Hydrology and Catchment Issues in the Victorian North East CRA/RFA Region
# Table of Contents

## Chapter 1: Introduction
- Introduction to the Brief and the Regional Forest Agreement Area 2
- Who Owns the Water 5
- The Murray Darling Cap 5

## Chapter 2: Site Specific Forest Hydrology Information in North Eastern Victoria
- Introduction 9
  - 2.1 The Cropper Creek Hydrologic Project 10
    - Project Aims 13
    - Expected Outcomes 13
    - Technical Aspects 13
    - Catchments Gauged 13
    - Measurement Periods 13
    - Clem Creek Treatment 14
    - Specific Aspects of the Forest Hydrology 14
  - 2.2 The Pine Creek Study 29
  - 2.3 The East Kiewa Hydrologic Project 30
    - Methodology 30
    - Effects of Logging on Stream Sediment Levels 31
    - Prediction of Sedimentation Effects in Junction Dam and Clover Dam 32
  - 2.4 The Lawrence Thesis 34

## Chapter 3: Issues of Water Yield
- 3.1 Introduction and General Comments 36
- 3.2 Water Yield of Ash Type Forests 37
- 3.3 Water Yield of Mixed Species Forests 43
- 3.4 The Water Yield Implications of Converting Pasture to Plantation 44

## Chapter 4: Water Quality Issues in North-East Victoria
- 4.1 Some General Comments on Water Quality and Stream Biota 49
- 4.2 Nutrient and Blue-Green Algae Issues 50
- 4.3 Fighting About Nutrients: An Example of Dispute 51
- 4.4 The Tarago River Work 52
- 4.5 Local Perceptions 53
- 4.6 Forest Roading and Water Quality 56
- 4.7 Timber Harvesting And Its Effects 57
- 4.8 Protection of Water Quality by Buffers in Native Forests 57
- 4.9 Code of Forest Practice Issues 58
- 4.10 Recreation Issues 60
- 4.11 Plantation Management 60
- 4.12 Power Generation Issues 61
- 4.13 Salinity Management 62

## Chapter 5: Riparian Environment Issues
- 5.1 General Introduction to Riparian Issues 65
- 5.2 Protection of Riparian Environments by the Use of Buffers 66
Conversion Factors

In some cases rainfall or water yield is given in millimetres (mm). In some other cases, to fit the context of the argument, rainfall and water yield are quoted in megalitres per hectare (ML/ha\(^{-1}\)). Since one megalitre is \(10^6\) Litres and one hectare is \(10^4\) m\(^2\), it follows that 100 mm water yield is equivalent to 1 ML ha\(^{-1}\).
Table of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>The approximate Regional Forest Agreement Area and locations of major studies, towns and water storages.</td>
<td>4</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Location of the Cropper Creek Project</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Plan of the three catchments</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2.3(a)</td>
<td>Example of hydrographs from Croppers Creek in summer</td>
<td>15</td>
</tr>
<tr>
<td>Figure 2.3(b)</td>
<td>Example of hydrographs from Croppers Creek in winter</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>Annual hydrographs for streams in the project area</td>
<td>17</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>Monthly flow in streams of the Cropper Creek Project compared to monthly flow in the local rivers</td>
<td>20</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>A storm hydrograph from a major storm. This was the largest storm experienced during the period of the study</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.7</td>
<td>Summer flow recession and low flow hydrology for a sustained low flow period in summer-autumn, and early winter</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>Example of the diurnal variation on Clem Creek</td>
<td>24</td>
</tr>
<tr>
<td>Figure 2.9</td>
<td>An example of a road hydrograph generated from a section of road, and a comparison of this with the runoff from the natural catchment</td>
<td>25</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>Ratio of road runoff to natural catchment storm runoff as a function of storm size</td>
<td>26</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>The regional stand age/water yield relationship for an ash type forest</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Suggested relationships between water yield decreases and mean annual precipitation for the complete afforestation of eucalypt and pasture by pine. Evapotranspiration differences between pasture and eucalypt for particular values of annual precipitation are given by the vertical difference ‘B’</td>
<td>46</td>
</tr>
</tbody>
</table>
Table of Tables

Table 2.1: Comparisons of concentrations of water nutrient concentrations for commercial bottled water and Clem Creek water 27

Table 2.2: Water yield of Ella Creek and the changes observed following the conversion from eucalypt to pine in 1980 29

Table 2.3: Approximate water balance computed from raw data given in Papworth, Hartland and Lucas (1990) 31

Table 2.4: Estimated sediment contribution from the experimental logging of alpine ash on Springs Catchment 32

Table 2.5: A comparison of the contribution of logging (based on a “medium level” event) to the background contribution of sediment for the catchment above Junction Dam and Clover Dam. All figures are given in tonnes per annum 33

Table 3.1: Ash Type Forest Cover in the NE RFA Catchments 38

Table 3.2: Net productive area (Ha) for commercial forest types in the North East Region 41

Table 3.3: Streamflow yields, ML/ha/annum for ash type forest by age and for varying rotation lengths 42

Table 4: A comparative statement of land use and estimated N and P loads in the Ovens Basin 54
Chapter 1: Introduction

This chapter outlines the consultancy brief and makes some general comments on the methodology used.
Introduction

Introduction to the Brief and the Regional Forest Agreement Area

North-eastern Victoria is a major source of Murray-Darling Basin water, and critically important for security of supply. Water is a major regional resource, and debates concerning water, water pricing, and water allocations have been a feature of the last century. The Commonwealth and Victorian governments are undertaking joint assessments as part of a process to arrive at a Regional Forest Agreement (RFA) for the north-east of Victoria. The catchments of the North East Regional Forest Agreement (NE RFA) region contribute significantly to the overall flows and health of the Murray Darling Basin and consequently have a high profile in relation to a number of topics including (see Appendix 1 for the terms of reference for the consultancy services):

- Changes in inflow to major water reservoirs;
- Downstream uses of water from the area;
- Irrigation allocations;
- Changes in quality and quantity of streamflow as a consequence of land use and operations within catchments with a special emphasis on road and track construction and maintenance;
- Groundwater and salinity levels in the north-west of the region; and
- Effects of existing plantations and impacts of possible expansions of plantations.

The objective of this consultancy is to provide an expert technical review of water issues relating to the NE RFA region, and an evaluation of the current levels of knowledge and gaps on hydrology and water management issues in the forested and non-forested catchments. The consultancy used the following methodology:

- Conduct of a literature review on forest hydrology and catchment management issues pertaining to the NE RFA region.
- Detailed discussions with staff from relevant government departments and statutory authorities.
- Examination of forest management practices on issues of water management relevant to the RFA process.
- Examination of downstream issues to support development of CRA options.
- Assessment of current levels of knowledge on relevant hydrology and water management issues and identification of information gaps and requirements for future research to address those gaps.
Introduction

Figure 1.1 shows the boundaries of the region and the location of a number of places referred to in the text. The NE RFA region covers most of the North East Catchment Management Authority area and about 30% of the Goulburn Broken Catchment Management Authority area. The area of the NE RFA region is about 3 million ha which is 3% of area of the Murray Darling Basin. The streamflow of the RFA region is 6,500 GL which is 50% of the flow in the Murray Darling Basin.

The NE RFA area is very diverse in terms of topography, vegetation cover and land use. About 60% of the area is public land with a native forest cover except for the alpine areas above the treeline and 50,000 ha of conifer plantation. The forest mainly occupies the slopes of the ranges. The lower river valleys and flood plains are largely in private ownership. About 60% of the freehold land consists of pasture land, 12% of the land is used for cropping and 11% retains a native vegetation cover. The remainder has a range of miscellaneous uses including that of horticulture.

The major storages for water from the NE RFA region are:

- Lake Dartmouth, a major storage at the headwaters of the Mitta Mitta River. About one third of the River Murray’s water comes from the Mitta Mitta catchment which is largely within the study area.

- Lake Hume, on the River Murray, upstream of Albury. Discharges from Lake Hume provide most of the regulated flows along the length of the River Murray. This storage is in turn recharged from Lake Dartmouth and natural flow. The catchment above this reservoir is the major source of River Murray water, and although it covers less than 1.5% of the total area of the Murray-Darling Basin it contributes 37% of the total inflow to the Murray in an “average” year.

- Lake Eildon - on the Goulburn River, both the lake and it’s catchment are partly within the NE RFA region.

Minor storages used largely for irrigation include Lake Buffalo on the Buffalo River, Lake William Hovell on the King River, Lake Nillahcootie on the Broken River, storages associated with the Kiewa Hydroelectric Scheme, the off-river irrigation storages of Lake Mokoan and Waranga Basin, and the large weir at Yarrawonga (Lake Mulwala). There is a plethora of small storages associated with town water supplies or the water supplies of individual properties. In terms of the Murray River Cap\(^1\) net water use from these storages counts as part of the cap allocation.

\(^1\) Limits are placed on taking water from streams in the Murray-Darling Basin.
Figure 1.1  The approximate Regional Forest Agreement Area and locations of major studies, towns and water storages.
Who Owns the Water

The question of who has rights to water has always been difficult and relies substantially on a body of “common law.” Traditionally land holders have the right to use water falling on their land or flowing past their land for “reasonable domestic use.” Similarly, with permission from the appropriate authorities they may impound water in dams and pump groundwater from under the ground surface.

Under the Water Act 1989, which provides for water resource management and allocation in Victoria, a number of changes have occurred to water administration. For example, “bulk water entitlements” have been introduced which allow water authorities to remove a prescribed amount of water for specific uses. The remaining water in the stream is the property of the Government, to be sold or otherwise allocated as it sees fit. These changes aim to:

(a) Protect the environment;
(b) Prevent erosion of existing water rights;
(c) Set rules about how water will be shared in droughts; and
(d) Provide a basis for the trade of entitlements to higher value uses, including entitlement incentives for efficiency.

The Murray Darling Cap

Since the early 1950s there has been a growing concern about the effect of the increasing use of water resources upon the environmental health of the Murray Darling System and the security of supply of existing water resource users. Symptoms include algal blooms, increasing salinity and diminishing flora and fauna diversity. The concern is illustrated by the fact that flow to the sea at Lake Alexandrina has fallen from about 10,000 GL/annum in the 1950s to about 2,000 GL/annum now. There are long periods of 8 months or more without any flushing flows. Following extensive debate and investigation, in 1995 the Murray Darling Basin Ministerial Council set a cap upon the amount of water which can be taken from the system. The “cap” is based on the amount of water which would have been diverted under 1993/94 levels of development. There is little community disagreement with this in principle but many questions have been raised relating to:

• The differences in methods of allocation between the states;
• How different forms of licence will be dealt with;
• What it means for different states, regions, towns, and land holders.

Victoria’s share of the cap is 1,620 GL/annum. The cap applies to water taken from the main stem of the Murray and tributaries such as the Mitta Mitta, Ovens and Kiewa Rivers. The State is currently allocating this resource cap among irrigators and urban authorities. In the context of the cap 1,000 ML are important. For example 1,000 ML would irrigate 100 ha of pasture for a year in a northern irrigation area. As a result of the cap a permanent right to irrigate new land has to be bought from existing entitlement holders. Current sales prices for rights amount to, a once off, $600 per/ML and purchasers then could pay an annual fee of $50 per ML. Perusal of the report “Sharing the Murray” by the Murray Water Entitlement
Committee (1997) indicates that the report does not appear to consider changes in water loss due to variation in plant cover. The authors consider this to be an important issue.

The Murray River Entitlement Committee Report attempts for Victoria, to define many issues and suggests various approaches to “Sharing the Pain.” The situation in NSW is more complex because of various historical precedents, although observers view it as likely that the NSW solution will mimic the Victorian one. Most of the debate has referred to areas downstream from the NE RFA region. However, the authors consider that the debate has had a number of influences in the NE RFA region:

1: It has made local residents generally and water diverters in particular sensitive to water issues.

2: Water resource managers and the community have become much more aware of the water use of crops and forests. For instance, consider an owner of 100 ha of land. He/she may not be allowed to divert 200 ML for irrigation because of the water cap but he/she can plant a crop which uses 200 ML more than the grasslands and thus, arguably, result an equivalent net reduction in streamflow. This will certainly influence perceptions of major plantation expansions in that some people might argue that this type of increased water use should also come under licence and “Cap” requirements.

3: There is a strong feeling amongst some land holders that water running off their land is theirs to use, and resent attempts to restrict use for “public good”. However, water resource managers are becoming increasingly concerned about the cumulative impacts of dams located on tributary streams.

There has been much debate about the issue of a flooding quota for the Barmah-Millewa red gum forest and some of the problems are well described in the Murray River Entitlement Committee Report (1997). The Barmah-Millewa forest as a complex of wetlands and forest of some 65,000 ha with some 29,000 ha located in Victoria. The forest requires 10 ML/ha of rainfall to survive. However as annual rainfall provides only 4 ML/ha another 6 ML/ha is required. Before regulation of the Murray and its tributaries this was provided by periodic springtime flooding. As the river has been increasingly regulated, these springtime floods have been replaced by long periods of high summer flows which do not result in regular flooding except for the permanent inundation of some areas close to the river. The report by the Entitlement Committee shows that without any allocation for flooding the number of medium level floods has dropped from 50 per 100 years to 15 per 100 years. These changes have resulted in reduced breeding opportunities for wetland species (e.g. egrets have abandoned nests at Barmah), changes in wetland vegetation due to long dry periods and localised red gum water logging due to prolonged summer flows.

According to the Entitlement Committee report there are also concerns about the impacts on fish, frogs and turtles.
Introduction

Victoria and New South Wales have allocated 100,000 ML to water the Barmah-Millewa forest but the water has been largely unused as no method exists to deliver it to the forest. The Entitlement Committee have examined ways of making more effective use of the 100 GL annual allowance such as saving it up and “piggy banking” it onto natural floods. Resolution of the Barmah-Millewa watering issues and other environmental issues will be a complex process.

One result of this process of resolution is a sensitivity to questions of water yield from upstream land users as to who owns upland water and whether there is some sort of overall “fairness” in terms of water use allocation.
Chapter 2 : Site Specific Forest Hydrology Information in North Eastern Victoria

This chapter examines the information collected directly by major field projects involving:

- on-site measurements
- measurements collected over at least two full years
- Substantial spatial components.

These are used to illustrate specific aspects of north-east forest hydrology.


Introduction

The following chapter will refer to forest hydrology research conducted both nationally and internationally.

Although there are many local reports on aspects of hydrology, there are only two longer-term studies on forest hydrology (Cropper Creek project and East Kiewa Project) in the region. There is a network of routine gaugings and much information is also concerned with the development of hydro-electric resources in the region. Some routine measurement with a forestry emphasis has also been collected near Pine Creek (Kilmore).

In reporting these regional forest hydrology studies, it is of interest to examine how they differ from more routine monitoring. These differences in general are:

1: Provision for a control catchment (i.e. a catchment in which the land use does not vary). This helps remove one major source of error;

2: Stream measurement by a well-constructed weir or flume with a stable flow-water level relationship;

3: Accurate, well-maintained instruments recording rainfall and streamflow and perhaps other variables;

4: A well-developed quality control servicing of equipment;

5: Trained scientific staff involved in examination and analysis of data; and

6: A set of testable hypotheses which can be used to analyse the data.

7: Information from the project disseminated in a series of published papers following peer review in leading hydrology journals.

By any standards such field measurement requirements are expensive and time consuming but ultimately they provide the most reliable data. Of the three studies cited below the Cropper Creek Hydrologic project would come the closest to meeting the above criteria. Usually the impetus for such work is some form of climate aberration usually floods or droughts. The information generated by the three studies has been used to convey some of the essential elements of the hydrology of the NE RFA region.
2.1 The Cropper Creek Hydrologic Project

This is a major forest hydrology research project conducted in north-east Victoria. It can be used to illustrate a number of points concerning hydrologic impacts in north-east Victoria. Figure 2.1 shows the location (22 km south-west of Myrtleford) while Figure 2.2 shows the catchments in detail. The project aims and resounds are also described in Appendix 2 which is a flier produced by the Cooperative Research Centre for Catchment Hydrology. In its period of measurement the Cropper Creek project has had a good range of hydrologic variation but has missed out on extreme storms (1974 and 1993). There have been no “episodic” (ie very extreme storms) for a long time. The extreme storms do appear to have the ability to completely mobilise the stream beds and give very different hydrologic results compared to many lesser storms.
Figure 2.1: Location of the Cropper Creek Project.
Figure 2.2: Plan of the three catchments.
Project Aims

The project has a number of facets but is best viewed as exploring the water yield and water quality aspects of radiata pine plantations in north-eastern Victoria. Specifically:

1: How much water is yielded by small catchments in north-east Victoria?
2: How does this yield change with conversion to radiata pine?
3: What is the nutrient composition of both the rainfall and the stream flow?
4: How is this water stored in the hillslopes and transmitted to the stream?
5: How does the flow of small streams compare to the flow of larger streams?

Expected Outcomes

- Estimates of the water yield of catchments of pine and native eucalypt forest.
- Examination of the impact of pine age on the water yield of the catchments.
- Examination of the impact of pine plantation growth, fertilisation, and thinning on water quality of the streams.
- Development of knowledge of continuous turbidity, pH, conductivity, and temperature variations in the streams to allow development of sampling techniques which give accurate values.
- Comparisons of direct measures of tree water use using sap flow methods with measures of water use from catchment water balances.
- Extrapolations from radiata pine water use in the small catchments to the effects of major plantation development in the headwaters of major rivers in the Murray-Darling Basin of Australia.

Technical Aspects

Catchments Gauged

- Clem Creek (46 ha). Continuously monitored stream flow, rainfall, turbidity, conductivity, temperature, pH. Samples for nutrient analysis using extremely accurate TCP techniques. Vegetation is 17 year old radiata pine.
- Ella Creek (113 ha). Continuously monitored stream flow, rainfall, turbidity. Vegetation is mixed species, mixed age class eucalypt forest.
- Betsy Creek (44 ha). Continuously monitored stream flow, rainfall.

Measurement Periods

Site Specific Studies

Clem Creek Treatment

1975-1979: mixed species, mixed age class eucalypt forest.
1979: Vegetation felled or bull dozed. 30 m buffer strip retained.
1980: Vegetation debris burnt, area planted with radiata pine.
1998: Pines to be fertilized.
1999: Pines to be thinned.

Work Planned

• Evaluation of water use, water quality, and effects of thinning and fertilising
• Comparison of direct measures of water use and catchment water balance measures of water use.
• Modelling of land use changes using the TOPOG catchment model.

Specific Aspects of the Forest Hydrology

The points mentioned below encapsulate the major features of the forest hydrology of the region, as revealed by the Cropper Creek project flier (see Appendix 2) while the list of references in Chapter 9 provides more formal information.

1: How Much of the Rainfall is Yielded as Streamflow?
As a rule of thumb for the catchments of the Cropper Creek area, the water yield, in mm, can be estimated by the following procedure:

• Nominate the annual rainfall in mm.
• Subtract 700 mm
• If the remainder is positive, divide by 50%,

Thus, for instance, a 1,000 mm annual rainfall would yield perhaps 150 mm runoff. A 1,500 mm rainfall would give 400 mm runoff. As such, compared to catchments located in humid areas around the world, the streamflow generated is relatively low.

Bren and Leitch (1986) looked at the percentage water yields for the pretreatment period and found that in the wetter periods the catchments would return perhaps 50% of rainfall as streamflow, but in the drier periods the return ranged from 0 to perhaps 10%. The effectiveness of the area in returning rainfall as streamflow greatly increases as the actual storm rainfall increased.
Figure 2.3(a): Example of hydrographs from Croppers Creek in summer.
Figure 2.3(b): Example of hydrographs from Croppers Creek in winter.
Figure 2.4: Annual hydrographs for streams in the project area.
2: **Characteristics of Rainfall Intensity in the Region**

Figure 2.3(a) and 2.3(b) gives a typical summer and winter hydrograph and hyetograph. It can be seen that:

- Rainfall intensities are low in winter (10-20 mm per hour) and most storms have long periods of low intensity rainfall.
- Summer thunderstorms provide short periods of high intensity rainfall, although by world standards the intensities are still quite low.
- By any standard of world hydrology the environment is a gentle one in terms of rainfall intensity.

3: **Seasonality of Runoff Events**

Runoff at Croppers Creek is a more distinctly seasonal event compared to, say, the water catchments of Melbourne. Figure 2.4 shows an annual hydrograph for Clem Creek. In particular:

- The major streamflows occur in the late winter and spring periods and give a relatively “flashy” hydrograph.
- The hydrograph can be characterised as consisting of:
  - January to May: low flow with occasional summer thunderstorms.
  - June to October: Long periods of low intensity rainfall, with perhaps four distinct periods of storm flow.
  - October to December: a strong recession from the higher spring flows to low or no flow.

4: **Scaling Relations from Small Streams to Large Streams**

Flow in the small streams is quite representative of flow in the large streams and rivers but there is a loss of volume. The pattern of seasonality of flows is very similar. In general the small streams make reasonable reduced scale models of the big streams in terms of flow prediction at least. Figure 2.5 shows monthly flow in Clem Creek compared to the major local rivers; the clear similarities in seasonality can be seen.

5: **Role of Groundwater in Hydrologic Processes**

In these upland environments groundwater movement is a major factor, but it is difficult to study the means by which water is moved. The study work showed:

- Groundwater was always the most dominant source of contributions to streams both at periods of high and low flow.
- The storm runoff process can be viewed substantially as one of fast recharge of groundwater and then fast discharge of groundwater into the stream.
- Overland flow generated in the natural catchment was relatively small in amount, although raindrop splash could be viewed as a downslope movement of overland flow.
- There was a deep seepage loss to groundwater in most catchments. This probably contributes to local or regional groundwaters
- The groundwater tends to exist and be transmitted in deep, weathered rock zones.
- The shape of the groundwater system is a dominant influence on the formation of the stream hydrograph.
6: **Storm flow hydrology**

Figure 2.6 shows a storm hydrograph from a major storm. In particular:

- Storms generally only involve rainfall, with inputs from snow being negligible.
- The volume of rainfall delivered is the key determinant in generating peak flows. The maximum short-term rainfall intensities (e.g. 15 minute, 30 minute, 60 minute intensities) are not useful predictors of the magnitude of the event, reflecting that the system is quite “damped”. Thus predictive models based on use of short-term rainfall intensities are not very accurate when applied to these catchments.
- Typically a storm would deliver about 100 mm over three days, with a storm of about 150 mm over three days creating some local flooding.
- Larger storms (e.g. 1993) occur episodically, but have not been measured during the course of this project. It appears that these have the ability to mobilise stream beds in both disturbed and undisturbed catchments, and that these disturbed beds are far easier to mobilise for some years after. Thus, a very large storm appears to “sensitise” these catchments to disturbance.

7: **Drought and Low Flow Hydrology**

The occurrence of very low flows is probably a good indicator of the long-term sustainability of the land use in the area, although this requires further research. Figure 2.7 shows a typical recession and low flow hydrograph. The research showed:

- It is the inherent nature of the smaller upland streams to “dry up” in summer and autumn. In some cases flows can be traced though old alluvial stream beds, but in many cases the catchments appear to be “leaking” water to deeper aquifers.
- Doubtless from long experience, the stream biota appears well adapted to this. One study (Dr Sam Lake, Monash University) showed that the biota of the streams that tend to dry up was more akin to that of wet soil, reflecting a precarious existence.
Figure 2.5: Monthly flow in streams of the Cropper Creek Project compared to monthly flow in the local rivers.
Figure 2.6: A storm hydrograph from a major storm. This was the largest storm experienced during the period of the study.
Figure 2.7: Summer flow recession and low flow hydrology for a sustained low flow period in summer-autumn, and early winter.
Site Specific Studies

8: Influence of Riparian Vegetation
The riparian vegetation makes its presence felt in various ways:

- Evaporation from this induces a diurnal variation in the streamflow, reflecting the sensitivity of outflow from the catchment slopes to the paretic behaviour of the vegetation along the stream.
- It is believed by the author that the presence of the riparian vegetation, by transpiring, reduces the transmissivity of the aquifer near the stream. The result is that water is conserved deep within the catchment slopes. This is currently under study.

Figure 2.8 shows an example of the strong diurnal variation that can be experienced in summer months. This can be found in both large and small streams emanating from or flowing out of forested areas.

9: Road Hydrology
A comprehensive study measured the generation of overland flow from the road and associated batters and compared it with the generation of streamflow by rainfall on the natural catchment. The study found:

- The road provided a very responsive overland flow system, with the main determinant of the volume of road runoff produced being the amount of rainfall.
- The road produced slightly more runoff than expected on the basis of depth of rainfall and area alone. This suggests that the road also intercepted some downslope subsurface flow.
- The ratio of runoff produced by the road to runoff produced by the natural catchment diminished exponentially with storm size. Thus larger storms produced a greatly diminished ratio of road to natural stream flow runoff, reflecting that the natural catchment ability to shed stormflow greatly increases as the storm size increases. The conclusion is hence that the contributions of roads to runoff are much more apparent for smaller or medium storms than large storms.
- Although not formally studied, the road runoff had large volumes of sediment. This was deposited downslope from culverts but quickly became colonised and therefore stabilised by herbs and shrubs.

Figure 2.9 shows an example of a hydrograph generated from a section of a road. Figure 2.10 shows the ratio of road runoff to natural catchment storm runoff as a function of storm size. The diminishing relative response with storm size is clearly evident.
Figure 2.8: Example of the diurnal variation on Clem Creek.
Figure 2.9: An example of a road hydrograph generated from a section of road, and a comparison of this with the runoff from the natural catchment.
Figure 2.10: Ratio of road runoff to natural catchment storm runoff as a function of storm size.
10: **Loss of Nutrients in Smoke When Burning**

This is reported in Stewart and Flinn (1985). They found that the burning of the debris on the Clem Creek catchment consumed 50% of all the debris and significantly increased pH, organic carbon, extractable phosphorus and calcium in the 0-2 cm soil layer. Extractable phosphorus also increased in the 2-4 cm layer. The quantities of total nitrogen and phosphorus and exchangeable potassium, calcium, and magnesium in the surface 20 cm of soil were all estimated before and after burning. Losses of nutrients as a proportion of the quantities estimated in the soil were:

- 1.7% phosphorus
- 6.5% nitrogen
- 17.2% potassium,
- 19.9% magnesium, and
- 32.8% calcium.

11: **Water Quality: Comparison With Bottled Waters**

The water from Cropper Creek (both before and after clearing native vegetation) is very pure by any standard (typical concentrations of nutrients are perhaps half that of the composition of bottled “mountain spring water”). Table 2.1 below shows the concentration of nutrients in a bottled water sample compared to a typical concentration of water at Croppers Creek. A recent sample from Betsy Creek soon after it had resumed flowing as a result of heavy rainfall had a turbidity of 0.3; this is about as low as one can get for natural water and only slightly higher than one would often obtain for deionised water.

<table>
<thead>
<tr>
<th></th>
<th>Brand 1 “Mount Franklin” Mineral Water mg/L</th>
<th>Brand 2 “Aroona” Pure Spring Water mg/L</th>
<th>Croppers Creek Rainfall mg/L</th>
<th>Streamflow mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>20</td>
<td>4.0</td>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td>Sodium</td>
<td>14</td>
<td>2.30</td>
<td>0.20</td>
<td>1.6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>5</td>
<td>0.62</td>
<td>0.25</td>
<td>1.20</td>
</tr>
<tr>
<td>Calcium</td>
<td>3</td>
<td>0.30</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>2</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>1</td>
<td>0.80</td>
<td>0.20</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Some of the streamflow concentrations roughly correspond to what one would expect after evapotranspiration has concentrated rainfall.
Site Specific Studies

Flinn, Bren, and Hopmans (1979) concluded that this was an unpolluted environment producing extremely high quality water. The resumption of chemical sampling in 1997 produced similar results suggesting that this aspect of the environment of the area had not changed.

The quality of water emanating from the forested catchments of north-east Victoria can only be viewed as a great asset.

12: Changes in Eucalypt Hydrology Induced by Plantation Formation
The change of Clem Creek catchment cover from native eucalypt forest to radiata pine plantation induced the following changes in the catchment hydrology:

- Increased streamflow from the first few storms of each year after clearing. The data analysis suggested that this was because of wetter slopes as a result of reduced transpiration rather than as a consequence of more direct physical change on the catchment. Most of the increase came as an increase in storm flow, but the peaks for the major storms appeared relatively unchanged.
- Relatively little change in the nutrient export of the catchment viewed in terms of mass.
- A reduction in the concentration of nutrients in the flow emanating from the catchment.
- An increase in the propensity of small, hitherto dry gullies to flow because of the increased slope wetness.

Figure 11 shows the increase in water yield caused by the conversion. The changes dissipated after about four years. The recommencement of data collection in 1997 did not give very clear results about the effects 18 years after conversion because of the unusually poor winter and spring rains, but the treated catchment appeared to have a quite similar flow and nutrient behaviour to its untreated version, suggesting that the effects of the land use change from eucalypt forest to radiata pine on the hydrology were not great.

13: International Comparisons
Data from the Cropper Creek has been used in a number of international comparisons concerning storm response. The analyses have shown that the Clem Creek catchments can be viewed as reasonably representative of small catchments in humid environments. Thus the results can be viewed as being generally applicable to the north-east and other regions with similar environmental and physical conditions.
Table 2.2: Water yield of Ella Creek and the changes observed following conversion from eucalypt to pine in 1980.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall</th>
<th>Ella Creek Yield (ML ha⁻¹)</th>
<th>Treatment Increase (ML ha⁻¹)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>18.7</td>
<td>7.7</td>
<td></td>
<td>Part Year</td>
</tr>
<tr>
<td>1976</td>
<td>9.2</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>10.4</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>16.5</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>15.2</td>
<td>4.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>15.2</td>
<td>3.3</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>20.9</td>
<td>9.2</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>5.8</td>
<td>0.05</td>
<td>0.3</td>
<td>Drought</td>
</tr>
<tr>
<td>1983</td>
<td>16.2</td>
<td>4.4</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>13.8</td>
<td>3.6</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>13.3</td>
<td>2.1</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>18.2</td>
<td>6.7</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>7.0</td>
<td>1.3</td>
<td>0.8</td>
<td>Part Year</td>
</tr>
</tbody>
</table>

2.2 The Pine Creek Study

Although the area is outside the NE RFA its location on the northern slopes of the divide near Kilmore makes the study outcomes region generally applicable to the NE RFA area.

A report by Hydrotechnology 1995 describes the afforestation of 320 ha of grassland catchment between 1986 and 1988. Streamflow and salt load monitoring commenced in 1988 and data up to June 1993 were analysed for trends using rainfall and two nearby monitored streams as controls. These controls had stable land use conditions. In 1991 trends on streamflow change in the afforested catchment were detected with 1993 flows about 50% less than would be expected. Salt loads dropped from 0.45 tonnes/ha/year to 0.14 tonnes/ha/year. This study gives an indication of the effects of afforestation on streamflow and salinity outputs.
2.3 The East Kiewa Hydrologic Project

This summary is derived from Leitch (1979), Leitch (1981), Leitch (1982) and Papworth et al (1990). The East Kiewa Project was an ambitious and well-conducted attempt to measure the sediment load associated with logging of alpine ash in areas of the Kiewa Hydroelectric project. The genesis of the project was concern by the (then) State Electricity Commission that logging could lead to sediment deposition in the storages of the hydroelectric project area and the erosion of turbine blades from suspended sediment. The work was conducted by the (then) Forests Commission Victoria. The basis of the project was:

- A “control-treated catchment” (i.e. paired catchment) approach with two contiguous catchments of similar size and geology.
- Measurement of stream flow through broad crested weirs created by the modification of existing structures.
- Periodic sampling of stream sediment using automated sediment samplers. These were sent to laboratories in Melbourne for filtering and weighing of samples.

The study was conducted between 1978 and 1987 with a logging treatment commencing in 1982. The work does not appear to have received the attention and publication that it merited and there are no peer-reviewed papers on it. The reports on the project are vague on points such as water yield but overall the analysis appears meticulous and painstaking. Perhaps it could be said that the statistical methodology detailed in the reports takes precedence over the account of the catchment hydrology. The location of the project is shown in Figure 1.1. The major value of the project is the good data collected on sediment loads in a high-rainfall area (1,600-1,900 mm).

Methodology

A paired-catchment approach was used with the underlying assumption that adjacent areas respond in a similar manner. These were Slippery Rock Creek (136 ha) and Springs Creek (244 ha), with the Springs Creek catchment being subject to logging. Then, as now, considerable difficulty was experienced dealing with the data processing load.
Effects of Logging on Stream Sediment Levels

The report concludes that the logging of the alpine ash in the catchment did not affect the distribution of flow from the catchment. An examination of the recession coefficient the ratio of flow on day \( n + 1 \) to flow on day \( n \) in sustained periods of flow suggests that the logging treatment had not caused any change.

Water balances for the catchments are not given. However, from the tabulated values of rainfall, streamflow, and area statements the following water balances can be derived:

Table 2.3: Approximate water balance computed from raw data given in Papworth, Hartland and Lucas (1990).

<table>
<thead>
<tr>
<th>Period</th>
<th>Rainfall at Bogong Village</th>
<th>Runoff from Springs Creek</th>
<th>Runoff from Slippery Rock Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>7,043 mm</td>
<td>35%</td>
<td>52%</td>
</tr>
<tr>
<td>Post-treatment</td>
<td>9,792 mm</td>
<td>33%</td>
<td>46%</td>
</tr>
<tr>
<td>Overall</td>
<td>16,836 mm</td>
<td>34%</td>
<td>48%</td>
</tr>
<tr>
<td>Average Annual</td>
<td>1,711 mm</td>
<td>585 mm</td>
<td>825 mm</td>
</tr>
</tbody>
</table>

Thus the catchments are high-yielding by Australian standards (which, of course, reflects the choice of the locale for the Kiewa Hydroelectric scheme).

The summary concluded:

- The two streams had consistent relationships with one another.
- The magnitude of any flow increase associated with roading was small, but this could also reflect a relatively dry period.
- A small increase in stream flow may have been associated with the third period of experimental logging. Although this increase was small, it was statistically significant.
- The summary gave a very qualified finding concerning whether there was an increase in stream sediment due to the logging. Firstly there were many “transient” high sediment readings in the data during periods of otherwise low flow or low sediment readings. Secondly, it was felt that there were many inadequacies in the sampling of the sediment. Thirdly, it concluded that significant increases in sediment concentration were observed in all logging periods except roading (which was done during a drought period).
Prediction of Sedimentation Effects in Junction Dam and Clover Dam

From the preceding work “predictions” (calculations of the actual effect?) were made concerning the effects of logging on sediment levels in Junction Dam (Lake Guy) and Clover Dam - two storages associated with the East Kiewa Hydroelectric Project. The areas proposed to be logged were about 2,000 ha. In the computations some disquiet was expressed that field sediment sampling had not sampled enough storms (notwithstanding that the sampling intensity was substantial compared to most such work).

The report is based on data collected from the field study logging. Table 2.4 below summarises the results of these studies.

Table 2.4: Estimated sediment contribution from the experimental logging of alpine ash on Springs Catchment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area to be Logged, ha</th>
<th>Sediment Contribution</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>From Road tonnes</td>
<td>From Coupe tonnes</td>
</tr>
<tr>
<td>1982</td>
<td>0</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>15</td>
<td>20.8</td>
<td>15.0</td>
</tr>
<tr>
<td>1984</td>
<td>33</td>
<td>38.3</td>
<td>49.7</td>
</tr>
<tr>
<td>1985</td>
<td>25</td>
<td>24.3</td>
<td>40.2</td>
</tr>
<tr>
<td>1986</td>
<td>0</td>
<td>24.9</td>
<td>37.0</td>
</tr>
<tr>
<td>1987</td>
<td>0</td>
<td>9.8</td>
<td>8.0</td>
</tr>
</tbody>
</table>

It is hard to view the results objectively. Firstly there are considerable reservations about the numbers expressed. Thus, for instance:

- “Firstly the roading operation was done during a drought period (1982-83) so that the sediment yield for that period would be low. To account for the low results the roading effect was scaled up in proportion to total event flow.” This then implies that the actual contribution of sediment from the road was actually far less than given in the results, which is somewhat distorts the fact, although it is attempting to put it on the basis of an “average year.”

- The report makes it hard to separate whether it is reporting fact or providing a prediction.

The report provides estimates from the above results based on the logging of the 2,000 ha of alpine ash. Various sediment regimes are given and computations consider both logging over four and eight year periods. For simplicity we have abstracted computations for a four-year “medium” sediment generation regime and presented them in Table 2.5 below.
Table 2.5: A comparison of the contribution of logging (based on a “medium level” event) to the background contribution of sediment for the catchment above Junction Dam and Clover Dam. All figures are given in tonnes per annum.

<table>
<thead>
<tr>
<th></th>
<th>Logging Contribution</th>
<th>Background Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coupe</td>
<td>Road</td>
</tr>
<tr>
<td>Catchment above Junction Dam</td>
<td>1300</td>
<td>610</td>
</tr>
<tr>
<td>Catchment above Clover Dam</td>
<td>270</td>
<td>120</td>
</tr>
</tbody>
</table>

The report examined the sediment contribution from various logging regimes and finds that, using different types of computations, that the additional sediment which could be attributed to logging and roading ranged from 4% to 15%.

The reporting of the work is not very specific on detail and makes few general comments. It avoids making “value judgements” on the magnitude of the sediment problem associated with ash logging in the Kiewa Project area. However the rates of sediment movement and erosion quoted are low by most standards, reflecting that erosion in this environment is not a major problem.
2.4 The Lawrence Thesis

Lawrence (1990) in a PhD thesis examined the effects of land use and vegetation change on the hydrology of the Bogong High Plains Area. As part of her thesis she analysed rainfall and streamflow data to determine whether wildfire and logging in alpine ash stands of the East Kiewa and West Kiewa Rivers had a detectable effect on streamflows. She was not able to detect any long term impact of the 1926 and 1939 fires. This was probably due to the lack of pre fire data, the varying levels of fire intensity within the stands, and for the East Kiewa the confounding effects of construction activity. She was able to detect a 10% (11 mm) decline in monthly streamflow (mainly baseflow) when the 1926 - 1959 streamflow period and the 1960 - 1982 streamflow period for the West Kiewa River were analysed. During the 1960 - 1982 period some 28% of the alpine ash forest (14%) of the catchment area was logged and regenerated. The streamflow decline is approximately that predicted by Kuczera (1985).
Chapter 3: Issues of Water Yield

In this chapter the issue of the water yield of large and small catchments in north-eastern Victoria is discussed, and the “what if” impacts of development of plantations on water yields are considered.
3.1 **Introduction and General Comments**

The water yield of an area of land is the difference between precipitation (snow, rain, and perhaps other minor sources) and catchment loss (principally evaporation but perhaps some deep seepage to remote aquifers). The water yield is generally taken as the accumulated sum of daily streamflow. In any discussion of water yield issues there are a number of factors that should be borne in mind:

1: The water yield of a catchment is variable from day to day, and usually has a strong seasonal component. In north-east Victoria the streamflow is usually at a maximum in late winter and spring but can be quite low at other times.

2: The water yield of catchments varies markedly from year to year, and there is limited evidence that there are longer term effects are also present. In particular periodic sequences of water yield of larger rivers may show a “Hurst Effect” (also called a Noah and Joseph Effect) of runs of higher annual yields followed by runs of lower annual yields. Thus, short runs of data can create a false impression of the long-term average. This is a particular reservation on acceptance of anecdotal evidence of the type ...“When I was young this stream always flowed...”

3: The water yield of a catchment is influenced by the vegetation along the stream or in close proximity to the stream, and to a lesser extent by vegetation further away from the stream. This effect has proven difficult to quantify, and is a current field of research.

4: The water yields of catchments can be misleading at low flows because much of the outflow will be through either alluvial channels associated with the stream bed or through groundwater aquifers. Thus in north-east Victoria in summer and autumn many streams and rivers will usually appear to “dry up” although digging may yield subterranean flows.

5: Measurements of streamflow in large streams and rivers using regular hydrographic stations tend to have large errors and this makes it difficult to use such regular measurements to assess relatively small effects due to vegetation changes unless the changes are widespread and significant (such as the changes associated with the fires and forest harvesting as reported by Lawrence 1990).

6: For larger catchments, the assessment of changes due to vegetation is usually rendered impossible by the cumulative effects of many small changes acting at different rates and with differing characteristics. Thus there may be five logging coupes in a year but also a network of older coupes of differing ages and species, new roads being added and old roads being rehabilitated, areas moving into and out of different farming practices, towns developing, and many competing users of water. The net effect is a complex stormflow hydrograph which can be difficult to interpret. Similarly, although a given forest type may have a relatively characteristic age-yield curve, it is unlikely that users on a large stream would notice any change in flow over time unless:
Water Yield Issues

• A large proportion of the catchment was forested with this particular species as the dominant tree cover, and
• The forest was all more or less the same age.

More usually the intermixing of different age classes and the diversity of vegetation in the area mean that any characteristic age-yield “signature” is not discernible in the stream flow.

3.2 Water Yield of Ash Type Forests

Jayasuriya et al (1993) review the interaction between forest stand condition and water yield in the ash type forests (Mountain Ash and Alpine Ash) of the Melbourne water supply catchments. The structure and age of ash type forests can be changed by unplanned events such as wildfire or planned events such as timber harvesting and regeneration actions. A program of research conducted over the past 30 years in the ash type forests of the Melbourne water supply catchments has shown that the conversion at the one time of a older ash type forest to a well-stocked regrowth condition causes a reduction in streamflow which reaches a maximum of 50% about 30 years after the conversion episode (Kuczera, 1985). Water yield can then be expected to recover over the next 70 years.

Figure 3.1 depicts the relationship between water yield and stand age in an ash type forest.

On a regional basis for the Victorian Central Highlands this represents a decline in water yield of 6 mm for every one percent of ash type catchment converted to a regrowth condition. The same effect may occur if mature stands of the wetter mixed species forests are converted to a regrowth condition as a result of forest harvesting and regeneration operations. Multi aged stands would show a much reduced impact but there is at the moment no available experimental data.

It is postulated that these water yield changes in the ash type forests are due to the reduction with time of the percentage of the stand leaf area held in the crowns of the eucalypt canopy and the shade cloth effect caused by the remaining eucalypt leaf area reducing radiation and wind received by the understory.

A silvicultural thinning of mountain ash stands of about 40 years of age has been found to increase streamflow by about 25% with the effect being detectable for about 15 years. Vertessy et al (1998) in an excellent industry report describe recent detailed process research which confirms the original research and explains in more detail the physical processes involved.

The Kuczera model was based on streamflows from both alpine ash and mountain ash covered catchments and to the extent that the ash forests of the NE RFA have similar fire response characteristics, soil type, and climate it can be expected that similar relationships should exist between stand condition and streamflow.
Ash type stands (mainly alpine ash) occupy substantial areas of the NE catchments as shown in Table 3.1.

Table 3.1: Ash Type Forest Cover in the NE RFA Catchments

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Total (ha)</th>
<th>% of Catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Murray</td>
<td>53,700</td>
<td>7.7</td>
</tr>
<tr>
<td>Kiewa</td>
<td>14,800</td>
<td>7.5</td>
</tr>
<tr>
<td>Ovens</td>
<td>18,600</td>
<td>2.4</td>
</tr>
<tr>
<td>Broken</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Goulburn *</td>
<td>127,000</td>
<td>7.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>214,000</td>
<td>5%</td>
</tr>
</tbody>
</table>

* Source D.W.R 1989

* Note This figure includes the total Goulburn catchment and has not been adjusted for the RFA area.

Assuming that the ash type forest of the NE RFA displays the same regional age/streamflow pattern as that found by Kuczera in the Central Highlands and setting a maximum conservative yield of 10 ML/ha/annum the long term average water yield of the 214,000 ha of the ash type forest could vary from 1,070 GL to 2,140 GL per annum depending on stand age. In reality the ash type forest comprises a mosaic of age classes and current yield will be between these extreme ranges. However the variation of about 1000 GL/annum is important given the problems associated with ensuring that Victoria does not, in the long term, exceed its 1620 GL cap on consumption of Murray/Darling water.
The forest management outcomes are twofold.

1) Fire Protection
   As severe wildfire in ash type forests can cause the death and regeneration of older stands with consequent long term declines in water yield, this factor reinforces the need for effective fire prevention, detection and suppression.

2) Water Yield Management
   In order to examine on a notional basis the gains in water yield which could be obtained by specific forms of silvicultural management a rotation age of 150 years has been selected from a number of strategies which could include early forest thinning.
Figure 3.1: The regional stand age/water yield relationship for an ash type forest. (After Kuczera, 1985)
Table 3.2 is a table from the draft CRA summary report which describes the hardwood resources.

Table 3.2: Net productive area (Ha) for commercial forest types in the North East Region.

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Benalla/Mansfield FMA</th>
<th>Wangaratta FMA</th>
<th>Wodonga FMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/OM Regrowth Unstocked</td>
<td>M/OM Regrowth Unstocked</td>
<td>M/OM Regrowth Unstocked</td>
</tr>
<tr>
<td>Alpine Ash</td>
<td>250 7.575</td>
<td>1,136 5.397</td>
<td>11,336 13,837 31</td>
</tr>
<tr>
<td>Mountain Ash &amp; Shining Gum</td>
<td>14 276</td>
<td></td>
<td>20,626 796</td>
</tr>
<tr>
<td>Mountain &amp; Alpine Mixed Species</td>
<td>928</td>
<td>20,435 621</td>
<td>10,167 60 37</td>
</tr>
<tr>
<td>Foothill Mixed Species</td>
<td>22,294 4,186 6</td>
<td>21,571 6,018</td>
<td>42,129 14,693 68</td>
</tr>
<tr>
<td>Total Areas</td>
<td>120,008 12,037 6</td>
<td>21,571 6,018</td>
<td>42,129 14,693 68</td>
</tr>
</tbody>
</table>

Source: DNRE Hardwood Area Resource Information System

It shows that some 39,000 ha of alpine ash is currently available for timber production. The bulk of the forest is in a regrowth condition dating mainly from logging commencing in the 1930s but peaking in the 1970s and early 1980s. There is also a regrowth component from the 1939 fires. The total regrowth forest area is some 27,000 ha.

The forest could have an estimated area weighted age of about 30 years. In terms of water yield most of the forest is in a recovery phase and assuming no further logging the expected water yield increase over the next 70 years could be about 5 ML/ha amounting in total to some 135,000 ML or 135 GL.

If it is assumed that the whole 39,000 ha is managed in perpetuity on a sustainable rotation basis a rough estimate can be made of the differences in long term average annual water yields caused by varying rotation ages using Table 3.3 following which is reproduced from O’Shaughnessy et al (1987).
Table 3.3: Streamflow yields, ML/ha/annum for ash type forest by age and for varying rotation lengths.

<table>
<thead>
<tr>
<th>Forest Age. Or Rotation Length</th>
<th>Yield with Forest Age for an Even Aged Forest</th>
<th>Yield from Varying Rotation Lengths (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>11.95</td>
<td>11.95</td>
</tr>
<tr>
<td>10</td>
<td>8.12</td>
<td>10.43</td>
</tr>
<tr>
<td>20</td>
<td>6.13</td>
<td>8.74</td>
</tr>
<tr>
<td>30</td>
<td>5.83</td>
<td>7.79</td>
</tr>
<tr>
<td>40</td>
<td>6.33</td>
<td>7.35</td>
</tr>
<tr>
<td>50</td>
<td>7.15</td>
<td>7.21</td>
</tr>
<tr>
<td>60</td>
<td>8.03</td>
<td>7.27</td>
</tr>
<tr>
<td>70</td>
<td>8.85</td>
<td>7.43</td>
</tr>
<tr>
<td>80</td>
<td>9.54</td>
<td>7.65</td>
</tr>
<tr>
<td>90</td>
<td>10.11</td>
<td>7.89</td>
</tr>
<tr>
<td>100</td>
<td>10.67</td>
<td>8.13</td>
</tr>
<tr>
<td>110</td>
<td>10.92</td>
<td>8.37</td>
</tr>
<tr>
<td>120</td>
<td>11.19</td>
<td>8.59</td>
</tr>
<tr>
<td>130</td>
<td>11.39</td>
<td>8.80</td>
</tr>
<tr>
<td>140</td>
<td>11.54</td>
<td>8.89</td>
</tr>
<tr>
<td>150</td>
<td>11.66</td>
<td>9.16</td>
</tr>
<tr>
<td>160</td>
<td>11.74</td>
<td>9.32</td>
</tr>
<tr>
<td>170</td>
<td>11.80</td>
<td>9.42</td>
</tr>
<tr>
<td>180</td>
<td>11.84</td>
<td>9.60</td>
</tr>
<tr>
<td>190</td>
<td>11.87</td>
<td>9.72</td>
</tr>
<tr>
<td>200</td>
<td>11.90</td>
<td>9.82</td>
</tr>
</tbody>
</table>

(Derived from Kuczera, 1985)

(*) These yields are derived from the age/yield relationship, assuming that a forest stand managed on a stable rotation length is comprised of the same number of equal areas as the rotation length, varying in number from one to the nominated rotation length.
Using the table long term average annual water yields for a 80 year rotation length can be compared with those from a 150 year rotation length. As a conservative measure yields have been adjusted for an 10 ML/annum maximum yield from alpine ash compared to 12 ML/annum for a mountain ash. When the nominal rotations were in place for the 150 year rotation there would be an increased water yield of 1.3 ML/ha/annum compared to an 80 year rotation. Applied to the 39,000 ha of available ash forest the difference is approximately 51,000 ML/annum or 51 GL. The increase for the major river systems in the RFA would be proportional to the available ash area in each system. This 51 GL is 3% of the Victorian water cap or less than 1% of the long term average streamflow of the NE RFA region.

While the volumes are important, the changes in annual flows would not be detectable at the catchment outlets due to the length of time required to obtain the increase, climatic variability and the limitations in accurately gauging stream volumes. There is also the risk that wildfire could disrupt such long term planning.

### 3.3 Water Yield of Mixed Species Forests

This is a far less explored area than the ash type forests, reflecting that much of the classical work for the ash type species was undertaken to provide information on the Melbourne Water Catchments.

The major difficulty in exploring the water yield of mixed species forests is that the forests of north-eastern Victoria tend to be uneven aged forests, with trees of differing size and age intermingled in a complex of patches. This reflects past selection logging, deaths and regeneration due to past fires and other factors. Thus, it becomes difficult to ascribe ages to the forest. Given this, the water yield of such forests becomes a function of the type of forest and the characteristics of the individual year.

Nandakumar and Mein (1993) reported that for eight catchments located in mixed species for a period when average annual rainfall was 1,250 mm average streamflows were 165 mm (1.65 ML/ha). Bren (see Chapter 2) found using Cropper Creek data (which has a mixed species forest cover) states that for the same rainfall a water yield of 275 mm (2.75 ML/ha) could be expected. Cornish (1989) predicts the same annual water yield. This variation in prediction could be due to problems in defining exact catchment boundaries and a certain capture of streamflow, variation in altitudinal location and for the same annual rainfall the increased runoff response to a few large storm events compared to many small storm events.

Langford and Kuczera in modelling catchment yields before and after wildfire on the central highlands were able to assume stable long term annual yields from the mixed species forest of 200 mm (2.0 ML/ha). This stability is probably due to the manner in which mixed species forests recover from wildfire. Usually most of the original stand survives and replaces its leaf area within say five years. Where a mixed species stand is clear felled and regenerated a modified ash type response may occur.
A number of research projects being undertaken by the CRC for Catchment Hydrology are addressing the issue of water use of mixed species forest. The research includes measurements of water use of individual trees of varying ages on an hour to hour basis using heat pulse techniques. These process studies indicate that a stand age/water use relationship may apply in silvertop ash forest.

Projects such as Croppers Creek also provide information on the water balance of catchments, but the problem of seepage loss associated with deep seepage, variations in rainfall across the catchment, and changes in deep soil moisture storage always results in a large but unknown error.

### 3.4 The Water Yield Implications of Converting Pasture to Plantation

As part of the RFA investigatory process the likely potential for plantation establishment on privately held cleared land has been investigated and is reported elsewhere in a NE RFA issues report (Wareing and Baker, 1998).

Firstly an investigation was undertaken of the area of suitable land in terms of productivity and slope class. Secondly calculations were then made of the net present value of production using a discount rate of 7%. This process used current market prices for the range of products and took into account harvesting and transport costs. Over a $1 \times 10^6$ ha of land was found to be suitable for hardwood plantation on slopes of less than 20° and on a similar basis about 900,000 ha of land was found to be suitable for softwood plantation.

As would be expected there was a large degree of overlap in location. However, when subjected to economic analysis the picture changed considerably. Assuming that a minimum of $1,500/ha NPV was needed to make land purchase economic only 10,000 ha of land located in the south-west of the RFA region near Seymour had an economic potential for the production of hardwood pulp quality material. This was largely influenced by the impact of transport costs on raw material of chipwood quality. This analysis does not allow for cases where the landholder might lease the land at a lesser land value charge, or allow for non-costed benefits such as salinity control, shade and aesthetic amenity. It also does not consider the production of sawlog for specialised end uses.

The economic analysis for softwood sawlog and pulp log production showed that about 290,000 ha of land could be both capable and economically viable for softwood plantation. Some of the best prospects were considered to be located on the extreme east of the RFA region where land prices are relatively low, various locations near Myrtleford and areas in and around the Strathbogie ranges south-west of Benalla.

As an aid to understanding the water yield implications of converting pasture to forest the water yield effects of three conversion scenarios were evaluated.

---

Vertessy, R. Pers Comm 1998
Water Yield Issues

1) An increase from the current softwood area of 50,000 ha to 75,000 (50%).

2) An increase from the current area to 150,000 ha (200%).

3) An increase from the current area to 200,000 ha (300%).

Cornish (1989) has investigated the likely effects of the conversion of rainfed pasture to a closed canopy softwood plantation.

Figure 3.2 is reproduced from Figure 4 of Cornish (1989). Based on a review of the world wide literature it shows that long term streamflow declines ranging from 100 mm (or 1 ML/ha) to approximately 400 mm (or 4 ML/ha) can be expected depending on average annual rainfall when pasture is converted to pine plantations. These differences are due to the higher interception or evaporation characteristics of the pine canopy and compared to pasture, the year long exploitation by the pines of soil and sub-soil moisture. For any one patch of pine the amount of evapotranspiration depends on the age and density of the stand. When the preferred locations for softwood plantation expansion are examined in terms of regional rainfall patterns it appears that average annual rainfall would be about 1000 mm/annum. Examination of figure 3.2 indicates that water yield declines of about 200 mm/annum 1 ha (2 ML/ha) could be expected. For hardwood plantation the declines would be about 180 mm/annum (1.8 ML/ha). This decline is less than that for softwood due to the lower canopy interception of hardwood foliage.

In terms of regional streamflow volumes for scenario 1 the possible declines amount to 50,000 ML/annum, (50 GL) for scenario 2, 200,000 ML/annum (200 GL) and for scenario 3, 300,000 ML/annum (300 GL). If scenario 1 were applied to a hardwood plantation the yield decline would be about 45,000 ML/annum. These volumes are important in relation to the Victorian cap of 1,620 GL/annum. These streamflow declines in particular those for scenarios 2 and 3 could have intra-regional implications for local streams and could be regarded by some as reducing the amount of the Cap available to irrigators. However, it should be noted that these declines would be gradual and take place over the period required for establishment, possibly 20 to 40 years.

These potential streamflow declines also raise the issue of the derivation of the “Cap”. System modellers predict Murray Darling flows from historic rainfall and runoff data. Changes in runoff due to the installation of dams and/or increases in evapotranspiration due to land cover change could require a new determination of system water yields and consequently a change in the Cap.

An evaluation of the costs of streamflow declines would need to take into account the benefits in some areas of potential water table declines and reductions in erosion as well as the economic benefits of wood production compared to the previous agricultural land use.
Figure 3.2: Suggested relationships between water yield decreases and mean annual precipitation for the complete afforestation of eucalypt and pasture by pine. Evapotranspiration differences between pasture and eucalypt for particular values of annual precipitation are given by the vertical difference ‘B’. (After Cornish, 1989)
Chapter 4: Water Quality Issues in North-East Victoria

This chapter examines the inter-related aspects of water quality and forestry in north-east Victoria, and looks at the potential effects of broadscale forestry on water quality.
4.1 Some General Comments on Water Quality and Stream Biota

The water quality of streams arising and flowing in undisturbed forested catchments is generally excellent due to their low levels of nutrients, dissolved solids and suspended solids. In undisturbed catchments these levels can rise due to events such as high rainfall, wildfire and landslips which at times can act synergistically. However, the impacts on water quality are normally of short duration. For water supply systems and consumers there are benefits from excellent water quality in terms of low reservoir siltation and high quality water which requires minimal treatment. Within the North East Regional Forest Agreement Area the upper reaches of the main streams are generally suitable for domestic use with minimal treatment only (Water Resources Victoria, 1989). However, as the streams enter and flow through the lower farmlands water quality deteriorates and more extensive water treatment such as flocculation and filtration is needed.

The following brief review examines some selected impacts of water quality on stream biota in order to provide a background to the discussion of water quality issues.

The relationship between water quality and stream biota has been and is the subject of increasing research. Metzeling et al (1995) provide an extensive review of the effects of salinity and sediment on aquatic ecosystems and this review provides the basis for most of the following discussion. They show that increasing salinity levels can adversely affect fish, macrophytes and invertebrates. A better understanding is needed on the sub-lethal affects of salinity on fish. Fresh water macrophytes can show delayed adverse reactions to salinity changes as little as 1 gram/l. Some laboratory studies have shown increased mortality among invertebrates when salinity levels rose by 1.2 to 2.4 gram/l. However, recent studies in Australian rivers have shown that the more common invertebrates can tolerate a wide range of salinity levels with total abundance remaining largely unaffected. However, diversity is reduced due to the absence of rarer taxa which appear to be more sensitive to high salinity levels.

The potential impacts of increased sediment levels are important. Sediment in streams can be present in a suspended form, settled on the stream bed or incorporated into the stream bed matrix. Most Australian mammals which use the stream habitat including the platypus are not directly affected by suspended solids concentrations but are indirectly affected where increased concentrations reduce the availability of food species. Amphibians such as frogs are affected when egg survival is reduced due to the smothering effects of sediment reducing oxygen exchange. Tadpoles may be adversely affected due to sediment affecting gill function.

Department of Water Resources Victoria (1989) shows that the forest streams of the NE RFA region support populations of native fish species, e.g. Australian Smelt, Macquarie Perch, Blackfish, Mountain Galaxias and Southern Pigmy Perch. Of these Blackfish and Macquarie Perch are of conservation concern. Most fish, both introduced and native, can be greatly affected by turbidity with observed symptoms being increased mortality, reduced stress and site displacement. Gill clogging by sediment and reduction in feeding capability for visual predators have been observed. Recent research has shown that impacts on stream biota of elevated levels of suspended solids is a function of concentration and the period of increased suspended solids levels. Deposited silt has been shown to greatly affect habitat by smothering the substrate and filling pools and scour holes. These effects reduce shelter, fill egg deposition sites, destroying rearing areas for juvenile fish and smother already laid eggs which may then
Water Quality Issues

cease development. Sudden and sustained increase in sediment levels caused for example by a failure in road drainage infrastructure can greatly reduce populations of native fish such as black fish. Thirteen Victorian fish species lay their eggs on or in the streambed, six of these species have a vulnerable potentially threatened status. When silt inputs cease fish numbers can increase depending on the rate of removal of settled and entrained sediment.

Macrophytic plants are also affected by sediment inputs due to smothering and the reduction of light intensity. This can occur at quite low levels of increase. Reduction in macrophyte density can in turn affect the population of those fish and invertebrates which feed on stream macrophytes.

Macro invertebrates in the larval stage have been shown to be affected by changes in suspended and settled sediment in terms of feeding and shelter. Metzeling et al (1995) list 45 species or genera which have been shown to be affected by sedimentation. Most of these studies relate to dam construction impacts which generally have far greater impact on stream sediment inputs than forestry operations. However, at least local effects could be expected from bad practice, during for example road building. What stands out from the research is the severe impact of long term declines in water quality.

4.2 Nutrient and Blue-Green Algae Issues

Concern about nutrient effects on inland waterways leading to algal blooms (and particularly blue-green blooms) has focused attention on the assumed nutrient effects of forest management. Thus, for instance the pamphlet accompanying the March 1995 release of the “Nutrient Management Strategy for Victorian Inland Waters” lists “runoff from forestry activities” as a major source of nutrients, rubbing shoulders with wastewater treatment plants, urban runoff, irrigation drainage, intensive animal industries, and agricultural runoff. The following sections discuss these matters in more detail.
4.3 Fighting About Nutrients: An Example of Dispute

The Goulburn-Broken Catchment

The NE RFA region includes all of the Lake Nillahcootie catchment and part of the Lake Eildon catchment. A large range of land uses is encompassed ranging from conservation, national park management, ski field management, pasture, cropping, fruit growing, commercial hardwood forestry and commercial softwood forestry. The area is an important tourist destination. Thus, for instance “Discover Victoria” has published an elaborate give-away brochure on the “Goulburn Murray Waters”, with superlatives (“magnificent”, “untouched”, “unsurpassed”, ….). This reflects the importance of the area as a tourist destination, with many businesses and towns relying on this expenditure. Water harvesting is a major concern, with the water being used for urban supplies (Melbourne, major regional towns), and irrigation supplies in the Shepparton Irrigation Area.

In 1995 the “Goulburn Broken Water Quality Working Group” published a report entitled “Dryland Diffuse Source Nutrients for the Goulburn Broken Catchment” This report concluded (amongst other things) that:

- The major diffuse source of nutrients is from upland areas where erosion rates are higher and adsorbed phosphorous is transported by soil erosion.
- Activities in some forested and upper catchment areas generate nutrient loads that are greater than for mid to lower catchment loads. Forestry activities such as roading and harvesting were blamed as contributing some 90% of the total phosphorus load from the dry land areas.
- Erosion from forest tracks and streams was implicated as significant sources of phosphorous from upper forested catchments.

The report continued to make conclusions concerning reductions in sediment load by restricting erosion from forest roads. This caused something of a furore amongst personnel involved in forestry who demanded evidence for these claims. The common (but telling) observation that streams emerging from forest land tend to be of much higher quality than streams emerging from farmland was used, and considerable anecdotal information concerning stream pollution in farmland was produced. There was considerable criticism of the report being based on unjustifiable figures. Thus, for instance “forestry” was assumed to have a phosphorous generation rate of 0.15 kg ha\(^{-1}\) year\(^{-1}\) compared to 0.1 for cropping , 0.02 for pasture, or 0.2 for irrigation. The adequacy of these figures was the subject of considerable critical comment. Given that the amount of land devoted to “forestry” was cited as 611,000 ha compared to 1,500 ha, 109,000 ha, and 1,500 ha for the agricultural activities the report concluded that “forestry” contributed some 90% of the phosphorus load. Critics of the report viewed such computations as being lenient on agricultural pursuits and hard on “forestry.” A further point of contention was the definition of the word “forestry” as used it appears to include forested land containing vehicular tracks. Much of this is in various forms of reserves.

Since the publication of the 1995 document further investigations were undertaken using a wider range of nutrient and streamflow data along with a revision of the area allocated to each land use. A revised report was published. (Goulburn Broken Water Quality Working Group (1996)) and several significant changes were made. Forest phosphorus production rates were revised from 0.15 kg per ha per year to 0.02 - 0.06 kg per ha per year. Irrigation phosphorus production rates went from 0.2 kg per ha per year to 1.0 kg per ha per year in
Water Quality Issues

the mid lower catchment. Forests phosphorous loads from about 600,000 ha of forest fell from 90% of the total catchment phosphorous production to 25% while for 12,000 ha of irrigated land the percentage of the total catchment phosphorous load was 8%. The revised report decided that measures to prevent stream bank and bank erosion should be a priority, that further investigation was needed into forest roads and tracks as a source of stream phosphorus and that the forest harvesting contribution should be minor if forest operations are undertaken according to an approved Code of Forest Practice.

Although it is easy to be critical of such reports as the 1995 report, the conflict highlighted a number of aspects:

1: The desire of land use managers to have accurate data on such indicators of sustainability.

2: The difficulty of finding applicable data.

3: The dubious nature of many of the assumptions that must be made, and

4: The need for careful definitions and data stratification. Thus, for instance, in the above the confusion between forested land on one hand and “forestry” on the other is not helpful to informed debate.

However, as water quality data collection and analysis systems are improved and as the Victorian Catchment Management Authorities become established it can be expected that the knowledge base relating to nutrient production and control will continue to improve.

4.4 The Tarago River Work

Although not in the study area, the Tarago River Project currently being completed by the CRC for Catchment Hydrology does address some of the questions raised in Section 4.3. With some restrictions the results can be viewed as being applicable to the mountainous regions of north-eastern Victoria.

The Tarago Catchment flows out of an upland region near Neerim South (Victoria). The river passes into a large reservoir which can be and is sometimes used for supplying metropolitan Melbourne. The major land use in the area is commercial forestry and agriculture. The major aims of the project were:

1: To assess the major sources of sediment and associated pollutants to the Tarago River.
2: To assess the performance of grass buffer strips and near-natural riparian vegetation for controlling the supply of sediment to the reservoir.

3: To assess the resource impacts of using buffer zones as a water quality control measure.

Subsidiary to these aims were the following questions:
- Where are catchment measures best targeted?
- How important is sediment delivery from road surfaces in the overall sediment and nutrient balances?
- How important is sediment delivery from stock tracks?

The results have been assembled in the volume “Controlling sediment and nutrient movement within Catchments” (Industry Report 97/9, October 1997) by the CRC for Catchment Hydrology. In particular the results found:
- The East Tarago River (draining predominantly agricultural land) had more frequent, elevated levels of turbidity, manganese, phosphorus, and nitrate.
- Much of the pollution was associated with surface runoff processes, which in turn are associated with compacted areas such as cattle tracks.
- An important mechanism for the transport of phosphorus was attachment to sediments.

It was also discovered that much of this was a consequence of the dominance of granite rock in the forestry areas and of sedimentary rocks (and clays) in the agricultural areas. The water quality differences are partly due to the fine nature of the sediments in the Tarago River East Branch compared to the West Branch and also partly due to land use practices in the East Branch, such as cattle grazing, which more directly affects the water body.

4.5 Local Perceptions

Discussions with senior staff of the North East and Goulburn Broken Catchment Management Authorities indicate that water quality issues relating to private land were their major concern. These issues relate to nutrient inputs, increasing turbidity levels and increasing salinity. They see the native forest areas as in general producing high quality water. Their major concern is that the Code of Forest Practice and other prescriptions are applied with enough rigour to ensure protection of the water resource. However not all residents share this view and there was also a perception that more intensive harvesting, roading and site preparation practices within pine plantations could be resulting in water quality problems.

The draft Ovens Basin Water Quality Strategy (1997) gives a perspective on land use and nitrogen and phosphorous inputs. Table 6 provides some comparative data.
Table 4: A comparative statement of land use and estimated N and P loads in the Ovens Basin

<table>
<thead>
<tr>
<th>Land Use</th>
<th>% of Catchment</th>
<th>% of P Load</th>
<th>% of N Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forested Public Land</td>
<td>48.0</td>
<td>8.4</td>
<td>9.6</td>
</tr>
<tr>
<td>Pine Plantation</td>
<td>3.5</td>
<td>4.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Irrigated Pasture</td>
<td>0.3</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Dryland Pasture</td>
<td>58.8</td>
<td>33.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Annual Horticulture</td>
<td>0.4</td>
<td>8.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Urban Stormwater</td>
<td>-</td>
<td>7.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Sewerage Treatment Plants</td>
<td>11.6</td>
<td>5.3</td>
<td></td>
</tr>
</tbody>
</table>


This table shows the greater effects of intensive land use and human settlement on nutrient loads compared to the effects of less intensive land uses such as those in native forests and plantations.

The following statement for Public Land and Forest Use is taken from the draft Water Quality Strategy 1997. It depicts the view of the water quality working group which has wide community representation.

7.5 FOREST INDUSTRIES AND PUBLIC LAND PROGRAM

A large portion of the Ovens Basin is forested, either with native forest or pine plantation. Although the nutrient and sediment loads coming from forested land are generally low compared to those from cleared land, there are situations where excessive water quality impacts can arise. These impacts are typically associated with roading and with logging activity. Major fires can also result in significant nutrient and sediment mobilisation.

Approximately half the 400,000 hectares of public land in the Ovens Basin is reserved for conservation purposes (as National park, State Park, Reference Area, or other Reserves). The other half is currently available for timber harvesting (as reserved Forest or Uncommitted crown Land). However, most of this available area is either not productive forest, has been previously logged, or is not considered commercially viable for harvesting. It is expected that timber harvesting within the Ovens Basin, over the 30 year planning horizon of this Strategy, will be restricted to a limited area of higher production forest (David Buntine, DNRE Forests, pers. com.).

The Code of Forest Practice, which has been recently revised (DNRE, 1996), defines the minimum standards required of forestry management practices, on both public and private land. For example, the Code defines the requirements for timber harvesting practices, roading design and construction, stream and drainage line crossings, and wet weather restrictions, necessary to protect water quality. Requirements to maintain buffer strips and filter strips along streams and drainage lines are defined precisely. In State Forest and the Victorian Plantations Corporation plantations, the Code of Forest practices is extended by local prescriptions. A range of other departmental policies (eg. The Code of Fire Practice) addresses potential water quality issues on Public Land.
Since the Code of Forest Practice only applies to commercial forestry activity, management of water quality impacts on most of the public land in the Ovens Basin not regulated by the Code. There is a considerable need for works beyond those required by the Code, particularly for remodelling of old eroding sections of roading and stabilisation of some actively eroding gullies. A recent review of the roading network in the State Forests of the North East has highlighted the need to upgrade much of the road network to Code standard.

Most of the timber plantation area in the Ovens Basin is managed by the Victorian Plantations Corporation, although there are some private plantations and considerable potential for future expansion. Approximately one third of the 20,200 hectare area of VPC pine plantations in the Ovens Basin is located on steep land, where, once disturbed, the potential for erosion exists. The risk is greatest between rotations, following harvesting, and before the establishment of ground cover or the new tree crop. Heavy rain during these periods could produce mobilisation of sediment and nutrients. Best Management Practices, many of which are currently being practiced, are recommended.

Roads are recognised as being a major source of sediment and nutrient loads in forest areas. In particular, the intensive roading networks established within the pine plantations and in hardwood logging areas lead to potential water quality impacts. There is a need for all forest roads to be constructed and maintained in accordance with the Code of Forest Practices.

There is also a need in the pine plantations for roading and gully stabilisation works, additional to Code requirements, to address problems arising from past activity. Buffer and filter strips have been found to be highly efficient at intercepting sediment and nutrients generated by forestry activity. Much of the plantation area in the Ovens Basin was originally established prior to the Code’s requirements for retention of buffer strips along creeks and drainage lines. Although not required under the Code, there is an argument for the establishment of buffer strips in the plantations at the next rotation, where appropriate.

Although more expensive than conventional harvesting techniques, cable harvesting can significantly reduce water quality impacts by avoiding the need for intensive roading and machine activity on steep slopes. Although not required under the code, cable harvesting is now routinely used by the VPC for harvesting operations on steep (ie. greater than 20°) slopes.”

4.6 Forest Roading and Water Quality

It has long been recognised that the deleterious effects on water quality which can occur following forest roading and harvesting operations are largely due to road construction and maintenance practices. This statement is supported up by recent literature reviews (e.g. Smith and O’Shaughnessy 1996 and Dargavel et al 1995). For example Grayson et al (1993) found that unsurfaced roads can generate between 55 to 76 tons of sediment per ha per annum of which about one-third is coarse sediment and two-thirds is suspended sediment. As shown in Section 4.1 of this report the continuous entry of continuous sediment and suspended solids into a stream can result in long term changes in biodiversity and biomass. Smith and O’Shaughnessy found that, for the Central Highlands, sediment leaving roads from culvert and drain outlets tends to form channels which on average can be about 20 m long with 20% of the channels being over 40 m long. When such channels flow directly into streams the potential for water quality degrade is at its highest. Smith and O’Saughnessy make a number of practical recommendations aimed at reducing sediment production from roads and reducing stream sediment input. These include cross drains across roads either side of stream crossings, the diversion of drain outflows away from streams, and the use of slash and logs to
Water Quality Issues

dissipate sediment laden flows and provide sediment deposition locations. O’Shaughnessy (1996) in a report on the protection of spotted tree frog habitat in catchments within the NE RFA area found that in some locations poorly drained fire trails and roads constructed for timber harvesting (prior to the adoption of the Code of Forest Practice) required urgent maintenance.

The North East Regional Catchment Strategy (1997) called for more information on roading and water quality effects particularly in regard to older roads and tracks. It stated that old roads and tracks are currently falling into disrepair and need upgrading.

The Goulburn Broken Catchment and Land Protection Board Strategy program (1997) entitled “How we will get there” notes in Section 3.4.3. that “roads and timber harvesting in public lands have the potential to generate significant sediment loads. Best management practices have been developed and documented in the Code of Forest Practice.”

It is understood that a road and stream crossing condition survey is currently in hand to allow the Forests Service to develop an estimate of the funds needed to rehabilitate roads and allocate priorities. In the author’s view the adequate rehabilitation and maintenance of road and tracks (with priority being the prevention of road drainage directly entering streams) is a major issue. It is recognised that decisions about total road closure have to balance the costs of maintenance with the need for fire protection access and recreational access.
4.7 Timber Harvesting And Its Effects

Given the sound application of Codes of Practice and associated prescriptions to harvesting operations, (for example, the Code of Forest Practices for Timber Production (1996) and the Management Prescriptions for Harvesting and Regeneration in Native Forests Benalla/Mansfield and North East Forest Management Areas (1997)), research has shown (e.g. Grayson et al 1993), that when roads are excluded from catchments the effects of forest harvesting on water quality can be barely detectable.

In 1997 an “Erosion in Forests” workshop was held at Bermagui by the Cooperative Research Centre for Catchment Hydrology. Relevant findings from summary papers presented at the workshop were:

- Soils are most vulnerable to erosion after harvesting and burning with runoff and erosion increasing with harvesting disturbance.
- Snig tracks are the major source of sediment.
- Most eroded material is redeposited within the harvested area or buffer strips.
- As regrowth occurs and litter is deposited, disturbed areas such as snig tracks produce much less sediment and runoff. The recovery period can take five years.

4.8 Protection of Water Quality by Buffers in Native Forests

While Chapter 5 deals in detail with riparian zone issues the Erosion in Forests workshop also discussed the use of buffer and filter strips.

Hairsine (1997) saw buffer zones next to streams as preventing or at least reducing the entry of pollutants into streams. Buffers work by:

a) Preventing the development of overland flow from disturbance; and
b) Slowing down overland flows thus causing sediment deposition; and
c) Providing for the infiltration of overland flows this allowing sediment deposition.

Hairsine reported (for a once only experiment at the one site) that a forested buffer 6 m wide trapped 90% of incoming sediment for a wide range of overland flow rates. For phosphorous the trap efficiency was 50% at low flows falling to 10% at higher flows. This was due to the passage of fine silt particles which act as a carrier for attached nutrients.

Hairsine considered that buffer effectiveness can be greatly reduced if sediment laden flows are guided into or form preferred pathways. Most importantly buffer zones must be located outside permanent or semi permanent saturated zones if infiltration is to occur. For effective protection of water courses, all drainage lines and streams should have buffers between them and any sediment source. Permanent sediment flows into a buffer require careful management.
to ensure that they are dispersed over a wide area. Smith and O’Shaughnessy (1996) found that channelized flows could pass through a 40 m forested buffer thus emphasising the need to disperse flows.

4.9 Code of Forest Practice Issues

The following documents (published by the Department of Natural Resources and Environment) were reviewed as part of a consideration of protective measures.


b) Management Prescriptions for Harvesting and Regeneration in Native Forests Benalla/Mansfield and North East Forest Management Areas (1997)

c) Code of Practice for Fire Management on Public Land 1995

d) North East region Fire Protection Plan (1990)

The following points are made by the authors in relation to fire management plans.

- Where possible fire breaks should be maintained by slashing rather than grading in order to reduce possible erosion.

- Specific reference should be made in the Fire Protection Plans of the need to protect watercourses by appropriate drainage of fuel breaks and access tracks.

- Specific reference should be made in the Fire Protection Plans about the protection of riparian vegetation during fuel reduction burning.

- The requirements in the Code of Practice for Fire Management for the prevention water yield and quality effects were noted. It states that fire management tracks must be constructed and maintained to avoid soil disturbance and erosion. It is suggested that the Code also refer to the need for stream protection infrastructure such as appropriately located road cross drains.
Water Quality Issues

The following comments, based on the authors’ collective experience, apply to the regional management prescriptions for timber harvesting.

- It is suggested that the north-east harvesting prescriptions would be more effective if it was made clear that erodability should be evaluated in terms of the soil horizons likely to be exposed.

- The guidelines for topsoil storage should be made more explicit in indicating where topsoil should be saved for later spreading.

- The flood design intervals for culverts and bridges are reasonable provided the appropriate design calculation for capacity are undertaken. Better environmental protection would be obtained if roads were designed and constructed to allow overtopping without erosion of the road surface and batters.

- It should become mandatory for the use of excavators rather than bulldozers in the placement and removal of stream culverts in order to reduce the direct placement of earth in stream channels.

- It is recommended that the regional management prescriptions lay more stress on the need for flows from culverts, runoff, and snig track cross drains to be actively dispersed by the use of rocks, logs etc. in order to avoid channelisation.

- As recommended in Smith and O’Shaughnessy (1996) the prescriptions should encourage where necessary the use of logs to divert road drainage at stream crossings into suitable areas for silt deposition and flow infiltration. In areas where fill batter slopes could affect streams the use of logs placed with continuous ground contact parallel to a road at the bottom of fill batters can be effective in preventing sediment movement.

- With future administration likely to be split between commercial forest management and general forest management the nomenclature of the current Code of Practice for Timber Production is too user specific and could lead to difficult resolutions about when a road is a production forestry road and/or a general management road. It is recommended that there be developed a Code of Forest Practice for Forest Management with the current Code being a subsidiary document. In regard to roads it would cover all users regardless of its use. Local Forest Service staff state that they apply the Code of Forest Practice to all new roads regardless of their purpose.

- This proposed code would also deal with recreational use of public forests and contain provisions relating to the management of camping, camping facilities hunting etc. Existing codes such as the Code of Practice for Fire Management could then be referred to and remain as stand alone documents.
Water Quality Issues

4.10 Recreation Issues

A favourite occupation of many Australians is to have a camping holiday. Many like to pitch their tents in remote areas and accessible riparian flats alongside streams are a favourite location. However this recreational pastime can lead to river bank erosion, a proliferation of informal access routes, stream pollution by food scraps, soapy water etc and bacterial pollution from faecal wastes.

The North East Catchment Management Strategy reports that visits to State Forest areas are increasing with 4,500 camper nights at Yackandandah Creek and 600 camper nights at remote Wheelers Creek in the far north east of the region. Other recreational issues identified by the strategy include horse riding and four wheel driving in steep terrain.

The draft Ovens Basin Water Quality Strategy of the North East Catchment Management Authority (1997) recognises the need for action in Table 7.1 of the Draft Strategy which lists programs and actions. Under program 5, Forest Industries and Public Land Program, action 5.5 requires that DNRE implement appropriate regulation of recreational use of public land particularly vehicle access to forest tracks and access to stream sites. The Goulburn Broken Catchment Management Authority draft Water Quality Strategy (1996) does not specifically mention recreation issues on public land, this is probably due to it being perceived as a minor issue compared for example, to the salinity and eutrophication issues on the alienated land which comprises 70% of the Catchment Management Authority area.

4.11 Plantation Management

In terms of the total land area of the NE RFA plantations occupy a relatively small area. However within the plantation areas forest management activities are intensive in terms of roading, road use, site preparation and timber harvesting. While the Catchment and Water Quality Strategies reviewed do not express specific concerns (apart from requiring that best management practice be implemented), the authors have become aware of local concerns.

There is a community water quality monitoring program at the Shelley plantation supported by the Victorian Plantations Corporation. As well the Corporation has put $80,000 towards the reinstatement of the Cropper Creek experimental area due to its interest in the water quality and yield issues being investigated in this program.
Water Quality Issues

The Corporation is also undertaking, at its own initiative, a number of steps to minimise the impact of plantation management activities on water quality (Penfold pers comm 1998\(^3\)). In summary these initiatives are:

- The use of cable harvesting and slash retention on steep slopes;
- Where possible, the use of existing roads rather than the construction of new roads. New roads are constructed well ahead of their operational use;
- The establishment of a major herbicide use trial which is aimed at developing practices which ensure the protection of ground and surface water quality, compliance with National Health and Medical Research Council (NHMRC) guidelines for drinking water and the protection of environmental values;
- Stream reserves previously planted to pine in some water supply catchments are being regenerated with native species so to negate the need for future operational activities and to improve environmental values;
- Plantation expansion in the area between Myrtleford and Wangaratta has the potential to arrest the current rapid use in underground water levels;
- The pine industry sees the need to actively adhere to the Code of Forest Practice for Timber Production in relation to water quality issues as being essential for the future operation and community standing of the industry.

4.12 Power Generation Issues

Hydro power generation using the East and West Kiewa Rivers was developed between 1938 and 1963. Although the power generated forms only a minor component of Victoria’s annual use it does provide valuable peak load power. The Kiewa Scheme operated by Southern Hydro was sold in December 1997 to a consortium of interests. The main issues relating to the NE RFA are the continuing application of good practice maintenance to the many kilometres of access roads and tracks managed by Southern Hydro and DNRE and the need to protect the alpine ash stands from fire thus allowing them to age with a consequent increase in water yield.

---

\(^3\) Simon Penfold, North East Zone Manager, Victorian Plantations Corporation
4.13 Salinity Management

This section deals with dry land salinity only, as much of the irrigation induced salinity is outside the NE RFA area. Both the Goulburn Dryland Salinity Plan (1989) and the Draft North East Salinity Strategy (1997) point out that large areas of the privately owned landscape are at risk from loss of primary production due to increasing dry land salinity. Generally this has been caused by tree removal in the upper slopes over the past 150 years resulting in increased down slope flows of water into adjoining flats and higher water tables. Tree removal on flat country has also caused local water tables to rise. These rising water tables can move up through saline sub soils and thus bring salty water to the surface. When such water tables get within about one metre of the surface evaporation can cause the deposition of salt on surface and in the upper profile. For the Goulburn Broken Catchment Management Authority (CMA) region, areas of risk within the NE RFA are located near Seymour, Euroa, Violet Town and Benalla. For the North East CMA region the North East CMA Draft Salinity Strategy identifies significant areas at risk most of which is inside the NE RFA area. About 180,000 ha of high priority area needing remedial action has been identified with high recharge areas totalling some 76,000 ha and discharge sites occupying 1600 ha. These areas are located in an area north east of a line drawn between Myrtleford and Wodonga. The estimated rate of spread of discharge areas is 5.8%/annum and it is estimated that about 12,000 ha will be affected in 30 years. Productive farmlands and important wetlands are at risk. Another issue is the increase in salt loads to the Murray. Some locations where remedial actions are needed include the Gretna, Carbor, Murmungee, Everton, Indigo Valley, and Wodonga areas. (See Figure 1 of the NE Draft Strategy). Farm Forestry and Break of Slope plantings are among the recommended measures to be taken to reduce or prevent water table rise.

The Goulburn Broken Dryland Salinity Management Plan Implementation Annual Reports of 1995/1996 and 1996/1997 indicate that the concept of break of slope plantings is being taken up enthusiastically by local farmers. Dense plantings are needed for maximum response and water table drops of 2 m within a 200 m radius of some plantings have been recorded. However experience indicates that break of slope plantings have to be very carefully located in the landscape so as to ensure maximum water use, yet at the same time ensuring that trees continue to receive flushing flows of water in order to prevent salt build up in the root zone and drought death. Similarly trees on flat irrigation country need to have their root zone salt content monitored and managed if tree death and slow growth are to be prevented. Soils with high hydraulic conductivity are preferred sites. These issues were discussed at a recent workshop convened by the CSIRO Division of Biomolecular Engineering at Parkville Melbourne in May 1997. It is understood that the workshop outcomes are to be published.

This question of salinity management does not generally relate to the management of State Forest and National Parks but it does relate to the protection and management of scattered reserves of native vegetation, both in public and private ownership.
Water Quality Issues

Tree planting is part of the solution to dryland salinity thus the proposed industrial plantation scenarios are of significance in that they have the potential to help control dryland salinity. It is not possible to be more definitive without detailed site analyses of likely plantation expansion locations.
Chapter 5 : Riparian Environment Issues

This chapter expands specifically on some of the issues concerning land close to streams. Some of these have been raised in previous chapters.
Riparian Environment Issues

5.1 General Introduction to Riparian Issues

The area adjacent to streams is known as the riparian zone. This zone is modified by its proximity to the stream, and in turn exerts an influence on the stream. The modification comes in the form of:

- Groundwater often close to the surface and reasonably available in alluvial and rock bed streams. Associated with this are high soil moisture contents due to downslope water movement.
- High humidity due to water spray.
- Generally sheltered because of their topographic position.

Because of the high moisture availability they have highly productive ecosystems, manifesting this by large trees, high biodiversity of flora and fauna, and often very attractive aesthetic appeal. The high biomass in turn provides bank stability in alluvial streams. In many rivers the woody debris component is now viewed as providing an essential component of the stream structure. This provides flow resistance which restricts stream velocities, helps entrain oxygen into the water, and provides micro-ecological environments suitable for native fish and substrates suitable for microfauna.

The streamside vegetation provides a flow of organic debris into the stream which, in turn, provides nutrient material for the micro-invertebrates. A commonly-expressed concern is that the changes in the type of debris due to vegetation change will lead to changes in the stream fauna, although this factor is generally only one in a large spectrum of changes.

Riparian environments often contain remnant stream channels (ox-bow lakes, cut off meanders), and these contain many species which generally may not always exist in the main channel or may die off under certain circumstances. At times of flooding these become reconnected to the main channel and allow some recolonisation or revitalisation of these communities.

Flooding of the streams allows stream fauna to make excursions onto the flood plain and to take advantage of new food sources suddenly made available. As the flood contracts the fish make their way back into the channel. However in some cases sudden cessation of flooding due to shutting of dam release gates can give inadequate time for the fish to find their way back to the river and results in the death of these on the floodplain.

The major riparian issue in the NE RFA region is the modification of riparian environments by domestic stock grazing. A recent study being completed by Tim Fletcher\(^4\), found virtually no difference between private land and stream frontage reserve in terms of indications of grazing and presence of weed species associated with grazing. The modification is substantially associated with giving stock access to water.

---

Riparian Environment Issues

A number of riparian forest issues are found within the region:

- River red gum forests and associated wetlands. The major river red gum forests are out of the study area but along the Goulburn River, Broken River and lower Ovens River are riparian river red gum forests which depend on occasional flooding for their survival. A number of dams including Buffalo Dam, Lake Hovell, and Lake Nillahcootie would have an effect on flow regimes but these storages are relatively small and the changes induced would be quite modest.

- The adequacy of stream buffers for protecting stream environments from logging and other land uses is discussed in Section 2 following.

- The disruption of riparian environments and the introduction of weed species by roads.

- The adequate conservation of unusual riparian communities. All known unusual riparian communities within state forest are protected by the appropriate management plan.

- The loss of riparian land for major water storages. Clearly the construction of Dartmouth Dam involved a loss of major riparian areas as well as forest. The idea of an enlargement of the relatively small Lake Buffalo by the “Big Buffalo” dam has recently reappeared as a means of giving increased security of supply. However this would result in the inundation of large areas of valuable forest (both native and plantation).

5.2 Protection of Riparian Environments by the Use of Buffers

A major method of protecting stream environments is by use of buffers - “no logging” areas directly adjacent to streams. In Victoria the usual buffer width adopted is a minimum of 20 m either side of the stream. This can result in the loss of land for timber production. For example, obligatory minimum buffer widths are provided in the Code of Forest Practices DNRE (1996) and research continues by a number of organisations into buffer strip provisions. Bren (1998) showed that in the Tarago river area of Gippsland this involved about a 10% reduction in loggable area and about a 10% reduction in timber resource value, although clearly these figures would vary with the density of the streams. In general, around the world, use of protective buffers is a well-accepted component of “good practice” timber harvesting. Buffers are viewed as protecting stream and riparian areas from mechanical damage due to tractor movement, providing an area for the infiltration of pollutants, and protecting the stream from direct insolation.

Although the use of buffer strips is well established the authors consider that there are a number of issues:

a. The “correct” width for buffers.

There is a feeling amongst some scientists that there is, or should be a “correct” or “optimum” width for buffers. However work in the Tarago Project (Hairsine 1998) showed that there are many criteria for buffer design that can be used and all will give quite different buffer layouts. It must be accepted that no “correct” width exists and
Riparian Environment Issues

that any decision on buffer strips will be a largely political tradeoff between perceived protection of the stream on one hand and resource utilisation on the other. Work by Bren (in press) showed that a single process “constant buffer loading” design method, when applied to a major catchment, gave quite different results, some of which may be incorporated into future buffer design methods, but others of which would be unacceptable. Thus the study showed that the spring heads of streams are unprotected by constant width buffer designs, but that the divergent slopes passing into larger streams are probably overprotected. Further research is being undertaken on this issue.

b. Is this dry gully a stream?

Dry gullies are prevalent in the uplands of north-east Victoria. Typically these are formed by natural erosion processes and may, to varying extent, have streambeds or defined flow courses. However they rarely (and sometimes never) appear to carry water flow. The question is whether they should receive the full protection of a stream or be viewed as a “drainage line” in which passage of machines is restricted. In areas such as the Clear Hills (Mansfield) the controversy has been intense. On the one hand the flows have, in the historic past, been strong enough to form a small valley. On the other hand there is normally little evidence of streamflow, although extreme events may generate flow. Full protection makes logging difficult while classification of the area as a drainage line only excites comments about “inadequate protection”, “not doing the job” etc. Current research is coming up with new and more objective methods of classification (e.g. absolute measures of the catchment area contributing to gullies, relative slope convergence, etc) but these require very detailed coupe mapping at a scale of 1:4 000 and are generally not at all easy to apply. It appears that this issue will remain controversial for the foreseeable future.
c. *Can we cross buffer lines?*

In many cases buffers come together to completely encircle unbuffered areas. The argument is whether tractors and trucks should be allowed to pass through buffered areas to gain access to the resource. Again it is argued on the one hand that the reason for having a buffer is being ignored. On the other hand, it is argued, the reason for the activity is to gain commercial yield of forest products and if access is not allowed then the logging can not be completed successfully. The problem is exacerbated as buffers are made wider. It appears at the current time that there would seem to be little alternative to the usual prescription of a minimum 20 m and acceptance of the ongoing controversy for marginal cases.
Chapter 6: Knowledge Gaps; Research and Development
Recommendations

This brief chapter outlines the gaps in knowledge.
Knowledge Gaps; Research and Development Recommendations

This chapter provides a brief listing of items which came to attention during the preparation of this report.

- The NE RFA is an important source of Murray River water in terms of the Murray Darling water resource management. An investigation is needed into the interaction between changes in catchment flows due to land use, the possibility for increases in environmental flows into the Snowy River, changes in current water resources allocations, and the water needs of the Barmah/Millewa red gum forest.

- A better knowledge for alpine ash stands of the relationship between water yield and stand age and structure.

- Particularly for the wetter mixed species subject to clear felling and regeneration, the development of a similar knowledge base to that needed for alpine ash is required.

- More knowledge is needed of external events and the manner in which sediments are sensitised for latter mobilisation.

- A better knowledge base would allow a more efficient evaluation of the balance between economics and environmental impacts in such matters as the determination of rainfall return periods for bridge and culvert sizes.

- A better knowledge is needed of the hydrology of all forest types in particular these growing in high rainfall zones.

- A better knowledge of the water resource, economic and environmental implications of extensive afforestation of cleared land. A cost/benefit analysis is required which needs to be site specific.

- More information on the best locations for “break of slope” plantations aimed at controlling the recharge of areas with shallow ground water. It is understood that the Cooperative Research Centre for Catchment Hydrology is currently investigating this issue.

- The development of low cost, low maintenance robust track and road drainage infrastructure systems is recommended.

- Standardisation at a national and state level of water quality measurements and benchmarking. This is required in order to evaluate the outputs of water quality treatment plants and the effects of land management practices.
Chapter 7 : Summary

This chapter provides an overview summary of each chapter together with some recommendations.
Summary

Introduction

Rather than provide a Summary and Conclusions after each chapter it was felt that a more balanced view would be obtained by presenting the information for each chapter within the one summary chapter.

Chapter One  - Introduction

This chapter shows the importance of the NE RFA region for Murray/Darling Basin streamflows and the pressure on Murray/Darling water resources caused by increasing water consumption.

The chapter explains the establishment of a cap upon further increases in water use from the Murray Darling basin and examines the possible implications on system resources for the use of crops with high water use and the use of water for environmental purposes, such as the maintenance of the Barmah/Mildura red gum forests.

Chapter Two  - Site Specific Forest Hydrology Information in North Eastern Victoria

Details presented about the Cropper Creek study show that eucalypt and pine water use are about the same. The importance of roads in producing much higher volumes of stormflow compared to undisturbed areas from low and medium rainfall events has been demonstrated. Water quality data show the high quality of the water produced from undisturbed forested catchments in the NE RFA region.

The small Pine Creek study near Kilmore demonstrated that the streamflow effects of conversion of grassland to plantation were able to be detected within five years of the conversion process commencing.

The East Kiewa Hydrologic Project found, for a short period of monitoring only, minor changes in streamflow due to the logging of the Alpine Ash stands on two small catchments. An increased sediment production rates of 4% to 15% was predicted, which in practice, would be hard to detect.

A study of the Bogong Plains Hydrology was not able to detect any long term effects of the 1926 and 1939 fires on streamflow due partly to data limitations and other confounding events. However, analysis did indicate declines in streamflow following extensive logging and regeneration in the alpine ash stands of the West Kiewa River.
Summary

Chapter Three  - Issues of Water Yield

This chapter provides some guidance for the assessment of water yield data and summarises the studies for the Melbourne catchments which determined the relationship between streamflow and stand age for the ash type forests. It postulates that the ash type forests of the NE RFA region could display similar relationships which allow the estimation of water yield differences due to varying forest management regimes. The differences in water yield are important enough to warrant further investigation. The likely benefits of fire protection support a continuing fire prevention and supervision program. It is recommended that the Cooperative Research Centre for Catchment Hydrology be approached to further investigate the alpine ash water yield relationship.

For mixed species forest it is postulated that the streamflow is normally constant on a long term basis varying according to the rainfall and of the altitudinal location of stands. If a mixed species forest is clear felled and regenerated a modified ash type response may occur particularly for the wetter forests. Research work being undertaken by the Cooperative Research Centre for Catchment Hydrology is investigating this possibility within the silvertop ash stands of the Eden area and early results indicate that such a relationship may exist.

The chapter also examined the implications for regional water yield of extensive softwood reafforestation on existing privately owned cleared land. The likely water yield declines are significant and need to be examined in an objective cost/benefit basis taking into account the benefits of salinity control, timber production benefits and streamflow declines. Possible attempts to charge for tree water use would be difficult to justify on the grounds of consistency in practice with other crops. Compounding issues are the allocations for red gum forest watering and the proposal to increase environmental flows into the Snowy River from the Murray Darling resource.

Chapter Four  - Water Quality Issues in North-East Victoria

While not based on data unique for the NE RFA region a review of the effects of water quality degrade on stream biota highlights the importance of managing activities to minimise the input of sediment to stream systems for the maintenance of biota diversity and abundance.

While there are local concerns that forest management will significantly increase nutrient levels there is no evidence that this is likely to happen. However there is a general expectation that forest operations will be conducted according to best management practices. Forest managers are aware of these community concerns and steps being taken by the Victorian Plantation Corporation and DNRE are noted. A major effort is needed to upgrade or retire the many kilometres of poorly maintained roads and tracks constructed prior to the introduction of the Code of Forest Practices and adequate resources should be provided. Some technical suggestions are made by the authors in relation to roading practice. Priority should be given to protecting streams from direct sediment inputs at stream crossings. Management of streamside camping could require detailed management.
Summary

The authors consider that a general Code of Forest Practice for the management of all forested public lands be developed with the current codes for timber production and fire protection being subsets.

In regard to power generation and forest management it was considered that as guided by the Code of Forest Practices, the implementation of best management practices for track and roads managed either by Southern Hydro or the Department of Natural Resources and Environment would safeguard against increased sediment inputs.

Tree establishment on private land will continue to be an important component of dry land salinity control strategies with an increasing need for better knowledge on tree placement in the landscape.

Chapter Five - Riparian Environment Issues

Riparian zones have an important influence on water quality and stream biota. Management practices which maintain a good riparian native vegetation cover are needed. The definition of stream type and the application of the appropriate buffer width is an issue. Research on buffer strip width determination is current and needs to continue. Current buffer width prescriptions appear adequate to protect riparian environment providing sediment laden inflows are dispersed and buffer strip widths are adjusted to meet special needs. However, protection of those stream beds which are dry most of the time is likely to continue to be a difficult issue.

Chapter Six - Knowledge Gaps; Research and Development Recommendations

Not summarised as the chapter itself is written as a summary.
References

Chapter 1


Chapter 2


Chapter 3


Chapter 4


Cooperative Research Centre for Catchment Hydrology (1997): Papers for Erosion and Forests Workshop, 3-6 March, Bermagui, NSW.

Department of Conservation and Natural Resources (1993): Central Gippsland Forest Management Area. Prescriptions for the control of harvesting of sawlogs and residential roundwood from native forests (Operator Summary).


North East Catchment Management Authority (1997): Draft North East salinity strategy, a component of the north east regional catchment strategy.
North East Catchment Management Authority (1997) Regional Catchment Strategy, pub. by NECMA.


Smith, N. and O’Shaughnessy, P.J. (1996): A review of the effects of current road construction and maintenance systems on sediment generation and transport in the Central Gippsland Forest Management Area. Internal report prepared for the Centre for Forest Tree Technology, Department of Natural Resources and Environment, Victoria.


Chapter 5


Acknowledgements

The authors wish to thank the following people for their assistance with one or more of the following activities, discussions, comments, and provision of literature.

Alison Boak
David Buntine
Geoff Earle
Veronica Lannigan
Timo Mantyverta
Rae Moran
Jim Morris
Bill O’Kane
Mr John Riddiford
Ted Stabb

The authors also thank the following people for their comments and editorial assistance.

Mark Edwards
Sue Holder
Ian Miles
Ray Spencer
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evapotranspiration</td>
<td>Discharge of water from the earth’s surface to the atmosphere by evaporation from streams and soil surface and by transpiration from plants.</td>
</tr>
<tr>
<td>Gigalitre (GL)</td>
<td>1000 megalitres</td>
</tr>
<tr>
<td>Megalitre (ML)</td>
<td>Equals a 1000 cubic metre or 1 million litres. One megalitre covers one hectare to a depth of 100 mm.</td>
</tr>
<tr>
<td>Run-Off</td>
<td>The discharge of water derived from rain or snow falling on a surface.</td>
</tr>
</tbody>
</table>
Appendix 1: Attachment “B” Terms of Reference for the Consultancy Services
ATTACHMENT B

TERMS OF REFERENCE FOR CONSULTANCY SERVICES

The consultant is required to:

• conduct a literature review on forest hydrology and catchment management issues pertaining to the North East CRA region
• examine possible impacts of forest management practices on issues of water management relevant to a CRA/RFA
• examine downstream issues to support development of CRA options
• assess current levels of knowledge on identified relevant hydrology and water management issues and identify information gaps and the requirements for future research to address those gaps

The consultant’s report will be based on the above requirements, and specifically address the following issues for water management in the CRA region:

• changes in inflow into the major water reservoirs for the CRA region:
• downstream allocations and use of water from the area in the context of usage from the Murray/Darling Basin system
• changes in the quality and quantity of natural waters emanating from the region as a consequence of operations within catchments with a special emphasis on road and track construction and maintenance
• salinity levels or groundwater pressures in irrigation areas
• affects of existing plantations and impacts of possible expansions
• identify information gaps on issues and outline requirements for future research to address those gaps.

The structure and content of the report would reflect a wide ranging literature review on the forestry-related hydrological issues for the North East, a consideration of the major forestry-related hydrological issues for the North East, a consideration of the forestry-related issues affecting water quality, quantity & usage and consideration of future directions for the issues identified as a consequence of the consultancy.

The consultant will deliver, by camera ready hard copy and disk copies (PC and Mac Word 6.0 versions), the final version of the report to the Bureau by 13 March, 1998. A draft of the report will be made available to the BRS for comment by early March and the consultant will make changes to address those comments in time for them to be incorporated into the final report.
Appendix 2 : Cooperative Research Centre for Catchment Hydrology Flier on Project FO3. Effects of Pine Plantation and Eucalypt Forest Management on Hydrology and Nutrient Export