Shoalhaven Environmental Flows Investigations

Determining and managing environmental flows for the Shoalhaven River Report 2

NSW Government
DEPARTMENT OF NATURAL RESOURCES

SYDNEY CATCHMENT AUTHORITY

Water for Life
NSW GOVERNMENT

Shoalhaven River

Water Supply Transfers and Environmental Flows

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Determining and managing environmental flows for the Shoalhaven River

Report 2 - Environmental Flows Investigations

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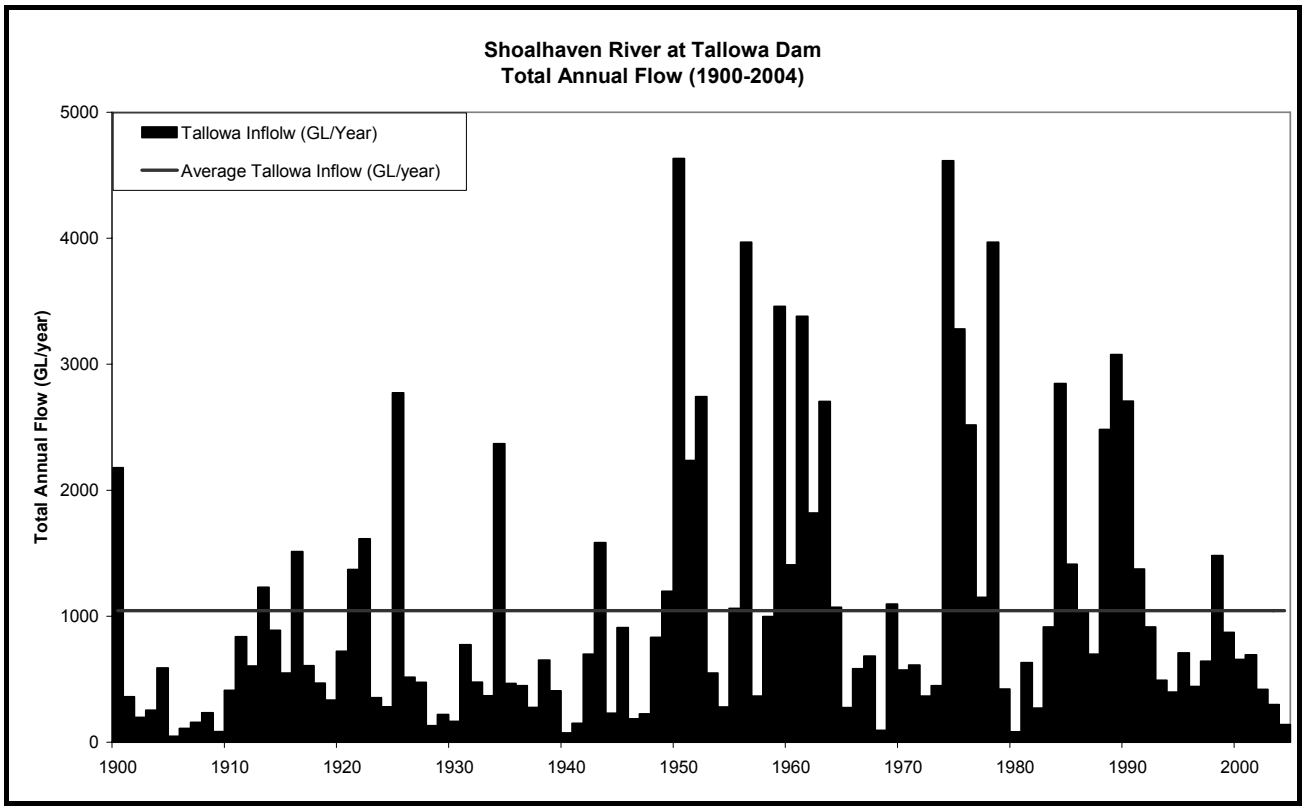

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Title page image:

Every river system has an individual or 'signature' flow regime with its own characteristic flow quantities, seasonal flow patterns, and cycles of flood and drought, with these flow characteristics having influences on river flora and fauna and key physical processes such as sediment transport. For example, this graph shows the historical sequence of total annual flows for the Shoalhaven River at Tallowa Dam. It can be seen that there are many years that are much lower or much higher than the average, showing how changeable flows are in this river system. Many native flora and fauna species will be dependant on this natural flow variability for their survival.

Once the flow characteristics for a particular river have been identified, they can be used to develop an environmental flow regime that will meet both the needs of river ecosystems and water and river use requirements. Because of this, flow analysis and modelling has been a critical and substantial part of the investigation of environmental flow requirements for the Shoalhaven River downstream of Tallowa Dam.

Image source: Jason Martin, Sydney Catchment Authority.

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Executive Summary

A new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam

The NSW Department of Natural Resources (DNR) is coordinating the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam, with a view to having a recommended regime ready for Government consideration at the end of 2006.

The development of the new environmental flow regime involves the following steps:

1. *Knowledge review* - Compilation and analysis of previous knowledge to provide an understanding of the Shoalhaven River downstream of Tallowa Dam, identify the known effects of the dam and its operation and reveal information gaps.
2. *Investigations* - Conduct of a range of investigations to address information gaps and provide specific information on environmental flow requirements.
3. *Values and uses assessment and community comment* - Identification of the water and river uses and values that are important to the community, and community comment on options for environmental flows for the Shoalhaven River downstream of Tallowa Dam.
4. *Determination of recommended environmental flow regime* - Process to integrate the results of the above steps, and from this develop a recommended environmental flow regime for Government consideration.

The knowledge review step was completed in 2005. The outcomes of the knowledge review are presented in the first report in this series, *Determining and managing environmental flows for the Shoalhaven River, Report 1 - Environmental Flows Knowledge Review*. That report also explains in detail the background to the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam.

This report provides information on the investigations step. The third 'values and uses assessment and community comment' step has been initiated, and the fourth and final 'determination of recommended environmental flow regime' step will be completed later in 2006.

The outcomes of Steps 3 and 4 will be published in the next report in this series, to be titled *Determining and managing environmental flows for the Shoalhaven River, Report 3 - Environmental Flows Options Analysis*.

For further information on the process for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam, please see Sections 1.1 and 1.2 of this report.

The holistic approach to the investigation of environmental flow requirements

DNR has taken the holistic approach to the investigation of environmental flow requirements for the Shoalhaven River downstream of Tallowa Dam. The holistic approach aims to assess the water requirements of the complete ecosystem, including such components as the source area, river channel, riparian zone, floodplain, groundwater, wetlands and estuary, as well as any particularly important features such as rare and endangered species. The approach involves first identifying the natural flow regime, including the timing, size, duration and variability of flows, and then

understanding the relationships between the flow regime and the river environment and key physical river processes.

To apply the holistic approach to the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam, the following investigations have been initiated:

1. Hydrologic (Flow) Analysis and Modelling.
2. Physical and Ecological Investigations:
   - Water Quality Assessment;
   - Thermal Regime Assessment;
   - Flora and Fauna Review;
   - Aquatic Invertebrates Study;
   - Physical Habitat Modelling;
   - Fish Passage Study; and
   - Estuary Modelling and Assessment.
3. Social, Economic and Cultural Heritage Assessments.

For further information on the holistic approach and its application to the Shoalhaven River, please see Section 1.3 of this report.

Hydrologic (flow) analysis and modelling

The holistic approach reasons that if certain features of the natural flow regime can be identified and adequately incorporated into a modified flow regime, then the river environment and the functional integrity of the riverine ecosystem should be maintained. Because of this, hydrologic (flow) analysis and modelling has been a critical and substantial part of the investigation of environmental flow requirements for the Shoalhaven River downstream of Tallowa Dam. The hydrologic analysis and modelling involves:

- establishing priority environmental flow objectives;
- analysing and modelling the flow regime to determine the environmental flow arrangements likely to meet the priority environmental flow objectives; and
- integrating the outcomes of the hydrologic analysis and modelling with the other investigations, which will be completed later in 2006.

Environmental flow objectives

The NSW River Flow Objectives provide the framework on which environmental flows for rivers and streams across the State have been, or are being, determined. Five of the twelve objectives have been identified as priority environmental flow objectives for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam:

RFO 2	Protect natural low flows.
RFO 3	Protect or restore a portion of freshes and high flows.
RFO 6	Maintain or mimic natural flow variability in all rivers.
RFO 11	Ensure that the management of river flows provides the necessary means to address contingent environmental and water quality events.
RFO 12	Maintain or rehabilitate estuarine processes and habitats.

Determining the environmental flow arrangements likely to meet these priority environmental flow objectives involves:

- identifying the critical flow components of the natural river flow regime;

- sourcing various modelled environmental flow arrangements from the Sydney Catchment Authority (SCA); and
- analysing the environmental flow arrangements to see which ones best protect the critical flow components.

Critical flow components

Identifying the critical flow components of the natural river flow regime involves first dividing the flow regime into 'flow classes' and then examining 'aspects of flow' for the flow classes.

The 'flow classes' used by the NSW Government are:
- low flows;
- moderate flows;
- freshes (which are substantial rises in the river for short periods after a rainfall event); and
- high flows.

Natural river flows are highly changeable in space and in time. Understanding the way in which flows dynamically change in the Shoalhaven River is essential for the development of an environmental flow arrangement that can meet the needs of the river. This involves examining the following 'aspects of flow':
- magnitude - volume of various flow events;
- duration - length of time for which the flow events occurs;
- seasonality - seasonal variation in flow events;
- variability - natural systems depend on variability in flow rates; and
- frequency - how often the flow event occurs.

Once the critical flow components of the natural river flow regime have been identified, various environmental flow arrangements can be assessed against the natural flow regime to determine which of the arrangements offer the greatest benefit for the river.

Shortlisted environmental flow arrangements

A range of environmental flow arrangements have been analysed using the methods described above. The environmental flow arrangements have incorporated a range of:
- operational variables for Tallowa Dam, including different Minimum Operating Levels (MOLs) for Lake Yarrunga (the lake formed by Tallowa Dam) and different pump marks for the commencement of pumping to the greater Sydney metropolitan region;
- different yield increases for the supply of water to the greater Sydney metropolitan region, initially under the 2004 Metropolitan Water Plan and later under the 2006 Metropolitan Water Plan; and
- different environmental flow rules, with a wide range of rules considered.

The following subsections discuss the shortlisted environmental flow arrangements, showing how they meet each of the five priority River Flow Objectives.

Protecting natural low flows - RFO 2

Low flows are small volume flows that occur regularly. They are important to maintain river ecosystems particularly in prolonged dry periods. Protecting low flows in the lower Shoalhaven River requires releasing water from Tallowa Dam based on the dam's inflows.

The current (interim) environmental flow rule requires that all inflows to the dam of up to 90 megalitres per day (ML/day) must effectively pass straight through the dam. Fixed volumes of water additional to the environmental flow are also released to facilitate Shoalhaven City Council's extraction at Burrier. The current environmental flow rule provides some natural flow variability for the downstream river when inflows to dam are between 0 and 90 ML/day. However when inflows exceed 90 ML/day, the dam contributes no additional water to river flow variability downstream.

The hydrologic analysis and modelling shows that is possible to increase the low flow rule at Tallowa Dam from 90 ML/day to somewhere in the range of 150 - 250 ML/day. A low flow rule within this range would better protect natural low flows downstream of Tallowa Dam and improve their variability.

Parts of the river could then better sustain plants and animals in drier periods. For example, more variable low flow over riffles (river shoals and rapids) would provide improved habitat for small fish, macroinvertebrates and other small aquatic animals (macroinvertebrates are animals without backbones that are large enough to be visible with the naked eye, examples include most aquatic insects, snails and crayfish).

The protection or restoration of a portion of moderate flows, freshes and high flows - RFO 3

Moderate flows and freshes are important to help maintain the river channel and riparian (riverbank) vegetation. They also trigger fish breeding events and increase the release and distribution of food supplies. High flows are floods that will continue to spill over the dam. They are important for rejuvenating rivers and estuaries.

To achieve the objective of protecting or restoring a portion of moderate flows and freshes, a proportion of all incoming flows in addition to the volume allocated for the low flows (i.e. 150 - 250 ML/d) would be released from the dam.

The hydrologic analysis and modelling shows that dam releases of up to 30% of Tallowa Dam inflows in the moderate to high range are achievable, while still delivering a long-term available water supply of 30 gigalitres per year (GL/year).

The 30% proportion of inflows would pass through the dam as variable volume flows, and would contribute to flow variability in the Shoalhaven River downstream. Downstream tributaries that enter the river below Tallowa Dam would boost this flow. High flows will continue to go over the top of the dam even when the SCA is pumping.

Maintaining or mimicking natural flow variability - RFO 6

Natural flow patterns are important to sustain native plants and animals that are dependant on naturally variable river flow conditions. The environmental flow rules for release of water from Tallowa Dam will (combined with naturally occurring spills) reflect the natural pattern of its inflows.

Contingent flows - RFO 11

Contingent flows are additional flows released from the dam for specific ecological or riverine purposes. Tallowa Dam will continue to have the capacity to provide such flow releases to meet contingencies. DNR, as the regulator, will continue determining when such dam releases are to be made as set out in SCA's Water Management Licence.

Maintain or rehabilitate estuarine processes and habitats - RFO 12

The proposed environmental flow rules above will assist in maintaining the Shoalhaven River's key estuarine processes. Because of its importance, DNR is undertaking additional investigations beyond the hydrologic analysis and modelling, as discussed in 'Estuary Modelling and Assessment' below. These estuary investigations include examining the relationship between Shoalhaven transfers and estuary salinity.

Summary of outcomes of hydrologic analysis and modelling

The hydrologic analysis and modelling has revealed that to deliver an additional long term yield of 30 GL/year:

1. The available water for the environmental flow downstream is dependant on pump mark and minimum operating level. These variables are associated with Tallowa Dam operations and Lake Yarrunga.
2. There is a range of environmental flow rules which have the best hydrologic outcome in terms of minimising flow changes downstream of Tallowa Dam compared to the natural flow patterns. The environmental flow rule can either allocate more water to the low flows, or alternatively allocate more water to the moderate flows or freshes.

For further information on the hydrologic analysis and modelling please see Chapter 2 of this report.

Ecological and physical investigations

The ecological and physical investigations are examining the river environment and river flow processes, drawing on the advice of specialists in NSW Government agencies and the conclusions of the initial 'knowledge review' step in the process for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam.

Water Quality Assessment

The Water Quality Assessment is examining the effect of Tallowa Dam on downstream water quality. A particular quality of water is needed to sustain the river environment, and is also desired for local uses (such as water supply, recreational and commercial uses) and for the supply of water to the greater Sydney metropolitan region. The effect of Tallowa Dam will be distinguished from other factors influencing water quality. The three fundamental determinants of water quality in the Shoalhaven River catchment are:

- the nature and degree of disturbance of the catchment;
- the materials that humans import to the catchment and which end up polluting waterways; and
- engineered changes to streams and rivers that change the way they function.

The Water Quality Assessment will be completed later in 2006. For further information please see Section 3.1 of this report.

Thermal Regime Assessment

The aim of the Thermal Regime Assessment is to provide an understanding of key factors affecting the water temperature regime of the Shoalhaven River downstream of Tallowa Dam. The assessment includes:

- a longitudinal (i.e. along the river) analysis of the effects of cold water releases and the recently commissioned de-stratification works in Tallowa Dam on surface water temperatures in the

Shoalhaven River ('stratification' is the development of distinct layers of different temperature, density and water quality at various depths in a dam or deep river pool, with a restriction of mixing throughout the water column);
- an analysis of thermal stratification in river pools; and
- understanding the relationships between flow and temperature.

The Thermal Regime Assessment will be completed later in 2006. For further information please see Section 3.2 of this report.

Flora and Fauna Review

The aim of the Flora and Fauna Review is to better understand the relationships between river flow and the flora and fauna species and communities that occur in, or rely upon, the Shoalhaven River downstream of Tallowa Dam, including the Shoalhaven estuary and riparian (riverbank) habitats. The key objectives of the Flora and Fauna Review are to identify:
- the flora and fauna species and vegetation communities documented for the area encompassing the Shoalhaven River downstream of Tallowa Dam (the study area);
- the flora and fauna species and vegetation communities in the study area that have conservation status under either State or Commonwealth legislation; and
- those threatened species and communities that have specific or known river flow requirements for their successful recruitment, growth and functioning.

The Flora and Fauna Review will be completed later in 2006. For further information please see Section 3.3 of this report.

Aquatic Invertebrates Study

Aquatic invertebrates are animals without backbones that live in wetlands and rivers. There are many types of aquatic invertebrate and some types include shrimps, crayfish and mayflies. They are used to measure river health because they are present everywhere and there are hundreds of species. The purpose of the Aquatic Invertebrates Study was to assess the current health of the Shoalhaven River from Tallowa Dam to Burrier and to review data collected by earlier studies.

The invertebrate data suggested that the river health below Tallowa Dam is poor for about 4 km downstream. River regulation and poor water quality explain the poor river health. The number of different types of animals increases after 4 kilometres and the river could be considered healthy by the time it reaches Burrier. However, only 80% of the species that could be expected to be present in the river are found there. This suggests that maybe river regulation is affecting the rest of the river as well. A comparison of the invertebrate data collected in the 1990s and comparing it with the 2005 sampling shows that the invertebrate community structure has changed little in the last 10 years. This means that the current environmental flow regime has not improved river health and that a new environmental flow regime is needed.

The Aquatic Invertebrates Study has been completed. For further information please see Section 3.4 of this report.

Physical Habitat Modelling

The following physical habitat studies have been initiated in the freshwater river reach between Tallowa Dam and Burrier, with the aim of relating changes in flow to physical habitats and in-stream processes:
1. Assessment of low-moderate flow thresholds for fish passage (reported in Physical Habitat Modelling Report 1 and in the separate Fish Passage Study described below).

2. Assessment of flow rates required for channel maintenance and moderate to high flow processes (to be reported in Physical Habitat Modelling Report 2).

Physical Habitat Modelling Report 1 suggests that a target flow range of 300-500 ML/day will provide minimum flow rates that will facilitate upstream migration by adult Australian bass through the natural riffle barriers below Tallowa Dam. Analysis of the frequency with which this target flow rate is attained by 80/20, 90/10 and 90/30 flow regime options indicate that an 80/20 flow regime, varied according to the monthly pattern of natural flows, is the best of the three options.

Physical Habitat Modelling Report 1 has been completed, and Physical Habitat Modelling Report 2 will be completed later in 2006. For further information please see Section 3.5 of this report.

Fish Passage Study

The Ecology Lab Pty. Ltd. was engaged to carry out a Fish Passage Study of the Shoalhaven River between Tallowa Dam and Burrier weir. The aim of the study was to:

- define, where possible, flow requirements for the passage of native fish species;
- identify flow-induced barriers to fish passage;
- determine whether any identified flow barriers can be mitigated by changes in flow regimes; and
- provide fish biology input into the option analysis.

The study found that fish passage between Tallowa Dam and the Shoalhaven River estuary is not interrupted by any vertical obstructions such as waterfalls, but there are areas where migration could be affected under different flow conditions. Increasing depth in these areas would assist migration, and the study evaluates options for achieving this.

The Fish Passage Study has been completed. For further information please see Section 3.6 of this report.

Estuary Modelling and Assessment

The environmental flow requirements of the Shoalhaven River estuary are being investigated using a methodology developed through the Environmental Flows Initiative of the National River Health Program. A major focus is the conduct of modelling to determine the response of salinity within the Shoalhaven River estuary to various river flows. The modelling includes examining the salinity response for river flows with water extraction from Tallowa Dam compared to river flows without water extraction. The University of New South Wales Water Research Laboratory, who developed the Environmental Flows Initiative methodology, has been engaged to carry out the flow and salinity modelling. The outcomes of the flow and salinity modelling will be used to assist in developing an environmental flow regime that is appropriate for the estuary.

The Estuary Modelling and Assessment will be completed later in 2006. For further information please see Section 3.7 of this report.

Cultural heritage, social and economic assessments

Cultural heritage assessments examine indigenous and historic heritage values. Social and economic assessments are used to predict the effects of decisions on people and communities.

Cultural Heritage Assessment

Biosis Research Pty. Ltd. was engaged to carry out a Cultural Heritage Assessment that has examined how cultural heritage values might be affected by changes in flow downstream of Tallowa Dam resulting from increased water transfers from the dam and a new environmental flow regime. Both Aboriginal and historic cultural heritage values have been identified and assessed.

The Cultural Heritage Assessment has been completed. For further information please see Section 4.1 of this report.

Social Assessment and Economic Assessment

The primary aim of the Social Assessment and Economic Assessment is to examine how changed operations at Tallowa Dam and a new environmental flow rule are likely to affect individuals, groups and businesses that use the Shoalhaven River. Key river uses include recreation, tourism, and commercial fishing.

The Social Assessment and Economic Assessment will be completed later in 2006. For further information please see Section 4.2 of this report.

1. Introduction

1.1 Development of a new environmental flow regime for the Shoalhaven River

The NSW Department of Natural Resources (DNR) is coordinating the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam, with a view to having a recommended regime ready for Government consideration at the end of 2006.

The development of the new environmental flow regime involves the following steps:

1. *Knowledge review* - Compilation and analysis of previous knowledge to provide an understanding of the Shoalhaven River downstream of Tallowa Dam, identify the known effects of the dam and its operation and reveal information gaps.
2. *Investigations* - Conduct of a range of investigations to address information gaps and provide specific information on environmental flow requirements.
3. *Values and uses assessment and community comment* - Identification of the water and river uses and values that are important to the community, and community comment on options for environmental flows for the Shoalhaven River downstream of Tallowa Dam.
4. *Determination of recommended environmental flow regime* - Process to integrate the results of the above steps, and from this develop a recommended environmental flow regime for Government consideration.

The knowledge review step was completed in 2005. The outcomes of the knowledge review are presented in the first report in this series, *Determining and managing environmental flows for the Shoalhaven River, Report 1 - Environmental Flows Knowledge Review* (Boyes 2006). That report also explains in detail the background to the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam.

From the conclusions of the knowledge review and the advice of specialists in NSW Government agencies, DNR initiated hydrologic (flow) analysis and modelling and a range of ecological and physical investigations to examine the Shoalhaven River environment and river flow processes. Social, economic, and cultural heritage investigations were also initiated.

This report provides information on the investigations step. The hydrologic (flow) analysis and modelling and ecological, physical and cultural heritage investigations are currently being completed. The economic and social investigations are to be completed later in 2006, as they need to be informed by the 'values and uses assessment and community comment' step.

1.2 Next steps

The third 'values and uses assessment and community comment' step has been initiated, and includes community comment on the *Shoalhaven Environmental Flows and Water Transfers Discussion Paper*.

As the fourth and final step, DNR will integrate the results of the knowledge review, investigations, values and uses assessment and community comment on the *Discussion Paper*. From this, DNR will develop a recommended environmental flow regime for Government consideration.

The outcomes of Steps 3 and 4 will be published later in 2006 in the next report in this series, to be titled *Determining and managing environmental flows for the Shoalhaven River, Report 3 - Environmental Flows Options Analysis*.

1.3 The holistic approach to the investigation of environmental flow requirements

1.3.1 Overview of the holistic approach

DNR has taken the holistic approach to the investigation of environmental flow requirements for the Shoalhaven River downstream of Tallowa Dam, in response to the advice of an interagency Scientific Advisory Panel. The interagency Scientific Advisory Panel comprises specialists from the Department of Natural Resources, Department of Environment and Conservation, Department of Primary Industries and Sydney Catchment Authority. It has provided DNR with expert advice throughout the process for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam.

The benefits of the holistic approach are discussed in the report *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Holistic Methodologies* (Arthington 1998), which is one of four reports arising from the project 'Comparative Evaluation of Environmental Flow Assessment Techniques' funded by Environment Australia, the Land and Water Resources Research and Development Corporation (LWRRDC) and the National Landcare Program. The report advises that the narrow focus on single issues (e.g. the flow requirements of fish) and the many drawbacks associated with the other flow assessment methods reviewed in the project (Arthington and Zalucki 1998) have stimulated the development of new approaches to the formulation of environmental flow guidelines. A holistic ecosystems approach to environmental flow assessment and river management has been long advocated by river ecologists, but the formulation and application of holistic methodologies is a relatively recent development originating largely in Australia and South Africa (Arthington 1998).

The holistic approach aims to assess the water requirements of the complete ecosystem, including such components as the source area, river channel, riparian zone, floodplain, groundwater, wetlands and estuary, as well as any particularly important features such as rare and endangered species (Arthington 1998). The approach involves first identifying the natural flow regime, including the timing, size, duration and variability of flows, and then understanding the relationships between the flow regime and the river environment and key physical river processes. Every river system has an individual or 'signature' flow regime with its own characteristic flow quantities, seasonal flow patterns, and cycles of flood and drought, with these flow characteristics having influences on river flora and fauna and key physical processes such as sediment transport (Arthington *et al.* 2004). Once these flow characteristics have been identified, they can be used to develop an environmental flow regime that will meet both water supply requirements and the needs of river ecosystems.

The holistic approach is consistent with the NSW River Flow Objectives, which were built on the principle of mimicking natural flows to improve and protect entire ecosystems (Arthington 1998).

1.3.2 Applying the holistic approach to the Shoalhaven River investigations

To apply the holistic approach to the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam, DNR needed to initiate investigations that would examine both the river flow regime and the relationships between the river flow regime and the river environment and key physical river processes. DNR sought advice from the Scientific Advisory Panel in this regard.

To determine the recommended investigations, the Scientific Advisory Panel examined the conclusions of the knowledge review, including the identified knowledge gaps, and developed a series of conceptual models to facilitate an understanding of the relationships between river flow and river ecosystems and processes. The Appendix (Section 7 of this report) shows how the investigations have addressed the knowledge gaps identified in the knowledge review. The development of the conceptual models involved the adaptation of the models in the DNR publication *Program framework for ecological monitoring and reporting of water sharing plans for unregulated rivers: scoping paper* (Chessman *et al.* 2006).

From the recommendations of the Scientific Advisory Panel, DNR initiated the following investigations:

1. Hydrologic (Flow) Analysis and Modelling.
2. Physical and Ecological Investigations:
   - Water Quality Assessment;
   - Thermal Regime Assessment;
   - Flora and Fauna Review;
   - Aquatic Invertebrates Study;
   - Physical Habitat Modelling;
   - Fish Passage Study; and
   - Estuary Modelling and Assessment.
3. Social, Economic and Cultural Heritage Assessments.

1.4 Contents of this report

This report presents information on the second 'investigations' step of the process for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam. For information on the steps involved in the development of a new environmental flow regime please refer to Sections 1.1 and 1.2.

Chapter 2 provides information on the **hydrologic (flow) analysis and modelling**.

Chapter 3 presents an overview of the **ecological and physical investigations**.

Chapter 4 presents an overview of the **cultural heritage, social and economic assessments**.

Chapter 5 presents a **glossary of terms and acronyms** used in this report.

Chapter 6 lists the report **references**.

Chapter 7 presents the report **appendix**.

2. Hydrologic (flow) analysis and modelling

The holistic approach reasons that if certain features of the natural flow regime can be identified and adequately incorporated into a modified flow regime, then the river environment and the functional integrity of the riverine ecosystem should be maintained (Arthington *et al.* 2004). Because of this, hydrologic (flow) analysis and modelling has been a critical and substantial part of the investigation of environmental flow requirements for the Shoalhaven River downstream of Tallowa Dam.

This Chapter discusses the methods used in the hydrologic analysis and modelling, and presents the outcomes to date. The hydrologic analysis and modelling involves:

1. Establishing *priority environmental flow objectives*. These priority objectives were determined at the commencement of the hydrologic analysis and modelling, and are discussed in Section 2.1.
2. *Analysing and modelling the flow regime* to determine the environmental flow arrangements likely to meet the priority environmental flow objectives. This analysis and modelling is well progressed, and has enabled the identification of two possible environmental flow arrangements that best reflect natural flow patterns while at the same time delivering the required water availability from the Shoalhaven scheme. The modelling and analysis methods are discussed in Section 2.2, and the resultant shortlist of environmental flow arrangements is discussed in Section 2.3.
3. *Integrating the outcomes* of the hydrologic analysis and modelling with the other investigations. This will be completed later in 2006, as discussed in Section 1.2.

2.1 Priority environmental flow objectives

The NSW River Flow Objectives provide the framework on which environmental flows for rivers and streams across the State have been, or are being, determined. The twelve River Flow Objectives are the agreed high-level goals for the management of flows for rivers, streams and other types of surface water. They identify the key elements of flow regimes that will both protect river health and provide the river environment needed for human uses such as recreation and aquaculture. Five of the twelve objectives have been identified as priority environmental flow objectives for the development of a new environmental flow rule for the Shoalhaven River downstream of Tallowa Dam. These priorities are shown in Table 1.

Table 1. Priority environmental flow objectives for the development of a new environmental flow rule for the Shoalhaven River downstream of Tallowa Dam.

River Flow Objective	Aspects of river flow critical for protection or restoration of river health	Priority environmental flow objectives for the development of a new environmental flow rule
RFO 1	Protect natural water levels in river pools and wetlands during periods of no flow.	Will be met by the upcoming Metropolitan Water Sharing Plan, which will provide the means to ensure that pools are protected. Additionally there is limited extraction in the freshwater reach.
RFO 2	**Protect natural low flows.**	**Priority for environmental flow rule development.**
RFO 3	**Protect or restore a portion of freshes and high flows.**	**Protecting a portion of moderate flows and freshes is a priority for environmental flow rule development. High flows will continue to occur as spill events.**

River Flow Objective	Aspects of river flow critical for protection or restoration of river health	Priority environmental flow objectives for the development of a new environmental flow rule
RFO 4	Maintain wetland and floodplain inundation.	Will be considered but not a priority for the development of the Shoalhaven Environmental flow rules. The focus of this objective is structures on floodplains that prevent inundation of floodplains and wetlands. Big flow events required to inundate the wetlands and floodplains below Tallowa Dam will be unaffected by proposals to transfer extra water from the Shoalhaven to greater Sydney.
RFO 5	Mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways.	The Shoalhaven River is a permanent stream, and not a naturally temporary waterway.
RFO 6	**Maintain or mimic natural flow variability in all rivers.**	**Priority for environmental flow rule development.**
RFO 7	Maintain natural rates of change in water levels.	Objective will be achieved through rules set to achieve RFO 6.
RFO 8	Manage groundwater for ecosystems.	Managed through Macro Water Sharing Plans for groundwater.
RFO 9	Minimise the impact of in-stream structures.	Already actioned: modifications to Tallowa Dam will improve fish passage and quality of water released.
RFO 10	Minimise effects of dams on water quality.	Already actioned: modifications to Tallowa Dam will provide better water quality releases.
RFO 11	**Ensure that the management of river flows provides the necessary means to address contingent environmental and water quality events.**	**Already actioned: priority for environmental flow rule: continued capacity to provide flows to meet contingencies will remain part of the operation of Tallowa Dam. DNR will continue to determine when such dam releases are to be made.**
RFO 12	**Maintain or rehabilitate estuarine processes and habitats.**	**Priority for environmental flow rule development.**

2.2 Analysing and modelling the flow regime

Determining the environmental flow arrangements likely to meet the priority environmental flow objectives listed above involves:

- identifying the critical flow components of the natural river flow regime;
- sourcing various modelled environmental flow arrangements from the Sydney Catchment Authority (SCA); and
- analysing the environmental flow arrangements to see which ones best protect the critical flow components.

2.2.1 Critical flow components

Identifying the critical flow components of the natural river flow regime involves first dividing the flow regime into 'flow classes' and then examining 'aspects of flow' for the flow classes.

The 'flow classes' used by the NSW Government are:

- low flows;
- moderate flows;
- freshes (which are substantial rises in the river for short periods after a rainfall event); and
- high flows.

Natural river flows are highly changeable in space and in time. During drought periods, natural river flows are typically low. However, during wet periods high flows (floods) can occur. For example, Figure 1 shows the historical sequence of total annual flows for the Shoalhaven River at Tallowa Dam. It can be seen that there are many years that are much lower or much higher than the average, showing how changeable flows are in this river system. Table 2 shows a summary of the annual flows.

The flow data shown in Figure 1 is for the years 1900 to 2004. As further time passes this record will be extended, increasing our understanding of Shoalhaven River flows.

Figure 1. Total annual flows in the Shoalhaven River for the years 1900-2004. (Source: J. Martin, SCA).

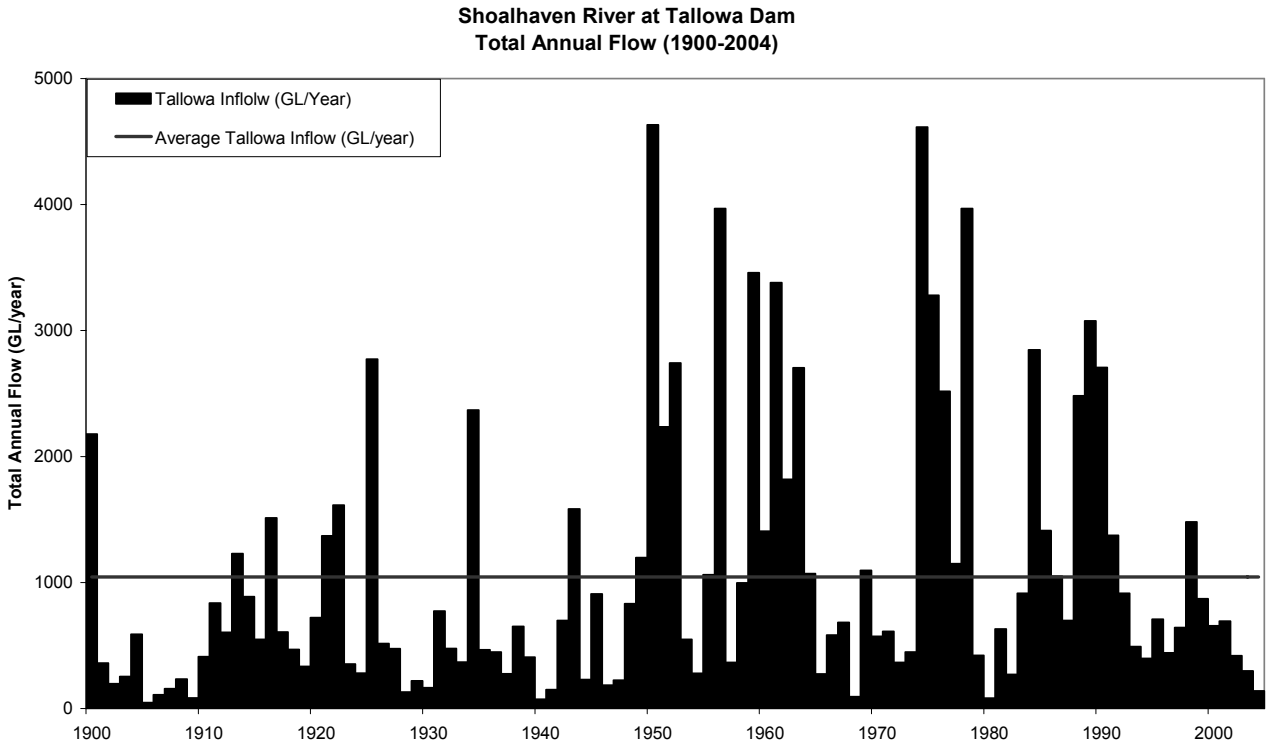


Table 2. Tabulated data for the total annual flow of the Shoalhaven River at Tallowa Dam, from 1900-2004. 1 GL = 1 gigalitre = 1,000,000,000 litres. (Source: J. Martin, SCA).

Years 1900-2004	Total Annual Flow (GL/year)
Average	1,043.9
Maximum (1950)	4,632.6
Minimum after 1909 (1940)	74.4
Minimum (1905)	47.4

Understanding the way in which flows dynamically change in the Shoalhaven River is essential for the development of an environmental flow arrangement that can meet the needs of the river. This involves examining the following 'aspects of flow':

- magnitude - volume of various flow events;
- duration - length of time for which the flow events occurs;
- seasonality - seasonal variation in flow events;
- variability - natural systems depend on variability in flow rates; and

- frequency - how often the flow event occurs.

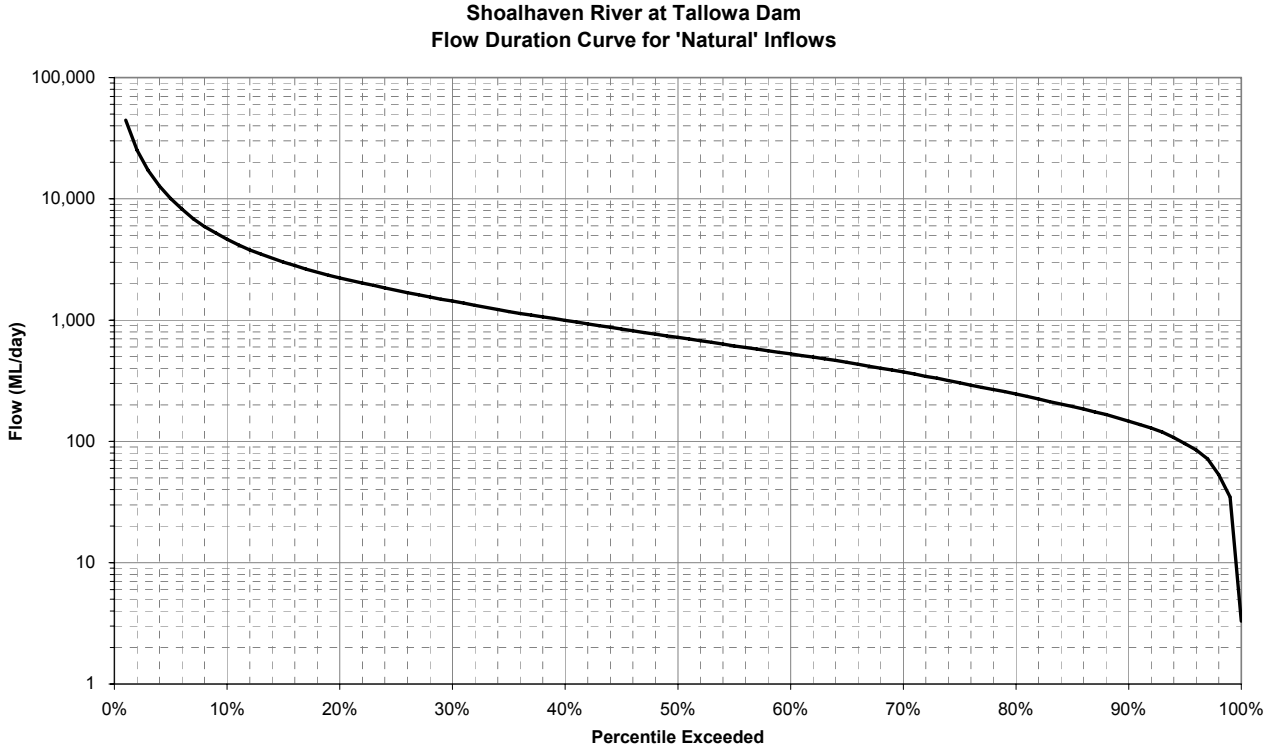
These aspects of flow were identified by the Hawkesbury-Nepean River Management Forum as being suitable indicators for understanding the water requirements for natural processes (HNRMF 2004).

2.2.2 Measuring flow magnitude and duration

The size (or magnitude) of river flow is measured in units of megalitres per day (ML/day). One megalitre is equivalent to one million litres, which is the contents of an average Olympic swimming pool. Very large flows are measured in units called gigalitres per day (GL/day). One gigalitre is 1,000 megalitres or 1 billion litres (1,000,000,000 litres).

Flow duration is measured by looking at the percentage of time that flows of a particular size occur. Figure 2 shows the flow duration curve of natural flows in the Shoalhaven River. It can be seen that natural flows in the Shoalhaven River can vary over a large range.

Figure 2. Flow duration curve for natural flows in the Shoalhaven River. (Source: J. Martin, SCA).



The percentiles for natural flows in the Shoalhaven River are given in Table 3. A percentile is the percentage of time that flows at a given site exceed a specific size threshold. For example, the 60th percentile has a flow value of 525 ML/day. This means that, for 60% of the time, flows in the Shoalhaven River at this site are larger than 525 ML/day.

Table 3. Natural flow percentiles for the Shoalhaven River. (Source: J. Martin, SCA).

Percentile Exceeded	Daily Flow (ML/day)
1%	44,582
2%	25,081
3%	17,143
4%	12,733
5%	10,038
6%	8,214
7%	6,835
8%	5,907
9%	5,229
10%	4,639
11%	4,175
12%	3,798
13%	3,499
14%	3,243
15%	3,013
16%	2,822
17%	2,632
18%	2,485
19%	2,345
20%	2,222
21%	2,118
22%	2,019
23%	1,932
24%	1,846
25%	1,762
26%	1,684
27%	1,615
28%	1,550
29%	1,490
30%	1,434
31%	1,380
32%	1,327
33%	1,273
34%	1,226
35%	1,178
36%	1,137
37%	1,100
38%	1,066
39%	1,030
40%	997
41%	964
42%	931
43%	902
44%	872
45%	844
46%	817
47%	791
48%	766
49%	742
50%	720

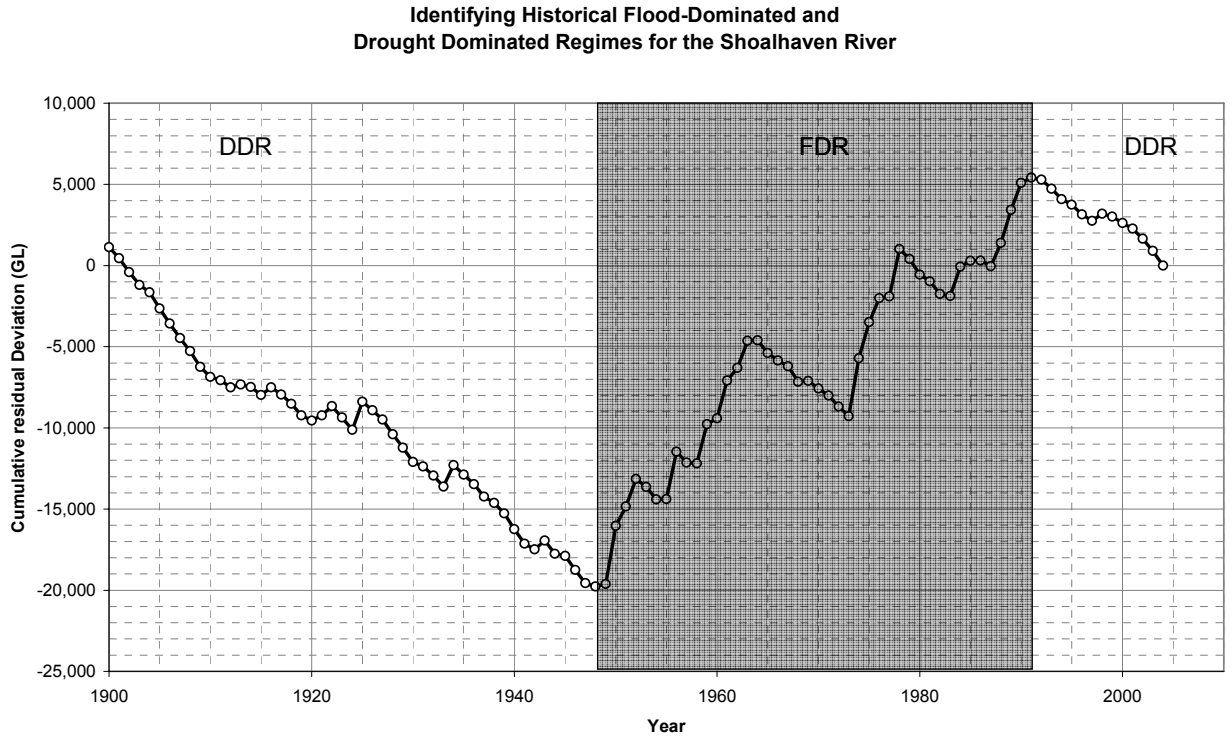
Percentile Exceeded	Daily Flow (ML/day)
51%	697
52%	677
53%	655
54%	635
55%	614
56%	595
57%	577
58%	559
59%	542
60%	525
61%	511
62%	495
63%	480
64%	464
65%	449
66%	433
67%	417
68%	402
69%	388
70%	374
71%	360
72%	344
73%	331
74%	317
75%	304
76%	291
77%	278
78%	267
79%	257
80%	246
81%	234
82%	223
83%	212
84%	203
85%	194
86%	185
87%	175
88%	167
89%	156
90%	147
91%	137
92%	129
93%	119
94%	108
95%	96
96%	85
97%	72
98%	53
99%	35
100%	3.3

2.2.3 Climatic variability

South-eastern Australia experiences marked climatic cycles of wetter-than-average conditions (these are called Flood-Dominated Regimes, or FDRs) and drier-than-average conditions (these are called Drought-Dominated Regimes, or DDRs). FDRs and DDRs can last from 30 to 50 years. Historical records of flows in the Shoalhaven River can be examined to identify FDR and DDR periods. Figure 3 plots the annual Shoalhaven River flows with a special mathematical transformation (called a cumulative residual deviation) applied. When the curve dips down for an extended period, this indicates a DDR. When the curve turns upwards for an extended period, this indicates an FDR. Figure 3 shows that 1900-1948 was a drier-than-average period (or DDR) in the Shoalhaven catchment; 1949-1990 was a wetter-than-average period (or FDR), and the period from 1991 to the present is another DDR.

Because of the uncertainty of the Australian climate, and the natural variability of flows in our rivers, planning and managing water resources is very important to ensure that our towns, cities, agricultural activities and industries do not run out of water. For this reason, we need dams and other water supply infrastructure in order to collect, store and harvest water for use during the times when river flows will be low.

Figure 3. Identifying Flood-Dominated Regimes (FDRs) and Drought-Dominated Regimes (DDRs) from the historical record of natural flows of the Shoalhaven River. (Source: J. Martin, SCA).



2.2.4 Seasonal flow patterns

In the Shoalhaven River, flows have a seasonal pattern, with flows tending to be higher in winter and lower in summer. These patterns broadly reflect the characteristic rainfall trends over the Shoalhaven catchment area. This rainfall is winter dominant. Figure 4 and Table 4 show the monthly trends in river flows in the Shoalhaven River. It should be noted that there is a good deal of 'scatter', or variability, in these monthly flows.

Figure 4. Scatter plot of 'natural' monthly total flows in the Shoalhaven River at a site immediately downstream of the present Tallowa Dam location. Each coloured symbol represents total flows for one month from the observed record. The average of each set of monthly values is also shown. (Source: J. Martin, SCA).

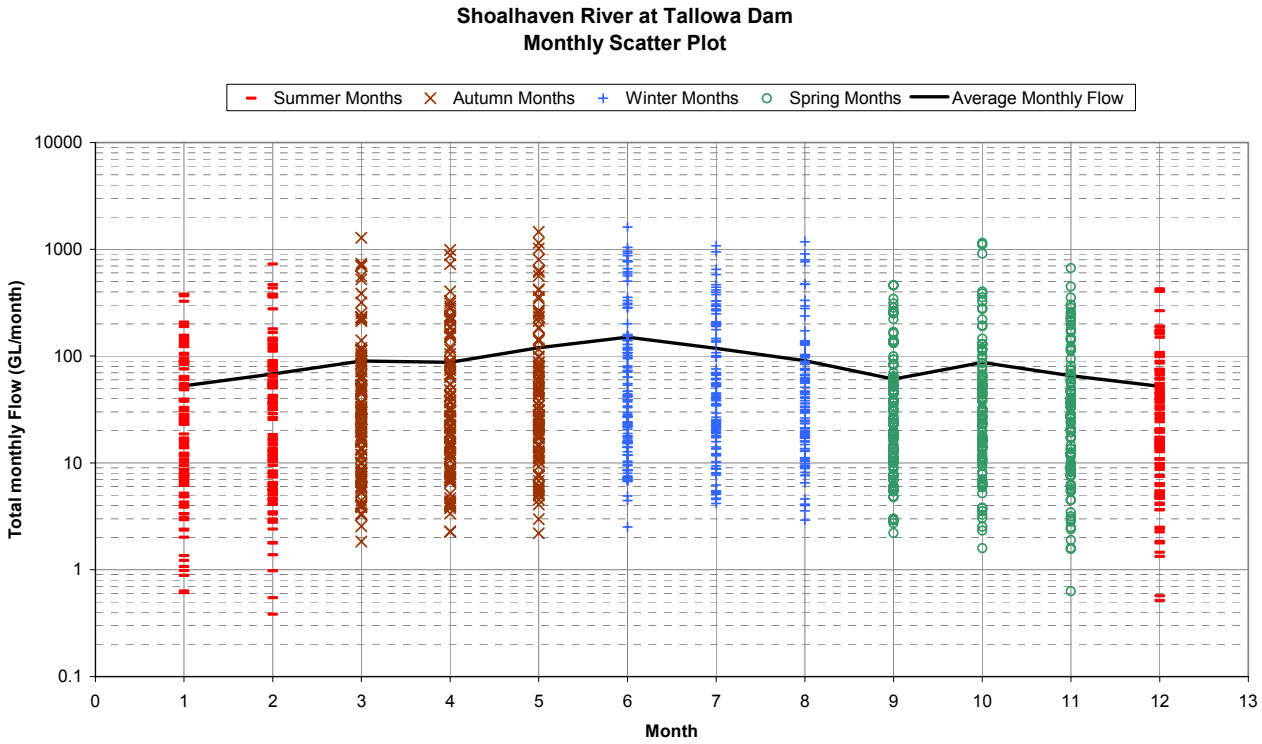


Table 4. Average total monthly flows in the Shoalhaven River. (Source: J. Martin, SCA).

Month	Average Monthly Flow (GL/month)
Jan	52.8
Feb	68.0
Mar	90.0
Apr	87.7
May	120.0
Jun	150.4
Jul	118.4
Aug	90.4
Sep	61.1
Oct	87.4
Nov	65.6
Dec	52.2

2.2.5 Flood frequency analysis

Apart from guaranteeing a supply of water, dams serve an important role in flood mitigation, and can reduce the severity of flooding in areas downstream of the dam. Studying the frequency of natural floods is very important for understanding how various environmental flow arrangements may or may not help to mitigate flooding on the Shoalhaven River floodplain. Figure 5 and Table 5 show the magnitude and return period (in years) of natural floods in the Shoalhaven River.

Figure 5. Flood frequency analysis of natural flows in the Shoalhaven River. This is a magnitude/frequency plot, which shows the return period, in years, of floods of different magnitudes. ARI = Average Return Interval (in years). (Source: J. Martin, SCA).

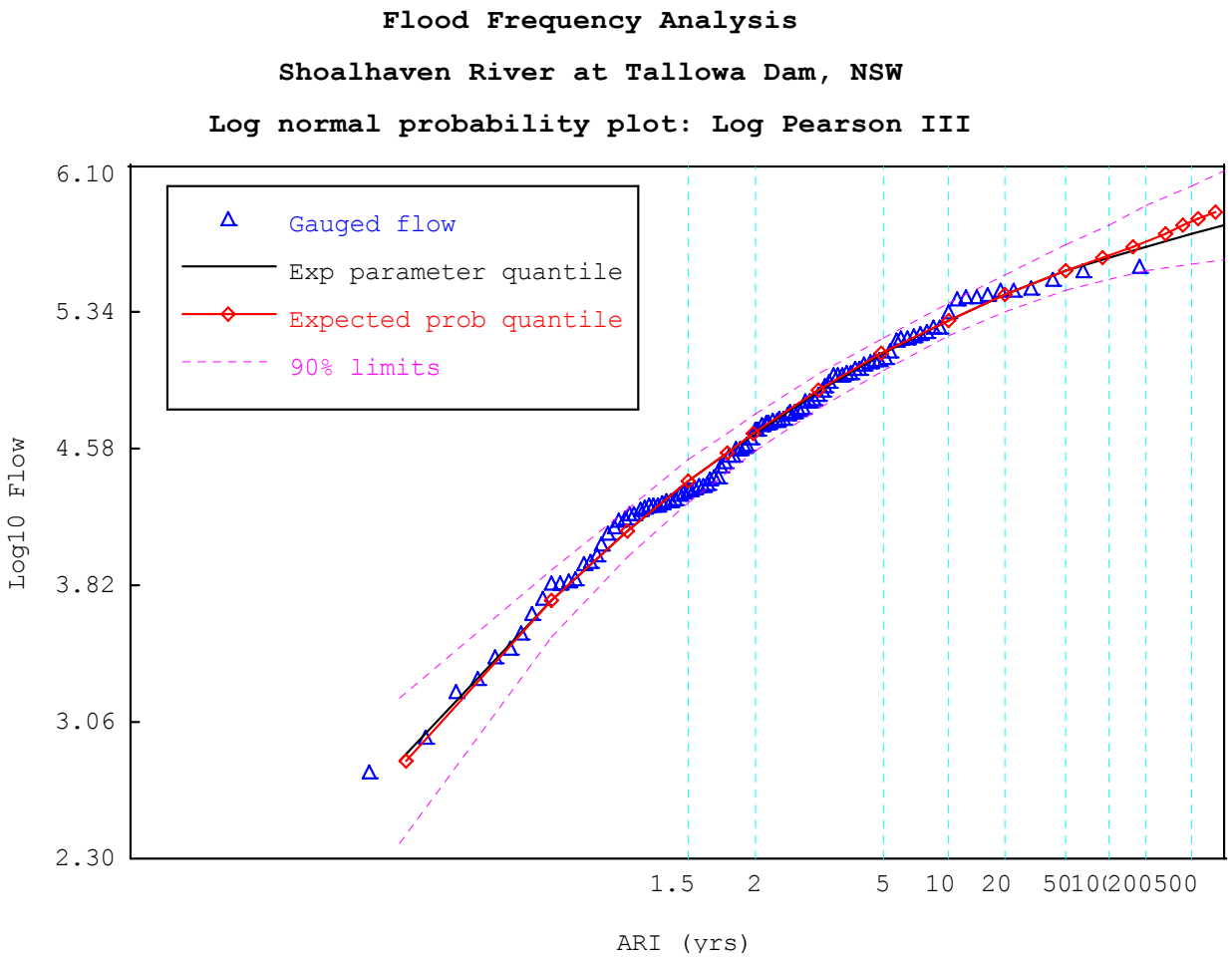


Table 5. Table of flood magnitudes and their return periods (in years) for natural flows in the Shoalhaven River. This information is summarised from Figure 5. (Source: J. Martin, SCA).

Return Period (years)	Daily Flood Magnitude (ML/day)
1.01	678
1.1	5,220
1.25	12,376
1.5	23,619
1.75	33,959
2	43,450
3	74,770
5	118,254
10	181,766
20	247,873
50	335,851
100	401,072
200	464,101
500	543,038
1000	598,963

2.2.6 Comparing environmental flow arrangements

Once the critical flow components of the natural river flow regime have been identified, various environmental flow arrangements can be assessed against the natural flow regime to determine which of the arrangements offer the greatest benefit for the river.

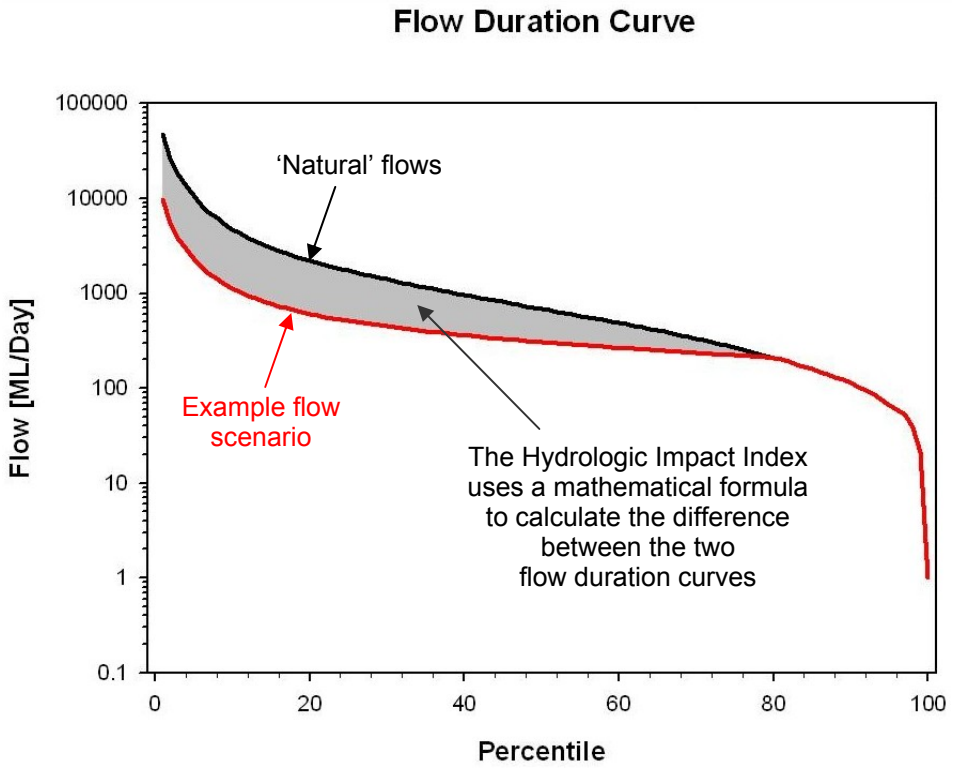
The two key hydrologic assessment tools that have been used to compare various environmental flow arrangements for the Shoalhaven River downstream of Tallowa Dam are:

- Hydrologic Impact Index; and
- Contour Plots.

Hydrologic Impact Index

The Hydrologic Impact Index is a hydrologic assessment tool which examines the degree of difference in the flow duration curves of two time-series of flows. For example, a modelling project may wish to compare various scenarios against the natural situation. Each scenario, in addition to the natural case, will generate its own time-series of flows. From each time-series, a flow duration curve can be prepared. The flow duration curve for the natural case may be plotted on the same graph as the flow duration curve for a given scenario, as shown in the hypothetical example in Figure 6. The difference between the two curves indicates the degree of departure of the scenario flow regime from the natural flow regime. If the objective is to identify the scenario which most closely resembles the natural flow regime, the ideal solution is the scenario which yields the minimum difference in flow duration curve compared to the natural flow duration curve. The Hydrologic Impact Index uses a mathematical formula to calculate the difference between the two flow duration curves.

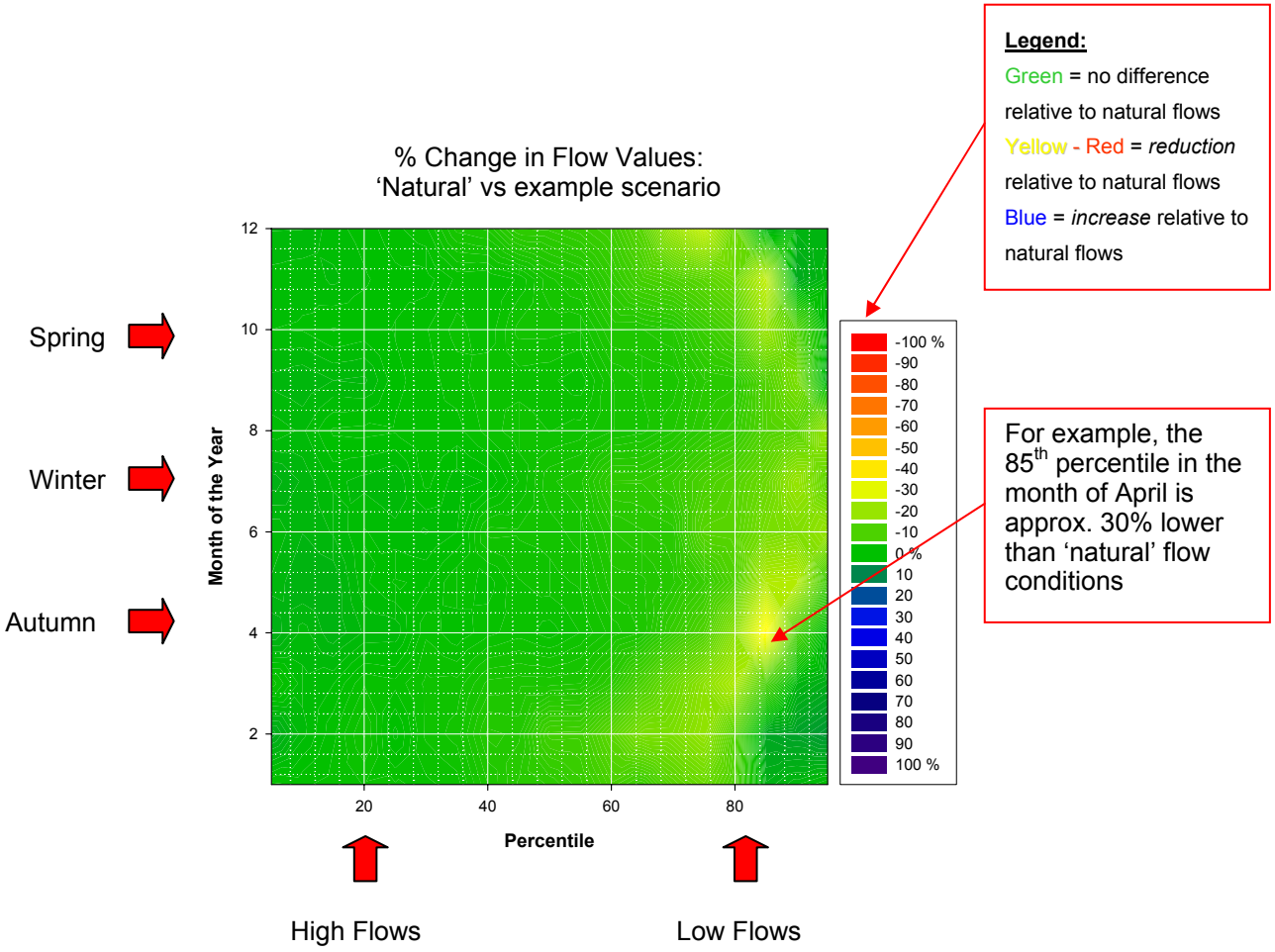
Figure 6. Determining the Hydrologic Impact Index for a hypothetical flow comparison. (Source: Adapted from R. Kidson, DNR).



Contour plots

Contour Plots are a three dimensional tool used to identify seasonal differences across the entire flow range between different environmental flow arrangements and natural flow patterns. It is important to understand these differences as seasonal flow patterns are important for the river environment, for example many fish species are reliant on flows in particular seasons for spawning and feeding cues. Contour Plots are prepared by applying a mathematical formula to average monthly flows across all flow classes. Figure 7 shows a hypothetical example Contour Plot which compares a given flow scenario to a natural flow situation.

Figure 7. Developing a Contour Plot for a hypothetical flow comparison. (Source: Adapted from R. Kidson, DNR).



2.3 Shortlisting environmental flow arrangements

A range of environmental flow arrangements have been analysed using the methods described in Section 2.2 above. The environmental flow arrangements have incorporated a range of:

- operational variables for Tallowa Dam, including different Minimum Operating Levels (MOLs) for Lake Yarrunga (the lake formed by Tallowa Dam) and different pump marks for the commencement of pumping to the greater Sydney metropolitan region;
- different yield increases for the supply of water to the greater Sydney metropolitan region, initially under the 2004 Metropolitan Water Plan and later under the 2006 Metropolitan Water Plan; and
- different environmental flow rules.

2.3.1 Range of environmental flow rules considered

The wide range of different environmental flow rules was considered, as shown in Table 6. The starting point for the development of this list of environmental flow rules was the Hawkesbury-Nepean River Management Forum recommendation: "That the existing environmental flow from Tallowa Dam on the Shoalhaven River be replaced by an environmental flow regime of 20 percent translucent flow and 80th percentile transparent flow. This flow will need to be confirmed by ecological, economic, social and engineering assessments of the Lower Shoalhaven River, its catchment and their relationship to Sydney's strategic water management plan" (HNRMF 2004). The use of transparency and translucency in environmental flow rules is explained in Section 2.3.2 below.

Table 6. Environmental flow rules considered in the hydrologic analysis and modelling.

Environmental flow rules Transparency / Translucency
97 / 0
95 / 0
95 / 5
95 / 10
90 / 0
90 / 5
90 / 10
90 / 30
80 / 0
80 / 20
60 / 0
30 / 30
0 / 80

2.3.2 Transparency/translucency in environmental flow rules

The total amount of water available to the environment downstream of Tallowa Dam is made up of both 'active' and 'passive' environmental water:

1. *Active environmental water* is the licensed environmental flow. It is rule-based, with the rule specifying the minimum amount of water that must be provided to the environment downstream of the dam. The rule is made up of 'transparent' and 'translucent' flow components.
2. *Passive environmental water* is additional to the licensed environmental flow. It is the surplus water remaining after inflow water has been allocated to the SCA and Shoalhaven City Council extractions and the licensed environmental flow.

Typically, active environmental water is delivered through controlled releases from outlets in the dam wall and passive environmental water is delivered through spills over the dam wall.

The behaviour of light through a piece of glass is a good analogy for understanding the 'transparent' and 'translucent' components of the licensed environmental flow.

'Transparent' means that the dam is made to behave as if it were see-through, or invisible. Dams are not allowed to store or extract inflows designated as 'transparent', and these flows must be

passed intact through the dam as if it was not there at all. All inflows pass straight through a transparently-operated dam just as all light passes straight through a transparent piece of glass.

'Translucent' means the dam acts similarly to a translucent (partly see-through) piece of glass, where some, but not all, of the light (or inflows) can pass through. The exact proportion of light (or inflows) that gets through is expressed as a percentage. For example, 20% translucency means that of the incoming light (or inflows) only 20% is passed through the piece of glass (or dam wall). If the translucency was set as 0%, no light would get through at all (an opaque piece of glass) and the dam would store and extract all inflows, passing nothing to the other side (downstream of the dam) (please note that this latter scenario of 0% translucency is not under consideration, and is described here only to aid understanding).

Tallowa Dam cannot be made to act transparently across the entire flow range. This would mean that all inflows would be passed downstream intact; completely removing the important functions of storage and extraction that Tallowa Dam was constructed to provide. Whilst complete transparent operation (the natural flow condition) might be the best possible outcome for the environment downstream of the dam, operational reality means that there is a need to compromise between necessary dam operation and downstream environmental flows. Hence, the concepts of 'transparency' and 'translucency' are applied to sections of the flow range rather than the entire flow range.

The purpose of applying 'transparency' and 'translucency' is to mimic natural flows as much as is possible within the operational constraints of a dam. The two concepts of 'transparency' and 'translucency' are used in combination in environmental water rules to create environmental flow regimes that seek to protect low flows, protect or restore a portion of freshes and high flows, and maintain or mimic natural flow variability. Low flows are passed transparently (up to a limit), and are thus fully protected. All remaining (higher) flows are passed translucently, which protects a portion of these higher flows and mimics natural variability. By consequence, the portion that is not passed is available for storage in and extraction from the dam.

'Percentile' in the hydrological sense means the percentage of time that a given flow (e.g. 250 ML/day) is exceeded, if a long record for a given site is statistically examined. There is an inverse relationship between percentiles and actual flows. A low percentile indicates a high flow value, and a high percentile indicates a low flow value. This is because a low flow has a high percentage of time when flow is higher (exceeded). The aim of most transparent flows is to protect low flows, which corresponds to high percentiles.

The statement 'transparent flows up to the 80th percentile' means that all inflows from percentiles 100 to 80 will be passed through the dam, with no extraction. Flows from the percentiles 100 to 80 correspond to actual flows of zero (flows exceed this flow all the time) up to a low flow value representing whatever the 80th percentile is for that river system (flow exceed this flow 80% of the time). For example, if the 80th percentile was 250 ML/day, all inflows from 0 to 250 ML/day would be passed through the dam without extraction.

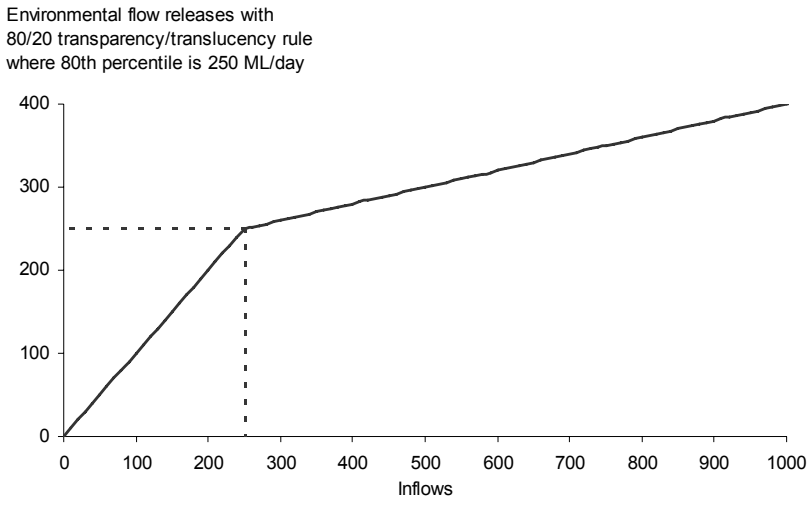
Transparency and translucency are typically expressed in environmental water rules as two numbers, for example '80/20'. The first number in '80/20' is the transparency threshold (in this example, 80th percentile). This designates the percentile up until which all inflows will be passed transparently. The second number in '80/20' is the translucency percentage (in this example, 20%). This is the percentage, or proportion, of inflows above the transparency threshold that will be passed. The transparency/translucency numbers do not have to total 100, each could be between 0 and 100 in its own right. Extending the example in the previous paragraph, the application of an 80/20 environmental water rule would pass all inflows up to 250 ML/day (i.e. the 80th percentile) through the dam plus 20% of all inflows higher than 250 ML/day, as shown in Figure 8.

Figure 8. Example: Application of an 80/20 (transparency/translucency) environmental water rule. (Source: R. Kidson, DNR).

Assuming that the 80th percentile of the river in question = 250 ML/day:

For inflows between 0 and 250 ML/day,
Environmental flow = Inflow.

For inflows above 250 ML/day,
Environmental flow = 250 ML/day + (20% x [Inflow - 250 ML/day]).



2.3.3 The shortlisted environmental flow arrangements

The following subsections discuss the shortlisted environmental flow arrangements, showing how they meet each of the five priority River Flow Objectives that were introduced in Section 2.1.

Protecting natural low flows - RFO 2

Low flows are small volume flows that occur regularly. They are important to maintain river ecosystems particularly in prolonged dry periods. Protecting low flows in the lower Shoalhaven River requires releasing water from Tallowa Dam based on the dam's inflows.

The current (interim) environmental flow rule requires that all inflows to the dam of up to 90 ML/day must effectively pass straight through the dam. Fixed volumes of water additional to the environmental flow are also released to facilitate Shoalhaven City Council's extraction at Burrier. The current environmental flow rule provides some natural flow variability for the downstream river when inflows to dam are between 0 and 90 ML/day. However when inflows exceed 90 ML/day, the dam contributes no additional water to river flow variability downstream.

The hydrologic analysis and modelling shows that is possible to increase the low flow rule at Tallowa Dam from 90 ML/day to somewhere in the range of 150 - 250 ML/day. A low flow rule within this range would better protect natural low flows downstream of Tallowa Dam and improve their variability.

Parts of the river could then better sustain plants and animals in drier periods. For example, more variable low flow over riffles (river shoals and rapids) would provide improved habitat for small fish, macro invertebrates and other small aquatic animals (macroinvertebrates are animals without

backbones that are large enough to be visible with the naked eye, examples include most aquatic insects, snails and crayfish).

The protection or restoration of a portion of moderate flows, freshes and high flows - RFO 3

Moderate flows and freshes are important to help maintain the river channel and riparian (riverbank) vegetation. They also trigger fish breeding events and increase the release and distribution of food supplies. High flows are floods that will continue to spill over the dam. They are important for rejuvenating rivers and estuaries.

To achieve the objective of protecting or restoring a portion of moderate flows and freshes, a proportion of all incoming flows in addition to the volume allocated for the low flows (i.e. 150 - 250 ML/d) would be released from the dam.

The hydrologic analysis and modelling shows that dam releases of up to 30% of Tallowa Dam inflows in the moderate to high range are achievable, while still delivering a long-term available water supply of 30 GL/year.

The 30% proportion of inflows would pass through the dam as variable volume flows, and would contribute to flow variability in the Shoalhaven River downstream. Downstream tributaries that enter the river below Tallowa Dam would boost this flow. High flows will continue to go over the top of the dam even when the SCA is pumping.

Maintaining or mimicking natural flow variability - RFO 6

Natural flow patterns are important to sustain native plants and animals that are dependant on naturally variable river flow conditions. The environmental flow rules for release of water from Tallowa Dam will (combined with naturally occurring spills) reflect the natural pattern of its inflows.

Contingent flows - RFO 11

Contingent flows are additional flows released from the dam for specific ecological or riverine purposes. Tallowa Dam will continue to have the capacity to provide such flow releases to meet contingencies. DNR, as the regulator, will continue determining when such dam releases are to be made as set out in SCA's Water Management Licence.

Maintain or rehabilitate estuarine processes and habitats - RFO 12

The proposed environmental flow rules above will assist in maintaining the Shoalhaven River's key estuarine processes. Because of its importance, DNR is undertaking additional investigations beyond the hydrologic analysis and modelling. These estuary investigations are discussed in Section 3.7 and include examining the relationship between Shoalhaven transfers and estuary salinity.

2.3.4 Summary of outcomes of the hydrologic analysis and modelling

The hydrologic analysis and modelling has revealed that to deliver an additional long term yield of 30 GL per year:

1. The available water for the environmental flow downstream is dependant on *pump mark* and *minimum operating level*. These variables are associated with Tallowa Dam operations and Lake Yarrunga.

2. Table 7 presents in summary the shortlisted range of environmental flow rules which have the best hydrologic outcome in terms of minimising flow changes downstream of Tallowa Dam compared to the natural flow patterns. The environmental flow rule can either allocate more water to the low flows, or alternatively allocate more water to the moderate flows or freshes.

Table 7. Shortlisted range of environmental flow rules.

Environmental Flow Rules	**RFO 2** **Protect natural low flows**	**RFO 3** **Protect or restore of a portion of moderate flows, freshes and high flows**	**RFO 6** **Maintain or mimic natural flow variability**	**RFO 11** **Contingent Flows**	**RFO 12** **Maintain or rehabilitate estuarine processes and habitats**
Current Rule	100 % protection of flows up to 90 ML/day.	Not protected above 90ML/day.	100% of inflows only up to 90 ML/day, and then after dam spills.	Continued capacity to provide flows to meet contingencies will remain part of the operation of Tallowa Dam	Currently no protection of freshes
Active Environmental Flow Rule Set 1	100 % protection of flows up to 150 ML/day.	Protect 30% of incoming flows above 150 ML/day.	100% of inflows up to 150ML/day, plus 30% of inflows above 150 ML/day.	Continued capacity to provide flows to meet contingencies will remain part of the operation of Tallowa Dam	Objective will be achieved through rules set to achieve RFO 6 and possibly RFO 11
Active environmental Flow Rule Set 2	100 % protection of flows up to 250 ML/day.	Protect 20% of incoming flows above 250 ML/day.	100% of inflows up to 250 ML/day, plus 20% of inflows above 250 ML/day	Continued capacity to provide flows to meet contingencies will remain part of the operation of Tallowa Dam	Objective will be achieved through rules set to achieve RFO 6 and possibly RFO 11

For further information on the hydrologic analysis and modelling please see the presentations given by Dr. Renée Kidson, DNR to the Shoalhaven Community Reference Group, which can be viewed on the SCA website www.sca.nsw.gov.au

3. Ecological and physical investigations

The ecological and physical investigations are examining the river environment and river flow processes, drawing on the advice of the interagency Scientific Advisory Panel and the conclusions of the initial 'knowledge review' step in the process for the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam. The conclusions of the 'knowledge review' step are presented in the first report in this series, *Determining and managing environmental flows for the Shoalhaven River, Report 1 - Environmental Flows Knowledge Review*. The Appendix (Section 7) shows how the ecological and physical investigations have addressed the information gaps identified in the 'knowledge review' step.

3.1 Water Quality Assessment

The Water Quality Assessment is examining the effect of Tallowa Dam on downstream water quality. Water quality is socially defined, depending on the desired uses of the water. For the purposes of this assessment, water quality is defined as the physical, chemical and biological characteristics that sustain aquatic ecosystems and water uses desired by humans. A particular quality of water is needed to sustain the river environment, and is also desired for local uses (such as water supply, recreational and commercial uses) and for the supply of water to the greater Sydney metropolitan region.

The effect of Tallowa Dam will be distinguished from other factors influencing water quality. The three fundamental determinants of water quality in the Shoalhaven River catchment are:

- the nature and degree of disturbance of the catchment;
- the materials that humans import to the catchment and which end up polluting waterways; and
- engineered changes to streams and rivers that change the way they function.

The environmental flow rule is not anticipated to have a significant influence on water quality downstream of Tallowa Dam. Rather, it is expected that the operation of the dam and Lake Yarrunga and the way in which the environmental flows are released from the dam will be the main determinant of downstream water quality.

The Water Quality Assessment is currently being completed, and a report will be available later in 2006.

3.2 Thermal Regime Assessment

The aim of the Thermal Regime Assessment is to provide an understanding of key factors affecting the water temperature regime of the Shoalhaven River downstream of Tallowa Dam. The assessment includes:

- a longitudinal (i.e. along the river) analysis of the effects of cold water releases and the recently commissioned de-stratification works in Tallowa Dam on surface water temperatures in the Shoalhaven River ('stratification' is the development of distinct layers of different temperature, density and water quality at various depths in a dam or deep river pool, with a restriction of mixing throughout the water column);
- a detailed analysis of thermal stratification in a deep river pool, termed 'pool 15'; and
- understanding the relationships between flow and temperature.

Temperature data collected at 30 minute intervals over summer 2005 - autumn 2006 will be correlated with concurrent flow data to assess threshold flow rates resulting in pool mixing.

Hydraulic models will be used to determine velocity thresholds producing mixing so that the results of the thermal stratification study in Pool 15 can be extended to other river pools in the Shoalhaven River system. The stratification data will be integrated with natural flow data (assessing the magnitude, frequency and duration of events resulting in pool mixing) to help better understand the relationship between flow and temperature.

The Thermal Regime Assessment is currently being completed, and a report will be available later in 2006.

3.3 Flora and Fauna Review

The aim of the Flora and Fauna Review is to better understand the relationships between river flow and the flora and fauna species and communities that occur in, or rely upon, the Shoalhaven River downstream of Tallowa Dam, including the Shoalhaven estuary and riparian (riverbank) habitats. The Flora and Fauna Review is not an Environmental Impact Statement (EIS) or a Species Impact Statement (SIS), and is not intended to be used as such. Rather, its purpose is to assist in understanding the relationship between the river flow regime and the river environment, as part of the application of the holistic approach to the development of a new environmental flow regime.

The key objectives of the Flora and Fauna Review are to identify:

- the flora and fauna species and vegetation communities documented for the area encompassing the Shoalhaven River downstream of Tallowa Dam (the study area);
- the flora and fauna species and vegetation communities in the study area that have conservation status under either State or Commonwealth legislation; and
- those threatened species and communities that have specific or known river flow requirements for their successful recruitment, growth and functioning.

The Flora and Fauna Review is currently being completed, and a report will be available later in 2006.

3.4 Aquatic Invertebrates Study

Aquatic invertebrates are animals without backbones that live in wetlands and rivers. There are many types of aquatic invertebrate and some types include shrimps, crayfish and mayflies. They are used to measure river health because they are present everywhere and there are hundreds of species. They are affected by local pollution and combine the effects of disturbance over time. To save costs, they are easy to sample with simple equipment.

The purpose of the Aquatic Invertebrates Study (Growns and Williams 2006) was to assess the current health of the Shoalhaven River from Tallowa Dam to Burrier and to review data collected by earlier studies. In autumn and spring 2005 aquatic invertebrates were sampled to provide a current baseline for predicting change, and historical information was used to assess how populations have changed over time.

Aquatic invertebrates were sampled from riffles (shallower parts of the river with fast flow) in the Shoalhaven River downstream of Tallowa Dam and according to the Australian River Assessment System (AUSRIVAS). This method is recommended by Environment Australia and the NSW Department of Environment and Conservation to assess river health.

The invertebrate data suggested that the river health below Tallowa Dam is poor for about 4 km downstream. There are types of animals that should be present, but are missing from that part of the river. River regulation and poor water quality explain the poor river health. The number of

different types of animals increases after 4 kilometres and the river could be considered healthy by the time it reaches Burrier. However, only 80% of the species that could be expected to be present in the river are found there. This suggests that maybe river regulation is affecting the rest of the river as well.

A comparison of the invertebrate data collected in the 1990s and comparing it with the 2005 sampling shows that the invertebrate community structure has changed little in the last 10 years. This means that the current environmental flow regime has not improved river health and that a new environmental flow regime is needed.

For further information on the Aquatic Invertebrates Study please see the following report:

> Growns, I. and Williams, S. (2006). *A review of the impacts of Tallowa Dam on the macroinvertebrate communities of the Shoalhaven River*. NSW Department of Natural Resources, March 2006.

3.5 Physical Habitat Modelling

The following physical habitat studies have been initiated in the freshwater river reach between Tallowa Dam and Burrier, with the aim of relating changes in flow to physical habitats and in-stream processes:

1. Assessment of low-moderate flow thresholds for fish passage (reported in the Physical Habitat Modelling Report 1 discussed in this section and in the separate Fish Passage Study described in Section 3.6).
2. Assessment of flow rates required for channel maintenance and moderate to high flow processes (to be reported in Physical Habitat Modelling Report 2, which will be available later in 2006).

3.5.1 Physical Habitat Modelling 1

In Physical Habitat Modelling 1 (Reinfelds *et al.* 2006), proposed environmental flow regime changes in the Shoalhaven River downstream of Tallowa Dam have been assessed in terms of effects on depth, velocity and fish passage across natural riffle/rapid barriers using a two dimensional hydraulic modelling approach. This study has focussed on passage requirements for Australian bass (*Macquaria novemaculeata*), an iconic fish species of major ecological and recreational angling importance for which minimum depth and maximum velocity tolerances for migration have been well established. For adult Australian bass, the minimum depth threshold to facilitate passage across shallow barriers is 20 cm. Velocity thresholds established for vertical slot fishways indicate that Australian bass 93 mm in length can negotiate velocities of up to 1.8 m/s (metres per second) over short (30-40 cm) distances.

This study focuses on upstream migrations and localised movement, as upstream passage through natural riffle/rapid barriers is considered more problematic than downstream passage. Downstream migration by adult bass is triggered by freshes and floods over autumn/winter. Fish passage across natural riffle/rapid barriers is therefore assisted by swimming with the prevailing flow direction in conjunction with elevated water levels. Upstream migrations and localised movements by Australian bass over spring/summer, however, may occur during low flow conditions. Upstream passage thus occurs against the prevailing current direction, particularly in shallow, high velocity riffle/rapid barriers.

A total of 17 major riffles/rapids occur between Tallowa Dam and Burrier over a river length of approximately 20 km. Reconnaissance investigations of riffles revealed the riffle characteristics most likely to cause problems for upstream bass passage under low flow conditions. Detailed

topographic surveys and hydraulic modelling was subsequently undertaken for two riffles identified as 'worst case' examples.

Hydraulic modelling results indicate that the current flow regime transparency threshold of 130 ML/day (megalitres per day) provides sub-optimal conditions for upstream migration of adult Australian bass through the modelled example of a wide-shallow riffle. At a flow rate of 130 ML/day, depths along the primary thalweg were less than 20 cm for a distance of 110 metres in the 300 metre long riffle (a thalweg is the line of maximum depth along the bed of the stream). Depths less than 15 cm occurred over a total distance of 23 m. At a flow rate of 300 ML/day, minimum depth conditions were substantially improved such that flow depths of 15-20 cm occurred over a total distance of only 2.6 m along the primary thalweg. Flow rates of 500 ML/day and 1000 ML/day provided further improvement in minimum depth conditions across the riffle with no part of the primary thalweg recording a depth less than 20 cm.

Hydraulic modelling results for the modelled example of a steep-turbulent riffle indicate that upstream travel distances through high velocity zones within the riffle decrease with increasing discharge. Flow rates of 300-500 ML/day were shown to substantially improve velocity conditions for upstream Australian bass passage compared to a flow rate of 130 ML/day. While velocities within the modelled steep-turbulent riffle are within passage limits for 93 mm sub-adult and larger Australian bass, it remains unclear whether the 8-10 m travel distances through the high velocity zones are within or beyond sustainable burst speed duration. It is possible that steep-turbulent riffle barriers such as the modelled example are negotiated by Australian bass during freshes and floods with flow rates substantially greater than the 1000 ML/day maximum flow modelled in this study.

The hydraulic modelling analysis suggests that a target flow range of 300-500 ML/day will provide minimum flow rates that will facilitate upstream migration by adult Australian bass through the natural riffle barriers below Tallowa dam. Analysis of the frequency with which this target flow rate is attained by 80/20, 90/10 and 90/30 transparency/translucency environmental flow rule options indicate that an 80/20 rule, where the transparency threshold is varied according to the monthly pattern of natural flows, is the best of the three options (for an explanation of transparency/translucency in environmental flow rules please see Section 2.3.2).

For further information on Physical Habitat Modelling 1 please see the following report:

> Reinfelds, I., Haeusler, T. and Williams, S. (2006). *Hydraulic modelling assessment of fish passage through natural riffles: Shoalhaven River below Tallowa Dam*. Department of Natural Resources, July 2006.

3.5.2 Physical Habitat Modelling 2

Physical Habitat Modelling 2 is currently being completed, and a report will be available later in 2006.

3.6 Fish Passage Study

The Ecology Lab Pty. Ltd. was engaged to carry out a Fish Passage Study of the Shoalhaven River between Tallowa Dam and Burrier weir (The Ecology Lab 2006). The aim of the study was to:

- define, where possible, flow requirements for the passage of native fish species;
- identify flow-induced barriers to fish passage;
- determine whether any identified flow barriers can be mitigated by changes in flow regimes; and
- provide fish biology input into the option analysis.

At present, Tallowa Dam is a virtually impassable barrier to upstream fish passage along the Shoalhaven River; however plans are being developed to construct a fishway at the dam wall. Between the dam and Burrier weir there are many naturally-occurring riffles that could potentially create a depth or velocity barrier for migrating fish. Previously, at least 28 species of fish have been recorded in the Shoalhaven River between Tallowa Dam and Burrier weir. Recent studies have reported fish, including Australian bass, occurring up the Shoalhaven River to Tallowa Dam, indicating that fish can migrate within this part of the system under at least some flow conditions. Data were found relating to the swimming abilities of five of the species occurring in the Shoalhaven River and two closely related species from New Zealand. Additional literature was found that provided background information about the relationship between fish migratory patterns and swimming ability, and relating to strategies that different species employ to navigate velocity barriers such as riffles and rapids.

Previous studies regarding minimum depth requirements for migrating fish indicated a minimum depth threshold of 20 cm for adult Australian bass. Observations reported in the literature also indicate that adult bass can swim on their sides in depths of 5 cm for short distances. Other fish that are smaller, or that have cylindrical or shallow body profiles are also likely to be capable of negotiating very shallow water. Notwithstanding this, the 20 cm depth within riffles was adopted as a threshold for fish passage in this study. The existing literature suggested two general thresholds for velocity in terms of fish passage:

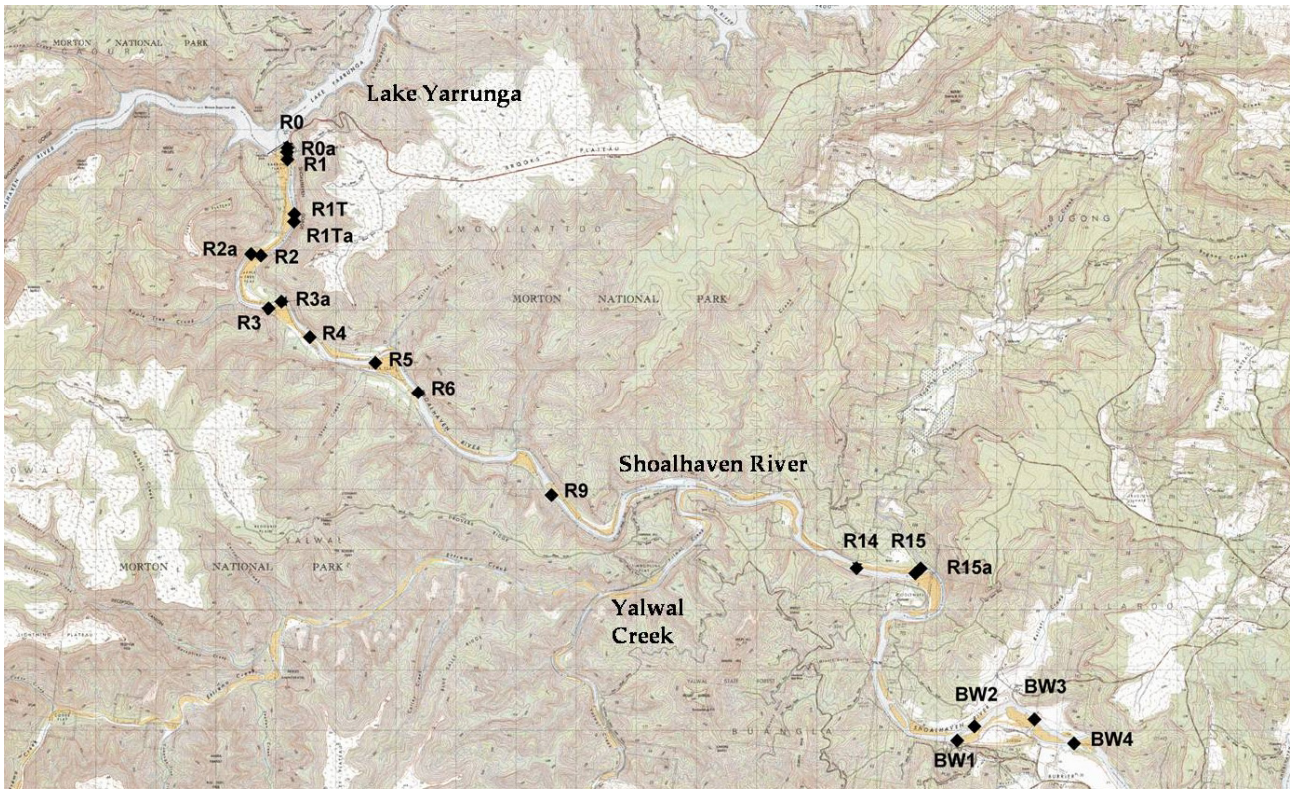
1. A threshold of 0.3 m/s (metres per second) at or below which most Australian freshwater fishes would have little difficulty in negotiating passage.
2. A threshold of 1.0 m/s above which passage would be problematic for most Australian freshwater fishes. An exception to this upper threshold was experimental work on Australian bass (*Macquaria novemaculeata*), which have been shown to be capable of negotiating short distances subject to water velocities greater than or equal to 1.84 m/s.

In this study, field data was obtained from the thalwegs of riffles during three flow rates: 90 ML/day, 130 ML/day and 300 ML/day. Fieldwork was carried out between October 2005 and January 2006 and 14 riffles were investigated in detail (Figure 9), with measurements often taken at two or more thalwegs in each. Depth and velocity measurements were taken along thalwegs at each riffle, with velocity recorded at the stream bed, approximately six-tenths depth and at the surface. Positions were recorded with a differential global positioning system (DGPS) and maps of each riffle were produced. Not all riffles were sampled under all three flow rates. Data was analysed to determine whether average depths and velocities varied significantly among riffles in relation to flow and to determine how depth and velocity varied, on average, within selected riffles. Depths and velocities were also assessed with distance along riffles to identify sections within riffles that may be problematic to fish passage.

The study found that fish passage between Tallowa Dam and the estuary of the Shoalhaven River is not interrupted by any vertical obstructions such as waterfalls, but there are several riffles that could affect migration under different flow conditions. Riffle R5 has at least three sections where the depth was shallower than the threshold for migration of adult Australian bass over short distances during 130 ML/day flow. The positions and extent of these sections show good agreement with the Physical Habitat Modelling (Section 3.5). Observations of bass in other studies indicate that they could negotiate these shallow sections without becoming stranded, but in doing so they would be subject to stress from exhaustion and they may also become more susceptible to predation from terrestrial (land-based) predators. Although R5 is very long, The Ecology Lab did record several deeper areas that could be used as a refuge, allowing bass to stage their migration up through the riffle. Moreover, some movement could occur at night, potentially reducing susceptibility to predation. Finally, other species of fish, and perhaps small bass, use other strategies for moving up riffles, including use of shallow, low velocity areas at the edges of the channel and darting (i.e. short swimming bursts) between the sheltered areas behind rocks. Notwithstanding this, increasing

depth within this riffle (as recorded under 130 ML/day flow) would be of advantage to adult Australian bass migrating upstream through R5 after spawning, namely, from late winter to early summer.

Figure 9. Map of riffles sampled by The Ecology Lab, October 2005 - January 2006. (Source: The Ecology Lab 2006).



This increase could be achieved in two ways. First, depths could be increased on a permanent or an intermittent basis by increasing flow. The 300 ML/day flow increased depths to or beyond the 20 cm threshold, but it is possible that a lesser flow (i.e. between 130 and 300 ML/day) would also achieve a significant increase in depth. Second, depth could be increased by engineering a deeper stream bed in those short distances considered to be critical to movement. R6 has been altered along one thalweg to facilitate canoe access and this alteration appears to have been relatively persistent. Thus, there may be merit in considering a trial to modify critical sections of R5 to determine if increased depth can be maintained. An advantage of the first approach is that it would also help to increase depth for fish passage in several other riffles, for example R6, R14, BW1, BW3 and BW4. A potential disadvantage with this approach, however, is that it could increase water velocities, which could become problematic in riffles such as R1, R1T, R3, the first 20 m or so of the downstream section of R5, and the upstream section of R9. It is possible, however, that under these conditions species may be able to use alternative strategies such as travelling along the edges of the stream to avoid strong currents.

Depth and water velocity in riffles below Burrier are subject to variation caused from offtake by Shoalhaven City Council within the weir pool. Thus a flow of 90 ML/day at BW1 and downstream equates to a release of approximately 130 ML/day from Tallowa Dam, assuming no inputs of water downstream of the dam (e.g. from Yalwal Creek, as shown in Figure 9). It is also understood that Council does not pump water continuously throughout the day, thus when not pumping, flows would become re-established up to the amount released from Tallowa dam plus any other inflows.

Overall, the study has shown from previous investigations and observations made during the study that a range of fish species, including Australian bass, occur in the Shoalhaven River upstream as far as Tallowa Dam. This suggests that conditions apply at least some of the time to facilitate upstream migration as far as Tallowa Dam. Notwithstanding this, there are several riffles where migration is likely to be limited by depth or velocity. Migration through these riffles could be improved by increasing flow beyond the current release of 130 ML/day and/or perhaps a small amount of physical alteration of critical sections.

Further work would be beneficial in measuring changes in depth and velocity under a larger range of flows (e.g. 200, 250, 350 ML/day), refining the ways in which depth and velocity are measured and acquiring a better understanding of strategies of migration utilised by fish. If a new flow regime is to be adopted, it is recommended that the distribution and abundance of fish be investigated quantitatively before and after changing the regime, so that the effectiveness of the change can be measured.

For further information on the Fish Passage Study please see the following report:

> The Ecology Lab (2006). *Fish Passage Study for Shoalhaven River Environmental Flows, Downstream of Tallowa Dam*. Report prepared by The Ecology Lab Pty Ltd for Department of Natural Resources, July 2006.

3.7 Estuary Modelling and Assessment

The environmental flow requirements of the Shoalhaven River estuary are being investigated using a methodology developed through the Environmental Flows Initiative of the National River Health Program. The National River Health Program supports the environmental components of the Water Reform Framework for Australia, which was agreed to in 1994 by the Council of Australian Governments (COAG). Reports published under the Environmental Flows Initiative provide an overview of the environmental water requirements of three major ecosystem types, an analysis of threats to these systems and methods for determining water allocations (DEH 2005).

One of the Environmental Flows Initiative reports, 'Environmental Water Requirements to Maintain Estuarine Processes' (Peirson *et al.* 2002) has drawn on these overseas and Australian studies to develop a methodology for assessing the risk to the estuarine ecosystems associated with reduced freshwater inflows that is suited to estuaries within Australia. The report was prepared by the Water Research Laboratory at the University of New South Wales.

The methodology is composed of two phases: a 'Preliminary Evaluation Phase' and a 'Detailed Investigative Phase'. The Preliminary Evaluation Phase aims to yield a classification of estuaries by significance and risk as well as the scope of more detailed investigative programs. The purpose of the Detailed Investigative Phase is to determine an appropriate level of environmental freshwater flow for any given estuary.

The Preliminary Evaluation Phase for the Shoalhaven River estuary was completed in March 2006, and the Detailed Investigative Phase is nearing completion. A major focus of the Detailed Investigative Phase is the conduct of modelling to determine the response of salinity within the Shoalhaven River estuary to various river flows. The modelling includes examining the salinity response for river flows with water extraction from Tallowa Dam compared to river flows without water extraction. The University of New South Wales Water Research Laboratory, who developed the Environmental Flows Initiative methodology, has been engaged to carry out the flow and salinity modelling. The outcomes of the flow and salinity modelling will be used to assist in developing an environmental flow regime that is appropriate for the estuary.

The Estuary Modelling and Assessment is currently being completed, and reports will be available later in 2006.

4. Cultural heritage, social and economic assessments

Cultural heritage assessments examine indigenous and historic heritage values. Water planning processes must provide for indigenous access to water resources and account for traditional cultural purposes (COAG 2004). Social and economic assessments are used to predict the effects of decisions on people and communities. These assessments provide an understanding of the distribution and scale of costs and benefits of change, and seek to maximise positive effects and minimise negative effects resulting from change. Social and economic assessments measure the effects that may arise from changes in policy or practice. An understanding of the nature and significance of these impacts is critical to making good management decisions.

The consideration of cultural heritage, social, and economic issues associated with environmental flows is relatively recent in Australia, so there is very little relevant published information. However, the significant water reforms that have occurred at a National and State level have formalised the consideration of cultural heritage, social, and economic issues in water management. The NSW Government response has included:

- establishing an Independent Advisory Committee on Socio-Economic Analysis in 1997;
- publishing guidelines and resources including *Water Sharing the way forward: Community Based Socio-economic Assessment* (DLWC 1998a); and *Water Sharing the way forward: The Social, Economic and Environmental Benefits of Water Management in NSW* (DLWC 1998b);
- incorporating principles addressing social, economic, cultural and heritage issues in the NSW *Water Management Act 2000*; and
- addressing social, economic, cultural and heritage issues in water management planning processes throughout the State.

Cultural heritage, social, and economic assessments have been initiated to assist the development of a new environmental flow regime for the Shoalhaven River downstream of Tallowa Dam. The cultural heritage assessment has been completed. The economic and social investigations will be completed later in 2006, as they need to be informed by the 'values and uses assessment and community comment' step.

The guidelines and resources produced through the water reforms have provided a basis for the cultural heritage, social, and economic assessments. Other key resources that have assisted include:

- the high priority social, economic, cultural and heritage issues identified for the Shoalhaven River by the Hawkesbury Nepean River Management Forum Independent Expert Panel (IEP 2004) which have been further assessed by DNR (shown in Table 8); and
- the community values identified in the Shoalhaven City Council *Shoalhaven River Estuary Data Compilation Study* (Umwelt 2005).

Table 8. Social, Economic, Cultural and Heritage Issues identified for the Shoalhaven River downstream of Tallowa Dam. (Source: Adapted from IEP 2004).

Issue	Reach 1 (Tallowa Dam to Burrier)	Reach 2.1 (Burrier to Nowra)	Reach 2.2 (Nowra to Pacific Ocean)
Social values	✓	✓	✓
Heritage values		✓	✓
Aboriginal values	✓	✓	✓
Water extraction - irrigation	✓	✓	✓
Water extraction - industrial		✓	✓
Water extraction - riparian		✓	✓
Commercial fishing activities (including oysters)		✓	✓
Recreational fishing activities (including oysters)	✓	✓	✓
Recreational amenity	✓	✓	✓
River related tourism	✓	✓	✓
Land use and land management	✓	✓	✓

4.1 Cultural Heritage Assessment

Biosis Research Pty. Ltd. was engaged to carry out a Cultural Heritage Assessment (Moody *et al.* 2006) that has examined how cultural heritage values might be affected by changes in flow downstream of Tallowa Dam resulting from increased water transfers from the dam and a new environmental flow regime. Both Aboriginal and historic cultural heritage values have been identified and assessed.

4.1.1 Aboriginal community consultation

Discussions with various members of local Aboriginal community groups show that the river is a defining element of country for the Aboriginal people of the Shoalhaven River. The river plays a key role in the formation of group and individual identity, characterised by strongly expressed cultural affiliations that encompass issues of social etiquette, including who can speak for different parts of the river country, and place-based knowledge, narratives, beliefs and daily practices. These are all linked to the maintenance of community health and wellbeing, and these in turn are linked to the health and wellbeing of the river and its environment. Activities such as fishing, food collecting, swimming and simply being 'in country' are important ways in which the natural resources and environment are used. The river as a source of food resources has been expressed to be of particular and ongoing importance. These activities also have teaching functions. The river is where children learn not only about resource gathering, but also about wider aspects of cultural life. Education was identified as a significant issue by the people that were spoken with, implicated with concerns that decreased access to land, increased environmental damage, decreasing natural resources and damage to cultural places will threaten the way in which cultural understandings are passed on to the next generation.

There are concerns about visitor damage, with the recognition that such damage is often unintended. This also raises the issue of broader community education regarding the cultural sensitivities of the land, and also about matters of cultural access. Clearly any restriction of access to country remains a major concern for Aboriginal people. Equally, in terms of future management decisions, the potential to retain an economic relationship with their country is important for the Aboriginal community.

Within the landscape, places are also important, and a number of potentially sensitive sites and places were identified in the landscape that could be potentially damaged by changed river flow

regimes. These include the estuarine islands, creek crossings, and the potential for burials in the banks of the river. In addition, there are ongoing concerns about destruction to sites by people visiting the river. This becomes a potentially greater threat if more artefact material is uncovered in the course of decline in vegetation cover and increased erosion impacts.

The main areas of attachment and concern that arose during discussions with Aboriginal representatives include:

- health of the river;
- the river as a landscape for education;
- access to country;
- natural resource use, particularly seafood gathering;
- swimming and fishing;
- economic opportunities in country; and
- ceremonial activities.

4.1.2 Historic settlement of the Shoalhaven area

Early settlement of the Shoalhaven area was focussed along the river, as it provided the easiest means of negotiating the landscape. The river allowed reasonably reliable boat access from the coastal shipping paths to as far upstream as the present location of Nowra. The first non-Aboriginal people to establish a presence in the Shoalhaven were cedar-getters. Eager to feed the cedar markets of Sydney, they targeted stands of cedar easily accessible from the river, floating the timber down the river to waiting ships. Encroachments on the traditional lands of local Aboriginal groups prompted a period of protracted conflict and resulted in early government restrictions on entry to the Shoalhaven.

As exploration parties mapped the terrain, settlers arrived to establish farm holdings and permanent settlements. Cattle grazing, hog farming and wheat cropping were some of the early agricultural pursuits of the area, although dairying grew to become the dominant agricultural industry. Alexander Berry, with the Berry Estate, capitalised on the potential of the Shoalhaven area. Berry amassed extensive land holdings and instituted several large-scale engineering works to improve the agricultural prospects of his estate. The importance of the river to early settlement of the area is exemplified by the construction of Berrys Canal. Berry instructed his assigned convicts to cut a canal between the Shoalhaven and Crookhaven rivers, negating the need for ships to cross the sandbar at Shoalhaven Heads. The work was completed on an understanding that safer river transport was essential to the sustained success of any settlement along its banks.

Although the river provided a focal point for successful settlement, it also provided an opportunity for large-scale destruction. Flooding along the Shoalhaven River was regular and pervasive. Historic writings give a picture of the devastation caused by floodwaters: settlements were abandoned and crops and livestock washed away, requiring extensive rebuilding and restocking programs after each flood. Regular flooding was an acknowledged characteristic of the river valley and it is some measure of the early economic significance afforded by the river that the lower Shoalhaven floodplains were not permanently abandoned.

4.1.3 Cultural heritage sites

Occupation of the Shoalhaven has left a physical mark on the environment, and this is evident in the numerous cultural heritage sites that have been identified and listed within the area. Aboriginal campsites, rock shelters, art sites and burials have been recorded along the banks of the Shoalhaven and its tributaries, while early houses, agricultural outbuildings, wharves, boatyards and ferries are just some of the historical recorded sites along the Shoalhaven River. This evidence is significant

as a tangible reminder of the human occupation of the area, and for having survived the forces of periodic flooding.

Cultural heritage sites have been impacted by previous flood events in different ways. Aboriginal and historic cultural heritage sites can be scoured, eroded and exposed by the forces of flood waters, while at the other extreme, the deposition of silt and sediment loads carried in flood waters can obscure sites, making them difficult to locate.

No previously unidentified heritage sites were recorded during survey work undertaken for the Cultural Heritage Assessment. This is considered to be a direct reflection of the river processes at work in the study area, and not a true reflection of prehistoric and historic occupation patterns.

4.1.4 Sensitivity of cultural heritage values to changes in flow

Increased water transfers from Tallowa Dam and a new environmental flow regime have the potential to affect river flows downstream of the dam. It is envisaged that under the proposed changes that low flows will be better protected however, greater volumes of water are likely to be harvested from Tallowa Dam during periods of moderate to higher flows. The alteration of flows can impact cultural heritage values by changes in:

- sediment scour and transport rates; or
- water quality and quantity, which could affect the social and cultural significance of the river to Aboriginal and non-Aboriginal users.

There have been no archaeological sites identified along the river margins in this area to date. The proposed increased water transfers are likely to reduce the size and frequency of moderate flows. Expected changes associated with these flows are likely to result in reduced sediment erosion and transport rates. Higher flows, such as floods, are responsible for high sediment erosion and transport rates; however, the risk of increasing existing scouring processes to physical sites under the proposed flow changes is unlikely.

Changes in flow may alter aquatic vegetation and instream habitats through changes in water quality and sedimentation. In addition, possible changes to moderate flows may impede fish passage through barriers. All of these may cause changes to fish populations that are of traditional value to the area.

Aboriginal values of the river are associated with (but not limited to) traditional resource procurement areas. Consultation has indicated that the riverine and estuarine resources of the river have been in decline since the construction of the Tallowa Dam, and there is a real concern that changes in flow could further restrict traditional Aboriginal use of the river.

4.1.5 Recommendations and further consultation

The Cultural Heritage Assessment has made the series of recommendations listed below. These recommendations:

- are informing a further stage of community consultation that is currently underway;
- will inform the determination of a recommended environmental flow regime; and
- can inform the ongoing activities of Shoalhaven City Council or any other management body undertaking work that could impact the cultural heritage values identified in the Cultural Heritage Assessment.

Recommendations:

1. *Recognition of the cultural heritage landscape.* It should be acknowledged that the cultural heritage values of the Shoalhaven River and immediate environment encompass the river as part

of a broad and significant cultural landscape. This includes not only the physical aspects of the landscape but also the attachments of the community to that landscape. All policy planners and decision-makers working in the lower Shoalhaven River catchment area should be provided an opportunity to read the Cultural Heritage Assessment.

2. *Protection and conservation of heritage values.* The governing principle of heritage management in Australia is conservation of the identified heritage values associated with a place. Wherever practicable, the protection, conservation and promotion of heritage assets and their attached values is the preferred management option. This principle not only applies to physical cultural heritage sites, but extends to intangible heritage such as attachment to *place* and the practices and community activities that form part of this attachment. Although there appears to currently be no substantial potential impacts to objects and sites, these attachments and practices have been identified as significant components of the cultural heritage values of the Shoalhaven River environment. As such, all these heritage values should be taken into consideration when considering potential impacts.

3. *Recognition of a changeable environment.* The Shoalhaven River is a dynamic natural feature, subject to ongoing natural impacts. The river has perennially flooded and this process is part of the environmental history of the wider catchment. The natural variability of the river has been shown to have cultural importance to the communities associated with the river, and hence cannot be separated from understandings of cultural heritage more broadly. Conservation principles must allow that complete control of the environment is unattainable and undesirable. Future flood events should be considered part of the natural order and a continuation of processes geologically observable in the basin over the last several thousand years. While natural flood impacts to cultural heritage sites should be minimised where possible, any such impacts should be considered as part of unavoidable and historical natural processes. Changes to water flows in the river as a result of changes to the operation of Tallowa Dam should avoid exacerbation of the effects of naturally occurring stream changes and flooding on places, sites and cultural heritage values.

4. *Additional community-based research.* An important component of a holistic cultural heritage assessment is an understanding of how communities, both indigenous and non-indigenous, form attachments to places. It is recommended that any further assessment of heritage values for the Shoalhaven environmental flows project engage with broad community consultation to understand the social values of the non-Aboriginal community, where *social value* is defined as 'embracing the qualities for which a place has become a focus of spiritual, political, national or other cultural sentiment to a majority or minority group' (ICOMOS 1999). These attachments, and an investigation of how local communities establish a 'sense of place' and give meaning and heritage values to the landscape, should be considered as broader components than issues of a socio-economic nature. Activities such as recreational fishing, picnicking, bushwalking and tourism are all important for the community and play a role in identity formation and attachment to the landscape. Further knowledge of these attachments would fill in current gaps in understanding the way in which changes to the river environment will affect cultural heritage values of the Shoalhaven River.

5. *Additional Aboriginal cultural research.* This primarily desktop assessment has shown that members of the relevant Aboriginal communities have significant cultural heritage values and attachments to the Shoalhaven River environment. Although this project has broadly documented some of these values, a more in-depth study is required that draws on cultural mapping and allows a more systematic identification of places, sites and attachments. This should include an oral history component that allows for a greater understanding of the histories, stories and memories that are layered within the landscape. It should also include a program of more detailed survey and investigation to resolve some of the visibility issues encountered during the current program of work, together with a predictive assessment of the locations of potential Aboriginal heritage places (archaeological and non-archaeological) within

500 metres of the river between the dam wall and the sea. This combined research would be a valuable management tool that would improve Aboriginal heritage conservation outcomes for the lower Shoalhaven River landscape.

6. *Ongoing involvement of the Aboriginal community.* The various Aboriginal community groups have a strong attachment to country for all or parts of the Shoalhaven River environment. Future decisions of management should be predicated on involvement of members of these communities in decision making, with consideration being given to a 'two-way' exchange of information (including research programs) and to community-based initiatives. The latter also takes into account that an economic relationship revolving around natural resource use is a significant component of long-term Aboriginal involvement with country, and plays a role in understanding heritage attachments. Ongoing consultation is important to allow Aboriginal involvement in decision making processes regarding possible mitigation of potential impacts, management of identified impacts, and a long term contribution to the affective management of the river environment.

For further information on the Cultural Heritage Assessment please see the following report:

Moody, S., Harrington, J. and Taylor-Wood, E. (2006). *Aboriginal and Historic Cultural Heritage Assessment and Options Analysis of the Shoalhaven River, Downstream of Tallowa Dam, NSW*. Report Prepared for Department of Natural Resources by Biosis Research Pty. Ltd., July 2006.

4.2 Social Assessment and Economic Assessment

The primary aim of the Social Assessment and Economic Assessment is to examine how changed operations at Tallowa Dam and a new environmental flow rule are likely to affect individuals, groups and businesses that use the Shoalhaven River. Key river uses include recreation, tourism, and commercial fishing.

The Social Assessment and Economic Assessment will:

- develop a community water use profile that identifies the current and future water use values of the Shoalhaven River downstream of Tallowa Dam, including direct use values, indirect use values, non-use values (e.g. those associated with flora and fauna, heritage and amenity) and the water required to maintain sustained growth; and
- identify and assess the social and economic effects of the narrowed range of environmental flow rules and dam operations.

The Social Assessment and Economic Assessment are currently being completed, and will be reported in *Determining and managing environmental flows for the Shoalhaven River, Report 3 - Environmental Flows Options Analysis* which will be available later in 2006.

5. Glossary

Aquatic macrophytes. Rooted and floating aquatic plants that are large enough to be visible with the naked eye.

DEH. Australian Government Department of the Environment and Heritage.

DLWC. NSW Department of Land and Water Conservation.

DNR. NSW Department of Natural Resources.

Fluvial geomorphology. The study of river processes and form.

Geomorphology. The study of landforms and the processes that form them.

GL. A gigalitre, where 1 gigalitre = 1 billion litres = 1,000,000,000 litres.

GL/day. A flow rate measured in gigalitres per day, where
1 gigalitre per day = 1 billion litres per day = 1,000,000,000 litres per day.

HNRMF. Hawkesbury-Nepean River Management Forum.

ICOMOS. International Council on Monuments and Sites.

IEP. Hawkesbury Nepean River Management Forum Independent Expert Panel.

Macroinvertebrates. Animals without backbones that are large enough to be visible with the naked eye. Examples include most aquatic insects, snails and crayfish.

ML. A megalitre, where 1 megalitre = 1 million litres = 1,000,000 litres.

ML/day. A flow rate measured in megalitres per day, where
1 megalitre per day = 1 million litres per day = 1,000,000 litres per day.

Riffle. A shallow area of a river or stream where water flows rapidly over a gravel or rocky stream bed, marking the point of inflection (the cross-over of energy line) between two bends of a channel. Riffle spacing is often from 5 to 7 times the channel width and their locations are semipermanent. They are very important in stream ecology.

Riparian. Relating to, or living or located on, the bank of a watercourse (usually, but not always, a river or stream).

SCA. Sydney Catchment Authority.

Stratified, Stratification. The development of distinct layers of different temperature, density and water quality at various depths in a dam, with a restriction of mixing throughout the water column. During winter and early spring, most dams are well mixed throughout their water column. Thermal stratification develops in late spring or summer when the upper layers of the dam are heated by solar radiation faster than the heat can disperse into the lower depths of the dam. The difference in the density of the surface and bottom layers retards mixing within the water column and can lead to the top and bottom layers having significantly different water qualities.

Thalweg. A line of maximum depth along the bed of a stream.

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7. Appendix - How investigations have addressed knowledge gaps

How the ecological and physical investigations have addressed knowledge gaps identified in the 'knowledge review' step	
Knowledge gaps	**Investigations being carried out and/or comments**
Fluvial Geomorphology	
Sediment transport - Tallowa Dam is known to have had an impact on sediment supply to the lower Shoalhaven River, but the extent of this impact is not known. More information is required on sediment transport processes, the impacts of Tallowa Dam on these processes, and the role of environmental flows in these processes. This information will help to identify how sediment supply and channel processes will respond to a new environmental flow regime, with channel geomorphology having an important role in determining habitat availability for various river organisms.	The *Physical Habitat Modelling* investigation is examining sediment transport and channel processes in the freshwater river reach between Tallowa Dam and Burrier. An examination of sediment transport and channel processes downstream of Burrier has been prevented by a lack of data. A long time period would be required for the collection of the necessary data, which would need to include sufficient data to be able to understand the ongoing changes in the lower estuary as a result of all major influences including Berrys Canal. The knowledge review step found that while geomorphology may be an important component of ecosystem function, the length of time needed for its study means that it may be more feasible to examine other equally important matters when developing an environmental flow regime. Sediment transport and channel processes downstream of Burrier can however be considered in the development of an adaptive management framework. The adaptive management of Shoalhaven River environmental flows is discussed in Section 3.6 of the Department of Natural Resources publication *Determining and managing environmental flows for the Shoalhaven River, Report 1 - Environmental Flows Knowledge Review* (Boyes 2006).

How the ecological and physical investigations have addressed knowledge gaps identified in the 'knowledge review' step	
Knowledge gaps	**Investigations being carried out and/or comments**
Hydrology	
Flow modelling - Most of the flow modelling for the Shoalhaven River downstream of Tallowa Dam has been based on monthly flow data. However, the Shoalhaven River experiences extreme variability in flow, with flows often changing from one day to the next. This means that models based on daily or even hourly flow data are required to facilitate an accurate determination of the amount of water required to provide suitable species habitat and a better understanding of the aspects of the flow that are important for the health and reproduction of various species.	The *Hydrologic (Flow) Analysis and Modelling* investigation has used daily flow data. It has not been practical or appropriate to use sub-daily or hourly data for this study because at present environmental flow releases from Tallowa Dam can only be varied on a daily basis for operational reasons. However, sub-daily data is being used in the *Estuary Modelling and Assessment* investigation because the tidal cycle is sub-daily.
Water extractions - The exact volume of water extracted for Basic Landholder Rights downstream of Tallowa Dam should be determined as these extractions affect the actual amount of water received by the environment.	Water sharing plans are prepared under the *Water Management Act 2000* to define the water sharing arrangements between the environment and water users, and between different categories of water users. A water sharing plan is currently being prepared for the greater Sydney Metropolitan region. The water sharing plan preparation process is assessing the volume of unlicensed water extractions downstream of Tallowa Dam, and will take this volume into account when defining the water sharing arrangements between the environment and water users.
Groundwater - More information on groundwater is desirable as the interaction of groundwater with the river can affect river hydrology and ecology.	Groundwater is not well understood in the Shoalhaven River catchment. DNR has no monitoring bores in the catchment, and there are few studies in existence. To collect sufficient useful information would require extensive groundwater monitoring and analysis. This is not practical or cost effective, as specialists in NSW Government agencies have advised that groundwater inputs are not likely to be large in the part of the river of interest.

How the ecological and physical investigations have addressed knowledge gaps identified in the 'knowledge review' step	
Knowledge gaps	**Investigations being carried out and/or comments**
Water quality	
Monitoring and analysis of water quality - Current monitoring and analysis of water quality downstream of Tallowa Dam is limited in its ability to detect the current extent of dam impacts or the future effects of a new environmental flow regime. The monitoring and analysis is inadequate in terms of the number of monitoring sites and their location, the variables that are measured, and the study design. There is also a lack of analysis of water quality data in terms of its relationship to ecology, and more focussed monitoring is needed of variables and indicators relevant to ecological outcomes.	The *Water Quality Assessment* study is reviewing available information for the whole Shoalhaven River catchment. The fundamental chemical characteristics of water flowing through the system are mostly determined by activities within the catchment. However, the presence of Tallowa Dam and the way that it is operated strongly influences the quality of water that flows from it. The current system of operation does result in potentially adverse water quality for several kilometres downstream of the dam, particularly when there are no spills. Downstream water quality considerations will be a primary factor in designing offtake structures and a fish passageway for Tallowa Dam.
Estuary salinity - Further investigation is needed to resolve uncertainty in regard to the salinity regime in the Shoalhaven River estuary, the impact of freshwater extractions on that regime and the effects of an environmental flow on that regime. This should involve detailed numerical modelling of the estuary, carried out in association with examining the inflow/salinity responses of estuarine plants and animals that are sensitive to changes in salinity.	The *Estuary Modelling and Assessment* investigation is carrying out numerical modelling of the estuary in association with examining the inflow/salinity responses of ecological indicators and other estuary values.
Other water quality issues - Further investigation is needed into the impact of flows and particularly flushing flows on water quality and the relationship between flow and the transport of organic matter and nutrients down the river.	A natural, variable flow regime mobilises in-stream and riparian organic matter and transports it to be utilised by aquatic organisms further downstream. Any impacts of a major change in these processes will be best identified by monitoring macroinvertebrate assemblages.

How the ecological and physical investigations have addressed knowledge gaps identified in the 'knowledge review' step	
Knowledge gaps	**Investigations being carried out and/or comments**
Ecology	
Macroinvertebrates - Most of the macroinvertebrate sampling conducted to date has been undertaken in the upper part of the catchment, with only limited sampling below the dam. Previous sampling has not been designed to detect changes along the river due to the presence of the dam, and as a result little is known about the effect of the dam or water transfers on macroinvertebrate communities and how far downstream these effects may extend. There has also been limited use of macroinvertebrate data for assessing ecosystem condition, as so far most analysis has focussed on describing community composition, distribution and abundance.	The *Aquatic Invertebrates Study* has examined how aquatic macroinvertebrates in the freshwater reach between Tallowa Dam and Burrier are likely to respond to a new environmental flow regime. The *Estuary Modelling and Assessment* investigation will facilitate an examination of the inflow/salinity responses of macroinvertebrates downstream of Burrier.
Other river dependent fauna - More information is needed on the current distribution, abundance, condition, habitat preferences and flow responses of other river dependent fauna such as platypus, turtles, water rats and frogs.	The *Flora and Fauna Review* is documenting river dependant flora, fauna and ecological communities downstream of Tallowa Dam, including threatened and significant species and ecological communities.
Aquatic macrophytes - Further investigation is needed to determine the extent of aquatic macrophytes, the presence of exotic species, and the response of aquatic macrophytes to a new environmental flow regime.	The *Flora and Fauna Review* is identifying aquatic macrophytes with a focus on common species, threatened species, pest species and their habitats. As aquatic vegetation is dynamic in response to the variation in natural flows, the focus is on identifying the response of species to a reduction of both natural variation and total flow.
Wetlands and waterbirds - There is little information available on waterbirds, and existing knowledge of wetland condition is also poor. Because of the flood mitigation and drainage works that have occurred on the Shoalhaven River floodplain, environmental flows are unlikely to be able to assist any of the riverine or floodplain wetlands. However, further investigation is needed.	The *Flora and Fauna Review* is documenting waterbirds, including threatened species and species covered by the China-Australia Migratory Bird Agreement (CAMBA) and Japan-Australia Migratory Bird Agreement (JAMBA). The *Estuary Modelling and Assessment* investigation is examining if environmental flows can assist floodplain wetland inundation.

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