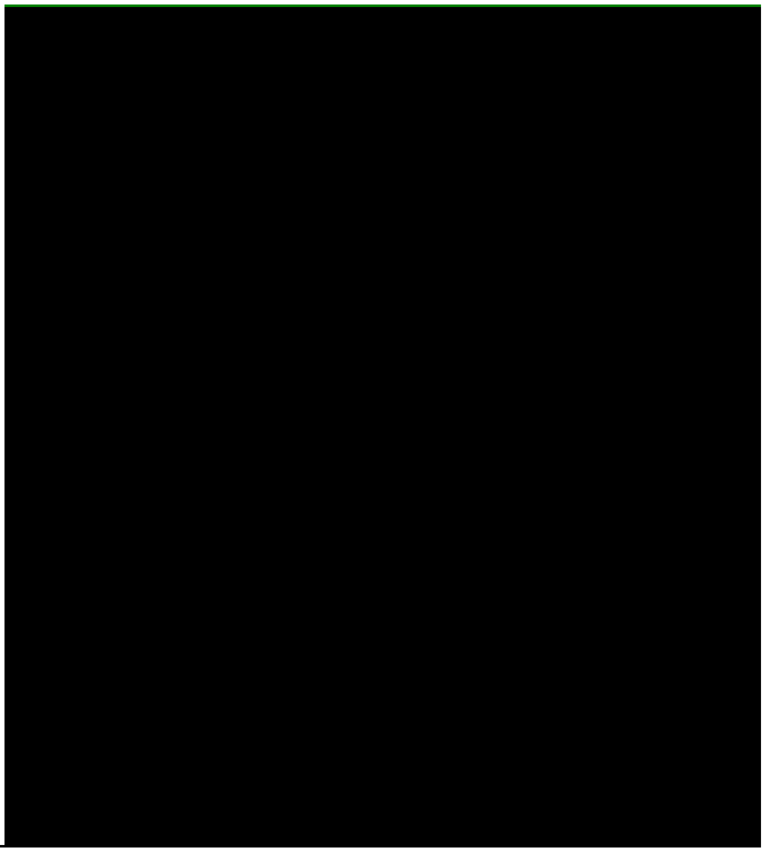
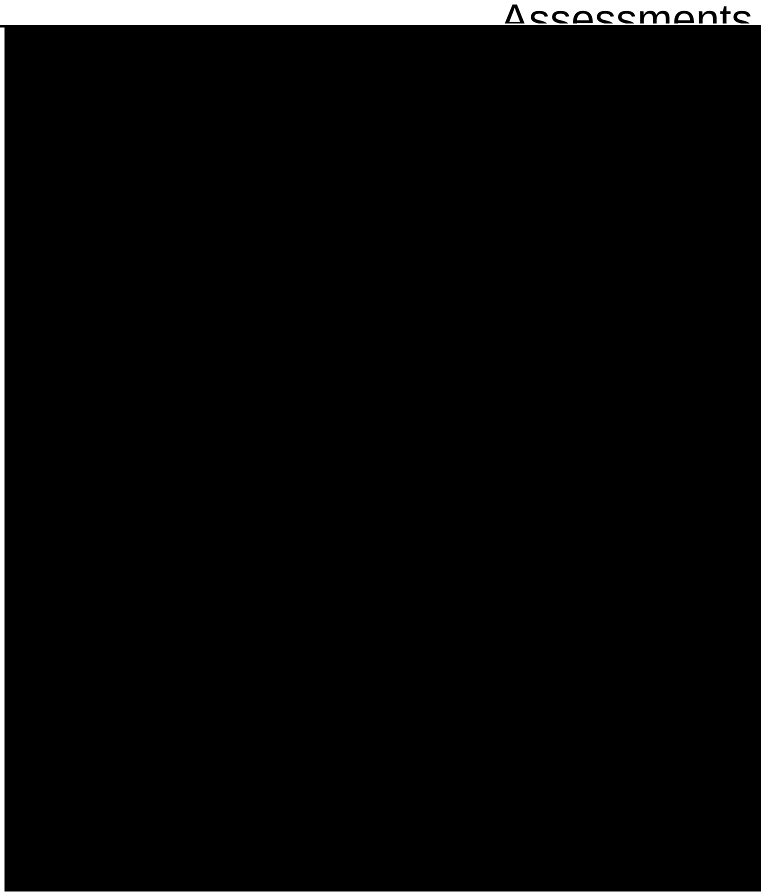


Economic Assessment of Water Values

Southern Region

A project undertaken as part of the NSW Comprehensive Regional Assessments



ECONOMIC ASSESSMENT OF WATER VALUES

SOUTHERN REGION

Hassall & Associates

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NS 26/ES

For more information and for information on access to data contact the:

Resource and Conservation Division, Department of Urban Affairs and Planning

GPO Box 3927
SYDNEY NSW 2001

Phone: (02) 9228 3166
Fax: (02) 9228 4967

Forests Taskforce, Department of the Prime Minister and Cabinet

3-5 National Circuit
BARTON ACT 2600

Phone: 1800 650 983
Fax: (02) 6271 5511

ISBN 1 74029 146 8

This project has been jointly funded by the New South Wales and Commonwealth Governments and managed through the Resource and Conservation Division, Department of Urban Affairs and Planning, and the Forests Taskforce, Department of the Prime Minister and Cabinet

The project has been overseen and the methodology has been developed through the Economic and Social Technical Committee which includes representatives from the New South Wales and Commonwealth Governments and stakeholder groups.

CONTENTS

Table of Tables

Table of Figures

PROJECT SUMMARY

This report describes a project undertaken as part of the comprehensive regional assessments of forests in New South Wales. The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth Governments will sign regional forest agreements (RFAs) for major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources.

Project objective/s

The objectives of this study were to estimate the potential economic impacts of changes in water quantity and quality from selected forest catchments within the South Coast and Tumut sub-divisions of the Southern RFA; to draw inferences for the economic impacts of the adoption of different forest management practices more generally throughout the South Coast and Tumut sub-divisions; and to contribute relevant results to the RFA for the Southern RFA region.

Methods

Representative catchments were examined for each of the South Coast and Tumut sub-divisions of the Southern RFA region. Within each catchment, the adopted logging scenario developed by SKM (1999) was utilised to analyse the impact of forestry activities on water quality and quantity. Each scenario was examined over both an economic timeframe (5, 10 and 30 years) and a longer time period (30 to 100 years) to differentiate temporal impacts. The adopted logging scenario in each catchment was applied to a forest of current age and an old growth forest, with the logging and tree growth components of the adopted scenario being examined together to understand the total impact on mean streamflow.

Utilising outputs from the Ecologically Sustainable Forest Management (ESFM) project, *"Water Quality and Quantity for the Upper and Lower North East and Southern Region"*, a relationship was determined between the change in water yield due to logging operations and the State forest area contained within each catchment. This relationship allowed changes in water yield to be expressed in terms of changes in mean streamflow at defined gauge locations. Once this change in streamflow was determined, the economic impacts arising from this change in streamflow were estimated. Economic impacts were estimated for a variety of activities that utilise water in the downstream section of each catchment.

Key results and products

For the South Coast sub-division:

- Within the Mongarlowe Creek catchment, the economic impacts associated with the implementation of the adopted logging scenario are small, positive and focussed upon a limited range of activities. In the longer time period (30-100 years) the increase in stream flow is more significant[1].

- In the Wandandian Creek catchment the economic impact on downstream water users and water dependant activities in the short to medium term will be slightly negative. Over the long term, impacts are deemed to be significant and positive. In the longer period (30-100 years), the increase in streamflow is significant.

- Region-wide, the analysis has shown that within an economic timeframe (30 years) the impact of different forest management options will be economically insignificant. In the longer term, there is potential for a positive impact on streamflow and consumption (irrigated agriculture and domestic riparian). Realisation of this positive impact will depend on "macro issues" such as policy settings 30 years hence and the impact of climate change.

For the Tumut sub-division:

- Implementation of the adopted logging scenario in the Buddong Creek catchment will result in short to medium term economic costs for downstream hydro-electric power generation and irrigated agriculture. In the long term (30 years) a slight positive economic benefit is incurred. In the longer term (30 to 100 years), the impact of the adopted logging scenario will lead to a significant increase in mean annual streamflow. Again, the extent to which this benefit is captured by downstream abstractors will depend on conditions at this time.

- Region-wide, a slight negative impact on streamflows is possible during the short to medium term. In the long-term (up to 30 years) this impact will be neutralised. In the longer term (30 to 100 years) potential exists for incremental irrigated agriculture and hydro-electric benefits.

[1] An impact is considered to be significant (insignificant) where the estimated impact is greater (less) than that which would occur with natural variation, due to seasonal and climatic conditions.

1. INTRODUCTION

1.1 PURPOSE OF THE STUDY

The purpose of this project was to assess the economic impacts associated with changes in water quality and quantity due to various forestry operations in a number of representative catchments in the South Coast and Tumut sub-divisions of the Southern RFA region.

The scale and nature of forestry operations may impose economic impacts on downstream water users, activities and infrastructure. Changes in water yield and quality due to forestry operations may impact upon downstream activities such as the production potential of irrigated agriculture, the availability and quality of town and domestic water supplies, use for primary recreation activities, the useful life of infrastructure and environmental streamflows.

To assess the differential economic impacts likely to arise from changes in water yields and quality under a range of forest management regimes, an initial investigation was undertaken by the Ecologically Sustainable Forest Management (ESFM) working group. The ESFM project involved identifying and documenting the extent of impacts on water quality and quantity in a range of "typical" catchments under a number of forest management regimes of varying intensities within the Southern RFA region. The outputs of the ESFM project are the inputs into this economic assessment.

This report was commissioned by Resource and Conservation Division (RACD), New South Wales Department of Urban Affairs and Planning (DUAP), to contribute to the RFA for the Southern New South Wales region. Hassall & Associates completed this analysis for RACD in December 1999.

1.2 BACKGROUND TO THE RFA PROCESS

RACD has been established to review forestry issues in New South Wales and to provide advice to the State Government for the development of its forestry and conservation policies and reforms. A key activity of RACD is the co-ordination of CRAs of forested land, to facilitate the establishment of Regional Forest Agreements (RFAs).

The CRAs provide the scientific basis on which the State and Commonwealth Governments will sign RFAs for major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources. The CRA process involves assessing the commercial values (such as timber, tourism, grazing, apiary) as well as the conservation values (such as species diversity) derived from State forests and evaluating the socio-economic and long-term ecological impact of the alternative uses of these resources.

The Southern region is the third region to be assessed in New South Wales: CRAs have been undertaken for the Eden and the Upper and Lower North-East areas of New South Wales.

1.3 OBJECTIVES OF THE PROJECT

The objectives of this project are:

- to estimate the potential economic impacts of changes in water quantity and quality from selected forested catchments within the South Coast and Tumut sub-divisions of the Southern RFA region;
- to draw inferences for the economic impacts of the adoption of different forest management practices more generally throughout the South Coast and Tumut sub-divisions; and
- to contribute relevant results to the RFA of the Southern New South Wales region.

1.4 SCOPE OF THE PROJECT

There are important links between this study and the ESFM Water Quality and Quantity project. Outputs from that project that are essential inputs to this economic assessment include:

- definition of catchments (based on treatment by Catchment Management Committees);
- literature review of water yield and forest streamflow effects for various categories of land, including forests, over time. For forests, more detailed assessment of effects of logging and plantations;
- pilot studies of trial catchments in the region. The pilot studies will include details of water usage in the respective catchments; and
- a profile of water usage for the region by sub-catchment (amount of water licensed, minor and major license holders, types of products produced, rural and urban water supplies, etc).

Potential economic impacts of changes in water supplies and quality arising from the use of different forest management regimes can be expected to occur through (positive and negative) effects upon:

- agriculture
- manufacturing
- infrastructure
- drinking water supplies (quantity)
- flood mitigation
- purification of domestic water supplies (quality)
- primary recreation activities
- tourism
- environmental flows

Where feasible, estimates were made of the potential magnitudes of economic values. Where quantitative data is not available, qualitative assessments were made with regards the nature, possible size (relative to other variables) and incidence of costs and benefits associated with such activities/uses.

2. METHODOLOGY

2.1 INTRODUCTION

The purpose of this section is to outline the key components of the methodology adopted to estimate the economic impact of changed water yields on downstream water users. The methodology adopted is consistent with the equivalent water values study undertaken for the Upper and Lower North East (UNE & LNE) RFA region[2].

Much of that methodology was based upon data provided by Sinclair Knight Merz (SKM) (1998) in the related study, *Water Quality and Quantity for the Upper and Lower North East and Southern Region: Draft Report*. SKM adopted a similar methodology for the study they undertook specifically related to the Southern RFA region (*ESFM Project: Water Quality and Quantity for the Southern RFA Region*).

The methodology outlined in the following section is based upon the SKM (1999) report for the Southern RFA region and also the SKM (1998) report for the Upper North East and Lower North East RFA regions.

2.2 CATCHMENTS EXAMINED

1.1.1 Catchment Selection

The catchments being examined within this study are based on those catchments chosen as part of the *ESFM Project: Water Quality and Quantity for the Southern RFA Region* (1999). Two catchments were selected for examination within the South Coast sub-division and a further catchment was analysed within the Tumut sub-division.

The two main criteria for catchment selection used by SKM (1999) were that the catchment had greater than fifty percent State forest cover and a stream gauging station in close proximity to the drainage point for the catchment. The State forests selected for analysis in this study and by SKM (1998) were of mixed native vegetation and excluded soft wood plantations.

SKM (1999) found a number of catchments within the Southern RFA region that met the criteria for catchment selection. Those examined as part of this study are Mongarlowe River (flows into the Shoalhaven River) and Wandandian Creek (flows into St George's Basin) from the South Coast sub-division and Buddong Creek, upstream of Blowering Reservoir, from the Tumut sub-division.

Table 2a lists the catchments being examined and some catchment-specific information.

[2] *Economic Assessment of Water Values: Upper North East and Lower North East NSW RFA Regions*, Hassall & Associates (1999a).

TABLE 2A CATCHMENTS IN THE SOUTHERN RFA REGION

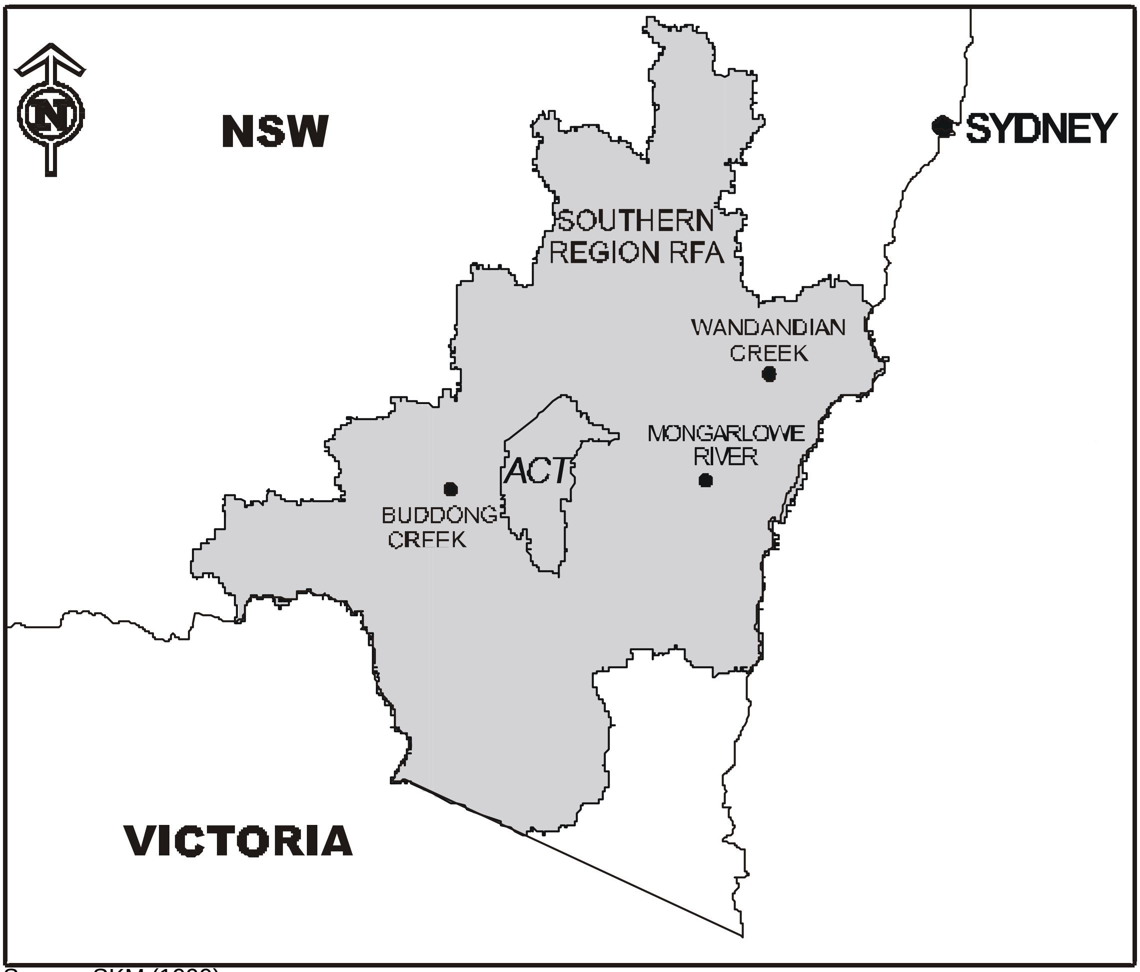
Catchment Name	State Forest Identification Number	Mean Annual Rainfall (mm)
South Coast sub-division		
Mongarlowe River	144	1 090
Wandandian Creek	920	1 310
Tumut sub-division		
Buddong Creek	560	1 530

Source: SKM (1999)

The National Climate Centre, Bureau of Meteorology, provided the rainfall data in table 2a. The data are averages for the area contained within each catchment. Data was estimated using a GIS layer that used 30-year (1961-1990) gridded climatological data (SKM, 1999).

Figure 2a provides a representation of where the selected catchments for this study are located within the Southern RFA region.

FIGURE 2A LOCATION OF SELECTED CATCHMENTS IN THE SOUTHERN RFA REGION



Source: SKM (1999)

For the economic analysis, areas downstream of the catchment that was defined for modelling purposes are also considered. This is due to the fact that many water users/activities occur downstream of the catchment that was defined for modelling purposes. Therefore, a wider catchment definition is used to assess economic impacts than that catchment definition adopted for logging scenario modelling.

2.3 LOGGING CASES EXAMINED

2.3.1 The Adopted Logging Scenario

Within each catchment, SKM modelled the impact of a plausible logging scenario on water yield[3]. The plausible or adopted scenario was based on the current age distribution of trees within the catchment and divided logging activity into thinning and selection logging (Single tree selection and Group selection). The nominal age of trees targeted was determined and the range of forest age studied, to ascertain whether the catchment provided sufficient forest resources to satisfy the adopted logging scenario.

The adopted scenario was intended to provide a reasonable management scenario on which to base modelling. It was not intended to pre-empt decisions related to the selection of a favoured logging scenario in each sub-division. Appendix 2a provides details of the adopted logging scenario for each of the three catchments within this study. Interpretation of these scenarios should be carried out with reference to SKM (1999).

2.3.2 Components of the Adopted Logging Scenario

The adopted logging scenario has two components:

- the tree growth component; and
- the logging component.

The tree growth component includes the impacts upon water yields that are directly related to the activity of tree growth in the forest. Effectively, it reflects the impacts on water yield over time assuming no logging takes place ("do nothing scenario"). The logging component, on the other hand, is used to measure the impact of logging activities on water yield over time.

Together, these two components combine to form the adopted logging scenario. Since the adopted logging scenario recognises both tree growth and logging impacts, the scenario can also be referred to as the tree growth plus logging scenario. Within this study, the terminology used will be adopted logging scenario.

2.3.3 Application of the Adopted Logging Scenario

The adopted logging scenario is modelled by assuming that it is applied in two different manners:

- applied to a forest of current conditions; and
- applied to a hypothetical, old growth forest.

Applying the adopted logging scenario to a forest of current conditions means that the forest being examined has a mixed-age profile that is representative of its current age in 1999. Impacts estimated under this approach are indicative of those forecast to occur if the adopted logging scenario was applied to an existing forest area today.

[3] State Forests of New South Wales compiled the adopted logging scenario.

Applying the adopted logging scenario to an old growth forest assumes that rather than having the characteristics of a mixed-age forest in 1999, the scenario is applied to a hypothetical old growth forest. Old growth conditions assume that the forest is entirely at the senescent stage of water usage.

2.4 CATCHMENT YIELD

2.4.1 Water Quantity

The impact of logging activities on water yield is dependent on the degree of forest disturbance, forest age and the interactions between climate, soils, vegetation and topography. Water yield impacts are linked to forest growth, and thus the impacts are very long-term in nature. In essence, changes in annual yield response are estimated to be a function of the fraction of canopy removed, time since logging, annual rainfall, age of forest, and region (SKM 1999).

There is a scarcity of information relevant to NSW forests in relation to water yield impacts. As a result, SKM (1999) adopted the form of yield response observed in Melbourne water supply catchments (for which good information is available) with a selection of parameters based on the limited evidence collected to date from NSW catchments. To characterise the expected yield changes to the NSW catchments, the available data was standardised by annual rainfall and the proportion of canopy removal.

The following steps summarise the approach taken by SKM (1999) to estimate the actual change in yield for specific sites:

1. Define a plausible logging scenario that takes into consideration the rate of logging, the nature and time sequence of activities such as thinning, selective logging and group selection, and the proportion of the forest available for logging;
2. Collect information for the catchment on mean annual rainfall and current age profile;
3. Simulate the impacts on water yield arising from application of the plausible logging scenario using a computer model. The computer model assesses and factors in the response of the impacts on water yield arising from the logging of an old-growth forest reflecting the degree of canopy removal and the age of the forest being logged;
4. Subsequent yield changes that correspond to the lumped response of the whole forest under consideration are reported on a per unit area basis for the following components:
   - the combined effects of forest growth and logging; and
   - the effects of forest growth only (the “do no logging” scenario).

   In addition to assessing the impacts of logging on a forest of current age, yield changes are also provided for the case where the logging scenario is applied to an old growth forest. The change in average age of the harvestable area and total forest due to logging is also tracked through time; and
5. Yield changes per unit area are converted to streamflow volumes, and are compared to current annual mean flow at (or near) the downstream boundary of the forest.

1.1.2 Water Quality

The greatest impact on water quality from logging activities is the increase in the level of suspended solids in streamflows. SKM (1999), for the purpose of quantifying impacts, identified the following two components as the main causes of disturbance that impact upon sediment production:

- logging activities within the general harvest and snig track area; and
- the maintenance and use of permanent access roads.

The amount of sediment exported from logging operations within the general harvest area and the amount of sediment generated by roading activities both depend upon many site-specific variables. Consideration of all site-specific variables such as terrain steepness and length of passage to drainage lines, unsealed road area and density, and level of soil disturbance, is not possible. Therefore the methodology developed by SKM (1999) attempted to take account of the important influences in a robust and credible manner. The overall approach was based on SKM (1998), and is summarised by the following steps:

1. Probabilistic event-based sediment generation rates for both general harvest and snig track area, as well as the permanent access roads, were derived from published and unpublished literature;
2. Vent-based sediment mobilisation rates were converted to site-specific annual loads using information on rainfall characteristics. For the general harvest and snig track area a relationship was also established to define the decline in sediment production as a function of time since disturbance, and separate generation rates were also provided for different classes of soil erodibility (Inherent Hazard Categories);
3. Spatial information describing drainage lines, roads, soil erodibility, and forested catchment boundaries was imported into a Geographic Information System (GIS) for the Southern region as for the Upper and Lower North East Regions. The information was analysed to provide site-specific relationships for the proportion of the mobilised sediment that reaches the stream from both the general harvest and snig track area, as well as the permanent access roads. In the Southern region, some of this information has not yet been released; and
4. Annual generation rates derived from Step 2 were combined with the site-specific delivery rates from Step 3 to calculate the annual sediment load reaching the drainage lines. The difference in sediment loads due to logging activities was then identified.

2.5 CONVERTING YIELD IMPACTS TO STREAMFLOW IMPACTS

2.5.1 Approach Adopted to Convert Yield Impacts into Streamflow Impacts

Data supplied by SKM showed the impact of the adopted logging scenario on water yield over time. In order to determine the impact of a change in water yield on water dependent activities, the impact on yield must be converted to an impact on streamflow.

Initially, the depth of run-off was determined for a specific unit area within the forest. This measure is defined as the depth per unit area and is measured in millimetres[4]. By multiplying the depth per unit area by the total forest area contained upstream of the gauging location, the

[4] Depth per unit area is a measure of the change in run-off from a specified unit of forest area. It provides a measure of the impact that logging has on water yield within a specified area of forest.

impact on streamflow can be measured. That is, the impact on yield as measured in millimetres can be converted to an impact on streamflow, as measured in megalitres.

For example, if the change in water yield in year one following the adoption of the logging scenario is a decline of 5mm, and the area of forest upstream of the gauging station[5] is $10km^2$, then the impact on streamflow is calculated as ($5mm * 10km^2$), or a decline of 50 megalitres.

2.5.2 Limitations to the Adopted Approach

There are limitations to the methodology adopted to convert yield impacts into streamflow impacts. Firstly, the analysis assumes that there are no transmission losses within a stream system. In reality, mean streamflow as measured at a gauging station does not necessarily equate to water availability at some downstream location. Depending on the length of a stream, types of soils, access to groundwater aquifers and other factors, there may be transmission losses as water travels throughout a system.

Secondly, there is limited catchment-specific data within the study. Although rainfall and forest areas are the main determinants of streamflow impacts, no account is taken of topography, soils and vegetation, all of which will influence downstream water availability and will be important determinants of variation between individual catchment streamflow impacts.

Finally, the hydrology analysis upon which this economic analysis is based (SKM 1999), considered only the impacts of logging scenarios on annual water yield. SKM (1998) points out that different combinations of catchment characteristics would probably affect the seasonality and frequency of flows. However, after reviewing the literature and analysing the available data, both SKM (1998) and SKM (1999) found that the impacts on the seasonality or frequency of flows could not be reliably assessed and thus impacts on water quantity are restricted to characterising changes in annual yields only.

Changes to high and low-flow regimes are important, and need to be taken into account. In the case of agriculture, changes to the flow regime will affect the marginal value product of water (relative to its scarcity). Failure to reflect impacts on low flow regimes will result in farmer economic risk not accurately reflecting reality. Furthermore, the use of averages (average rainfall) also ignores the sequencing of dry and wet years. Such sequencing (especially sequential dry years) will influence farmer economics, viability and finances, and will have important flow-on effects on catchment communities.

2.6 GAUGING STREAMFLOW

Within the UNE & LNE study, two gauging stations were used in order to determine the impact of the adopted logging scenario on water dependent/related activities. This study is somewhat different, in that only one gauging station is utilised within each catchment.

The gauging station used to monitor streamflow is located immediately downstream of the forested area of the catchment. Streamflow data provided from this gauging station allows average annual streamflow at this point to be determined. In order to measure the economic impact of changes in water yield on water dependent activities, average annual impacts over time are compared to this mean annual streamflow level.

[5] Gauging stations are discussed in more detail in the following section.

2.7 INTERPRETING IMPACTS - TIMEFRAMES

Whereas estimated impacts on yield are assessed over a 150-year period, economic studies tend to limit their period of analysis to significantly shorter periods of time. NSW Treasury (1997) state that conducting economic analysis over periods of greater than 20 to 30 years' duration is of limited value due to the impact of discounting of future costs and benefits and the difficulties involved with forecasting over long time periods.

However, the impact of the adopted logging scenario on water yield, and therefore streamflow, will vary over time, with the potential for important repercussions for downstream water users. Changes to the forest age profile in subsequent decades (greater than 30 years) will alter the impact that the logging scenario has on mean streamflow. Generally, trends in estimated impacts upon water yield will reverse after twenty to thirty years. This is due to the influence of factors such as the average age of the forest and the average age of the harvestable area.

Therefore, within this study, estimated impacts are reported:

- for the purpose of estimating the economic impact on downstream water users associated with the adopted logging scenario; and
- for the purpose of examining longer-term trends in impacts upon water yields and commenting upon the influence that such trends would have on downstream water users over the longer-term.

Economic impacts associated with changes in water yields are not estimated over the longer-term. The three analysis periods adopted for the economic analysis are:

- short-term (one to five years);
- medium-term (six to ten years); and
- long-term (eleven to thirty years).

Qualitative conclusions are drawn on the likely impact of longer-term trends on downstream water users. For this analysis longer-term trends are defined as up to, and including, 100 years of data.

2.8 PRESENTATION OF RESULTS

The impact of the adopted logging scenario is presented by listing both the actual and percentage impact on mean streamflow over each of the time periods described above. Results are provided for:

- the impact incurred when the adopted logging scenario is applied to a forest of current conditions;
- the component of this impact that is related specifically to tree growth;
- the component of this impact that is related specifically to logging; and
- the impact incurred when the adopted logging scenario is applied to an old growth forest.

Therefore, results related to the application of the adopted logging scenario to a forest of current conditions are presented in full, as well as being disaggregated to reflect the relative tree growth and logging components. Results related to the application of the adopted logging scenario to an old growth forest are only listed in terms of aggregate impact (that is, the tree growth and logging components are not individually specified).

2.9 DATA

SKM provided the majority of the data that was utilised within this report. For each catchment this included:

- data related to the impact of the adopted logging scenario on yield[6];
- data related to catchment area, forest area and net harvestable area;
- annual rainfall data;
- gauging station data; and
- streamflow data.

Other data and sources that were utilised included data related to water quality and water use (from the New South Wales Department of Land and Water Conservation), aerial photographs of each catchment and catchment profile data supplied by State agencies and other individuals for each of the catchments.

Data limitations prevented detailed statistical analysis from being carried out within this study. In addition, margins of error associated with scenario modelling were not reported. Therefore, some care must be taken when interpreting economic impacts of small magnitudes, e.g., zero or one percent impacts.

[6] This data covers impacts associated with application of the adopted logging scenario to both a forest of current conditions and an old growth forest.

3. ECONOMIC IMPACTS

3.1 INTRODUCTION

The purpose of this section is to provide an overview of the likely impacts incurred by downstream water users and water dependant activities due to the implementation of the adopted logging scenario. The likely impacts associated with both a decline and an increase in mean annual streamflow are discussed.

The analysis of likely economic impacts is based on the assumption that each activity has access to additional streamflow that may become available, or will lose some proportion of their current usage volume if streamflow declines. In practice, this will not occur as regulatory mechanisms limit the ability of particular sectors to utilise additional streamflow (for example, agricultural abstractions greater than entitlement) or protect existing allocations from any proportional decrease (for example, environmental streamflow and high security irrigation entitlements).

Furthermore, where water activities and uses are exclusive, additional streamflow may only accrue to one particular industry. Extractive uses such as agriculture, manufacturing and drinking water supplies are deemed exclusive[7]. For instance, additional water cannot accrue to both manufacturing and drinking water supplies simultaneously. The use of additional water by manufacturing industry precludes the use of this water for the purpose of supply of drinking water.

The likely impacts that are associated with different types of water users and water dependent activities are discussed in the following sections. Likely economic impacts incurred by agriculture are estimated quantitatively. This is due to the fact that agriculture is generally the largest water user in most catchments[8], and data estimating economic impacts associated with variations in the supply of water to agriculture is readily available.

Due to data and time constraints, economic impacts associated with variations in access to water amongst other (non-agricultural) sectors and activities are estimated qualitatively[9].

[7] Recycling of water for future use in other industries is ignored.

[8] This does not include the environment as a user of water, as in a technical sense, the environment is the largest user of water within each catchment.

[9] This includes impacts associated with water quality. In the UNE & LNE, detailed data was available to help estimate implied impacts on water quality associated with the adopted logging scenario in each catchment. In this study, time constraints prevented this analysis from being undertaken.

3.2 IMPACTS ON ABSTRACTORS

3.2.1 Agriculture

A change in streamflow will either increase or decrease the water available to agriculture. One method of examining the economic impact associated with additional access (or less access) to marginal water supply is to examine the marginal value product of the resource (that is, the value at which the resource could be traded).

Hassall & Associates (1999) noted that NSW Agriculture and the Centre for Water Policy Research have derived the marginal value product of water for a number of New South Wales river valleys. Estimates range between $35 and $75 per megalitre depending upon the production characteristics of the valley and the seasonal conditions involved[10].

An indicative method of estimating the economic impact of providing additional water to agriculture can be calculated by multiplying the marginal value product of a megalitre of water by the amount of water that is made available to the industry in excess of current allocations. This is the approach adopted within this study[11].

Another method by which to estimate the economic impact of additional water to agriculture is to examine the returns generated from those activities in which the water is used. Examining the gross margin derived from a particular enterprise will give an insight into the net returns (excluding fixed costs) derived from an irrigated enterprise.

A decrease in annual average streamflow may limit the annual allocation of water to irrigated agriculture. For instance, instead of irrigators receiving 100% of their entitlement, they may only be allocated some proportion of that allocation, all other things being equal.

The effects of a reduction in water supply will include water resources being shifted out of low value enterprises into high value enterprises, improved efficiency of water use and greater structural adjustment pressures being placed on water users.

The economic impact of a reduction in water allocation can be measured by:

- examining the returns derived from the enterprises in which production is forgone;
- calculating the value of forgone water (marginal value product multiplied by volume of water lost); or
- analysing the impact on underlying farm financial indicators such as farm business income and net farm profit.

In this study, the economic impact on irrigated agriculture of a decrease in mean streamflow is estimated by analysing the potential value of forgone water (that is, the volume of water forgone multiplied by the marginal value product per megalitre).

[10] In this study, an estimated marginal value of $45 per megalitre is adopted within the South Coast sub-division and a marginal value of $60 is adopted within the Tumut sub-division (reflecting the higher value irrigated production within the Murrumbidgee catchment). For the purposes of this study, seasonal influences that affect the marginal value product of water, such as the sequencing of dry and wet years, are assumed to have no influence on marginal value. In reality, the relative scarcity and security of water supplies will impact upon the marginal value product of water associated with agriculture.

[11] It is assumed that impediments to realising the marginal value product of water do not exist.

Within the wider catchments[12] examined as part of this study, the profile of agriculture (and associated water use) is characterised by:

- Mongarlowe River: predominantly grazing and pasture production with 1 042 megalitres extracted for irrigation in 1998 (DLWC, 1999);
- Wandandian Creek: a small area of vegetable and turf production with a total extraction for all users[13] of 22 megalitres in 1998 (DLWC, 1999); and
- Buddong Creek: no extractions for agriculture within the catchment, however, irrigated agriculture downstream of Blowering Reservoir uses water from that is indirectly supplied from Buddong Creek.

3.2.2 Manufacturing

An increase in average streamflow may result in greater impetus for manufacturing industry to expand production, or for other industries to establish a production base within the region. Measured strictly in terms of the net value associated with increased production, the economic benefit derived from higher streamflow can be readily measured.

The economic impact on manufacturing of a decline in average annual streamflow will most readily be measured by a reduction in output if the industry is reliant upon water as a key input in the production chain. Depending upon the nature of the industry (high value versus low value output), the economic impact of such a decline will vary.

A decline in the amount of water available will also place pressure on manufacturing industry to increase efficiency of water use if they seek to maintain production levels. Cost efficiency savings may be able to be gained, thus offsetting at least some of the impacts that a reduction in water availability would otherwise cause.

Within the catchments examined as part of this study, the profile of manufacturing is characterised by:

- Mongarlowe River: no industrial water use in the catchment;
- Wandandian Creek: no industrial water use in the catchment (the sawmill situated on Wandandian Creek uses water supplied from Nowra); and
- Buddong Creek: no extraction for manufacturing, however, water is used to generate hydro-electric power at Blowering Dam.

3.2.3 Drinking Water Supply

An increase in mean streamflow will increase the security of domestic water supply. Measuring the economic value derived from such increased security would involve the adoption of techniques such as contingent valuation. A positive willingness-to-pay for increased security of domestic water supply would only be recorded either where drinking water is in short supply or

[12] The term ‘wider’ catchments refers to the fact that to gauge the impact of logging scenarios on downstream water users, water users outside of the catchment boundaries defined for the logging modelling must be examined. That is, the users of water are assumed to be located both within the catchment as defined for the logging modelling as well as downstream of this catchment, within the ‘wider’ catchment.

[13] This incorporates other abstractors in addition to agriculture.

where supplies are unreliable or inconsistent. One surrogate for this benefit would be avoided costs associated with seeking alternative supplies during shortages.

An increase in average annual streamflow, if reflected in an increase in drinking water supplies, may also lead to an increase in the treatment costs associated with the provision of domestic drinking water supplies. This therefore represents a negative outcome (in terms of drinking water supplies), arising from increased mean streamflow.

Just as an increase in mean streamflow will increase the security of domestic water supply, a decrease in mean streamflow will exert some negative pressures on this security. If this pressure is significant, this could result in additional costs (trucking water, installation of rainwater tanks) in some communities.

Within the catchments examined as part of this study, the profile of drinking water supply is characterised by:

- Mongarlowe River: does not supply drinking water directly, however, water from Shoalhaven River, of which the Mongarlowe River is a tributary, is diverted seventy kilometres below the confluence of these two rivers to supply part of Sydney’s drinking water demand;
- Wandandian Creek: does not supply drinking water; and
- Buddong Creek: does not supply drinking water.

3.3 IMPACTS ON WATER DEPENDENT ACTIVITIES

3.3.1 Tourism and Recreation

Water-based recreation activities will generally benefit from an increase in streamflow. Activities undertaken within State forests that may benefit from an increase in mean streamflow include fishing, swimming and other water-based activities such as caneoing (Hassall & Associates, 1999b). The scale of this benefit, as measured in economic terms, depends upon a number of factors, including the proximity of recreational activities to urban centres, the provision of substitute sites for recreational activity and the importance of recreation activities to the community (NSW EPA, 1998).

Measuring the economic benefit derived from recreation activities is difficult. Some measure of the amenity value of recreation will provide an indicator of the benefit derived by individuals from having the opportunity to partake in recreation activities. However, these values are only valid if they “create” a benefit derived from recreation activity in addition to the current “stock” of benefit.

Examining the expenditure directly associated with tourism and recreation activities also provides an estimate of the value derived from such activities. Such an estimate depends upon estimating total visitor numbers associated with water-dependent tourism and recreation activities and estimating only that proportion of expenditure that was directly related to undertaking these water-based activities.

A decrease in mean streamflow will impact upon recreation activities if they reduce the “stock” of recreational benefit. Unless this “stock” of recreational benefit is reduced, there will be no costs associated with a decrease in mean streamflow. A decrease in expenditure associated with water-based tourism and recreation activities in the catchment will also indicate the magnitude of negative economic impact associated with a decline in mean streamflow.

Within the catchments examined as part of this study, the profile of water-based tourism and recreation is characterised by:

- Mongarlowe River: few or no tourism and recreation activities are dependent on the river;
- Wandandian Creek: few or no tourism and recreation activities are dependent on the creek; and
- Buddong Creek: few or no tourism and recreation activities are dependent on the creek, which is narrow and shallow, however public facilities are available for visitors at Buddong Falls.

3.3.2 Environment

Measuring the economic impact on the environment from an increase in streamflow is a difficult exercise given the lack of research that has been conducted in attempting to value environmental costs and benefits.

An increase in streamflow may benefit the environment, especially in relation to the provision of environmental flows. Increases in streamflow of an ample nature may be sufficient to allow an increase in the certainty of minimum environmental streamflow requirements being met. Indicators of the benefit derived by the environment from increased water flow include impacts upon the aquatic ecosystem, fish populations, bird habitats and the riverine environment (including wetlands).

Alternatively, the potential does exist for increases in mean streamflow to damage the environment. Undesirable changes to the water ecosystem may arise from more regular flushing of the river system. Habitat destruction is an example of a negative impact on the environment that may arise via the provision of increased streamflow.

A decrease in annual average streamflow is likely to have significant costs for the environment. The already stressed state of many riverine environments within NSW means that any decline in average flow levels will exacerbate conditions within already stressed environments.

Measures that can be used to examine the impact of decreased streamflow include eutrophication, turbidity, bank erosion and impacts on wetlands. There are other downstream indicators of the impact of a decrease in mean streamflow. For South Coast catchments, these impacts include changes in fish, prawn and oyster estuary yields.

In order to gain some insights into the impact of the adopted logging scenario relative to the range of natural variation that could be expected to occur in the absence of logging activities, the impacts estimated under the adopted logging scenario should be examined relative to the impacts estimated under the tree growth only representative case. The tree growth only component effectively models the impacts on mean annual streamflow under a case where no logging activities are carried out. Therefore, it provides a surrogate of the likely natural variation in streamflow that would be expected over time if no logging activities were undertaken within a catchment.

Within the catchments examined as part of this study, the profile of the riverine environment within the wider catchment (incorporating areas downstream of the catchment that is defined for logging modelling purposes) is characterised by:

- Mongarlowe River: has high conservation value as identified by NSW Fisheries and NSW NPWS; currently has a medium environmental stress rating (NSW DLWC, 1998);
- Wandandian Creek: has environmental value and high conservation value as identified by NSW Fisheries and NSW NPWS; currently has a medium environmental stress rating (NSW DLWC, 1998); and
- Buddong Creek: no stress rating available, however the environment is the greatest user of water with no other abstractions occurring within the catchment.

3.4 IMPACTS ON OTHER RELATED ITEMS

3.4.1 Water Quality

Numerous recent studies have been undertaken using techniques such as contingent valuation and choice modelling to determine consumer willingness to pay for improved water quality. The Centre for International Economics (1997), Morrison, Bennett and Blamey (1998), Hill (1994), Dwyer Leslie (1991) and Carlos (1991) all directed effort into determining some measure of the consumer value derived from improved water quality. Estimates of willingness to pay ranged between $20 and $170 per person (1997 dollars) depending upon the survey methods utilised and region of focus.

Undertaking a similar task to determine a quantitative consumer value for improvements in water quality in the selected catchments is beyond the scope of this study. Given data and time limitations, a straightforward qualitative approach provides a more realistic method of determining the impacts of changes in mean streamflow on water quality.

Turbidity provides a measure by which to examine the impact of the adopted logging scenario on water quality. An increase in the amount of suspended solids within a stream may result in a decline in water quality and therefore an increase in environmental costs. Some indicators of increased costs include:

- loss of stream environmental health;
- increase in blue-green algae outbreaks; and
- additional water treatment costs.

3.4.2 Flood Mitigation

Assuming an increase in streamflow causes an increase in either the extent or frequency of flood events, this will lead to an increase in the costs associated with flood mitigation.

The costs of flood mitigation will depend upon two key dimensions of the flood profile: the extent of the flood event and the duration of the flood event. The larger the flood event that occurs, the longer the peak flow level is maintained and the longer it takes for flood levels to recede, the greater the costs associated with a flood event.

Costs involved with flood mitigation include agisting stock, purchasing alternative feed supplies, re-establishing persons and livestock at risk of being displaced by a flood event and protecting infrastructure which is susceptible to flood damage.

Assuming the flood profile and catchment hydrology is typical, a decline in average annual flow level will generally decrease the extent and likelihood of a flood event occurring, therefore resulting in a decline in the mitigative effort required to avoid flood damage. Resultant benefits, given the magnitude of the scenarios examined, are unlikely to be significant.

3.4.3 Infrastructure

An increase in average annual streamflow, if sufficiently large, may impact negatively on existing infrastructure. Roads, bridges and buildings that are in the immediate proximity of waterways may become more susceptible to the impacts of high streamflow events. The costs involved with repairing or replacing damaged infrastructure will depend upon the scale and frequency of events that cause such damage. Small increases in streamflow are unlikely to result in identifiable cost increases.

It is assumed that a decline in average annual streamflow will have no negative economic impact on infrastructure. With a smaller volume of water flowing within waterways, it is assumed that infrastructure will be subject to less damaging, streamflow-related stress. The total marginal positive impact is thought to be insignificant.

3.5 INDIRECT ECONOMIC IMPACTS

In addition to the direct economic impacts that are incurred by water users/activities, there will be indirect (flow-on) impacts that are also induced. These impacts will include flow-on effects upon income, expenditure and employment within the local community in which the direct impacts are incurred. These secondary impacts are important components to be examined when undertaking an extensive economic study. However, for the purpose of this study, such impacts are not analysed.

4. MONGARLOWE RIVER

The purpose of this section is to provide an overview of the estimated impacts associated with the adopted logging scenario within the wider Mongarlowe River catchment. For the purposes of this study, the wider Mongarlowe catchment is identified as including that area defined as catchment for the purposes of modelling the logging scenario, as well as downstream areas that include users and activities that access streamflow.

A brief profile of the catchment is provided, including a description of forestry activities, water use, streamflow and water quality. The impact of the adopted logging scenario on mean annual streamflow is measured and the potential economic impact associated with changed streamflow is assessed.

4.1 CATCHMENT PROFILE

The Mongarlowe River catchment is contained within the Shoalhaven River Basin. The river flows to the east of Braidwood through Monga, Mongarlowe and Marlowe before intersecting with the Shoalhaven River. Many small tributaries flow into the river before its confluence with the Shoalhaven River. There is some agricultural land near the confluence of the Mongarlowe River with the Shoalhaven River and along the river flats of the Mongarlowe River closer to the forested area.

4.1.1 Land Use

Land use in the Mongarlowe River catchment is dominated by forestry. The dominance of forested lands within the catchment (as defined for the modelling of the logging scenario) is detailed in Table 4a.

TABLE 4A FORESTRY CHARACTERSITICS, MONGARLOWE RIVER CATCHMENT

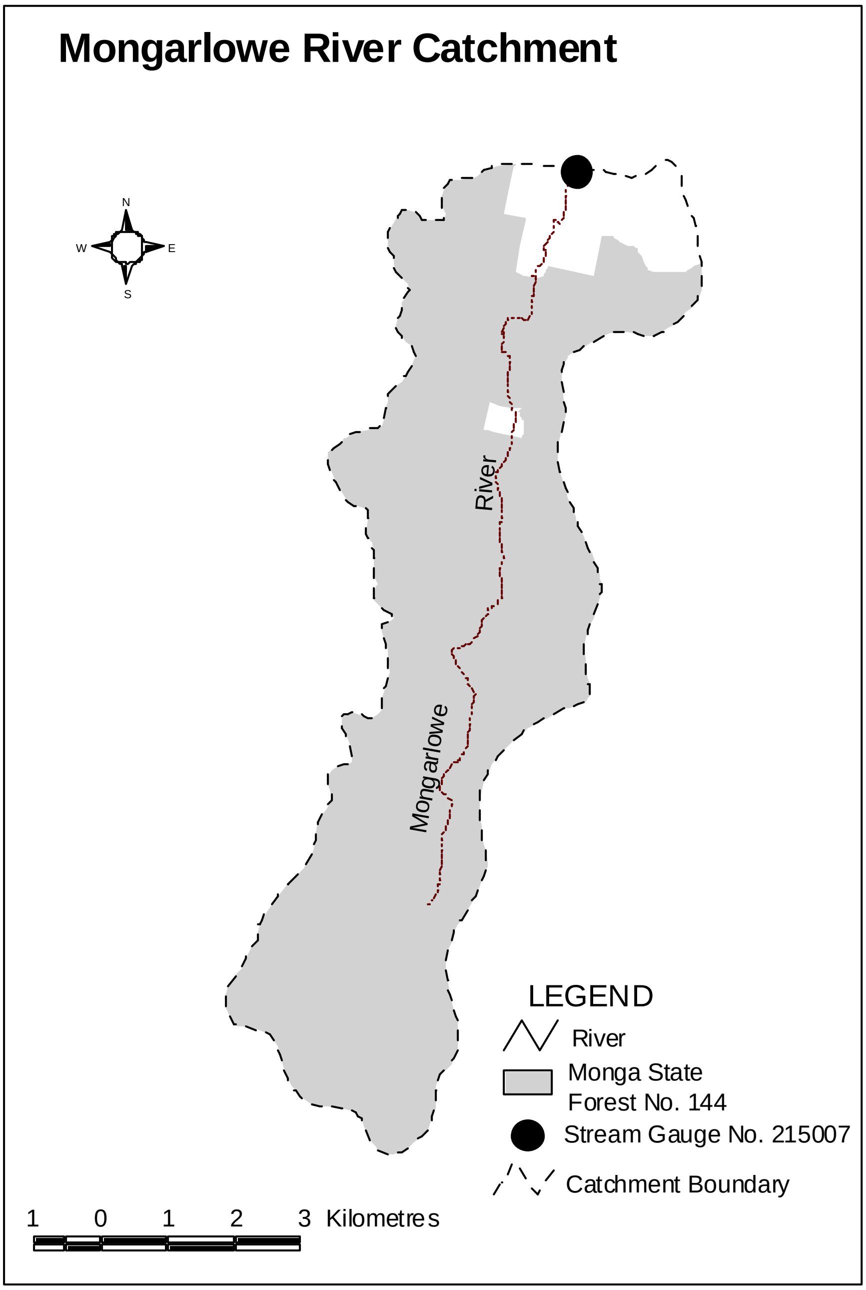
Characteristic	Estimated Area (hectares)
Catchment Area (ha)	4 319
Forest Area (ha)	3 952

Source: SKM (1999)

Therefore, 91.5% of the catchment that is analysed for modelling purposes is forested. The remainder of the wider catchment (including downstream areas), is devoted to agricultural use, although this is limited to dryland grazing enterprises in most parts due to the timbered nature of much of the land.

Figure 4a illustrates the dominance of forested land within the catchment that was defined for modelling purposes. This does not reflect downstream agricultural areas within the wider catchment.

FIGURE 4A MONGARLOWE RIVER CATCHMENT



Source: SKM (1999)

4.1.2 Water Use

The most comprehensive estimate of water usage within the wider Mongarlowe River catchment is derived from New South Wales Department of Land and Water Conservation (DLWC) data collected as part of the Stressed Rivers Program. This data was specifically collated for the purpose of deriving hydrological indicators of rivers. For the purposes of this study, the data is intended only as an indicative estimate of water usage patterns within this catchment.

Table 4b provides estimates of water usage in the entire Mongarlowe River catchment (that area above the Shoalhaven River), for those months in which irrigated agriculture utilises water extractions[14]. Estimated usage is divided into irrigation usage and other usage, which includes other industries, towns and supply of water for stock and domestic purposes.

TABLE 4B ESTIMATED ANNUAL WATER USAGE, MONGARLOWE RIVER CATCHMENT

Industry	Month						
	January	February	March	April	November	December	Total[1]
Irrigation (ML)	203	178	152.52	114.39	190.62	203.33	1,042
Other (ML)	1.39	1.22	1.05	0.78	1.31	1.39	7

Source: DLWC (1999a)
Note:
1. Estimates of total usage refer only to those months in which irrigation extractions take place.

Table 4b shows that irrigated agriculture is the predominant water user in the wider Mongarlowe River catchment. The small usage estimated for other water users indicates that there is only very limited domestic and/or industrial water demand within the wider catchment.

4.1.3 Streamflow

Streamflow is measured using a gauging station within the catchment. Characteristics of this gauging station are listed in table 4c.

TABLE 4C GAUGING STATION CHARACTERISTICS, MONGARLOWE RIVER CATCHMENT

Characteristic	Indicator
Stream Gauge No.	215007
Gauge Latitude	$35^0$32'30"
Gauge Longitude	$149^0$55'35"

Source: SKM (1999)

Streamflow characteristics within the Mongarlowe River catchment as measured at this gauging station are listed in table 4d.

TABLE 4D STREAMFLOW CHARACTERISTICS, MONGARLOWE RIVER CATCHMENT

Characteristic	Estimate
Mean Annual Flow (ML)	15 117

Source: SKM (1999)

[14] Estimates of water usage are provided for current usage.

4.1.4 Water Quality

The NSW DLWC, as part of the Stressed Rivers Program, categorised the Mongarlowe River catchment in terms of stress classifications. The definition of the Mongarlowe River catchment for the purposes of the Stressed Rivers Program differed from the definition used within this report. Stress ratings were developed for the larger Mongarlowe River catchment. As a result, they encompass a larger area than that being considered for this report. This larger area will in turn encompass a greater variety of landuse activities.

Despite these differences in catchment definition, these stress ratings provide a useful guide as to environmental stress ratings in the region being examined. These classifications are summarised in Table 4e.

TABLE 4E ENVIRONMENTAL STRESS CLASSIFICATIONS, MONGARLOWE RIVER CATCHMENT

Category	Stress Classification
Overall Stress Classification	Low Environmental Stress [1]
Full Development Stress Classification	Medium Environmental Stress [1]
Hydrology Stress Rating	Low
Environmnetal Stress Rating	Medium

Source: DLWC (1998)
Note:
[1] assumes low proportion of water extractions.

As can be seen, the Mongarlowe River catchment has been given a low overall stress classification. However, both NSW Fisheries and National Parks and Wildlife Service have identified the Mongarlowe River catchment as having high conservation value. Therefore, any impacts of changed mean streamflow must be carefully assessed to ensure future degradation of the river environment is not forecast given the implementation of the adopted logging scenario.

4.2 IMPACT OF THE ADOPTED LOGGING SCENARIO

Impacts of the adopted logging scenario on streamflow are reported using two methods:

- the actual impact on streamflow, measured in megalitres; and
- the percentage impact on annual streamflow.

Impacts are provided for each of:

- the adopted logging scenario when applied to a forest of current conditions;
- the tree growth component of this total impact;
- the logging component of this total impact; and
- the adopted logging scenario when applied to an old growth forest.

For reporting purposes, these four are collectively referred to as representative cases.

4.2.1 Impacts Measured Within an Economic Timeframe

The average annual impact on mean streamflow under each of the four representative cases is outlined in table 4f. Impacts are listed in terms of average annual impact on mean streamflow, measured in megalitres.

TABLE 4F AVERAGE ANNUAL IMPACT ON MEAN ACTUAL STREAMFLOW (ML), MONGARLOWE RIVER CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Short term	**40**	-168	208	178
Medium term	**182**	-123	305	207
Long term	**845**	933	-88	-306

Therefore, under the adopted logging scenario, mean annual streamflow is forecast to progressively increase over time. An analysis of the logging only component of the adopted logging scenario reveals that it is the main driver behind this increase in mean annual streamflow in the short and medium-term. The magnitude of the increase in mean streamflow in the short and medium-term under the adopted logging scenario is not considered to be significant.

Despite an increase in mean streamflow over time, an interesting component of the results is that relative to a situation in which no logging is modelled (tree growth only component), the logging scenario results in:

- an increase in mean annual streamflow over the short and medium-term, whereas without logging activities mean streamflow would decline; and
- a smaller increase in mean streamflow over the long-term relative to that which would be expected when no logging activities are undertaken.

Variations in the impact on mean annual streamflow over time (both positive and negative) relate to changes in the average age of the forest and the logging profile adopted.

To gauge a measure of the magnitude of these actual average impacts, table 4g presents impacts as measured as a percentage of mean annual streamflow.

TABLE 4G AVERAGE ANNUAL PERCENTAGE IMPACT ON MEAN STREAMFLOW, MONGARLOWE RIVER CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Short term	**0%**	-1%	1%	1%
Medium term	**1%**	-1%	2%	1%
Long term	**6%**	6%	-1%	-2%

When comparing the adopted logging scenario with the tree growth only component, it can be seen that there is little variation in estimated impacts over time. This suggests that the adoption of the logging scenario does not lead to significant changes in mean streamflow from what would otherwise be expected in the absence of logging activity.

Therefore, under the adopted logging scenario, impacts on mean annual streamflow are deemed insignificant, particularly in the short and medium-term. It is assumed that year-to-year variations in mean streamflow in the absence of logging activities will be at least equivalent to those estimated under the adopted logging scenario. Therefore, it is anticipated that economic impacts associated with changes in mean annual streamflow will be small and positive, though insignificant.

4.2.2 Impacts Over the Longer Term

Impacts on mean annual streamflow over the longer-term (from year 30 up to year 100) are provided in table 4h. Impacts are provided both in terms of change in actual average streamflow and the percentage change in mean annual streamflow.

TABLE 4H LONGER TERM IMPACT ON MEAN ANNUAL STREAMFLOW, MONGARLOWE RIVER CATCHMENT[1]

Type of Change in Mean Annual Streamflow	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Change in ML	**2 080**	3 509	-1 429	-1 582
% Change	**14%**	23%	-9%	-10%

Note:
1. Represents average for impacts for years 30 to 100.

Over the longer term, by comparing the adopted logging scenario with the tree growth only component, the impact of the adopted logging scenario relative to a case where no logging takes place can be estimated. It can be seen that when no logging is undertaken, there is a larger increase in mean annual streamflow than is estimated to occur under the adoption of the logging scenario. Therefore, logging results in smaller increases in mean annual streamflow over the longer-term than would be expected in the absence of logging activities.

In addition, the magnitude of the increase in mean streamflow over the longer-term, relative to impacts exhibited under shorter time periods, has the potential to impact upon downstream water users and activities in a significant manner. Although economic costs and benefits associated with such impacts are not estimated, it is important to be aware that over the longer-term, the adopted logging scenario will lead to a significant increase in mean annual streamflow. Types of economic benefits and costs that may occur as a result of this increase in streamflow include positive impacts (if additional streamflow was accessed and utilised by agriculture, industry or for drinking water supplies) and negative impacts (if additional streamflow led to alterations to the riverine habitat or a decline in water quality).

A graphical portrayal of the impact of the adopted logging scenario on average annual mean actual streamflow (measured in megalitres) and the percentage impact on mean annual streamflow (measured in percent) is provided within appendix 4a. These graphs incorporate impacts under the economic timeframe (short-term, medium-term and long-term) as well as longer-term impacts.

4.3 POTENTIAL ECONOMIC IMPACTS

Within the Mongarlowe Creek catchment, the economic impacts (up to year thirty) associated with the implementation of the adopted logging scenario are estimated to be small, positive and focussed upon a limited range of activities.

As the Mongarlowe River intersects with the much larger Shoalhaven River, economic impacts are only incurred directly within the catchment[15] (within Buddong Creek catchment economic impacts are also incurred downstream of the catchment, as water is stored within a reservoir for future downstream use).

Quantitative estimates of economic impact are provided for agriculture, whilst a qualitative assessment procedure was adopted in determining economic impacts on other downstream water users and water dependent activities. Estimates of economic impact are derived by assuming that additional streamflow can be accessed by each water user or water dependent

[15] Sydney Water uses Lake Yarrunga and Tallowa Dam to divert water from the Shoalhaven River for drinking water supply in Sydney. This is at least 70 kilometres downstream of the confluence of Mongarlowe River and Shoalhaven River, so impacts associated with changes in mean annual streamflow in the Mongarlowe River are assumed to be insignificant in terms of their impact on drinking water supply for Sydney Water.

activity. When determining total economic impact across all users/activities, mutually exclusive water uses should be recognised so that benefits attributed to increased streamflow are not double counted.

The following section outlines the economic impacts associated with the adopted logging scenario.

4.3.1 Economic Impacts within Mongarlowe Creek Catchment

Impacts on Abstractors

Table 4i estimates the economic impact of the adopted logging scenario on abstractors of water within the catchment.

TABLE 4I ANNUAL ECONOMIC IMPACT ASSOCIATED WITH ABSTRACTORS

Activity	Economic Impact ($ per annum)
Agriculture	$1 800 (ST) $8 000 (MT) $38 000 (LT)
Manufacturing	Nil
Drinking water supplies	Insignificant

Note:
1. ST= Short term (5 years), MT = Medium term (10 years), LT = Long Term (30 years)

Given small positive impacts are estimated under the adopted logging scenario, the scale of economic impacts associated with agriculture is relatively small. By assuming that the per megalitre value of additional water supplied to agriculture is equivalent to the marginal value product of a megalitre of water, the annual economic benefit derived by agriculture is estimated to range from $1 800 in the short-term to $38 000 in the long-term under the adopted logging scenario. Given that the increase in average annual streamflow in the long-term is 845 megalitres and present irrigated water usage is only 1 027 megalitres, it is unlikely that all of this additional streamflow would be utilised by agriculture.

Impacts on other abstractors are assumed to be nil for manufacturing, given there is no industrial water use within the catchment, and insignificant for drinking water supplies.

If the adopted logging scenario is applied to an old growth forest, an annual economic benefit in the order of $9 000 is derived by agriculture in the short and medium term. Over the long-term, an annual economic cost is incurred by agriculture in the order of $13 500.

Impacts on Water Dependent Activities

Table 4j estimates the economic impact of the adopted logging scenario on water dependent activities.

TABLE 4J ANNUAL ECONOMIC IMPACT ASSOCIATED WITH WATER DEPENDENT ACTIVITIES

Activity	Economic Impact
Tourism and Recreation	Insignificant
Environment	Insignificant

Given an increase in mean streamflow is estimated, economic benefits would be expected to accrue to these water dependent activities. However, the small scale of the estimated impacts on mean annual streamflow lead to insignificant positive impacts on both the environment and tourism and recreation.

Impacts on Other Related Items

Table 4k estimates the economic impact of the adopted logging scenario on other water-related items.

TABLE 4K ANNUAL ECONOMIC IMPACT ASSOCIATED WITH OTHER RELATED ITEMS

Activity	Economic Impact
Water quality	Insignificant
Flood mitigation	Insignificant
Infrastructure	Insignificant

Economic impacts related to water quality, flood mitigation and infrastructure are all assumed to be insignificant. Once again, this is reflective of the fact that the scale of estimated impacts on mean annual streamflow under the adopted logging scenario are relatively insignificant over all three economic analysis periods.

4.4 CONCLUSIONS

4.4.1 Economic Impacts

The economic impact on downstream water users and water dependent activities associated with the implementation of the adopted logging scenario is estimated to be slightly positive, yet insignificant. Annual benefits derived over the long-term are significantly greater than those derived over the short and medium-term.

It is assumed that year-to-year variations in mean streamflow that are a direct result of seasonal and climatic variation (for example, variation in rainfall) will have just as much if not larger impacts upon annual streamflow and therefore on the economic benefit derived by water dependent uses and activities. It is on this basis that estimated impacts under the adopted logging scenario are assumed to be insignificant.

4.4.2 Longer Term Impacts

Though not quantified, the impacts incurred over the longer-term (year 30 through to year 100) are important to keep in mind as impacts on mean annual streamflow over this time period are significant and will have associated implications for downstream water uses/activities. Within the Mongarlowe River catchment, a comparison of the adopted logging scenario with a scenario that does not involve logging (tree growth only component), reveals that there would be a larger mean annual increase in streamflow if no logging activity was undertaken over this time period.

5. WANDANDIAN CREEK

The purpose of this section is to provide an overview of the estimated impacts associated with the adopted logging scenario within the Wandandian Creek catchment. For the purposes of this study, the wider Wandandian catchment is identified as including that area defined as catchment for the purposes of modelling the logging scenario, as well as downstream areas that include users and activities that access streamflow.

A brief profile of the catchment is provided, including a description of forestry activities, water use, streamflow and water quality. The impact of the adopted logging scenario on mean annual streamflow is measured and the potential economic impact associated with changed streamflow is assessed.

5.1 CATCHMENT PROFILE

Wandandian Creek flows from Yerriyong State Forest and discharges on the coast at St Georges Basin, just south of Jervis Bay. The creek flows through the small township of Bewong and discharges near the township of Sussex Inlet. There appears to be some small areas of irrigated agriculture along that part of the creek system that supports landuse (that is, the area not forested). The main tributary that flows into Wandandian Creek is Gnatilia Creek, which is somewhat narrower than Wandandian Creek.

5.1.1 Land Use

Land use in the wider Wandandian Creek catchment is predominantly forestry, with small areas of agricultural production limited to the immediate river frontage. Townships and industry also feature in the catchment.

Table 5a shows the proportion of the catchment (as defined for modelling purposes) that is devoted to forested lands.

TABLE 5A FORESTRY CHARACTERISTICS, WANDANDIAN CREEK CATCHMENT

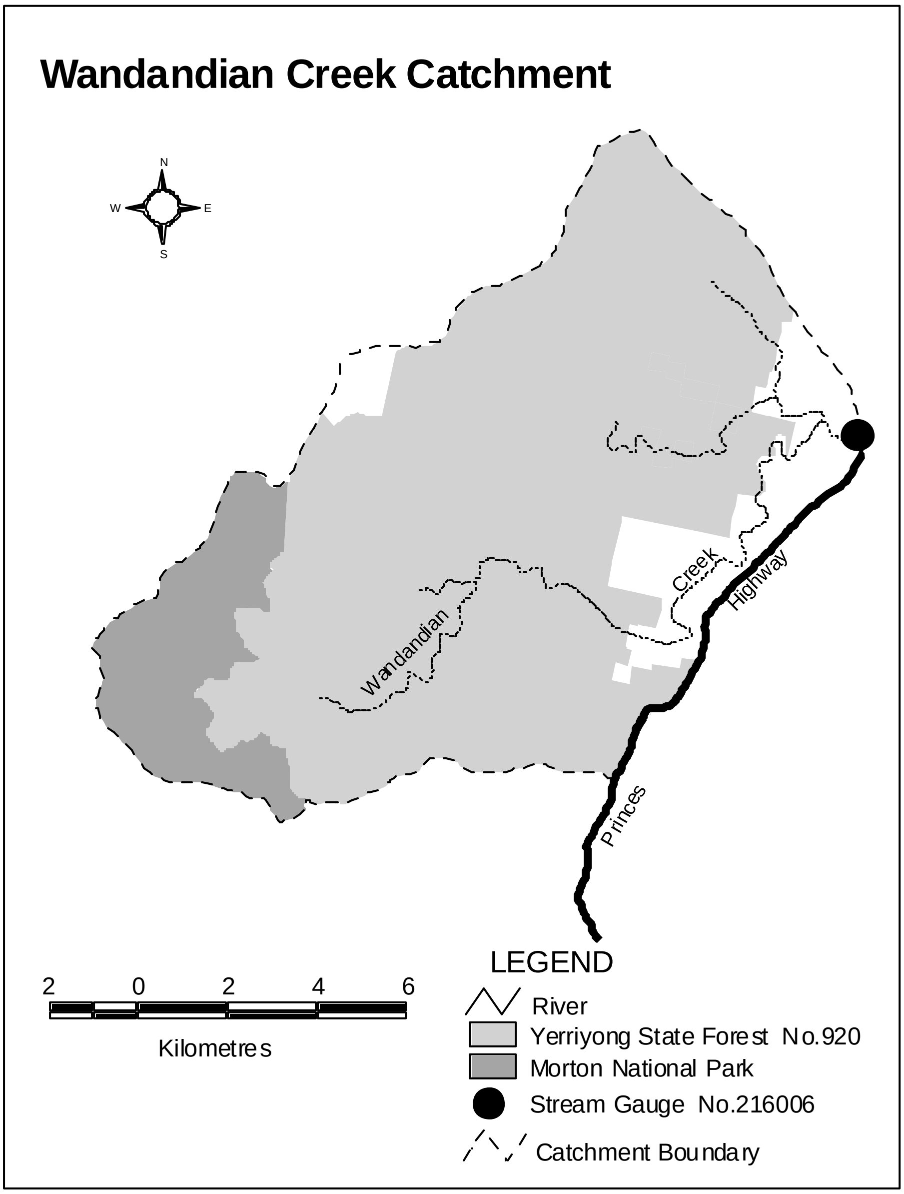
Characteristic	Estimated Area (hectares)
Catchment Area (ha)	14 176
Forest Area (ha)	10 794

Source: SKM (1999)

Therefore, 76% of the catchment (defined for modelling purposes) is forested. This is significantly less than the proportion forested in the other two catchments of the Southern RFA region. However, it still shows that landuse within the catchment is dominated by forests.

Figure 5a illustrates the Wandandian Creek catchment. This does not include areas downstream of the catchment that form part of this economic analysis.

FIGURE 5A WANDANDIAN CREEK CATCHMENT



Source: SKM (1999)

5.1.2 Water Use

As with the Mongarlowe River catchment, estimates provided by the NSW DLWC form the basis of estimated water usage within the wider Wandandian catchment. Once again, this water usage data refers to a larger catchment area than is outlined in figure 5a. This allows an understanding to be gained not only of water usage within the catchment being examined for logging modelling purposes, bit also water usage in downstream areas of the wider Wandandian Creek catchment.

Table 5b lists monthly extraction estimates.

TABLE 5B ESTIMATED ANNUAL WATER USAGE, WANDANDIAN CREEK CATCHMENT

Industry	Month						
	January	February	March	April	November	December	Total[1]
Total (ML)	4.22	3.7	3.17	2.38	3.96	4.22	**21.65**

Source: DLWC (1999a)
Note:
1. Estimates of total usage refer only to those months in which irrigation extractions take place.

Unlike the previous catchment, water usage data for the wider Wandandian Creek catchment was unable to be divided into that used by agriculture and that used for other purposes. Advice received from NSW DLWC suggests that extractive use includes domestic use, permitted without a license as part of landholders riparian rights, some turf, vegetables, and other agriculture (Ryan, W., DLWC, pers. comm., October 1999).

The small aggregate usage estimates indicate that there is only very small domestic and agricultural water demand within the wider catchment. Bewong township and the sawmill situated along Wandandian Creek obtain water from the Nowra water main which runs along the highway down to Sussex Inlet (Taylor, L., Shoalhaven City Council, pers. comm., October 1999).

5.1.3 Streamflow

Characteristics of the gauging station used to measure streamflow within the catchment are provided in table 5c.

TABLE 5C GAUGING STATION CHARACTERISTICS, WANDANDIAN CREEK CATCHMENT

Characteristic	Indicator
Stream Gauge No.	216006
Gauge Latitude	35^{0}6'0"
Gauge Longitude	150^{0}30'0"

Source: SKM (1999)

Streamflow characteristics within the Wandandian Creek catchment as measured at this gauging station are listed in table 5d.

TABLE 5D STREAMFLOW CHARACTERISTICS, WANDANDIAN CREEK CATCHMENT

Characteristic	Estimate
Years of Streamflow Record	1971-82
Mean Annual Flow (ML)	68 000

Source: SKM (1999)

Streamflow in the Wandandian Creek catchment is significantly greater than streamflow in either of the other two catchments within the Southern RFA region. However, water use, as a proportion of mean annual streamflow is insignificant.

5.1.4 Water Quality

The NSW DLWC, as part the Stressed Rivers Program, categorised Wandandian Creek sub-catchment in terms of stress classifications. These classifications were developed with reference to a larger catchment area than that being explicitly examined as part of this study, however, they do provide useful overview indicators of environmental classifications within the catchment we are examining. These classifications are summarised in table 5e.

TABLE 5E ENVIRONMENTAL STRESS CLASSIFICATIONS, WANDANDIAN CREEK CATCHMENT

Category	Stress Classification
Overall Stress Classification	Medium Environmental Stress[1]
Full Development Stress Classification	Medium Environmental Stress[2]
Hydrology Stress Rating	Low
Environmnetal Stress Rating	Medium

Source: DLWC (1998)
1. assumes low proportion of water extractions.
2. assumes medium proportion of water extractions.

The Wandandian Creek catchment has a medium overall stress classification. In addition, both NSW Fisheries and National Parks and Wildlife Service have identified the Wandandian Creek catchment as having environmental value and high conservation value. If full development is achieved in terms of water extractions, the creek may be placed within a high stress category.

5.2 IMPACT OF THE ADOPTED LOGGING SCENARIO

As for the previous catchment, impacts of the adopted logging scenarios are reported using:

- the actual impact on streamflow, measured in megalitres; and
- the percentage impact on annual streamflow.

Once again, impacts are reported against each of the four representative cases described in section 2.3 of this report.

5.2.1 Impacts Measured Within an Economic Timeframe

The average annual impact on mean streamflow under each of the four representative cases is outlined in table 5f. Impacts are listed in terms of average annual impact on mean streamflow, measured in megalitres.

TABLE 5F AVERAGE ANNUAL IMPACT ON MEAN ACTUAL STREAMFLOW (ML), WANDANDIAN CREEK CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Short term	**-626**	-626	0	0
Medium term	**-574**	-807	233	108
Long term	**2 750**	1 787	963	-45

Under the adopted logging scenario, impacts on mean annual streamflow vary significantly over time. In the short and medium-term, a roughly equivalent negative impact on mean annual streamflow is estimated. This is due to the influence of the tree growth only component, which contributes to a decline in streamflow across both analysis periods. However, by the long-term, estimated impacts on mean annual streamflow are positive and significantly larger than the corresponding decreases in the earlier time periods.

The change in the mixed-age profile of the forest is the main reason why there is an inflection in the trend for impact on mean annual streamflow over the long-term. As can be seen, in the long-term the tree growth only component begins to discharge greater volumes from the forest area. If the adopted logging scenario is applied to an old growth forest, there is also some variation in impacts over time. Mean annual streamflow increases initially, but declines over the long-term.

To gauge a measure of the magnitude of these actual average impacts, table 5g presents impacts as measured as a percentage of mean annual streamflow.

TABLE 5G AVERAGE ANNUAL PERCENTAGE IMPACT ON MEAN STREAMFLOW, WANDANDIAN CREEK CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Short term	**-1%**	-1%	0%	0%
Medium term	**-1%**	-1%	0%	0%
Long term	**4%**	3%	1%	0%

Based on table 5g, we can conclude:

- the adopted logging scenario has insignificant negative impacts on mean annual streamflow in the short and medium-term;
- however, over the long-term, a small, positive impact on mean streamflow is estimated; and
- in the short and medium-term, the influence of the logging component of the adopted logging scenario is assumed to be neutral. Over the long-term it is assumed to be slightly positive, though insignificant.

5.2.2 Impacts Over the Longer Term

Impacts on mean annual streamflow over the longer term are provided in table 5h. Once again, impacts are provided both in terms of change in actual average streamflow and the percentage change in mean annual streamflow.

TABLE 5H LONGER TERM IMPACT ON MEAN ANNUAL STREAMFLOW, WANDANDIAN CREEK CATCHMENT[1]

Type of Change in Mean Annual Streamflow	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Change in ML	**3 760**	8 727	-4 967	-5 616
% Change	**6%**	13%	-7%	-8%

Note:
1. Represents average for impacts for years 30 to 100.

There is not a particularly large variation in the estimated increase in mean annual streamflow between the long-term (11 to 30 years) and the longer-term (30 to 100 years). This differs from the Mongarlowe River catchment where there was a larger variation over the two periods. The reason for less variation in the Wandandian Creek catchment is because impacts on streamflow are negative for a shorter period of time before they become positive (in response to changes in the age-mix profile of the forest).

Despite this, the impacts over the longer-term are still significant and should be considered when interpreting the impacts associated with the adopted logging scenario. As with the Mongarlowe River catchment, a comparison of the impacts under the adopted logging scenario and those incurred under the no logging (tree growth only component) scenario, reveal that when no logging activities are modelled, impacts on mean annual streamflow are larger relative to those that are incurred under the adopted logging scenario. This suggests that over the longer term, the logging activities have a negative influence on mean streamflow relative to expected impacts if logging activities were not undertaken.

A graphical portrayal of the impact of the adopted logging scenario on average annual mean actual streamflow (measured in megalitres) and the percentage impact on mean annual streamflow (measured in percent) is provided within appendix 5a. These graphs incorporate impacts under the economic timeframe (short-term, medium-term and long-term) as well as longer-term impacts.

5.3 POTENTIAL ECONOMIC IMPACTS

Within the wider Wandandian Creek catchment, economic impacts are assumed to be very small and negative over the short and medium term and slightly positive over the long-term. Since Wandandian Creek discharges at the coast, the economic impacts associated with the adopted logging scenario are all incurred within the wider catchment itself (rather than some being incurred downstream).

The following section outlines the quantitative and qualitative economic impacts associated with the adopted logging scenario. Assumptions regarding the impact of changed streamflow on different users and activities and the aggregation of total economic benefits and costs are the same as outlined for Mongarlowe River.

5.3.1 Economic Impacts Within Wandandian Creek Catchment

Impacts on Abstractors

Table 5i estimates the economic impact of the adopted logging scenario on abstractors of water within the catchment.

TABLE 5I ANNUAL ECONOMIC IMPACT ASSOCIATED WITH ABSTRACTORS

Activity	Economic Impact ($ per annum)
Agriculture	Maximum of $1 000 decline in short and medium term.
Manufacturing	Nil
Drinking water supplies	Nil

Note:
1. ST= Short term (5 years), MT = Medium term (10 years), LT = Long Term (30 years)

If supply of water to agriculture was impacted by the decline in mean annual streamflow over the short and medium-term, than the scale of this impact would be capped at the economic value associated with current water use. Since current use is presently in the order of 20 megalitres per year, this volume represents the maximum that could potentially be lost due to a decline in average streamflow. Based on the marginal value approach adopted in this study, it is estimated that the loss to agriculture would be no greater than $1 000. Obviously, if the industry was completely extinguished, the economic cost associated with this would be significantly higher. In reality, it is unlikely that this would occur as a result of a change in the order of the magnitudes forecast.

Similarly, over the long-term the economic value to agriculture associated with an increase in mean annual streamflow is not estimated. Agriculture would only be able to use an extremely small portion of the increase in annual streamflow given current development. The value of the economic benefit gained from this access to increased streamflow is estimated to be equivalent in magnitude to the loss estimated for the short and medium-term.

It is assumed that there are no impacts on manufacturing and drinking water supply as no current abstraction exists for these uses.

Impacts on Water Dependent Activities

Table 5j estimates the economic impact of the adopted logging scenario on water dependent activities.

TABLE 5J ANNUAL ECONOMIC IMPACT ASSOCIATED WITH WATER DEPENDENT ACTIVITIES

Activity	Economic Impact
Tourism and Recreation	Insignificant
Environment	Positive

It is assumed that there are no current uses associated with tourism and recreation[16]. The economic impact associated with the environment is assumed to be slightly negative but insignificant in the short and medium term, but slightly positive in the long-term. This recognises that increased flows are provided within the system, but not of a magnitude that would result in the destruction of existing riverine habitats[17].

Impacts on Other Related Items

Table 5k estimates the economic impact of the adopted logging scenario on other water-related items.

TABLE 5K ANNUAL ECONOMIC IMPACT ASSOCIATED WITH OTHER RELATED ITEMS

Activity	Economic Impact
Water quality	Insignificant
Flood mitigation	Insignificant
Infrastructure	Insignificant

Economic impacts related to water quality, flood mitigation and infrastructure are all assumed to be insignificant. Once again, this is reflective of the fact that the scale of estimated impacts on mean annual streamflow under the adopted logging scenario are relatively insignificant over all three economic analysis periods.

[16] Tourism and recreation within St Georges Basin is assumed to be associated with the tidal reaches of the river.

[17] Depending upon existing interactions between tidal and riverine influences, some flushing impacts may occur given this increased mean streamflow. However, due to time limitations, this issue could not be more fully explored.

5.4 CONCLUSIONS

5.4.1 Economic Impacts

Over the short and medium-term, it is estimated that economic impacts on downstream water users and water dependent activities would be slightly negative, though insignificant[18]. Over the long-term, impacts are deemed to be small, though significant and positive. Quantifying the magnitude of this economic benefit is difficult, as the most readily quantifiable use, agriculture, is unable to utilise all of the estimated increase in mean annual streamflow[19]. It is assumed that the environment would be the main recipient of economic benefits associated with this increase in annual streamflow.

5.4.2 Longer Term Impacts

There is not considerable variation between the impacts incurred under the long-term (eleven to thirty years) and the longer-term (beyond thirty years up to one hundred). Mean streamflow will continue to rise over time, leading to greater potential positive impacts being derived (relative to shorter time periods) via agricultural use, although present development constrains much of an increase from present scale. Increases in mean streamflow over time may also place increasing pressure upon water quality measures and upon the existence of environmental habitats in their present form. Such economic costs and benefits must be considered over the longer-term.

Relative to the adopted logging scenario, a case that does not model logging activities (tree growth only component), will result in larger average annual impacts on mean streamflow. This suggests that the implementation of the adopted logging scenario causes mean annual streamflow to increase by a smaller amount relative to estimated impacts under a scenario where no logging was modelled.

[18] Year-to-year climatic variations are assumed to provide greater impacts than those under the adopted logging scenario in the short and medium-term.
[19] Based on present development.

6. BUDDONG CREEK

The purpose of this section is to provide an overview of the estimated impacts associated with the adopted logging scenario within the Buddong Creek catchment. Unlike the catchments within the South Coast sub-division, the Buddong catchment as defined for the economic analysis is the same area as that defined for the purposes of modelling the logging scenario.

A brief profile of the catchment is provided, including a description of forestry activities, water use, streamflow and water quality. The impact of the adopted logging scenario on mean annual streamflow is measured and the potential economic impact associated with changed streamflow is assessed.

6.1 CATCHMENT PROFILE

The Buddong Creek catchment is contained within the Upper Murrumbidgee River Basin. The creek flows into Jounama Pondage, which is the channel linking Talbingo and Blowering Reservoirs. Prior to the intersection of the creek with Jounama Pondage, the stream passes through a small area of open grazing land.

6.1.1 Land Use

Land use in the Buddong Creek catchment is dominated by forestry. There are also small areas of cleared dryland grazing country fronted by Jounama Pondage. This dominance of forested lands within the catchment is detailed in table 6a.

TABLE 6A FORESTRY CHARACTERSITICS OF THE BUDDONG CREEK CATCHMENT

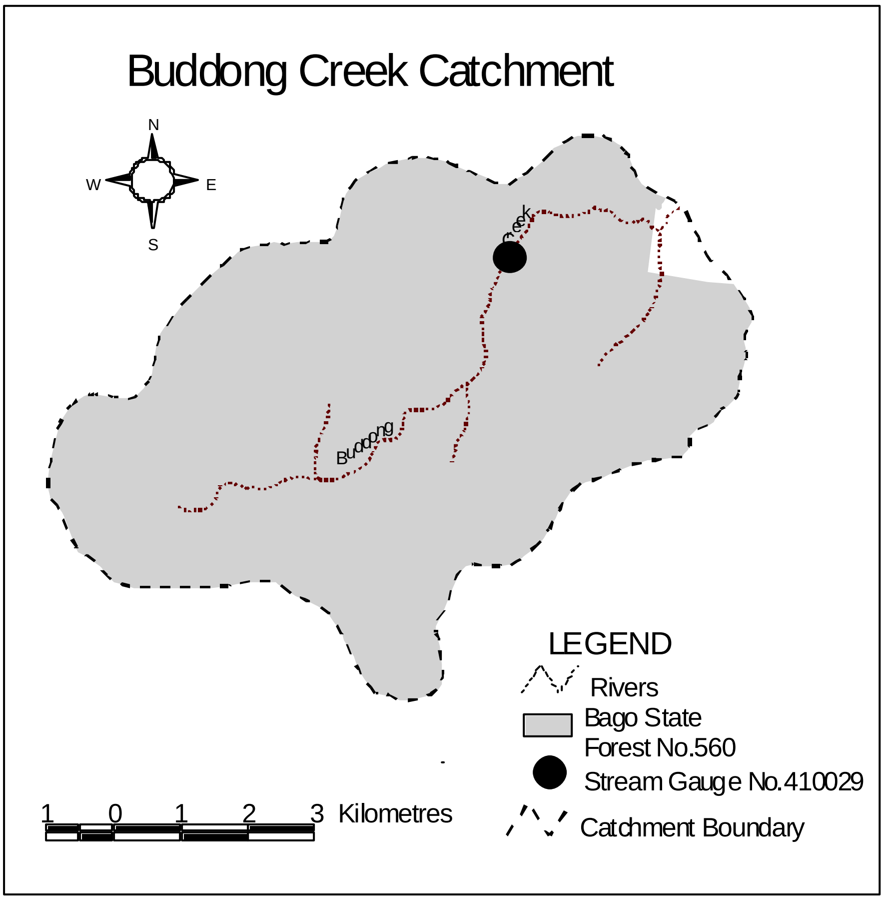
Characteristic	Estimated Area
Catchment Area (ha)	4 942
Forest Area (ha)	4 862

Source: SKM (1999)

Therefore, 98% of the catchment is forested. The remainder is devoted to dryland agricultural use.

Figure 6a illustrates the Buddong Creek catchment. The small area of agricultural land can be readily seen.

FIGURE 6A BUDDONG CREEK CATCHMENT



Source: SKM (1999)

6.1.2 Water Use

There are no industry or agriculture abstractions from Buddong Creek. This is understandable, given the dominance of forested areas within the catchment. Furthermore, there are no tourism and recreation uses within the creek, as it is a narrow, shallow creek, with limited access. It appears that the direct user of the streamflow within the creek is the environment.

However, given the creek flows into a downstream storage area (Blowering Reservoir), there are downstream uses associated with this streamflow. These uses are:

- water used for generating hydro-electric power at Blowering Dam; and
- water used for downstream irrigated agriculture.

Therefore, despite there being no direct uses associated with streamflow within the catchment itself, apart from environmental use, there are downstream uses that indirectly depend upon the streamflow within the creek.

6.1.3 Streamflow

Streamflow is measured using a gauging station within the catchment. Characteristics of this gauging station are listed in table 6b.

TABLE 6B GAUGING STATION CHARACTERISTICS OF THE BUDDONG CREEK CATCHMENT

Characteristic	Indicator
Stream Gauge No.	410029
Gauge Latitude	$35^{0}39'0"$
Gauge Longitude	$148^{0}13'0"$

Source: SKM (1999)

Streamflow characteristics within the Buddong Creek catchment as measured at this gauging station are listed in table 6c.

TABLE 6C STREAMFLOW CHARACTERISTICS OF THE BUDDONG CREEK CATCHMENT

Characteristic	Estimate
Years of Streamflow Record	1922-78
Mean Annual Flow (ML)	21 000

6.1.4 Water Quality

No information was provided by DLWC (1998) with relation to water quality within the Buddong Creek catchment. It is anticipated that the catchment would have low environmental and hydrology stress ratings, given it is a natural flowing stream with no abstractions.

6.2 IMPACT OF THE ADOPTED LOGGING SCENARIO

6.2.1 Impacts Measured Within an Economic Timeframe

The average annual impacts on mean streamflow under each of the four representative cases is outlined in table 6d. Impacts are listed in terms of average annual impact on mean streamflow, measured in megalitres.

TABLE 6D AVERAGE ANNUAL IMPACT ON MEAN ACTUAL STREAMFLOW (ML), BUDDONG CREEK CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted logging scenario	**Tree growth only component**	**Logging only component**	**Logging scenario**
Short term	**-318**	-833	515	430
Medium term	**-682**	-1,272	590	460
Long term	**42**	427	-386	-599

Therefore, in the short and medium term, the adopted logging scenario leads to a decline in average annual streamflow. It is only in the long-term that mean streamflow actually increases under the proposed scenario. Examination of estimated annual streamflow impacts, reveals that year 23 is the first year that impacts on streamflow become positive (that is, leads to an increase in mean streamflow).

The impact of the logging component of the adopted scenario is characterised by:

- positive impacts on mean annual streamflow in the short and medium term; and
- negative impacts over the longer term.

Positive impacts associated with the logging component in the short and medium term are due to the increased discharge associated with the forest area.

To gauge a measure of the magnitude of these actual average impacts, impacts are presented as a percentage of mean annual streamflow. The average annual percentage impact on mean streamflow under each of the four representative cases is presented in table 6e.

TABLE 6E AVERAGE ANNUAL PERCENTAGE IMPACT ON MEAN STREAMFLOW, BUDDONG CREEK CATCHMENT

Timeframe	Representative Case			
	Current Conditions			Old Growth
	Adopted logging scenario	**Tree growth only component**	**Logging only component**	**Logging scenario**
Short term	**-2%**	-4%	2%	2%
Medium term	**-3%**	-6%	3%	2%
Long term	**0%**	2%	-2%	-3%

Therefore, under the adopted logging scenario, percentage impacts on mean streamflow are estimated to:

- be slightly negative, though insignificant in the short and medium-term; and
- neutral in the long-term, due to the offsetting impacts associated with the tree growth and logging only components of the adopted logging scenario.

6.2.2 Impacts Over the Longer Term

Impacts on mean annual streamflow over the longer term are provided in table 6f.

TABLE 6F LONGER TERM IMPACT ON MEAN ANNUAL STREAMFLOW, BUDDONG CREEK CATCHMENT[1]

Type of Change in Mean Annual Streamflow	Representative Case			
	Current Conditions			Old Growth
	Adopted Logging Scenario	Tree growth only component	Logging only component	Adopted Logging scenario
Change in ML	**2 481**	5 825	-3 343	-3 580
% Change	**12%**	28%	-16%	-17%

Note:
1. Represents average for impacts for years 30 to 100.

Over the longer term, the influence of the tree growth only component becomes more significant relative to the logging only component. This means that the two components no longer offset each other and the aggregate impact of the adopted logging scenario is a significant increase in the mean annual streamflow.

The outcomes of this significant increase in streamflow would include:

- both benefits and costs accruing to the environment (as the only water user within the catchment) as streamflow was increased to a level that may provide flushing impacts and lead to the alteration of some existing riverine habitat; and
- an increase in the inflow of water to the Jounama Pondage. This would lead to more water being available for downstream water usage (that is, usage downstream of Blowering Dam).

Despite there being an increase in mean streamflow being estimated under the adopted logging scenario over the longer term, the annual increase in mean streamflow is smaller under the adopted logging scenario than it is when the tree growth only component (no logging scenario) is modelled.

A graphical portrayal of the impact of the adopted logging scenario on average annual mean actual streamflow (measured in megalitres) and the percentage impact on mean annual streamflow (measured in percent) is provided within appendix 6a. These graphs incorporate impacts under the economic timeframe (short-term, medium-term and long-term) as well as longer-term impacts.

6.3 INCLUDING THE EFFECTS OF TREE MORTALITY

In addition to estimating the modelled impacts of the adopted logging scenario as described above, SKM (1999) also modelled a variation to the analysis for Buddong Creek. This variation took the form of a change in the composition of tree species present within the Buddong Creek catchment. A variation was incorporated to reflect a specific species of tree that is prevalent within this region; Alpine Ash. The unique characteristic of the Alpine Ash species that necessitates a separate analysis of the modelled impacts of the adopted logging scenario is that this species does not live longer than approximately 130 years. Other species of tree within the catchment live for substantially longer periods of time (350 years).

The implications of this change in the composition of tree species within the catchment is important as by modelling a species that exhibits a shorter lifespan than other species, impacts on water yield over the longer-term will differ. For that reason, an analysis of the estimated impacts on mean annual streamflow over time must be carried out assuming this altered composition of tree species within the catchment.

SKM (1999) acknowledge that neither the exact life expectancy of Alpine Ash, nor the proportion of the forested canopy within the catchment that is represented by Alpine Ash, are known. Therefore, assumptions are made in order to facilitate the analysis:

- the effect of tree death in terms of impact on water volume is assumed to be the same as that incurred under logging;
- it is assumed that tree death has no impact in terms of sediment generation; and
- it is assumed that all trees within the Buddong Creek catchment live only to 130 years.

Given the importance of these underlying assumptions, estimated impacts under the altered scenario that incorporates tree death should be interpreted with some care. Reference to SKM (1999) is encouraged for further background information on this modified scenario.

The average annual impacts on mean streamflow and the average annual percentage impact on mean streamflow when tree mortality impacts are included within the analysis are the same when measured within an economic timeframe as those estimated under the other Buddong Creek catchment analysis. It is not until the longer-term, that impacts on mean streamflow will differ from those previously estimated for Buddong Creek catchment[20].

Table 6g outlines the mean annual impact on streamflow associated with the Buddong Creek analysis over the longer-term, when tree mortality is incorporated into the analysis.

TABLE 6G LONGER TERM IMPACT ON MEAN ACTUAL STREAMFLOW, BUDDONG CREEK CATCHMENT WITH TREE MORTALITY

Type of Change in Mean Annual Streamflow	Representative Case			
	Current Conditions			Old Growth[1]
	Adopted logging scenario	Tree growth only component	Logging only component	Logging scenario
Change in ML	**661**	3 158	-2 497	-3 579
% Change	**3%**	15%	-12%	-17%

Note:
1. SKM (1999) notes that introducing tree mortality has implications for the old growth case, as technically trees do not reach this age. However, this case is included for illustrative purposes by assuming all trees within the Buddong Creek catchment live to 130 years only.

In comparison to the original Buddong Creek catchment analysis, introducing tree mortality leads to:

- estimated impacts under the adopted logging scenario being smaller than those estimated when tree mortality was not factored into the analysis;
- estimated increase in mean annual streamflow being lower under the tree growth only component; and
- the logging only component contributing to a lower decline in mean annual streamflow.

Therefore, introducing tree mortality into the analysis results in lower positive impacts on mean annual streamflow over the longer-term. As with the previous analysis, the impact of the adopted logging scenario relative to a case where no logging is modelled (tree growth only component), is such that logging activities lead to smaller increases in mean annual streamflow over the longer-term than would otherwise occur.

[20] This is because over the longer-term, the influence of tree death begins to impact upon water volumes. Over shorter time periods, the influence of tree death does not become apparent.

For the purposes of this study, recognition is made of the lack of information presently available to more closely define the tree mortality scenario. On this basis, conclusions for the Buddong Creek catchment do not refer to this variation on the modelled logging scenario.

6.4 POTENTIAL ECONOMIC IMPACTS

6.4.1 Introduction

In the case of Buddong Creek, potential economic impacts are estimated recognising impacts that may occur within the catchment as well as impacts that occur downstream. Downstream impacts are estimated for this catchment due to the fact that streamflow from Buddong Creek is stored within Blowering Reservoir for subsequent downstream use.

The following section briefly outlines the economic impacts associated with the adopted logging scenario, both within the catchment and upon downstream water-dependant activities.

6.4.2 Economic Impacts within Buddong Creek Catchment

The only economic impacts within the catchment will accrue to the environment. In the short and medium-term it is estimated that there will be a slight, though insignificant negative impact on the environment. In the long-term, it is assumed that the economic impact on the environment will be neutral.

Over the longer-term, both benefits and costs will accrue to the environment as a result of a significant increase in mean annual streamflow. However, these impacts are not estimated as part of the economic analysis in this study.

6.4.3 Downstream Economic Impacts

The defined downstream uses of water from Buddong Creek that is subsequently stored in Blowering Reservoir are:

- hydro-electric power
- agriculture

The mean annual discharge from Blowering Dam is approximately 1.6 million megalitres (DLWC, 1999b). Given the mean annual change in streamflow being measured for Buddong Creek is measured in the hundreds of megalitres, it is assumed that impacts of changes in streamflow on other activities (industry, infrastructure, tourism and recreation) are insignificant. Certainly, the proportion of variation in mean streamflow within Buddong Creek relative to total discharges from Blowering Dam, are well within natural variations associated with seasonal and climatic impacts.

The economic impact is, however, measured for hydro-electric power generation and agriculture, as these two activities represent industries that can easily generate marginal benefits from additional available streamflow[21].

Economic impacts associated with hydro-electric power generation are estimated by examining the value derived from water that is used to generate electricity. Water discharged from

[21] So long as regulatory mechanisms do not prevent this.

Blowering Dam passes through a turbine where the average conversion is 0.17 MWh of energy for each megalitre of water. It is assumed that the long-term energy value is $45 per MWh (Fiumara, A., Snowy Hydro, pers. comm., October 1999). Economic impacts associated with agriculture are estimated using the marginal value product approach used in the previous two catchments.

Table 6h summarises the downstream economic impacts associated with the adopted logging scenario in the Buddong Creek catchment.

TABLE 6H DOWNSTREAM ANNUAL ECONOMIC IMPACTS

Activity	Economic Impact ($ per annum)
Hydro-electric power generation	-$2 400 (ST) -$5 100 (MT) $300 (LT)
Irrigated agriculture	-$19 000 (ST) -$41 000 (MT) $2 500 (LT)
Total	-$21 400 (ST) -$46 100 (MT) $2 800 (LT)

Therefore, in the short and medium-term, downstream hydro-electric power generation and irrigated agriculture will incur annual economic costs as a result of the implementation of the adopted logging scenario within the Buddong Creek catchment. The magnitude of the annual loss associated with agriculture is significantly greater than the loss attributable to hydro-electric power generation. In the long-term, a slight, positive economic benefit is incurred.

6.5 CONCLUSIONS

6.5.1 Economic Impacts

The only within catchment economic impacts associated with the adopted logging scenario are those incurred by the environment[22]. However, the magnitude of these impacts is assumed to be insignificant, particularly over the long-term.

In addition, if changes in streamflow were to impact upon water use for those activities that indirectly use water from the Buddong Creek catchment, downstream economic impacts would be incurred by hydro-electric power generation and irrigated agriculture. Over the short and medium-term these impacts would be negative, however, over the long-term slight annual economic benefits would accrue to these industries. When examined relative to the aggregate value added associated with each of these activities within the Murrumbidgee catchment, economic impacts are assumed to be insignificant.

6.5.2 Longer Term Impacts

Over the longer term (that is, from 30 to 100 years), the impact of the adopted logging scenario will lead to a significant increase in mean annual streamflow. This will potentially create positive (additional flow) and negative (habitat alteration) impacts upon the environment within the Buddong Creek catchment. In addition, this will allow downstream water users to access this additional flow once it is released from Blowering Dam. Although benefits associated with this

[22]This is because there are no abstractions for industry, agricultural production, tourism and recreation or drinking water supplies within the catchment. There are, however, abstractions for agriculture downstream of the Buddong Creek catchment.

increased streamflow are insignificant relative to the aggregate benefits derived from regulated water supply in the Murrumbidgee catchment at present, it is important to account for these annual longer-term economic benefits.

Also, it must be recognised that increases in mean annual streamflow as estimated under the adopted logging scenario over the longer-term are in fact smaller than the estimated increase in mean streamflow that would occur if no logging activities were conducted within the catchment (as exemplified by the tree growth only component).

7. REGIONAL IMPACTS

Utilising the economic results presented in previous sections, the purpose of this section is to draw inferences for the economic impacts of the adoption of different forest management practices more generally throughout the South Coast and Tumut sub-divisions of the Southern RFA region. Each sub-division is briefly discussed below.

7.1 SOUTH COAST SUB-DIVISION

7.1.1 Impacts Within an Economic Timeframe

Based on the results of the economic analysis for the Mongarlowe River and Wandandian Creek catchments, it is estimated that economic impacts on water users and water dependent activities accruing from the adoption of different forest management options more generally though the South Coast sub-division will not be significant.

This inference is based on two main premises:

- the relatively undeveloped nature of water usage withn the catchments that were examined; and
- the small nature of estimated impacts on mean annual streamflow under the adopted logging scenario.

Generally, impacts on mean streamflow within the two trial catchments in the South Coast sub-region were either slightly negative or insignificant in the short and medium term and either slightly positive or insignificant over the long-term (up to thirty years).

7.1.2 Impacts Over the Longer Term

Over the longer-term, impacts associated with the adoption of forest management practices more generally throughout the sub-division are estimated to be significant and positive. This is due to the fact that over the longer-term, impacts of the adopted logging scenario on mean annual streamflow are significantly greater than those estimated under economic analysis periods. Generally, the longer the timeframe under which these impacts are examined, the greater the positive increase in mean annual streamflow within catchments, and the larger the associated impacts on water users and water dependent activities.

Although economic impacts over the longer term are not quantified as part of this study, the nature of the magnitude of increase in mean streamflow within catchments over this time period is such that they may lead to alterations in the existing profile of water usage within each catchment. Changes to existing water usage profiles will lead to variations in the value attributable to water use within each catchment, thereby altering the economic impact associated with the adopted logging scenario.

One potential scenario is that scope exists for the intensification or expansion of agriculture or additional abstractors for domestic usage. However, it is noted that any such change in use will be dependent on “macro” issues such as policy settings (30 to 100 years hence) and the impact of climate change.

7.1.3 Catchment Variation

When drawing inferences for the entire sub-region from results associated with two trial catchments, variations between catchments must be taken into account. Variation include differences in:

- the underlying physical nature of catchments including streamflow, topography, soils, landscape, groundcover and groundwater hydrology;
- the extent of forested area within each catchment as a proportion of total landuse;
- the extent of development within each catchment, reflecting the size and existence of industrial water users, stream-dependent townships, agricultural industries and tourism and recreation opportunities;
- environmental and hydrology stress ratings of catchment rivers and streams; and
- the degree to which future development (with regards water use) will allow the sustainable use of water resources.

In reality, each of these characteristics must be taken into account when estimating the impacts of catchment-specific forest management regimes. Although results from trial catchments can provide useful indicators of likely impacts, variations in physical and developed characteristics between catchments must be reflected to ensure accuracy of results.

In summary, the analysis has shown that within an economic timeframe (thirty years) the impact of different forest management options will be insignificant region-wide in the long-term. In the longer-term (30 to 100 years), there is potential for a significant positive impact on mean streamflow and consumption.

7.2 TUMUT SUB-DIVISION

7.2.1 Impacts Within an Economic Timeframe

In the Tumut sub-division, inferences based on results in the trial catchment include:

- within the catchment in which the adopted logging scenario is implemented, over the short and medium-term, economic impacts associated with the adopted logging scenario are slightly negative. Over the long-term (up to thirty years), economic impacts are neutral; and
- in areas where water from catchments is stored for subsequent downstream use, impacts may be more significant, particularly if they are focussed upon specific activities such as hydro-electric power generation and irrigated agriculture.

Given that the scale of water use within many Tumut sub-division catchments in which adopted logging scenarios are implemented is not significant, economic impacts accruing within the catchment itself, when measured over an economic timeframe, are assumed to be insignificant. More significant impacts would be incurred where the capacity exists to store water within reservoirs and dams for subsequent downstream use.

7.2.2 Impacts Over the Longer Term

Over the longer term, impacts associated with the adoption of general forest management practices more generally throughout the sub-division will become significant. Significant increases in mean annual streamflow are forecast to occur, with these increases becoming larger the longer the period of analysis.

Within the catchment in which the adopted logging scenario is implemented, these impacts will be focussed upon the environment and water quality. This is due to the fact there are limited other water users and water dependent activities within each catchment. Other water users will however, incur downstream impacts. If present capacity exists to store additional streamflow for downstream use, and if regulatory mechanisms do not prevent its use in specific industries, then additional streamflow can provide economic benefits if utilised by irrigated agriculture and/or hydro-electric power generation.

7.2.3 Catchment Variation

As noted in the South Coast sub-division, variation between catchments must be accounted for when using trial results to draw inferences more generally for other areas. In particular in the Tumut sub-division, variations in the existence of capacity to store increased streamflow will strongly influence the economic costs and benefits associated with the adopted logging scenario. If storage capacity does not exist, than most impacts associated with the adopted scenario will be incurred directly by the environment within the catchment in which the scenario is adopted, rather than by downstream water users.

In summary, for the Tumut sub-division the analysis has shown that there will be a slight negative impact on streamflow in the short to medium-term and an insignificant impact in the long-term. In the longer-term (30 to 100 years) potential exists for incremental agriculture and hydro-electric benefits. Capture of these benefits will be dependent on “macro” rather than regional issues.

8. RECOMMENDATIONS FOR FUTURE STUDIES

In order to continually improve the analysis undertaken as part of RFA's, the authors make the following recommendations on how the economic assessment of water values could be improved in future[23]. These recommendations are based on this and the previous water values study undertaken, and comment received from persons who have reviewed these reports. Recommendations are made realising the importance of incorporating the requirements of both the water values study as well as the ESFM Water Quality and Quantity project.

1. Catchment Selection

The economic assessment of water values is most influenced by the catchments that are selected for analysis. If selected catchments incorporate a wide degree of downstream water users, a more detailed economic assessment can be undertaken. This strengthens the economic assessment as a wider range of potential activities that will be influenced by changes in streamflow can be incorporated.

It is recognised, however, that catchment selection must primarily take account of the requirements of the ESFM project, particularly in relation to data availability and suitability of catchments with regards the application of adopted logging scenarios.

2. Catchment Profiling Information

Associated with the issue of catchment selection is the background catchment profiling information that is provided. Obviously, the wider the array of different water users and activities within a catchment, the more detailed profiling information can be provided. However, it is recognised that catchment selection must meet the requirements of the ESFM Water Quality and Quantity project.

3. Incorporating Seasonal Influences

The present economic analysis adopts an average-based approach to estimating economic impacts. This issue has been discussed within this report and is a product of the average-based approach adopted within the ESFM project.

Future economic assessments may be able to be based upon other data that allows inter and intra-seasonal impacts to be investigated. This would allow important issues such as variations in seasonal flow conditions, variations in demand for water by water users and the sequencing impacts of seasonal conditions to be investigated. However, it is recognised that data limitations may constrain the degree to which improvements on the present approach could be adopted.

[23] Particularly when studies are undertaken for the RFA of the Western Division of New South Wales.

4. Water Quality

A stronger emphasis on examining the impacts of the adopted logging scenario on water quality within each catchment would strengthen the entire study. A simple method of expanding the present study to account for impacts of logging scenarios on water quality would be to formulate a dose-response relationship with regards incremental changes to sediment load within streams. The dose-response relationship would allow the incremental change in sediment load to be translated to an associated change in economic costs. For example, the adopted logging scenario may lead to an increase in turbidity within streams. This would require an increase in alum in the water treatment phase to ensure standards for drinking water supplies were continually met. Costing this requirement would allow a link to be made between changes in sediment load and economic costs associated with drinking water supplies.

5. Natural Variability

In future, greater emphasis could be placed on defining and describing natural variation within each catchment. This would encompass an analysis of historical variation in streamflow and rainfall within each catchment. An analysis of natural variation would enable the impacts estimated under modelled logging scenarios to be interpreted in context relative to natural variations that would be expected to occur in the absence of logging scenarios.

To some extent, this analysis is already undertaken within the present study. The tree growth only component of the adopted logging scenario models impacts where no logging is assumed within the catchment. Extension of the work related to natural variation would strengthen this analysis.

6. Discounting Economic Impacts

Future economic assessments could incorporate the technique of discounting to add some sophistication to the economic analysis. Where economic losses (and gains) are incurred over a period of time and can differ between years, they can be converted to a ‘present value’ so that they can be compared on an equivalent basis. The conversion to a present value is undertaken by applying a discount rate. Mathematically, applying a discount rate for future amounts is the reverse of applying an interest rate to an amount today to find its future value.

To incorporate the influence of discounting, the analysis period for the economic analysis would need to be specified. Economic impacts are then discounted over this time period. Discount rates that are commonly adopted and are consistent with NSW Treasury guidelines are 7%, with sensitivities conducted at 4% and 10%.

If economic losses (gains) were discounted within the water values study, comparison of results estimated within the water values study with results from other RFA studies would need to be undertaken ensuring a consistent approach to discounting was adopted across all studies.

9. CONCLUSIONS

Based on the economic assessment undertaken within this study, the following conclusions are reached:

Economic Impacts

- the economic assessment was carried out using three periods of analysis: short-term (one to five years); medium-term (six to ten years); and long-term (eleven to thirty years);
- the annual impacts associated with the adopted logging scenario are positive in the short, medium and long-term in the Mongarlowe River catchment. Benefits are only considered significant in the long-term;
- the annual impacts in the Wandandian Creek catchment are negative in the short and medium-term and positive in the long-term. Impacts are only deemed significant in the long-term; and
- the annual impacts in the Buddong Creek catchment are negative in the short and medium-term and slightly positive in the long-term. Positive long-term impacts are associated with downstream water use following release of regulated supply from Blowering Dam. These positive impacts are not considered significant.

Longer Term Impacts

- over the longer term (from 30 to 100 years) the adopted logging scenario leads to a significant increase in mean annual streamflow across all catchments;
- this indicates that impacts associated with this increase in mean annual streamflow will be significant over this time period. Impacts may be both positive (related to increased agricultural and industrial use) and negative (related to adverse environmental impacts); and
- particularly in catchments with in-catchment storage capacity that facilitates downstream use, the economic benefits associated with increased mean annual streamflow will be more readily realised.

Inferences Drawn for Regional Impacts

- in the South Coast sub-region, economic impacts associated with the adoption of forest management practices are estimated to be slightly positive within the first thirty years. There is potential for positive economic impacts to increase over the longer-term (year 30 to 100) as mean annual streamflow increases significantly; and
- in the Tumut sub-region, economic impacts associated with the adoption of forest management practices are estimated to be slightly negative in the short and medium-term and slightly positive in the long-term (up to 30 years). Where existing storage capacity facilitates downstream water use, significant, positive economic impacts may be derived in the longer-term (30 to 100 years).

10. REFERENCES

Carlos, C (1991) 'What is Town Water Worth?' *Australian Journal of Soil and Water Conservation* vol. 4 (3), pp: 32-36.

Centre for International Economics (1997) *A Study to Assess Environmental Values Associated with Water Supply Options: Community Values Study Final Report*, ACTEW Corporation, Canberra.

Dwyer Leslie (1991) *Cost-Benefit Analysis of the Drinking Water Quality Program: A Contingent Valuation Approach*, Report prepared in conjunction with the Sydney Water Board.

Hassall & Associates (1999a) *Economic Assessment of Water Values: Upper North East and Lower North East NSW RFA Regions,* a project undertaken as part of the NSW Comprehensive Regional Assessments, Final Report, February 1999.

Hassall & Associates (1999b) *Tourism and Recreation Study: Southern CRA Region*, a project undertaken as part of the NSW Comprehensive Regional Assessments, Draft Report, November 1999.

Hill, C.M. (1994) *Water Quality Improvements in the Darling River: A Contingent Valuation Study*, WPD Occasional Paper Series 94.1, Department of Water Resources.

Morrison, M.D., Bennett, J.W. & Blamey, R.K. (1998) *Valuing Improved Wetland Quality Using Choice Modelling*, Choice Modelling Research Report No. 6, University College, University of NSW.

NSW Department of Land and Water Conservation (1999a) *Catchment Water Usage Data*, provided upon request by Justine Harris, Water Analysis & Audit Officer, NSW DLWC, Parramatta.

NSW Department of Land and Water Conservation (1999b) *Blowering Dam Releases*, data supplied upon request by NSW DLWC, Tumut.

NSW Department of Land and Water Conservation (1998) *Stressed Rivers Assessment Report: NSW State Summary*, NSW DLWC, Sydney.

NSW Department of Land and Water Conservation (1997) *A Stressed Rivers Approach to the management of water use in unregulated streams*, NSW DLWC, Sydney.

NSW Environment Protection Authority (1998) *NSW EPA Environmental Valuation Database*, NSW EPA, Chatswood.

NSW Treasury (1997) *NSW Government Guidelines for Economic Appraisal*, Office of Financial Management, Policy & Guidelines Paper.

Sinclair Knight Merz (1999) *ESFM Project: Water Quality and Quantity for the Southern RFA Region*, a project undertaken as part of the NSW Comprehensive Regional Assessments, Project Number NA 61/ESFM.

Sinclair Knight Merz (1998) *ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions*, a project undertaken as part of the NSW Comprehensive Regional Assessments, Draft Report, September 1998.

11. ABBREVIATIONS USED IN THIS REPORT

CRA	Comprehensive Regional Assessment
DLWC	Department of Land and Water Conservation (NSW)
DUAP	Department of Urban Affairs and Planning (NSW)
EPA	Environment Protection Authority (NSW)
ESFM	Ecologically Sustainable Forest Management
LNE	Lower North East (of NSW)
RACD	Resource and Conservation Division
RFA	Regional Forest Agreement
SFNSW	State Forests of NSW
SKM	Sinclair Knight Merz Pty Ltd
UNE	Upper North East (of NSW)

12. APPENDICES

APPENDIX 2A ADOPTED LOGGING SCENARIOS

Mongarlowe River Logging Scenario

Years of Operation	Percentage of whole forest canopy removed	Logging operation*	Target Tree Age	Harvest within Age range
	%		(Years)	(Years)
2000-2004	3.70	G	140	50-180
2005-2014	2.04	T1	35	30-40
2010-2019	2.47	S	70	50-90
2015-2019	3.70	G	140	50-180
2025-2034	4.09	T2	70	55-70
2030-2034	3.70	G	140	50-180
2035-2039	0.56	T1	35	30-35
2035-2044	4.44	S	70	50-90
2045-2049	3.70	G	140	50-180
2050-2054	0.56	T1	35	30-35
2055-2059	1.11	T2	70	60-70
2055-2059	3.08	G	140	50-180
2065-2069	0.56	T1	35	30-35
2070-2074	1.11	T2	70	65-70
2070-2074	3.08	G	140	50-180
2075-2084	2.86	S	70	50-90
2080-2084	0.56	T1	35	30-35
2085-2089	1.11	T2	70	65-70
2085-2089	3.08	G	140	50-180
2090-2094	3.70	G	140	50-180
2095-2099	0.46	T	35	30-35

Source: SKM (1999)
Key:
* Logging operations are denoted: ‘T1’ or ‘T2’ for thinning; ‘S’ for single tree selection; and ‘G’ for group selection.

Wandandian Creek Logging Scenario

Years of Operation	Percentage of whole forest canopy removed	Logging operation*	Target Tree Age	Harvest within Age range
	%		(Years)	(Years)
2005-2014	1.37	T1	35	30-40
2010-2019	6.1	S	70	50-90
2010-2019	7.43	S	70	50-90
2025-2034	2.74	T2	70	50-70
2035-2044	10.97	S	70	50-180
2055-2059	2.05	G	140	50-180
2055-2064	4.13	S	70	50-90
2070-2074	2.05	G	140	50-180
2075-2074	6.1	S	70	50-90
2085-2089	2.05	G	140	50-180
2095-2099	7.43	S	70	50-90
2095-2099	0.31	T	35	30-35

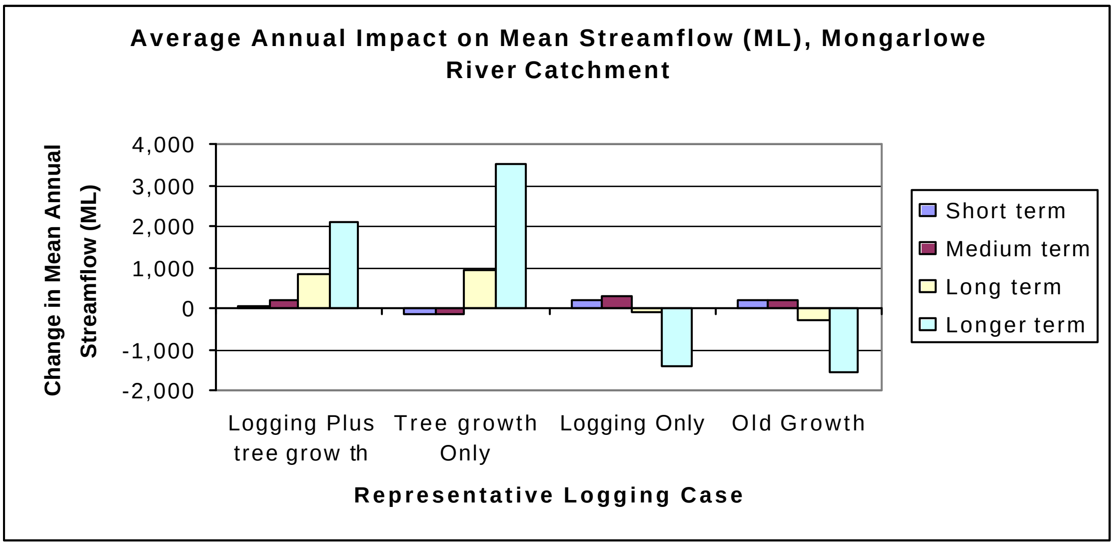
Source: SKM (1999)
Key:
* Logging operations are denoted: ‘T1’ or ‘T2’ for thinning; ‘S’ for single tree selection; and ‘G’ for group selection.

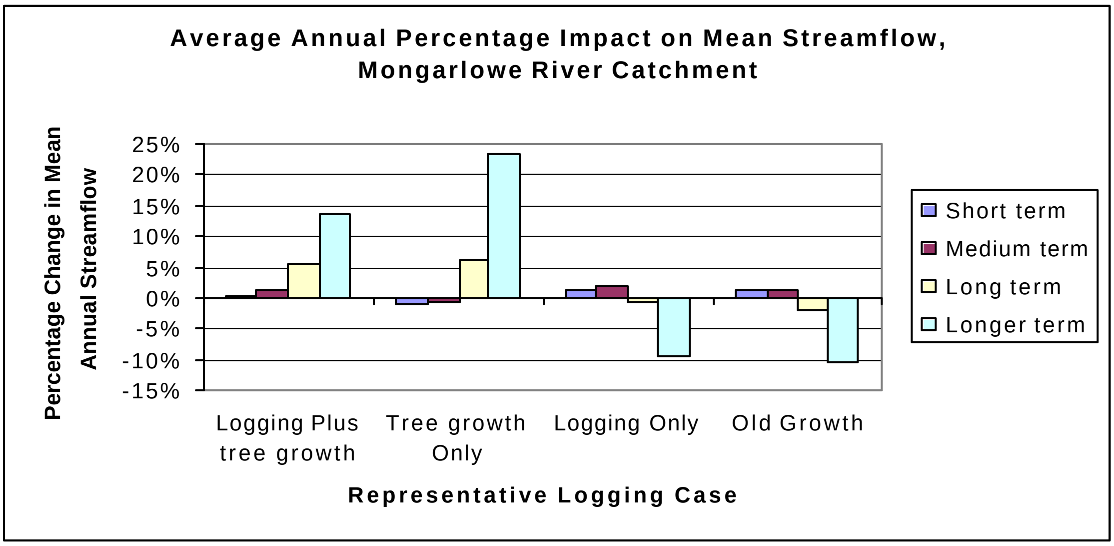
Buddong Creek Logging Scenario

Years of Operation	Percentage of whole forest canopy removed	Logging operation*	Target Tree Age	Harvest within Age range
	%		(Years)	(Years)
2000-2004	3.86	0.23G + 0.77S	80	50-120
2005-2009	0.74	0.23G + 0.77S	80	50-120
2010-2014	3.05	0.23G + 0.77S	80	50-120
2015-2019	0.22	0.23G + 0.77S	80	50-120
2020-2024	3.99	0.23G + 0.77S	80	50-120
2025-2029	3.86	0.23G + 0.77S	80	50-120
2030-2034	0.74	0.23G + 0.77S	80	50-120
2035-2039	3.05	0.23G + 0.77S	80	50-120
2040-2044	0.22	0.23G + 0.77S	80	50-120
2045-2049	3.99	0.23G + 0.77S	80	50-120
2050-2054	3.86	0.23G + 0.77S	80	50-120
2055-2059	0.74	0.23G + 0.77S	80	50-120
2060-2064	3.05	0.23G + 0.77S	80	50-120
2065-2069	0.22	0.23G + 0.77S	80	50-120
2070-2074	3.99	0.23G + 0.77S	80	50-120
2075-2079	3.86	0.23G + 0.77S	80	50-120
2080-2084	0.74	0.23G + 0.77S	80	50-120
2085-2089	3.05	0.23G + 0.77S	80	50-120
2090-2094	0.22	0.23G + 0.77S	80	50-120
2095-2099	3.99	0.23G + 0.77S	80	50-120

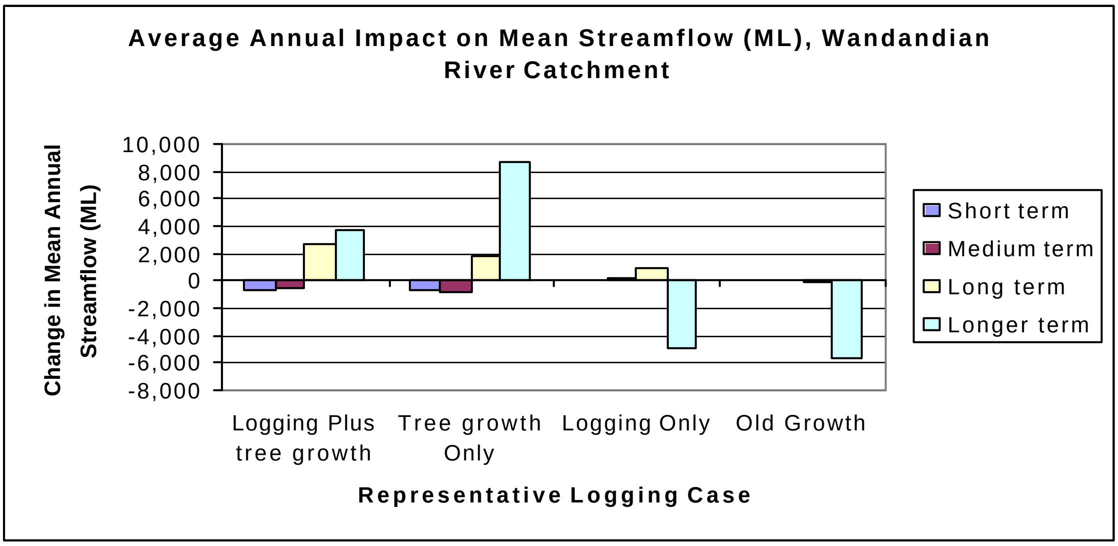
Source: SKM (1999)
Key:
* Logging operations are denoted: ‘T1’ or ‘T2’ for thinning; ‘S’ for single tree selection; and ‘G’ for group selection.

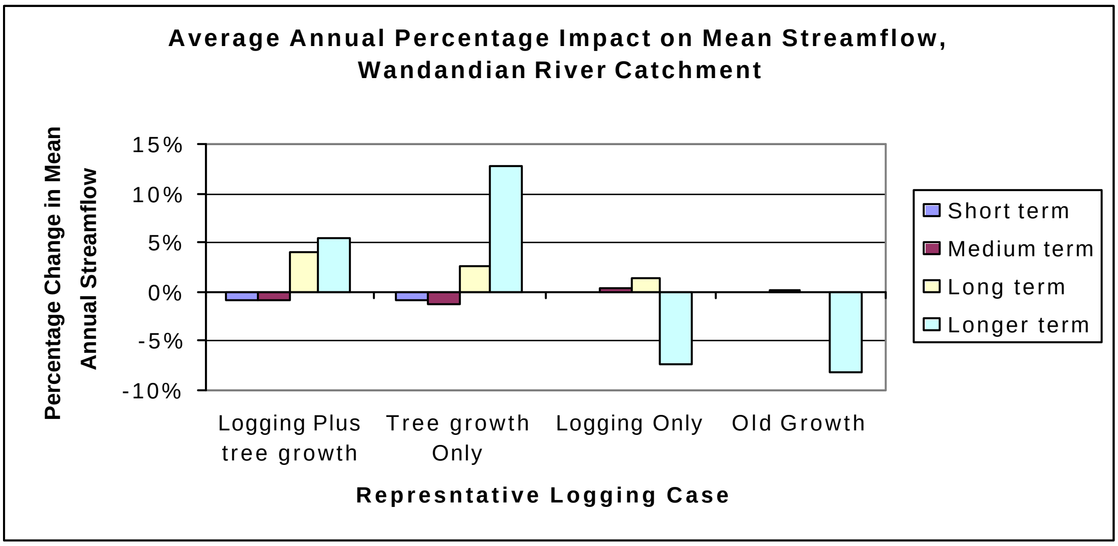
APPENDIX 4A IMPACTS ON MEAN STREAMFLOW, MONGARLOWE RIVER CATCHMENT





APPENDIX 5A IMPACTS ON MEAN STREAMFLOW, WANDANDIAN CREEK CATCHMENT





APPENDIX 6A IMPACTS ON MEAN STREAMFLOW, BUDDONG CREEK CATCHMENT