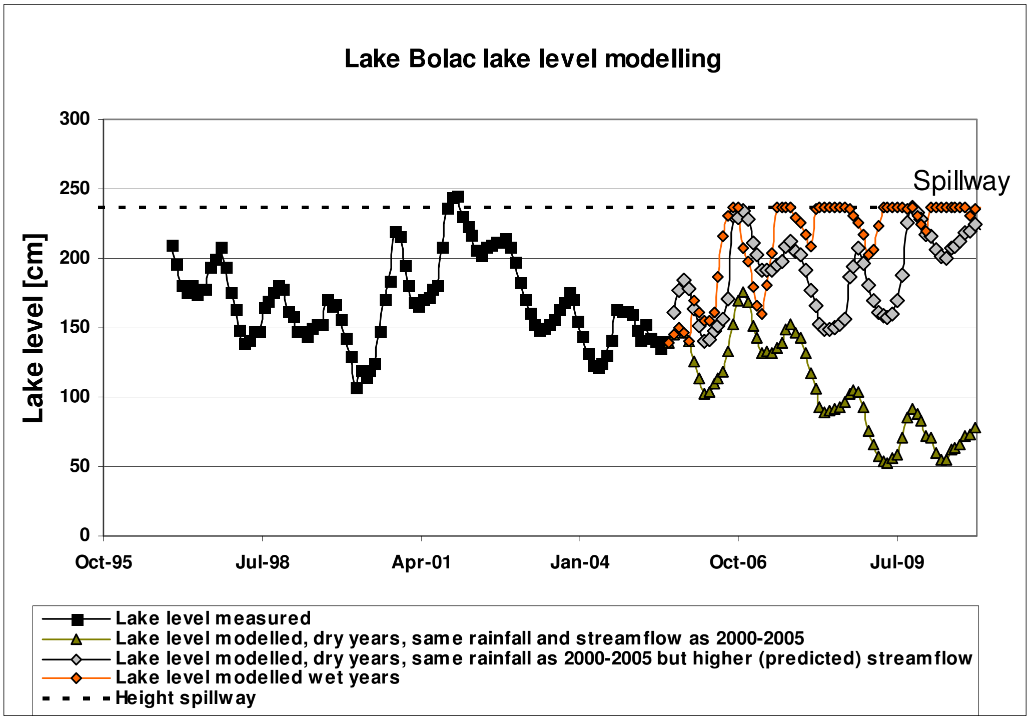

Figure 5: Lake Bolac water level modelled under different rainfall conditions (M. Raiber, unpublished data).

4.4 Water Quality

Water quality in Lake Bolac has been monitored for many years. There is a wide range of water quality data available from a wide range of sources, including community organisations, universities and government agencies. In the 1950's the State River and Water Supply Commission routinely collected physio-chemical data such as turbidity and ion balances from Lake Bolac. Gauging stations on Fiery Creek at Streatham and Lake Bolac have also been routinely monitored since 1972. More recently (1969 onwards) DSE has monitored water levels, conductivity and gauge height in addition to the previously mentioned monitoring occurring at the gauging stations. Landcare has also monitored conductivity at many sites on the Fiery and Salt Creek.

In addition to these routine activities, the Warrnambool Institute of Higher Education, now Deakin University, established "Lab Talk", a program similar to Waterwatch whereby schools collected water samples from many of the lakes and waterways in the western district that were then analysed at the Institute for conductivity and ion analysis. The program ran from 1976-79 and provides additional support to the other data sources relating to conductivity. More recently, two thesis have investigated Lake Bolac and the catchment. Bostock (2000) studied the limnology of the lake, looking at physio-chemical parameters, nutrients and the biology of Lake Bolac. Ernest's (2004) study of the hydrogeology and hydrochemistry of the area looked at the interactions between Lake Bolac, the ground water and other water bodies within the region. Most recently, the Victorian EPA has monitored and reported on the water quality of the lake after the recent eel deaths in January 2006 (Leahy *et al* 2006).

Some reports in the past (Bostock 2000) indicate that water quality in Lake Bolac was quite uniform. However recent information suggests that water quality across

Lake Bolac is variable, particularly with respect to salinity (anon). This is most probably due to the low flows over recent years entering the lake.

In addition to the reports reviewed for this project there is a body of published scientific literature relating to wide range of topics including water quality, flora and fauna. For example Williams and Dedecker have published several papers relating to water quality in Western Victorian lakes and included discussion on fauna assemblages (zooplankton). Specific actions may warrant further investigation of this literature. Water quality results have been presented below for Lake Bolac and Fiery Creek. There was no literature or reports located relating to water quality in Salt Creek.

4.4.1 SEPP Guidelines

While there are many guidelines and water quality standards, the CMA measures water quality data against the State Environmental Protection Policy (SEPP) guidelines. The regionally derived criteria were taken from the Glenelg Hopkins Salinity Management Plan (2005). To meet the SEPP guidelines, water quality parameters must be below the target levels for >%70 of the time. Table 5 details the guideline values and the range of the various parameters (Lake Bolac) or the percentage of the time that the guideline targets have been achieved (Fiery Creek).

Table 5: Guideline values and the range or percentage of time that the guidelines have been met, data for Salt Creek not available.

Parameter	SEPP	Regional derived criteria	Lake Bolac	Fiery Creek @ Streatham SEPP & Regional	Salt Creek
TN (mg/l)	<0.9	<0.13	3.3-5.9	(37%) & (0%)	NA
TP (mg/l)	<0.04	<0.098	0.15-0.30	(37%) & (86%)	NA
Turb (ntu)	<10	<4		(68%) & (44%)	NA
EC (µs/cm)	<1500	<6000	4000 - 14000	(20%) & (92%)	2100-18140

4.4.2 Dissolved Oxygen (DO)

Bostock (2000) found that there was no thermocline or halocline in Lake Bolac during the study carried out between August 1999 and March 2000. While this study found no thermocline to exist in the lake during the time of the study, over the summer months a thermocline does develop in the lake (Bill Allan, *pers. com.*, 2006). Due to the shape and depth of the lake, the thermocline is likely to develop over the summer months quite quickly, however this very feature of the lake (large surface area and shallow) also means that the lake can be rapidly turned over and mixed by the prevailing winds. Any stratification in the lake will be temporary and changes between stratified and unstratified may occur several times throughout the warmer months.

Bostock (2000) found that dissolved oxygen levels decreased over the period of the study and ranged between 8.7 – 12.3 mg/L. This coincided with a decrease in lake level and increase in salinity and temperature, which would be expected to result in a decrease in DO levels. These DO concentrations are well above the critical level at which the health of the lake ecosystem would be compromised (6mg/L) as described in the ANZECC guidelines (1992).

4.4.3 Salinity

It is important to note that the two sub-catchments, particularly H11, are naturally saline to some extent as is reflected by the naming of Salt Creek. The data suggests that salinity within Lake Bolac has been steadily increasing over time (Figure 6). It is important to consider the different processes that could be responsible for increased salinity levels. Firstly, there are long term increases in salinity where changes in land use and impacts on ground water may be responsible for either saline runoff or discharges of saline ground water into surface waters. Secondly, there are the short-term processes that may be considered seasonal, such as the concentration of salts and increased salinity levels as a result of increased evaporation and decreased precipitation over the hotter months of the year. Salinity levels in Lake Bolac rose from approximately 27,000EC in September 2006 to approximately 85,000EC in March 2007 as water level decreased to less than 200mm (Paul Leahy *pers.com*. March 2007).

Salinity levels have been increasing over time (Figure 6). Suggestions that the increased salinity was due to leakage from saline lakes to the north-west (Lake Paracelmic and Gentine) were disproved after analysis of bore data. Ernest (2004) found that Lake Bolac topographically sits higher than the two salt lakes to the northwest proving that increased salinities could not be due to leakage from these lakes.

Salinity problems are compounded by the very nature of the lake. During periods of low flow (when the lake is not spilling which has not occurred since 2001) Lake Bolac acts as a sink for salt from the upper catchment. Through the processes of evaporation and concentration, moderately saline water which enters Lake Bolac is concentrated and results in increased salinities. This phenomenon is best illustrated by figure 1 where salinities have increased significantly as stream flow at Streatham has reduced since 1982 (M. Raiber unpublished data). Unpredictable weather patterns and below average rainfall reduces the benefits of flushing and compounds the problems. In addition to the data referenced above it must be noted that there has been a substantial amount of data collected throughout the catchment by Landcare groups.

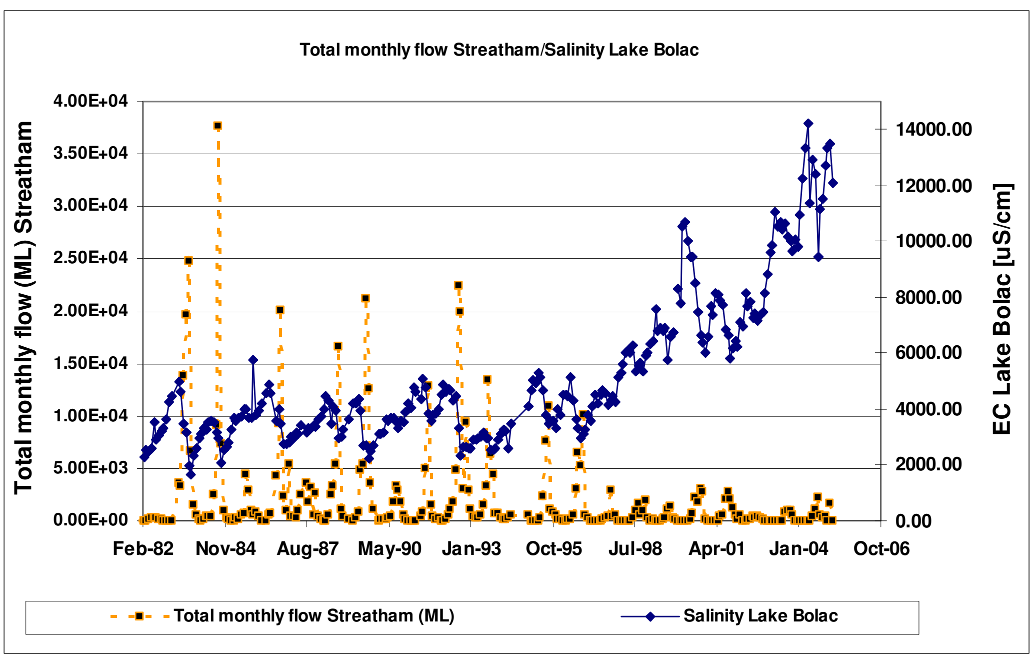

Figure 6: Lake Bolac conductivity and stream flow at Streatham from 1982 – 2004 (M. Raiber unpublished data)

The observed salinity problems seen in Lake Bolac are likely to primarily be the result of erratic rainfall and reduced runoff as can be seen in Figure 6. The discharge of high saline water to the catchment and therefore Lake Bolac is a secondary cause contributing a small amount of salinity to Lake Bolac. However as stream flows reduce the impacts of increased conductivity to the catchment are exacerbated and may increase as demonstrated in Figure 7. Additionally data collected by Landcare indicates that salinity levels are variable in Fiery Creek (data not presented).

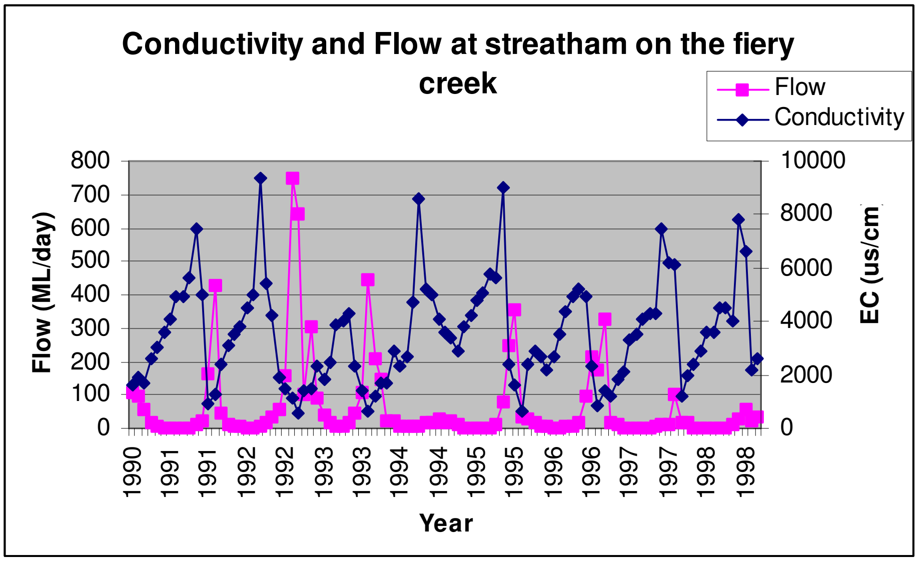

Figure 7: Conductivity and flow at the Streatham Gauging Station (water quality data warehouse).

Figure 8 illustrates salinity changes over time at two sites on Salt Creek. Both sites are located on the property of "BOOROOK", the bridge site and ford site are approximately 3km and 7km south of Woorndoo respectively. Salinity levels appear to fluctuate greatly and without flow data it is difficult to draw conclusions from this data. However it is fair to say that salinity levels can get extremely high in Salt Creek.

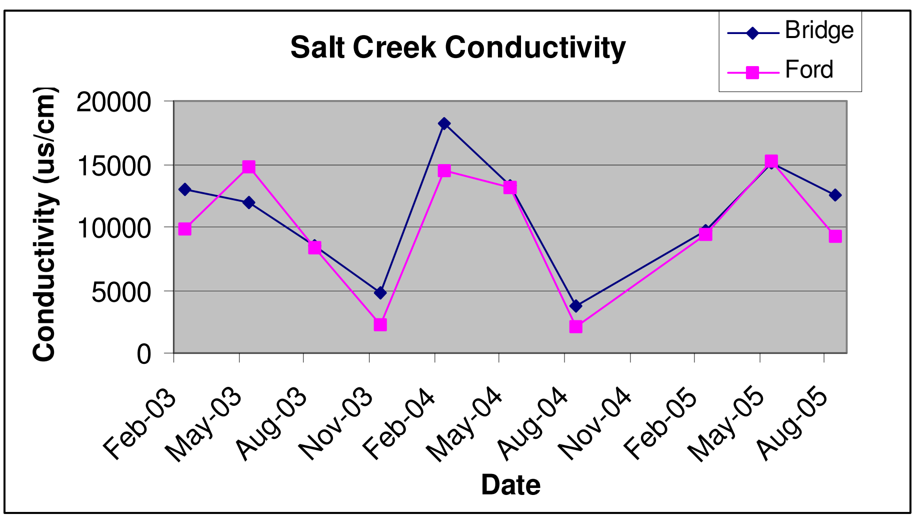

Figure 8: Conductivity at two locations on Salt Creek (data collected by Landcare with Waterwatch kit)

4.4.4 Ground Water Salinity

A recent investigation into ground water in the region was conducted by Ernest (2004). The following information has been sourced from this thesis unless otherwise stated and refers to both the H11 and H12 sub-catchments. Ground water depth varies over the region (Figure 9) and is dependent on the geology of the area. Over the period of the investigation ground water could be found close to the surface within 1-2 meters in the Dorondong Sands region (detailed as non basalt in Figure 10), which is present in the area south of Lake Bolac on the western side of Salt Creek. The remainder of the catchment is dominated by newer volcanics and ground water can be found between 8-12 meters (Figure 9). The overall long term trend indicates that ground water levels are decreasing by up to 2.5m and indicate the extraction is outstripping recharge, which may be expected given the recent dry conditions. Recharge of the ground water occurs across both sub-catchments as water percolates through the soil into the ground water. However the dominant recharge areas are located in the north and east of the H12 sub-catchment. The presence of geological features (deep leads) made it difficult to determine specifically where recharge is occurring.

As Ernest concluded, the flow in Fiery and Salt Creek's are influenced by ground water from the catchment. Summer flows are primarily dependent on inputs from ground water sources and may be influenced by salt lakes (not Lakes Paracelmic and Gentine) discharging to Fiery Creek via the ground water. There are many salt lakes in both sub-catchments and the specific influence is beyond the scope of the report however Figure 10 illustrates the variability of ground water salinity in the catchments. This will provide some indication of areas where saline discharge may be affecting Fiery Creek and subsequently Lake Bolac. However, it is worth noting that there are other lakes with elevated salinity levels including Chinamans Swamp (52.9 ms/cm), which had the highest salinity levels behind Lake Paracelmic (206 ms/cm) and Lake Gentine (209 ms/cm). Should the influence of saline ground water discharge to Fiery Creek be further investigated and specific point sources be identified, the community and landholders will be able to contribute a substantial amount of knowledge and information in addition to the information from Ernest (2004) and Raiber (unpublished data).

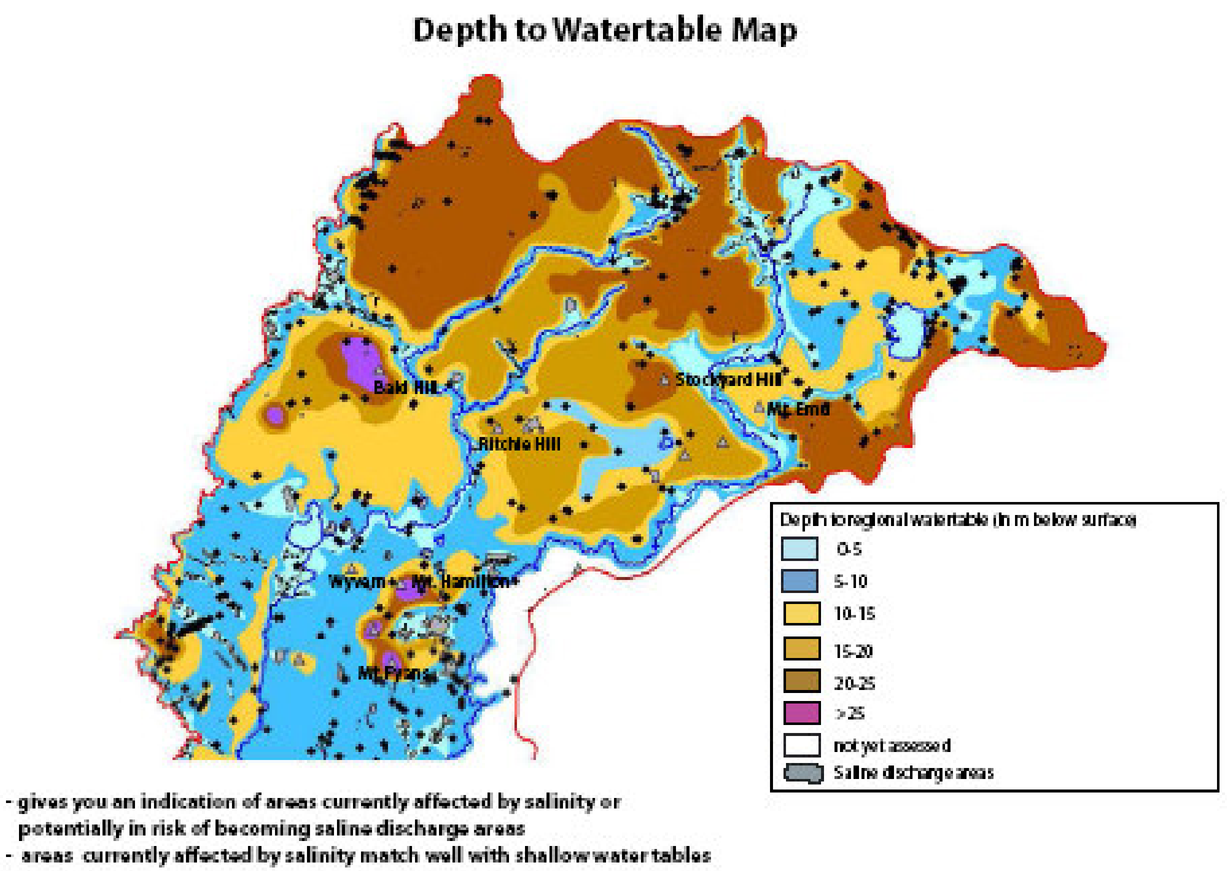

Figure 9: Ground water depth (M. Raiber unpublished data)

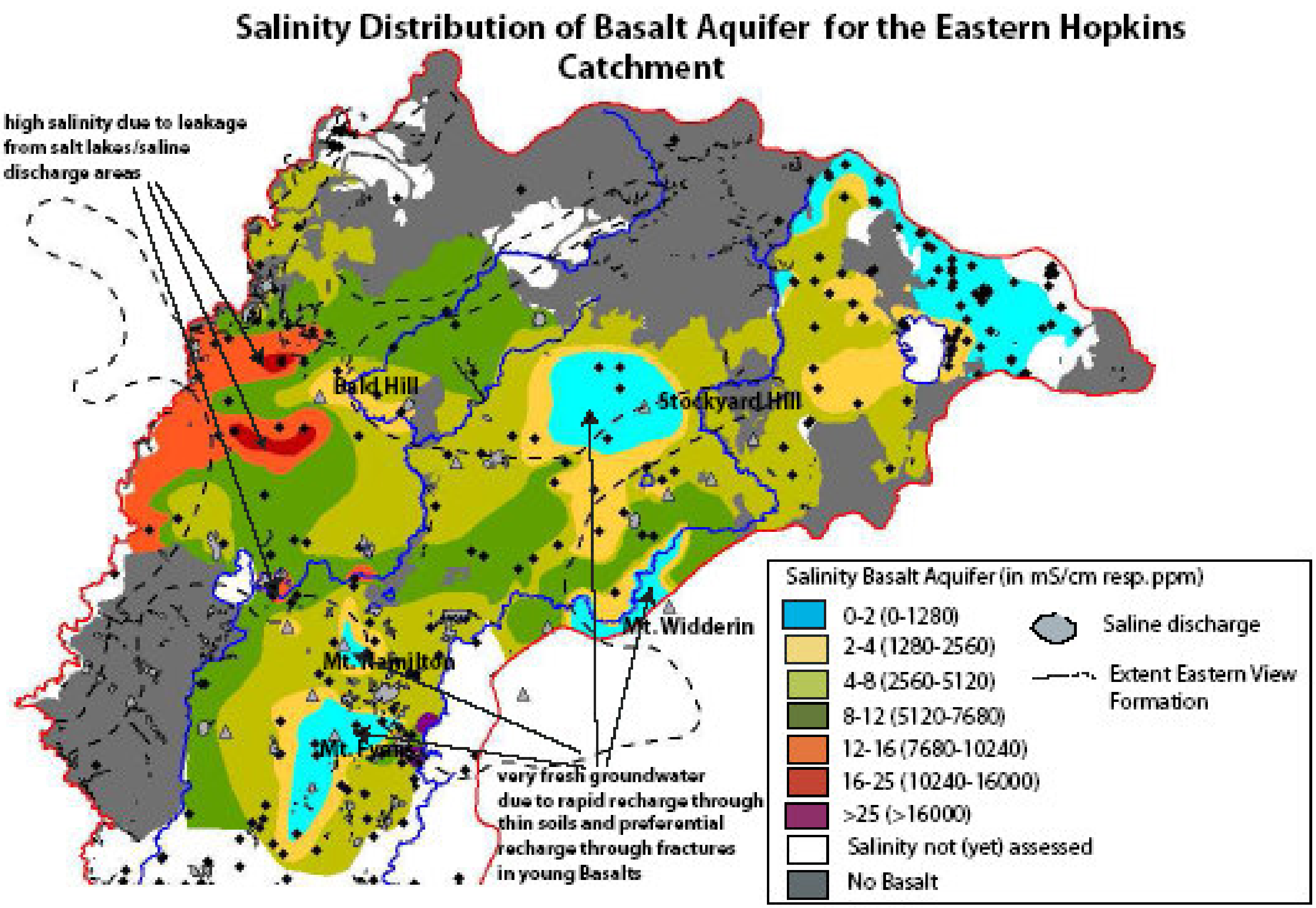

Figure 10: Groundwater salinity levels (M. Raiber unpublished data

4.4.5 Suspended solids and turbidity

Elevated turbidity levels can have a strong influence on the ecosystem functions of a lake. Elevated turbidity levels decrease the penetration of light into the water column, which can drastically affect primary productivity (plant growth including algae and aquatic plants) in the lake. While data suggests that lakes of the western district generally have elevated turbidity levels (DeDeckker & Williams 1998), the levels in Lake Bolac were extremely high during Bostock's (2000) study. The elevated turbidity levels are most probably due to wind generated turbulence and wave action that disturbs the sediments; this is a common characteristic of shallow lakes, which are poorly vegetated. Some additional processes that may contribute to turbidity include foraging fish disturbing the sediments and algal derived turbidity associated with elevated nutrient levels and algal blooms. Neither of these processes is likely to be the major cause of turbidity in Lake Bolac.

The sediment on the lake bed is generally a sink for nutrients entering the system; generally nutrient and sediment enter the lake and settle to the lake bed. Nutrients and other pollutants can be bound to the sediments and retained there until the sediment is disturbed. However, the processes that result in resuspension of the sediments will also result in the release of nutrients and pollutants to the water column. Essentially these processes would not allow the sediment to act as a sink due to the constant resuspension of sediments.

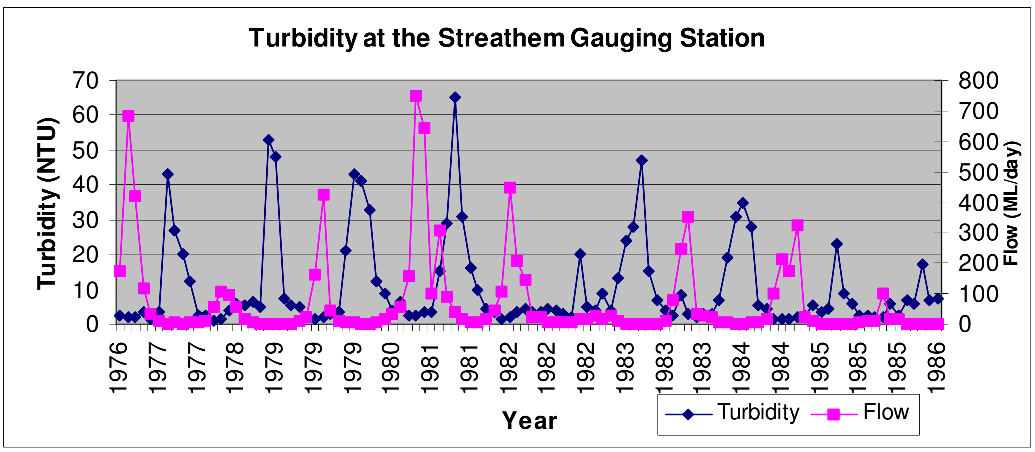

Figure 11: Turbidity levels on Fiery Creek at Streatham (water quality data warehouse)

Turbidity levels in Fiery Creek at Streatham have been recorded as high as 65 turbidity units (Figure 11). The peaks in turbidity levels did not correlate with peak flows. Turbidity levels achieved SEPP guidelines 68% of the time.

No data was located for Salt Creek.

4.4.6 Nutrients

The major nutrients of concern are total nitrogen and total phosphorus and ranged from 3.3-5.9mg/l and 0.15-0.30mg/l respectively. Bostock (2000) found that nutrient levels were generally elevated in Lake Bolac and exceeded the SEPP guidelines and the regionally derived guidelines. As the lake is utilised for recreational activities it is worth noting that the nutrient levels exceeded the specified levels for recreational use established by the ANZECC (1992). The elevated nutrient levels were in a range where algal blooms would be expected when weather conditions permit. However the high turbidity levels restrict light penetration, primary productivity and the growth of algae.

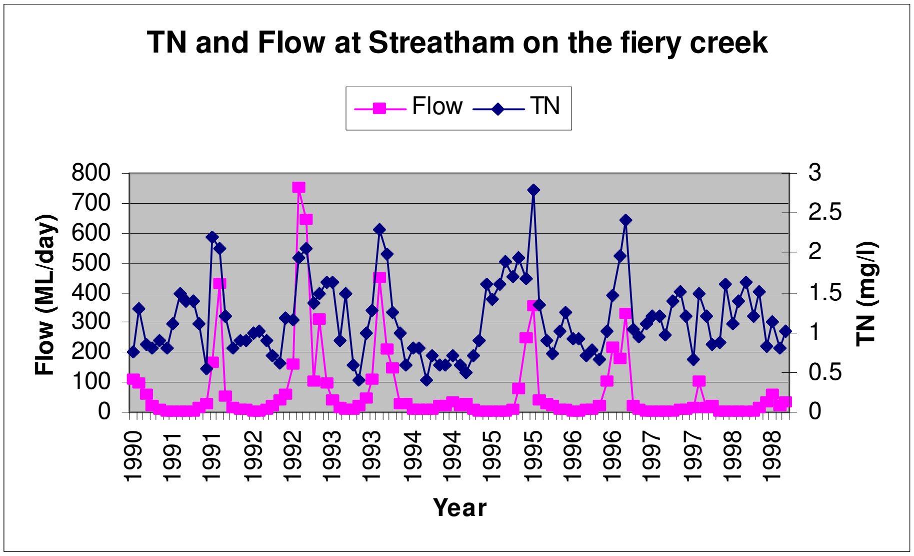

Figure 12: Total nitrogen concentrations in Fiery Creek as measured at the gauging station in Streatham (water quality data warehouse)

Peaks in total nitrogen (TN) levels correlated with peak flow events (Figure 12). TN levels achieved SEPP guidelines 37% of the time however; the regionally derived guidelines were never met.

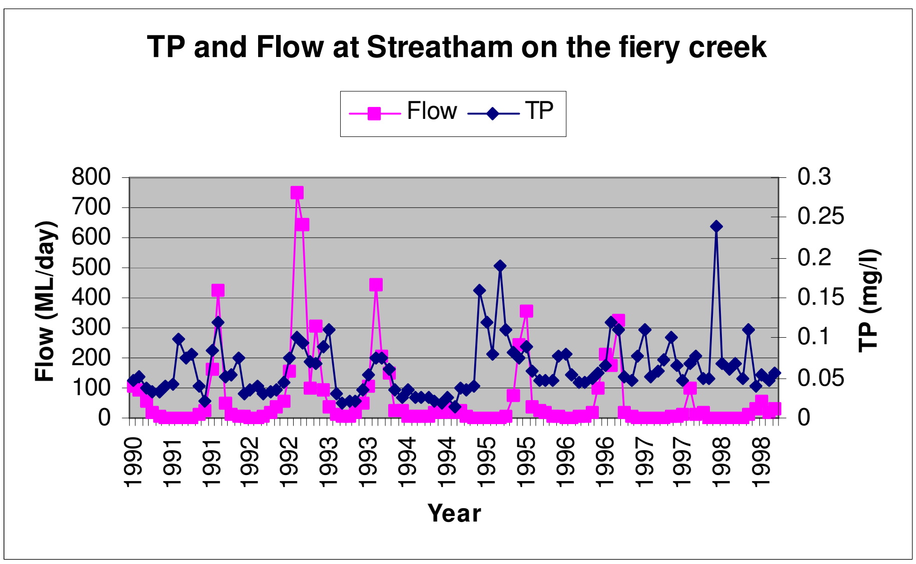

Figure 13: TP and flow at the Streatham gauging station (water quality data warehouse)

The total phosphorus (TP) levels do not appear to correlate with peak flow events (Figure 13). The SEPP guidelines were met 37% of the time and the locally derived guidelines were met 86% of the time. In general, TP levels are normally correlated with peak flow events and the associated erosion that may occur at this time. However in this case TN levels are more closely correlated with flow. The data presented here indicates that TN levels are more of a concern than TP levels at this point on Fiery Creek. However it should be noted that nutrient levels at this point in the catchment have implications for water bodies further down stream and particularly Lake Bolac.

No nutrient data was located for Salt Creek.

The nutrient management plan (GHCMA 2002) has identified gully erosion as a high priority in areas of the upper catchment of the H12 sub-catchment. The upper Fiery Creek, lower Fiery Creek and upper Salt Creek have been identified as priority areas for stream bank stabilisation. Issues relating to gully erosion and stream bank stabilisation are addressed via the respective action plans under the Dryland Agriculture Program (GHCMA 2002). The desired outcome of both plans is to decrease nutrient and sediment runoff via fencing and revegetation and to encourage environmental best management practices.

4.5 Habitat

4.5.1 Lake Bolac

The type and location of vegetation around Lake Bolac has been well documented including comprehensive lists of endemic, native and introduced species found at the site (School of Forestry, 1998). A number of recommendations relating to land management and the vegetation were also made. The Lake Bolac Foreshore committee using indigenous species of regional provenance has carried out most of the revegetation projects around Lake Bolac.

Aquatic vegetation is very sparse in the lake (Bostock 2000). Only two aquatic macrophyte species were identified, *Triglochin procera* and *Phragmities australis,* although reports suggest that in the past there have been a number of other submerged macrophyte species present including *Vallisneria sp* and *Myriophyllum sp*. It is possible that a shift in the species composition of aquatic macrophytes may be attributed to increased salinity with recent reports of *Lamprothamnium sp* and *Rupia sp* (pers com. Michelle Cassanova), which are salt tolerant species.

The lake is shallow enough to support a dense growth of macrophytes provided turbidity can be reduced, bird grazing can be minimised and there is a suitable seed source. Other well developed macrophyte beds have the capacity to reduce wave action, the resuspension of sediment, and wave driven erosion of the lake banks. In addition to these benefits they provide a significant amount of habitat for birds and fish. However the establishment of major stands of macrophytes may not be compatible with other uses of the lake, for example water skiing and sailing.

Fish, algal and zooplankton species that have been identified in Lake Bolac include those listed in Table 6. Included in this list are blue green algal species that are present in most water bodies and are of no concern unless blooms occur, which has not been reported in Lake Bolac. These species and many others are likely to exist in the catchments, lake, creeks and wetlands. A wider search of the scientific literature or survey may identify more species. Additional references where this information may be located are provided in Appendix 2.

Table 6:Fish, Algal and zooplankton species identified in the H11 & H12 sub-catchments.

	Scientific name	Common name
Fish	*Anguilla australis*	Short-fin eel $_n$
	Anguilla reinhardtii	Long-fin eel $_n$
	Philypnodon grandiceps	Flat headed gudgeon $_n$
	Galaxias maculatus	Common galaxaid $_n$
	Nannoperca australis	Southern pigmy perch $_n$
	Retropinna semoni	Australian smelt $_n$
	Perca fluviatilis	English perch $_i$
	Cyprinus carpio	European carp $_i$
	Carassius auratus	Wild goldfish $_i$
	Tinca tinca	Tench $_i$
	Rutilus rutilus	Roach $_i$
	Salmo trutta	Brown trout $_i$
	Salmo gairdneri	Rainbow trout $_i$
	Maccullochella peelli	Murray cod $_i$
	Facquaria ambigua	Golden perch $_i$
	Gambusia affinis	Mosquito fish $_i$
Algae	*Oocystis spp.*	
	Botryococcus braunii	
	Ankistrodeomis spp.	
	Microcystis aaeruginosa	
	Euglena acus	
	Scenedesmus spp.	
	Ceratium spp.	
	Cocconeis spp.	
	Fragillaria ulna	
	Cyclotella meneghiniana	
Zooplankton/ macroinvertebrates	*Daphnia*	
	Ostracods	
	Calanoid sp.	Seed shrimp
	Brachiomus plicatilis	
	Ciliates	
	Collembola sp.	Springtails.

n=native, i= introduced into waterway

5 Catchment Condition

5.1 Vegetation and Riparian Health

Riparian vegetation in the H11 catchment can be considered poor as only 3% of the waterways in the catchment have a good natural vegetation cover (GHCMA 2004). Endangered ecological vegetation classes (EVCs) for the catchment are listed in Table 8. A detailed list of EVCs within each catchment is located in the Habitat Network Action Plan (Miller *et al* 2006). Revegetation targets have been set at 15% (12885ha) of the catchment to be revegetated with endangered EVCs by 2030 (GHCMA 2006a). To date GHCMA partnership projects have resulted in the revegetation of 282 ha (Table 7) including streamside revegetation.

Table 7: Details of revegetation via partnership projects between 1997 and 2006(GHCMA).

Region	Area revegetated (ha)
Upper Fiery	282.67
Lower Fiery and Salt Creek	176.3
Total	458.97

Riparian vegetation in the H12 catchment can be considered poor as only 7% of the waterways in the catchment have a good natural vegetation cover (GHCMA 2004). Endangered EVCs for the catchment are listed in Table 8. Revegetation targets have been set at 15% (13,200ha) of the catchment to be revegetated with endangered EVCs by 2030 (GHCMA 2006a). To date GHCMA partnership projects have resulted in the revegetation of 176 ha (Table 7) including streamside revegetation.

In addition to revegetation works facilitated and promoted by the GHCMA, Landcare has supported revegetation in the catchment. To date approximately 16km of Salt Creek has been fenced to exclude stock access (David Allen *pers com.* 2006). There are also many other revegetation works that have not been included here – this would include revegetation by landholders without the assistance of partners such as the CMA and Landcare.

Table 8: EVCs listed as endangered or vulnerable (GHCMA 2004).

EVC	H11	H12
Creekline tussock grassland	*	
Plains grassy woodland	*	
Creekline grassy woodland	*	*
Riparian woodland/escarpment shrubland	*	
Floodplain riparian woodland	*	*
Riparian woodland	*	
Plains grassland/plains grassy woodland mosaic	*	*
Riparian forest		*
Riparian woodland		*
Plains Grassy wetland#		*

presumed to be extinct
* indicated presence in that sub-catchment

5.2 Rare and Endangered Species

There are a number of rare, endangered or threatened fauna and flora species found in the H11 and H12 catchments. Full details of the flora and fauna of national and state significance can be found in the Habitat Network Action Plan (Miller *et al* 2006). Some of the species listed have been included in Table 9.

Table 9: List of threatened, endangered, vulnerable or rare flora and fauna species (GHCMA 2004)

	Common Name	Species Name	H11	H12
Fauna	Brolga	*Grus rubicunda*	*	*
	Eastern Barred Bandicoot ?	*Perameles gunnii*	*	
	Fat-tailed Dunnart	*Sminthopsis crassicaudata*	*	
	Grey Goshawk ?	*Accipiter novaehollandiae*	*	
	Australasian Shoveler	*Anas rhychotis*		*
	Hardhead	*Aythya australis*		*
	Mountain Galaxias	*Galaxias olidus*		*
	Reagent Honeyeater ?	*Xanthomyza phrygia*		*
	Corangamite Water Skink	*Eulamprus tympanum*	*	
	Platypus	*Ornithorhynchus anatinus*		*
	Growling Grass Frog	*Litotia raniformis*	*	
	Warty Bell Frog[#]	*Litoria raniformis*	*	
	Plains-wanderer[#]	*Pedionomus torquatus*	*	
	Striped Legless Lizard[#]	*Delma impar*	*	
		Ardea alba	*	
		Biziura lobata	*	
		Childonias hybridus	*	
		Platalea regia	*	
		Stictonetta naevosa	*	
		Oxyura australis	*	
		Sterna caspia	*	
		Cereopsis novaehollandiae	*	
Flora	Hairy tails	*Ptilotus erubescens*	*	*
	Small Golden Moths	*Diuris sp. Aff. Lancelota (Laverton)*	*	
	Small Milkwort	*Comesperma polygaloides*	*	
	Yarra Gum	*Eucalyptus yarraensis*		*
	Wiry Bossiaea	*Bossiaea cordigera*		*
	Adamson's Blown-Grass	*Agrostis adamsonii*		*

? May no longer be present in the catchment
[#] Protected under EBPC
* indicated presence in that sub-catchment

The only threatened species to occur in or around Lake Bolac is *Eulamprus tympanum marnieae* (Corangamite Water Skink). It is known to exist at two sites around the lake and is also present in the Nerrin Nerrin wetlands. This species is listed as a critically endangered species under Commonwealth and State legislation (Petersen 2004). Any future activities that may impact on this species, particularly changes in environmental flows and the hydrology of the Nerrin Nerrin wetlands, will need to be approved at both the State and Federal level. The waterways and wetlands also provide habitat for a number of other important species including the Growling Grass Frog, which is listed as a species of national significance, and many bird species (eg. Brolga).

5.3 Introduced Flora and Fauna (Weed and Pest potential)

A list of catchment weed species can be found in the Glenelg Hopkins Weed Action Plan (GHCMA 2000). This plan identifies the priority weeds in the catchment and the plan outlines programs to address the issue. Specifically noted pests and weeds listed in Table 10 include gorse which has been identified as a significant weed in the catchment, particularly in the upper Fiery Creek catchment. These infestations are mostly on waterways and roadsides. GHCMA & DPI are working with landholders to identify and undertake works to remove and manage the infestation of gorse in the catchment with RCIP funding under the "Restoring Riparian EVCs in the Upper Hopkins" program. Willows are also reported at locations (Middle Creek) through out the catchment and creeks.

It should be noted that the updated Glenelg Hopkins Weed Plan is under development (March 2007). The priority for weed works will follow an assets / threats approach and will be as follow:

1. Prevention of new weed species
2. Early intervention and eradication of new and emerging terrestrial and aquatic weed species,
3. Reduction and containment of established weeds that threatening natural assets.

Table 10: Some weed species found in the H11 and H12 sub-catchment

Flora	Common name	Species Name	H11	H12
	Willow	*Salix spp.*		
	Bridal Creeper	*Asparagus asparagoides*		
	Hawthorn	*Crataegus monogyna*		
	Boxthorn	*Lycium ferocissimum Miers*		
	Paterson's curse	*Echium plantagineum*		
	Broom	*Cytisus scoparius*		
	Serrated tussock	*Nassella trichotoma*		
	Spiny Rush	*Juncus acutus*		
	Bathurst burr	*Xanthium spinosum*		
	Gorse	*Ulex europaeus*		
	Bent Grass			
Fauna	Fox	*Vulpes vulpes*		
	Rabbits	*Oryctolagus cuniculus*		
	Mosquito fish	*Gambusia holbrooki*		
	Carp	*Cyprinus carpio*		

5.4 Significant Wetlands/natural impoundments

Western Victoria is home to many natural wetlands. Specifically, the H12 catchment has 242 wetlands covering an area of 2293 hectares while the H11 catchment has 801 wetlands covering an area of 9639 hectares (GHCMA 2006b). It should be noted that these figures are dynamic due to drought and the ease at with which wetlands can be drained. While the total volume of water held in these wetlands is not known, the area covered suggests that the wetlands in both catchments will intercept a large volume of runoff. This report has classified wetlands in accordance with the Ramsar Convention (1971).

> “Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”

Highly valued wetlands in the catchment include the Nerrin Nerrin Wetlands and Chinaman’s Swamp (GHCMA 2004). The Nerrin Nerrin wetland system is located approx. 11km east of Lake Bolac. It consists of an inlet from Fiery Creek (a designated waterway), 3 Crown land wetlands (managed by Parks Victoria) and 2 linking private wetlands. Overflow from this system flows south into Paddy Lake and terminates at Lake Gellie. The Nerrin Nerrin wetlands are considered a high priority asset in the Glenelg Hopkins Regional Wetlands Status Report (2006) and are listed in the national Directory of Important Wetlands in Australia for the following reasons:

> *It is a good example of a wetland type occurring within a biogeographic region in Australia.*
>
> *It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.*
>
> *The wetland supports 1% or more of the national populations of any native plant or animal taxa.*
>
> *The wetland supports native plant or animal taxa or communities, which are considered endangered or vulnerable at the national level.*

The area covered by the listing includes: Nerrin Nerrin Swamp 320 ha, Lake Oundell 90 ha, Lake Jollicum 77 ha, The Waterway 22 ha and The Shallows 15 ha, totalling 526 ha (http://www.environment.gov.au/water/wetlands/database/index.html). The wetlands support a number of significant species including the Corangamite Water Skink (*Eulamprus tympanum*), which is listed as critically, endangered as detailed in section 5.2. Along with the other wetlands they form an important habitat for many bird species including the Brolga and are recognised as important wetlands under the Jamba and Camba agreements as they support vulnerable and endangered migratory bird species.

There is a current informal agreement over the Nerrin Nerrin wetlands, which allows water to flow into the wetland system once Lake Bolac has overflowed for 48 hours. This system has been in place for more than 50 years and has been a focus of discussion in the local area particularly during the recent years of drought and low flows. Water is otherwise regulated by a series of weir structures that are monitored and opened by the local landholder when advised that Lake Bolac has overflowed for the 48 hour period. It is unclear whether this agreement is actually still in practice at present as there is no physical record of this agreement, even though it is widely accepted that it exists. The future management of these significant wetlands needs to be addressed and considered by all stakeholders, the Glenelg Hopkins CMA being a key partner.

Any future actions or specific catchment management plans must consider and address the impacts, risks and threats to these assets, particularly as they are home to rare and endangered species. A number of the legislative bodies including the Glenelg Hopkins CMA and stakeholders will need to be consulted regarding any future actions that may impact this site.

5.5 Eel Fishery

Eels have been associated with the Lake Bolac area for a long time. The area was a significant resource to the local Aboriginals (Clark 1990) also see section 3. Lake Bolac supports an eel fishery that services both the recreational fishermen and a commercial fishing business (88 Golden Eels Aust Pty Ltd). It is believed that early European Settlers translocated brown elver from the Hopkins Falls to the Bolac wetlands (Lake Bolac) some time between the 1880's and 1900's as eels from the region were appearing in Melbourne markets (Bill Allan, *pers. com.*, 2006). Until the 1950's the eel fishery was based on supplying bait to lobster and shark fishing industries (McKinnon 2002), at this stage the annual catch was only 9-12 tonnes. Commercial eel fishing for human consumption began some time around the 1950's and by the early-mid 1960's frozen product was being exported to Europe and the annual catch for the state had growth to 44 tonnes (McKinnon 2002). In the late 1960's eel stocking was investigated and the practice now supports a significant portion of the industry. By the mid 1980 the annual catch had grown to 450 tonnes, with 60% caught from wild stock and the remainder from cultured stock as a result of introducing juvenile individuals to water bodies (Lake Bolac) to be captured as adults. There is an annual catch of between 12,000 and 25,000 kg (Bill Allen, *pers. com.*, 2006). Improved water quality in the lake would have a beneficial impact on the fishery.

There is limited information relating to the recreational eel fishing in the state, however anecdotal evidence suggests that the annual recreational catch is significant (McKinnon 2002) and recreational fishing for eels does occur in Lake Bolac. The eel fishery is subject to an existing Management Plan declared under the Fisheries Act in July 2002 and due for review in 2007.

5.6 Eel Deaths

The eel deaths reported in Lake Bolac in late December 2005 and early 2006 are among a number of events that have occurred in lakes in the Western District and have prompted the formation of a working group by the EPA to investigate. All information provided below has been sourced from EPA April 2006.

It was reported that more than 5000 eels died during the event and that no other species was significantly impacted (EPA 2006). To date the deaths have not been attributed to a single cause, but an interaction of factors including below average rainfall over ten years. The EPA investigation has included monitoring of salinity, pH, DO, temperature, turbidity, metals, pesticides, bacteria, industrial pollution and tests for blue green algae. While temperature, salinity and turbidity levels were elevated the general water quality results indicate that the Lake Bolac was comparable to other lakes in the region. Salinity levels were the highest they have been since 1969 (half strength sea water). These elevated parameters were attributed to the low water levels and environmental conditions at the time and could not be responsible for the eel deaths alone but may be a contributing factor. Eels from the lake have been examined for bacteria, viruses, parasites, and pollution. Bacteria was found in some specimens but not considered the cause of the eel deaths. Pathologists have determined that it was unlikely that parasites or infectious diseases were responsible either. The report concluded that Lake Bolac was an aquatic system under stress as a result of drought related issues. If the low rainfall conditions continue, it is possible that fish kills may occur again, particularly during summer. Detailed findings can be found in Leahy and others (2007).

5.7 Climate Change

In 2004, the State Government produced a number of summary documents that aimed to give each of the ten CMA regions a snapshot of the potential impacts of climate change. The following information is a summary of that information and more information can be found at www.greenhouse.vic.gov.au or in the publication entitled 'Climate change in the Glenelg Hopkins Region' (DSE 2004). GHCMA also commissioned a report in 2005 that investigated the likely impact of climate change on communities in the region (WatLUC, 2005). Neither of the documents re-modelled likely changes, instead they have used CSIRO data that calculates climate change scenarios to the years 2030 and 2070.

In short, there will be an annual warming of 0.2 to 1.4ºC by 2030 and 0.7 to 4.3ºC by 2070 with more days over 35ºC and less days below 0ºC. Whilst there is likely to be an annual precipitation decrease, the change in annual precipitation may be +3 to -10% in 2030 and +10 to -25% in 2070. Droughts are likely to become more frequent, longer and more intense and winter storms may also become more frequent. As a consequence of the predicted changes in rainfall and temperature, evaporation rates are likely to increase and runoff into streams and groundwater recharge is likely to decrease.

6 Land Management

6.1 Pollution

Non-point sources of pollution do not have a direct point of discharge. For example nutrient runoff from a paddock could be considered a non-point source of pollution. Many other land practices have the potential to result in pollution. Nutrient runoff, sediment runoff (erosion) after ploughing, and chemical contamination is sources of pollution that are governed by land practices. Pollution sources are not only restricted to rural regions of the catchments. Storm water and domestic sources also contribute to pollution in the catchments waterways. Stormwater runoff from residential allotments and roads has the potential to pollute waterways. Specific pollutants include fertilisers, detergents, grease, soil, oils and heavy metals. The other major pollutant source from residential areas is sewage effluent. As most residential centres in the catchment do not have reticulated water and sewage systems, most residents rely on septic tanks. Poorly operating septic tanks are responsible for a significant amount of pollution in the Yarra River although it is a much more densely populated catchment the risks remain (DSE 2006). Lake Bolac is amongst a number of rural communities that have recently been considered for upgrades of their sewage systems under the Country Town Water and Sewage Scheme, while not named as one of the towns to receive an upgrade it is likely to be considered in the future. A storm water management plan has also been prepared by Ararat City Council, which addresses stormwater management in Lake Bolac and across the municipality. Additional sources of residential pollution in the catchment include, Streatham and Raglan.

6.2 Land practices and salinity

The Glenelg Hopkins Salinity Management Plan 2005-2008 (GHCMA, 2005) classified all of the sub-catchments based on the salinity hazard, assets (agricultural, environmental and infrastructure) and the opportunity to influence the underlying groundwater flow system. Most of the H11 sub-catchment was classified as an area with moderate to high value assets affected by salinity. The groundwater system is not considered to be responsive to recharge control options; therefore discharge management options are more appropriate. The H12 sub-catchment is a little more varied with some high and low valued assets present with the higher valued assets located in the foothills of the Great Dividing Range. Salinity management options for the sub-catchment include recharge control in the upper areas of the catchment these options are excluded from the lower part of the catchment. Discharge management options were suitable for all areas.

Primarily actions to address salinity are outlined in the Land Management Program of the Glenelg Hopkins Salinity Management Plan and include discharge revegetation, fencing discharge sites, perennial pasture, tree blocks and tree belts. The targets and recommendations in the Glenelg Hopkins Salinity Management Plan 2005-08 should guide any actions relating to the management of salinity within the H11 and H12 catchment.

6.3 Land-use change

Proportions of land uses in sub-catchments H11 and H12 are graphically displayed in Figure 14 and Figure 16 and the percentage figures in Table 11 and Table 12. Areas of different land uses in 1990 and 2003 were obtained from the relevant Agricultural Census (administered by the Australian Bureau of Statistics) and the 2010, 2020 and 2030 figures are modelled predictions, based on best available knowledge (calculated during the Water and Land Use Change (WatLUC) study that was undertaken in the Glenelg Hopkins and Corangamite CMA regions in 2004/ 2005).

The different land use change scenarios result in different hydrologic responses in the catchment. As this information is based on predicted scenarios, the lines in Figure 15 and Figure 17 represent an envelope of possibilities rather than definite results. The scenario that is the most likely is the 'base case' scenario as it is based on industry estimates of the likely rate of change or the future extent of land uses. Further information on the scenarios can be found in Appendix 5 and a full description of the project and the process undertaken to develop the scenarios can be found in the WLUC document (WatLUC, 2005).

6.3.1 H11 Sub-Catchment – Lower Fiery & Salt Creek & Lake Bolac

Since 1990 there has been a general shift in agricultural land use from broad acre agricultural activities to cropping (Table 11) (WatLUC 2005). The classification of dairy production in the catchment has been questioned by local residents and would need to be clarified if management actions were based on these figures. Native vegetation covers less than 10% of the catchment. Targets under the native vegetation plan are to see 15% of the catchment revegetated using endangered EVCs by 2030. It is predicted that broad acre agricultural activities will continue to decline with a small increase in dairy production and a large shift to crop based agriculture. It is predicted that there may be a small percentage (<1%) of the catchment planted to sugar gums by 2030. Only a minimal area of blue gum plantations may be planted in the sub-catchment in the foreseeable future.

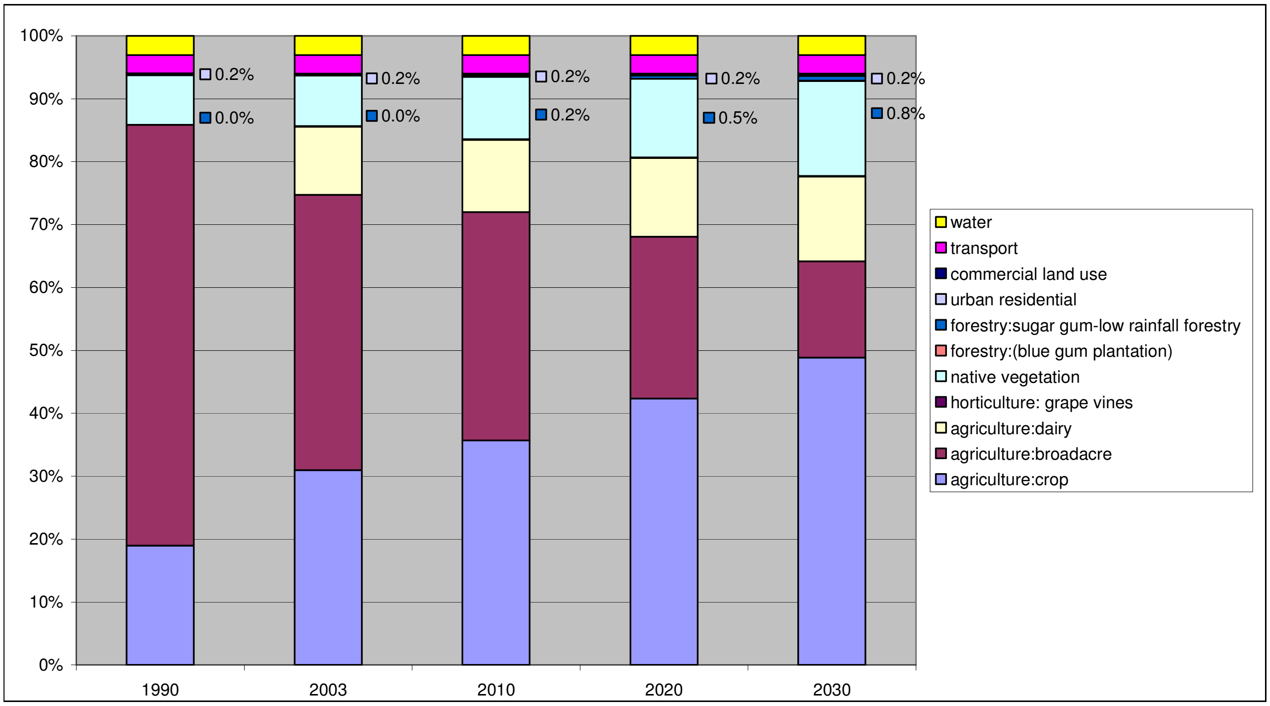

Figure 14- Measured and predicted land use to 2030 in sub-catchment H11

Table 11- Measured and predicted land uses in sub-catchment H11

	1990	2003	2010	2020	2030
Agriculture- crop	19.0%	31.0%	35.7%	42.3%	48.8%
Agriculture- broadacre	66.9%	43.7%	36.3%	25.7%	15.3%
Agriculture- dairy	0.0%	10.8%	11.5%	12.5%	13.5%

Horticulture- grape vines	0.0%	0.1%	0.1%	0.1%	0.1%
Native vegetation	7.9%	8.1%	9.9%	12.5%	15.1%
Forestry- blue gum plantation	0.0%	0.0%	0.0%	0.0%	0.0%
Forestry- sugar gum-low rainfall sp.	0.0%	0.0%	0.2%	0.5%	0.8%
Urban residential	0.2%	0.2%	0.2%	0.2%	0.2%
Commercial land use	0.1%	0.1%	0.1%	0.1%	0.1%
Transport	2.9%	3.0%	3.0%	3.0%	3.0%
Water	3.0%	3.0%	3.0%	3.0%	3.0%

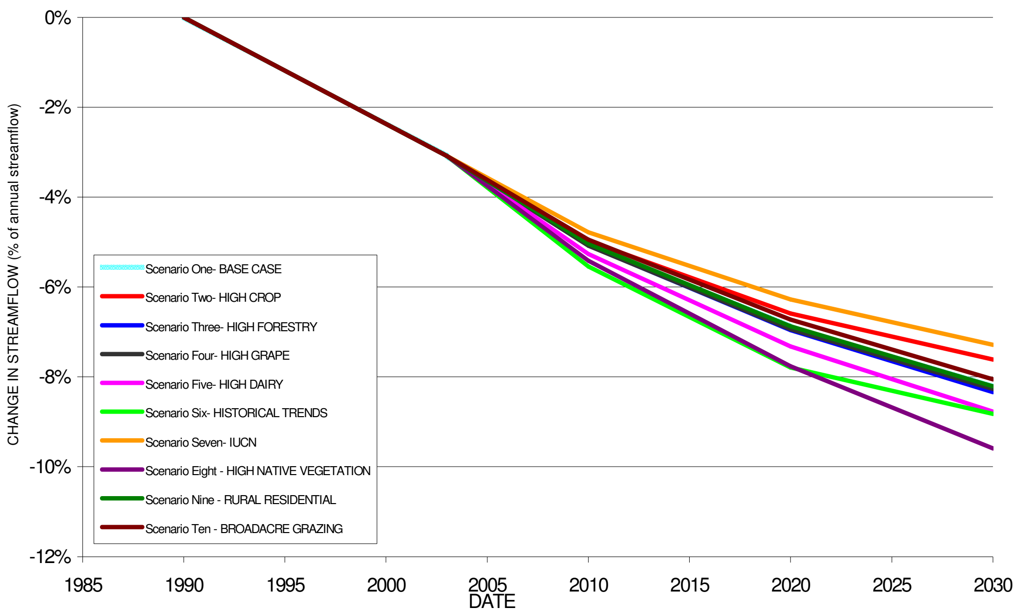

Figure 15- Predicted change in streamflow (mean annual flow) in response to land use change scenarios in sub-catchment H11

6.3.2 H12 Sub-Catchment – Upper Fiery Creek & Wongan

Similarly to the H11 sub-catchment, there has been a major shift in agricultural land use since 1990, which is expected to continue in the future (Table 12). Primarily there has been a shift from broadacre agriculture to crop agriculture. Native vegetation cover is expected to increase into the future. The primary difference to the H11 sub-catchment is the presence of blue gum plantations and the anticipated gradual increase of this land use into the future. As of 2003, blue gum plantations only cover 4% of the catchment and this land use is only expected to reach 8% by 2030 (WatLUC 2005).

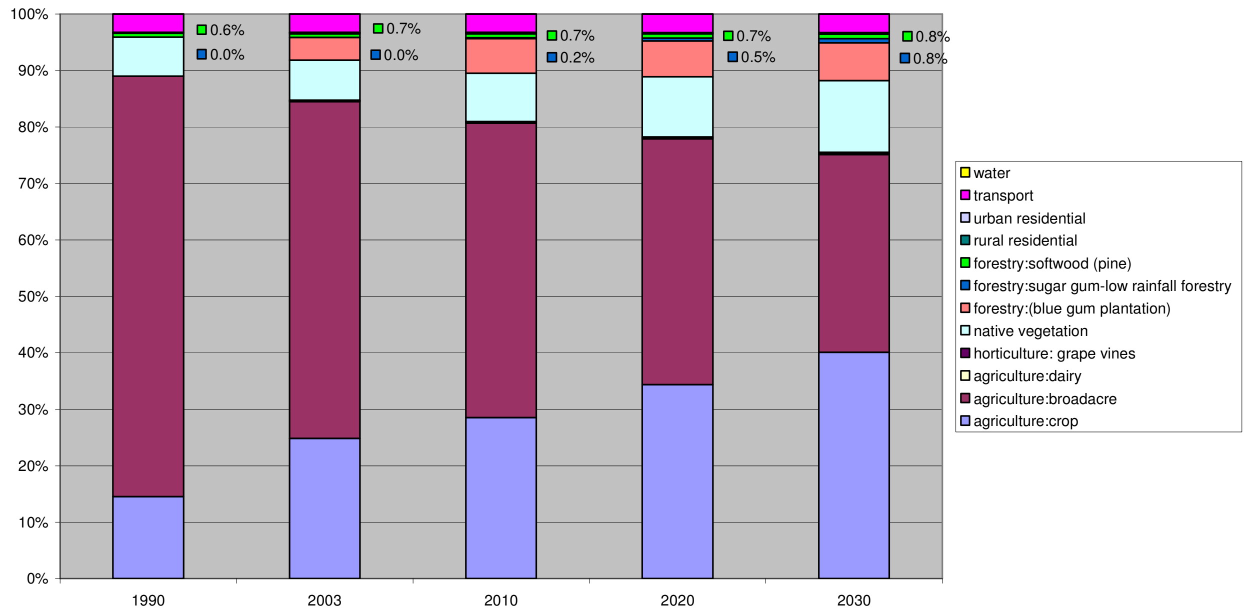

Figure 16- Measured and predicted land use to 2030 in sub-catchment H12

Table 12- Measured and predicted land uses in sub-catchment H12

	1990	2003	2010	2020	2030
Agriculture- crop	14.5%	24.9%	28.5%	34.4%	40.1%
Agriculture- broadacre	74.4%	59.6%	52.2%	43.5%	35.0%
Agriculture- dairy	0.0%	0.2%	0.2%	0.2%	0.2%
Horticulture- grape vines	0.0%	0.1%	0.1%	0.2%	0.2%
Native vegetation	6.9%	7.1%	8.5%	10.6%	12.7%
Forestry- blue gum plantation	0.0%	4.0%	6.1%	6.4%	6.7%
Forestry- sugar gum-low rainfall sp.	0.0%	0.0%	0.2%	0.5%	0.8%
Forestry- softwood (pine)	0.6%	0.7%	0.7%	0.7%	0.8%
Rural residential	0.1%	0.1%	0.1%	0.1%	0.2%
Urban residential	0.1%	0.1%	0.1%	0.1%	0.1%
Transport	3.2%	3.2%	3.2%	3.2%	3.3%
Water	0.0%	0.0%	0.0%	0.0%	0.0%

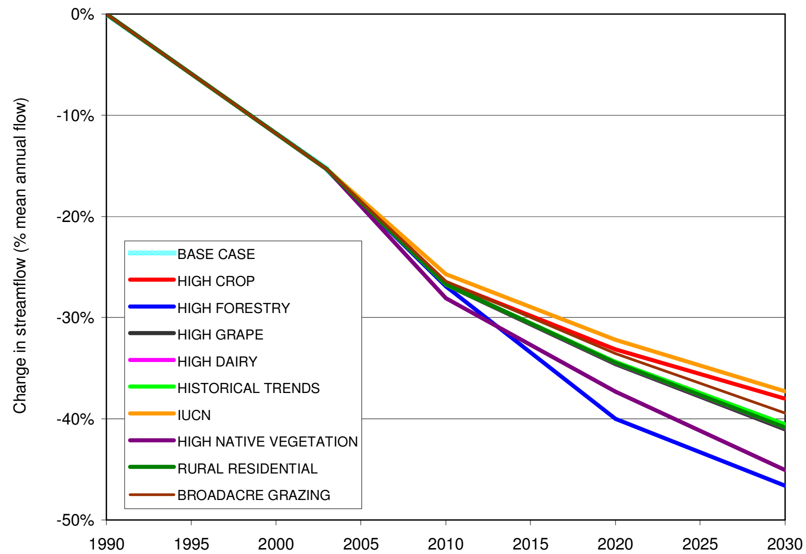

Figure 17- Predicted change in streamflow (mean annual flow) in response to land use change scenarios

Generally, land use is expected to change across the entire catchment in the future. All of these changes will have impacts on runoff and water flows in the catchments waterways. **All scenarios modelled in the WatLUC (2005) study concluded that streamflows will decrease even if the ratios of land use remain the same**. These predications coupled with the unpredictable weather pattern add up to increased pressure and stress on an already stressed system. Even changes in land use that are beneficial on the larger scale such as revegetation projects will have at least a short term negative impact on runoff and recharge.

7 Conclusions and Summary

Every attempt has been made to obtain and review the literature relating to the topic. Given the large area of the region and the wide scope of the project there are a number of other primary sources of information available. For example detailed information on the geology of the region, ground water and aquatic community of Lake Bolac, Fiery & Salt Creeks is available in the scientific literature (journals). It is intended that the reports and references utilised here will provide a link to references relating to the finer details of the broad topics.

7.1 Threats

It is clear to see from the data presented in this report that the surface water resources are stressed. Large flows (<100ML/day) have not occurred in Fiery Creek (Streatham) since 1995. This decrease in flow has resulted in impacts further down the catchment with water levels decreasing in Lake Bolac, which has not spilled since 2001. This has also resulted in no flows to Salt Creek from Lake Bolac since at least this time and reports (anecdotal evidence) indicate that Salt Creek has only had some small local flows from springs and the catchment in the past seven years. The salinity discharge pattern from the Fiery Creek does not appear to have changed a great deal from 1990-98. However, with decreased flow the impact of elevated salinity levels in Fiery Creek are exacerbated and this is reflected in the increased salinity levels in Lake Bolac which are unprecedented and have had a dramatic impact on water quality. The implications of low flows and poor water quality in the catchment are most strongly illustrated at Lake Bolac as it acts as a collection point for the upper catchment and is reflected in decreased visitor numbers since the eel kill and reduced agricultural production around the lake. While there is a substantial amount of information available relating to Fiery Creek and Lake Bolac there is very little information available about Salt Creek.

Considering the information detailed in this report, with the guidance of the steering committee the following knowledge gaps have been identified, and actions to facilitate progress in the management of the catchments waterways have been proposed. However it is evident that the long-term management of the situation will require a coordinated and cooperative approach by all stakeholders with guidance from non-government and government agencies alike. The development action plans will need to consider all stakeholders in the catchment where appropriate, and planning will be critical as there are a wide range of stakeholders that utilise the catchments water resources. Anecdotal evidence will be particularly important when developing actions at the smaller scale (eg. landholder knowledge). The ultimate benefit of the proposed actions should be reflected in a cost benefit analysis where appropriate.

Most importantly, the participation of the local communities and landowners in the catchment will be required at all levels including the planning and implementation stage if key recommendations are to meet their full potential.

8 Identified Knowledge Gaps & Recommendations

1. Investigate ways to optimise flows in the Fiery & Salt Creek system that would not have a detrimental impact on Lake Bolac (high salt water would be a concern) or the agricultural productivity of the region.

2. Consider alternate weir option for the outlet to Lake Bolac

3. Ensure all low flow diversions are in place on in-stream weirs and dams

4. Identify salinity sources in the catchment and take remedial action where appropriate. Some of these actions and activities are already addressed under the Salinity Management Plan.
    a. Identify sources of saline discharge to the creek system where possible, including natural drainage of saline ground water and artificial drainage of wetlands etc. Identification of these areas may require further on ground works and research
    b. Methods to address natural saline discharge are addressed in the salinity management plan.

5. Undertake a salt budget and water budget, leading to the development of a water management plan. Specific actions would include:
    a. Detailed water budget
    b. Detailed salt budget
    c. Investigate volumes of water taken as “free of right”; this may be achieved based on stock density and water requirements.
    d. Further investigation into volumes extracted under license and potential illegal extractions and their impact on stream flow particularly during dry periods.

6. Conduct further research on Fiery & Salt Creek:
    a. Further research into flows, salinity and the local catchment
    b. A more detailed survey of the Fiery Creek to highlight high value areas which may not be assessed in ISC data

7. Hold community workshops to convey the findings of this report.

8. Develop a communication plan outlining processes and methods to keep the community informed of the progress of recommendations proposed in this report and those that may develop in the future.

9. Obtain further information and research relating to water use in the catchment. Actions may include:
    a. Investigations into the effect of changes in land use patterns eg increased cropping and decreased grazing. If additional information not already provided in the WatLUC (2005) is required
    b. Look at flows in the Fiery Creek (proposal may be put forward for new gauging station.)

10. Establish a community group to assist in the implementation of recommendations. Include government agency representatives where appropriate.

11. Indigenous Heritage – audit and identify sites of cultural significance in the catchment. The two major sites around Lake Bolac have been documented. Neil Murray identified many additional sites during the 2006 hEELing walk between the headwaters of Fiery Creek and Lake Bolac.

12. Revegetation is an ongoing action addressed in both the Salinity Management Plan (GHCMA 2005) and the Native Vegetation Plan (GHCMA 2006a). Both plans identify revegetation as actions for different reasons.
    a. Revegetation used to combat salinity in certain regions as outlined in the salinity management plan (GHCMA 2005)
    b. 15% of the catchments to be revegetated with endangered EVCs (GHCMA 2006a)
    c. Quantifying the amount of revegetation in the catchment including Landcare

13. Continue to collect and collate all current and new research and information pertaining the H11 and H12 catchment and water quality.

9 Potential Funding Sources

Community
- B&S Ball
- Local businesses

State & Federal funded programs

Glenelg Hopkins CMA Community Landcare Facilitators can assist with accessing State and Federal Funding. The two major funding programs administered by Glenelg Hopkins CMA via the Regional Catchment Investment Plan (RCIP) are Natural Heritage Trust (NHT) and National Action Plan for Salinity and Water Quality. These programs are now in the final funding year and applications for funds have closed. The federal Government has announced that there will be new programs, however the details of these are unknown as of January 2007.

Glenelg Hopkins CMA Partnership Program provides technical assistance and funding support to landholders for onground works that protect and or enhance waterways. Glenelg Hopkins CMA produces a Grants and Incentives Guide that details a wide range of fund sources. Contact the CMA for a copy or downloaded it from the CMA web site www.glenelg-hopkins.vic.gov.au.

Other
- Regional industry groups (agribusiness, fertiliser/herbicide/pesticide companies, bluegum plantation companies, grain and livestock associations etc)
- Philanthropic grants

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Lake Bolac, Fiery and Salt Creeks Community Steering Committee:

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Neville Oddie
Peter O'Rorke,
Tania Parker
James Richardson
Ruth Raleigh
Daryl Scherger
Bill Sharp
Naomi Turner
Bill Weatherly

Additionally many community members took the time to either provide their own thoughts in writing or were interviewed and to them we extend our thanks. The research and work carried out by Mattias Raiber was of significant value and greatly adds to the report, his support and information was greatly appreciated.

There may be additional information pertaining to the study area that has not been reviewed. One of the recommendations coming from this report is to continue to collect and collate existing and new research and information. Information may be submitted to Glenelg Hopkins CMA for consideration in future versions of this report.

The report has been prepared for Glenelg Hopkins CMA by:

Dion Gervasi

P & P Design

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www.vicwaterdata.net ISC 2004 hydrology score for reaches 25, 26, 27, 28 and 29 in Basin 36.

Appendix 1: List of Stakeholders and Government Agencies

Organisation	Address	Town
Legislative Responsibilities		
Department of Primary Industries	1 Spring St	Melbourne
Department of Sustainability and Environment	8 Nicholson St	East Melb.
Southern Rural Water	132 Fairy St	Warrnambool
Parks Victoria	Level 10 535 Bourke St	Melbourne
Glenelg Hopkins CMA	French St	Hamilton
Environmental Protection Agency	40 City Road	South Bank
Framlingham Aboriginal Trust	9 Wangoom-Warrumyea Rd	Purnim
Central Highlands Water	PO Box 152	Ballarat 3353
Ararat City Council	PO Box 246	Ararat 3377
Community		
Lake Bolac & District Kindergarten	"Glenleith"	Streatham
Lake Bolac & District Historical Society Inc	Sth Beach Rd.	Lake Bolac
Lake Bolac Angling Club	Station Street	Mininera
Lake Bolac Aquatic Club	Address unknown	
Lake Bolac B & S Ball	Montgomery Street	Lake Bolac
Lake Bolac Ballet School	PO Box 102	Lake Bolac
Lake Bolac Boat Club	Address unknown	
Lake Bolac Bush Nursing Centre	Montgomery Street	Lake Bolac
Lake Bolac Cemetery Trust	Montgomery Street	Lake Bolac
Lake Bolac College Council	"Greenvale"	Willaura
Lake Bolac College Parents Club	"Burnbank"	Tatyoon
Lake Bolac Craft Group	Montgomery Street	Lake Bolac
Lake Bolac Cricket Club	C/- Post Office	Lake Bolac
Lake Bolac Development Assoc Inc	PO Box 34	Lake Bolac
Lake Bolac District News	RMB	Wickliffe
Lake Bolac Eel Festival Committee	"Greenacres" Karmala Lane	Lake Bolac
Lake Bolac Fire Brigade	Glenelg Hwy	Lake Bolac
Lake Bolac Foreshore Committee	Glenelg Highway	Lake Bolac
Lake Bolac Golf Associates	Frontage Rd.	Lake Bolac
Lake Bolac Golf Club	PO Box 101	Lake Bolac
Lake Bolac Guides	Caramut Road	Chatsworth
Lake Bolac Information & Business Centre	2110 Glenelg Highway	Lake Bolac
Lake Bolac Ladies Bowls Club	"Glen Eynord"	Woorndoo
Lake Bolac Land Protection Group	Wyvern	Lake Bolac
Lake Bolac Lions Club	C/- Post Office	Lake Bolac

Lake Bolac Music Club	PO Box 79	Lake Bolac
Lake Bolac Public Hall	PO Box 79	Lake Bolac
Lake Bolac Recreation Complex	C/- Lake Bolac College	Lake Bolac
Lake Bolac Red Cross	RMB	Wickliffe
Lake Bolac RSL	PO Box 79	Lake Bolac
Lake Bolac Scout Hall	RMB L535	Streatham
Lake Bolac Senior Citizens	Leach Rd	Lake Bolac
Lake Bolac Squash Club	Post Office	Lake Bolac
Lake Bolac Swimming Club	Chatsworth Road	Wickliffe
Lake Bolac Tennis Club Inc	Greenacres Karmala Lane	Berrambool
Lake Bolac Yacht Club	Address unknown	
Lake Bolac Youth Group	Chatsworth Road	Caramut
Lake Bolac Bowling Club	Montgomery Street	Lake Bolac
Scots Uniting Church Lake Bolac	Avonlea	Willaura
Southern Farming Systems	Greenacres Karmala Lane	Berrambool
St Bernards Catholic Church Lake Bolac	South Beach Road	Lake Bolac
St Marks Anglican Church Lake Bolac	Montgomery Street	Lake Bolac
VFF Lake Bolac Branch	Tara Road	Mininera
Wickliffe/Lake Bolac Football Club	C/- Post Office	Lake Bolac
Wickliffe/Lake Bolac Netball Club Inc	RMB	Wickliffe
Buangor Landcare Group	Refer to GHCMA	
Raglan & district Landcare Group	Refer to GHCMA	
Lake Goldsmith Landcare Group	Refer to GHCMA	
Broken Creek Landcare Group	Refer to GHCMA	
Fiery Creek Landcare Group	Refer to GHCMA	
Woorndoo Landcare Group	Refer to GHCMA	
Lake Bolac Landcare Group	Refer to GHCMA	

Appendix 2: Additional References

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Appendix 3: Conversion Table

1 km^2	100ha		
1m^3	1000L		
1ML	1000m^3	1000000 litres	
Seawater	54000 us/cm	35ppt	At 25 ^oC

Appendix 4: Methodology for stream flow stress ranking

Taken from http://www.vicwaterdata.net/vicwaterdata/isc2004/note/HydroRating.htm (accessed 17/05/2006)

Hydrology Rating Table

Index	Description
Variability index	This index reflects variability in monthly streamflows. Seasonal variation in flow is relatively predictable and acts as an important hydrological driver of aquatic ecosystems. Rises in water levels are known to provide important life-history cues for many plant and animal species.
High flow index	The high flow index measures the highest and second highest monthly flows in a year. Flood flows determine the maximum depths, velocities and shear stresses that occur in a river system. High flows drive geomorphic process in rivers through transporting and depositing sediment and altering channel form. High flows act as a natural disturbance in river systems, removing vegetation and organic matter and resetting successional processes. A reduction in the magnitude of flood flows is likely to correspond with a reduction in overbank flows, important in providing connectivity between rivers and their floodplains.
Low flow	The low flow index is a measure of the change in low flow magnitude under current and natural conditions and measures the lowest and second lowest monthly flows in a year. Low flow periods are a natural feature of Australian river systems but are generally regarded as a period of high stress for aquatic biota. Increasing the magnitude of low flows reduces the availability of in-stream habitat, which can lead to a long term reduction in the viability of populations of flora and fauna.
Zero flow index	This index measures the proportion of time that the stream is dry (or nearly so). Periods of zero flow are a natural feature of ephemeral rivers and creeks, however increases in the natural duration of cease to flow periods are regarded as harmful to aquatic ecosystems. In many ways they can be regarded as extreme low flow periods when habitat availability is restricted and water quality prone to deterioration. Extended cease to flow periods can result in partial or complete drying of the channel. This can lead to loss of connectivity between pools and even complete loss of aquatic habitat. Under natural conditions aquatic biota are able to recolonise dried sections of creek channels once flow returns.
Seasonality index	The seasonality index is a measure of the shift in the maximum flow month and the minimum flow month between natural and current conditions. Floods stimulate biological productivity in aquatic ecosystems, while low flows are a time of reduced biological productivity. The timing of periods of flooding and low flow has an important influence on how floodplain and riverine ecosystems respond. In temperate Australia plants and animals are generally adapted to the natural occurrence of floods in winter/spring and low flows in summer/autumn. Changes to these flow patterns, such has occurred though regulation, are thought to have caused significant changes in some communities.

The index values range between 0 (stressed) and 10 (pristine). Winter, summer, and annual scores are determined by averaging the winter, summer, and annual sub-indices for each site.

The final scores are classified using a three alphanumeric code of the form “#PI”, where:
- is an integer between 0 and 10 that denotes the overall annual score for the site;
P - denotes the period of the year that is most stressed, where S represents summer

(December to March, inclusive) and W represents the winterfill season (July to October, inclusive); and

I - denotes the annual sub-index with the lowest score (i.e. which of the flow components is most stressed when all months of the year are considered). The letters used to denote each flow component are as follows:

V - annual variability index
H - annual high flow index
L - annual low flow index
Z - annual zero flow index
S - annual seasonal periodicity index

Thus, for example, typical scores might be reported as:

- 9SL - a catchment in near pristine condition, where the summer season is more stressed than winter, and the low flows are most affected.
- 8WV - some stress evident, where the winterfill season is more stressed than summer, and the variability of flows is the flow component most impacted upon
- 2SZ - a highly stressed catchment, where summer conditions are more stressed than in winter, and the proportion of zero flows is the component most affected.

Appendix 5: Landuse change scenarios

The following information has been sourced from the Water and Land Use Change technical document (SKM, 2005). It describes the basic information behind the different land use change scenarios and was applied to each sun-catchment in the study area. The ten scenarios were the base case, historic trend, high cropping, high dairy, high forestry, high revegetation, International Union for the Conservation of Nature (IUCN), high rural residential, high grape, and broadacre grazing.

- *Base case* – industry estimates of the likely rate of change or future extent of relevant land uses:

Dairying	Industry representatives found it difficult to predict the outlook for dairy. They suggested that the area of land under dairying would remain relatively static over the outlook period. A base rate of expansion of 1% of the 2003 area (p.a.) was used. In areas where the AC indicated dairying was declining, the area under dairy pasture continued to decline (to zero area if necessary).
Cropping	Cropping industry representatives were upbeat about the prospects for cropping within the region. Some representatives foresaw no reason why cropping would not continue to grow at its historical rate, others were a little more circumspect. The adopted rate of change for cropping in the base case was 75% of the rate from the AC, relative to the 2003 area. Cropping was increasing in all areas. The 1990 crop scenario was based on 1990 AC data.
Softwood plantations	The softwood industry is a mature one, with very slow rates of change. 2003 area estimates were based on PIRVic land use mapping. A rate of 0.5% growth relative to the 2003 area was used, where softwood plantations were already present. No new plantation areas were introduced in areas where softwood plantations were not present in 2003.
Hardwood plantations	Representatives of Blue Gum plantation companies considered that expansion in the Corangamite region was at about its limit on the basis of land prices and competition from other uses. They foresaw better growth opportunities in the Glenelg Hopkins region. Their estimate was that the industry would grow to about 18,000 and 105,000 ha, respectively, within the next few years. For convenience, these areas were assigned to 2010. The area under Blue Gums was then assumed to grow at 0.5% of this area at locations that already supported Blue Gum plantations. It was assumed that in 1990 there were no Blue Gum plantations. The use of low rainfall farm forestry species, such as Sugar Gum is being advocated by DPI and farm forestry groups. Growth in this land use of the order of 600 ha/y across relevant parts of the region was assumed (lower rainfall, basalt plains country). It was assumed that this land use was incorporated into 2003 (and 1990) estimates of hardwood plantation.
Revegetation	Native vegetation plans for the two regions (CCMA, 2003c; GHCMA, 2000) propose substantive investment in new conservation plantings, mostly on private land. The base case revegetation scenarios assume that the optimistic targets set in the native vegetation plans will be achieved by 2050, rather than 2030 as proposed. The targets adopted for the scenarios are that all endangered EVCs be increased to 10 or 15% of their pre-1750 coverage, for the Corangamite and Glenelg-Hopkins regions, respectively. Vegetation cover was backcast to 1990 assuming that the rate of change was 5% of the annual change from 2003. It is assumed that revegetation on rural residential land will not be to EVC and that any such revegetation would be additional to that required to achieve regional native vegetation restoration targets.
Horticulture	Non-wine grape horticulture continues to expand or contract at historical (AC) rates. Estimates of rates of change in viticulture are based on industry estimates of excess production capacity in cool climate wines for much of the next decade (McGrath-Kerr Business Consultants, 2003; Sinclair Knight Merz, 2004). The adopted rate of change was the historical trend or 3% increase relative to the 2003 area, whichever was least.

Rural residential	The amount of rural residential land use and the rate of change vary according to proximity to Melbourne and the main regional population centres. Three zones of rural residential growth were identified: ▪ High growth – areas with a relatively large amount of rural residential land and high likely growth rate. Growth at 4 times the low growth rate (relative to 2003 area). ▪ Moderate growth – areas with moderate amounts of rural residential land, and less growth potential because they are more remote from major regional centre. Growth at 2 times the low growth rate (relative to 2003 area). ▪ Low growth – areas with little or no rural residential land and few growth prospects. Growth at 2% p.a. relative to the 2003 area.
Urban/ commercial	As above, except that the low growth rate of expansion is 0.5%
Transport	Transport is a major land use across the region. The assumed growth rate is 0.05% p.a., relative to the 2003 area.
Broadacre grazing	The rate of change, before adjustment for non-agricultural land uses continues at the historical trend.

- *Historical* – changes in agricultural land uses continue at the historical rate prior to adjustment for non-agricultural land uses. Non-agricultural and horticultural land uses change at the base rate.
- *High cropping* – this scenario is based on an optimistic view of the cropping industry. Expansion progresses at 125% of the 1990-2001 rate. Non-agricultural and horticultural land uses change at the base rate, with agricultural land uses adjusted to reflect these changes.
- *High dairy* - this scenario is based on a relatively optimistic view of the dairying industry. Expansion progresses at 5% p.a. relative to the 2003 area, compared with 1% for the base case. Non-agricultural and horticultural land uses change at the base rate, with agricultural land uses adjusted to reflect these changes.
- *High forestry* – under this scenario, the industry expands beyond what are currently considered to be the limits to growth. Under this scenario, the Blue Gum plantation estate would increase to a total of 150,000 ha in the Glenelg Hopkins CMA region and about 25,000 ha in the Corangamite region by 2020. Growth continues beyond that time at 0.5% p.a. relative to the 2020 plantation area. Softwood plantation area grows at 1% p.a. relative to 2003, which is double the base case rate. Low rainfall farm forestry expands at 900 ha/y in the relevant parts of the study area.
- *High revegetation* – under this scenario the Corangamite and Glenelg Hopkins CMAs' targets for restoration of endangered EVCs are achieved within the nominated 2030 timeframe.
- *IUCN* – this is a lower change revegetation scenario, in which vegetation restoration proceeds to achieve 5% cover for all endangered EVCs, relative to their pre-1750 distribution, a target consistent with that of the International Union for the Conservation of Nature (IUCN).
- *High rural residential* – the low rate of growth for rural residential land is 3% p.a., relative to the 2003 area, compared with 2% for the base case.
- *High grape* – where the area of land under vineyards expands at 10% p.a.
- *Broadacre grazing* –this scenario reflects relatively buoyant conditions in broadacre livestock grazing enterprises. Broadacre grazing is not displaced by dairying (from 2003) and the rate of expansion in cropping is half the rate indicated by the AC. The rate of forestry expansion is curtailed to 0.1% for Blue Gum and softwood plantations (post 2010) and at 200 ha/y for Sugar Gum.

Appendix 6: Water Quality Modelling Parameters

Essentially the modelling to date has been carried out as a water balance for Lake Bolac and has included:

- the estimated groundwater inflow and outflow,
- the rainfall (multiplied by the lake area),
- loss due to evaporation (over the lake area),
- surface water inflow (Fiery Creek).

From these components monthly change in lake height has been calculated and compared it to the lake level measurements to calibrate the model. The model works well when there are no outflows from the Lake but needs refining to better account for outflows. Several scenarios were compared to look at the impact of changing rainfall patterns on the Lake level. However these models have not considered the effect of landuse change.

Appendix 7: Glossary & Abbreviations

DO -	Dissolved Oxygen, this is the level of oxygen present in the water.
EVC -	Ecological Vegetation Class is a classification system of the vegetation community. There may be many EVCs for one region
Fen –	A freshwater wetland occurring on low, poorly drained ground and dominated by herbaceous and shrubby vegetation. Soil is typically organic peat.
Halocline –	as for the thermocline however this refers to salinity. Water with a higher salinity will form the bottom layer, as it is denser than fresh water, which will be present as the surface layer.
ML -	mega litre = 1,000,000 litres
Thermocline –	scientific term for transition point when waterbodies become stratified. Warmer water is present as a layer at the surface and cooler water is at the bottom, the two layers do not mix unless environmental conditions permit.
TP -	Total Phosphorus
TN -	Total Nitrogen
Turbidity -	A measure of the clarity of the water, generally related to the amount of suspended material in the water.
TSS -	Total Suspended Solids – a measure of the filterable matter in a water sample