EXECUTIVE SUMMARY

This Environmental Review document is the second in a series of six reports which describe Hydro Tasmania's operations and provide an overview of aquatic environmental issues in each of the major catchment areas that are influenced by hydro-generation activities. This document fulfils key commitments in Hydro Tasmania's Aquatic Environmental Policy. A major part of Hydro Tasmania's Water Management Review process is community consultation. As Hydro Tasmania commences its Water Management Review of the Derwent Catchment, this document will assist community members and organisations to understand the environmental issues and management operations which currently exist in the catchment.

The Derwent Catchment covers an area of approximately 8,800 km^2 in south-east and central Tasmania. The area encompasses the catchments of the Derwent River and several tributary rivers including the Ouse, Nive and Dee. The Great Lake Catchment, which drains part of Tasmania's Central Plateau, previously contributed water to the Derwent Catchment. However, since the construction of the Poatina Power Scheme in 1965, the majority of the water from this catchment is now diverted into the South Esk Basin. Information about the Great Lake Catchment is contained in the South Esk – Great Lake Environmental Review document (Hydro Electric Corporation, 1999a).

The hydro-electric power developments in the Derwent Catchment that are currently operating form a relatively complex system, which can be simplified into three main components. The upper Derwent system utilises water from the upper Derwent River and its headwaters and from several small diversions, it consists of 2 storages and 2 power stations. The Nive-Dee system generates electricity using water mostly from the Nive and Dee rivers and includes 9 storages and 2 power stations. The lower Derwent system is a cascade of 6 storages and 6 power stations on the lower Nive and Derwent rivers and utilises water diverted from both the upper Derwent and Nive-Dee systems. A fourth part of the Derwent Catchment is the Ouse-Shannon system, the function of which is irrigation storage. The Ouse-Shannon comprises 3 storages and defunct water diversion infrastructure.

The environmental issues relating to hydro-electric developments in the Derwent Catchment have been outlined in four major categories in this document. These are water quality, biological, geomorphological and multiple use.

Overall, water quality in the Derwent Catchment is very good. Relatively small volumes of water with high nutrient levels enter the system below Wayatinah, mainly from agricultural tributaries with varying levels of water abstraction (Dee, Ouse and Clyde). These are diluted by the higher flows in the upper parts of the system. The Lagoon of Islands and Shannon and Penstock lagoons have previously experienced water quality problems, but by using water level and nutrient information, Hydro Tasmania with assistance from the Inland Fisheries Service, have implemented successful short- to medium-term management actions for these water bodies. Successful long-term management strategies for these lakes will require further information on lake nutrient cycling. Hydro Tasmania has implemented a system-wide Waterway Health Monitoring Program which has provided an understanding of water quality in the catchment's lakes and rivers and, combined with monitoring results from other catchments, this information is leading to a better understanding of the processes affecting water quality.

In the Derwent Catchment, there are a number of issues related to threatened species, fish migration and exotic species. The presence of dams, in particular, Meadowbank Dam pose significant barriers to fish migration within the catchment. A joint study with the Inland Fisheries Service is currently investigating the effectiveness of elver transfers from below Meadowbank Dam to upstream waters. The influence of Hydro Tasmania operations on threatened fish, aquatic invertebrate, frog and wetland bird species is largely unknown, however no pressing issues have been identified. The major threats to the biological environment appear to be through the spread of exotic species, particularly redfin perch. Hydro Tasmania is analysing potential fish dispersal pathways as part of its Aquatic Environment Program. The presence of willow along waterways is a major issue for the Derwent Catchment as is the spread of less obvious species such as Canadian pond weed (*Elodea canadensis*).

There are a number of geomorphological issues related to Hydro Tasmania waterways in the Derwent Catchment. Some of these issues are associated with alterations to downstream flow and sediment load which result in changes to channel morphology and lake shoreline erosion. The issues include erosion at the Echo Power Station forebay spillway, the erosion of Ripple Canal and the continued nutrient input into the Lagoon of Islands, shoreline erosion at Lake St. Clair at high lake levels. Hydro Tasmania has programs in place to investigate these issues and has in place a major investigative study associated with Ripple Canal and the Lagoon of Islands. Hydro Tasmania has undertaken some revegetation and fencing work on Ripple Canal in order to limit further erosion and nutrient release. Hydro Tasmania has also undertaken numerous other erosion control works around the catchment, including a diversion channel in the Dee River upstream of Dee Lagoon to prevent flood flows from destabilising the sediment delta.

Multiple uses and community values drive important aspects of Hydro Tasmania’s water management in the Derwent Catchment. Hydro Tasmania maintains a number of operational agreements (both formal and informal) in relation to multiple uses and community values and, therefore, many of the related issues in the Derwent Catchment are already managed through existing Hydro Tasmania operating rules and legislation. Some of these constraints include the needs to ensure water availability in the Ouse River for irrigation, supply of water to the Lawrenny Irrigation Scheme, maintenance of fresh water flows to supply Hobart Water’s Bryn Estyn water treatment plant and Norske Skog’s Boyer mill downstream of Meadowbank Dam and water supply for aquaculture at Wayatinah Lagoon. In addition, Hydro Tasmania provides water for recreational events (for instance in Woodwards Canal) and has agreements with the Inland Fisheries Service to maintain flows for trout spawning (for instance in Waddamana No. 2 Canal) and manage the level of several lakes in the Nive-Dee system for the trout fishery.

Hydro Tasmania is addressing aquatic environmental management issues as part of its ongoing Aquatic Environment Program, which puts into practice commitments made in Hydro Tasmania’s Aquatic Environmental Policy. Important initiatives are:

- the Waterway Health Monitoring Program;
- targeted investigative studies of issues such as Lagoon of Islands water quality, fish migration, threatened species, environmental flows;
- the potential impacts of changes to Hydro Tasmania operations as a result of Basslink; and
- Hydro Tasmania’s Water Management Reviews, which are examining current and potential future Hydro Tasmania operations in light of community concerns and environmental issues. These reviews aim to produce catchment-based plans for sustainable water management. This report is the first step in the Derwent Water Management Review.

ACKNOWLEDGMENTS

This document was commissioned as part of Hydro Tasmania's Aquatic Environment Program, and is the outcome of the first stage of Hydro Tasmania's Water Management Review for the Derwent Catchment.

Compilation, writing and editing of this document was coordinated by Helga Grant from Hydro Tasmania's Environmental Services section. Assistance in compiling the document was given by Noel Carpenter and Jacqueline Griggs and editing assistance was given by Kate Hoyle and Anita Wild, all of Hydro Tasmania Environmental Services.

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Members of the Department of Primary Industries, Water and Environment and the Inland Fisheries Service gave advice on various issues.

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ABBREVIATIONS

ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Environment and Conservation Council
ASFB	Australian Society for Fish Biology
AUSRIVAS	Australian Riverine Assessment System
CAMBA	China-Australia Migratory Bird Agreement
DPIWE	Department of Primary Industries, Water and Environment
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
ESAA	Electricity Supply Association of Australia
FNARH	First National Assessment of River Health
FSL	full supply level
GTSPOT	Geo Temporal Species Point Observations Tasmania
GWh	Gigawatt Hours
HEC	Hydro-Electric Commission/Corporation
IFS	Inland Fisheries Service (previously Inland Fisheries Commission)
IFSBC	Inland Fisheries Service Biological Consultancy (previously Inland Fisheries Commission Biological Consultancy)
IFIM	Instream Flow Incremental Methodology
IUCN	International Union for the Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
kW/m^3	kilowatt per cubic metre
LLA	lake level agreement
mASL	metres above sea level
mg/L	milligrams per litre
m^3/s	cubic metres per second (cumecs)
Mm^3	mega cubic metres (10^6 cubic metres)
MW	megawatt
NMOL	normal minimum operating level
NRHP	National River Health Program
NHMRC	National Health and Medical Research Council
NTU	Nephelometric turbidity units (measure of turbidity)
PEV's	Protected Environmental Values
PMOL	planned minimum operating level
PWS	Parks and Wildlife Service
RIVPACS	riverine predictive model for assessing river health (Britain)
RMPS	Resource Management Planning System

RWSC	Rivers and Water Supply Commission
SALTAS	Salmon Enterprises Tasmania Pty Ltd
STP	Sewage Treatment Plant
TALC	Tasmanian Aboriginal Land Council
TDSC	Tasmanian Dams Safety Committee
TFGA	Tasmanian Farmers and Graziers Association
TKN	total kjedhal nitrogen (measure of nitrogen)
TN	total nitrogen
TP	total phosphorus
TSPA	*Threatened Species Protection Act 1995* (Tasmania)
µS/cm	micro Siemen per centimetre (measure of conductivity)
WHA	Tasmanian Wilderness World Heritage Area
WHMP	Waterway Health Monitoring Program (Hydro Tasmania)

1. INTRODUCTION

1.1 Purpose

This Environmental Review document is the second in a series of six documents that report on each of Hydro Tasmania's six major catchment areas. The South Esk – Great Lake Catchment has already been reviewed (Hydro-Electric Corporation, 1999a). This 'Environmental Review' series is part of Hydro Tasmania's Aquatic Environment Program, the main purpose of which is to meet commitments of Hydro Tasmania's Aquatic Environmental Policy. Hydro Tasmania developed an Environmental Policy in 1992, and an Aquatic Environmental Policy in 1998, in which it has undertaken to manage the resources it controls in a responsible and sustainable manner. These policies are included as Appendix 1.

In its Aquatic Environmental Policy, Hydro Tasmania recognises that water is central to its business, and emphasises sustainable management of this resource. Under this policy, Hydro Tasmania also recognises the modifications that its developments have made to the environment. Hydro Tasmania commits to responsible environmental management by operating its business in a way that takes into account community views and values, and aims to maintain healthy functioning of aquatic ecosystems. Hydro Tasmania endeavours to pro-actively comply and cooperate with relevant environmental policies and legislation. It commits to making good water management decisions, based on consultation with the community, with other government organisations, and based on good scientific information. Hydro Tasmania is also committed to reviews of its environmental performance.

This document is intended to describe Hydro Tasmania's infrastructure and operations in the Derwent Catchment in a manner that is readily understandable by the general public. The document identifies the impacts and issues surrounding Hydro Tasmania operations on aspects of the aquatic environment, in-so-far as Hydro Tasmania is aware of these issues at the time of preparing this document.

More importantly, release of this document to the general public is a key first step in a review being undertaken by Hydro Tasmania of its water management practices in the Derwent Catchment. Hydro Tasmania has already commenced such a review in the South Esk – Great Lake Catchment. The *Water Management Act 1999* allows for the development of Water Management Plans. Hydro Tasmania's review of its water management practices is being undertaken in conjunction with the Department of Primary Industries, Water and Environment (DPIWE) and the community in a manner which will enable the results to be incorporated into DPIWE Water Management Plans for the relevant catchments in the future. At the same time, implementation of the *State Policy on Water Quality Management 1997* is under way. This policy requires the setting of Protected Environmental Values (PEV's) for each waterway, and Hydro Tasmania is actively cooperating in this process.

Hydro Tasmania's Water Management Review for the Derwent Catchment will adopt a similar process to that used for the South Esk – Great Lake Water Management Review. Hydro Tasmania is planning to systematically review all of its operations in Tasmania. The Derwent Catchment is the second of six catchments to be reviewed.

1.2 Report Content

This document broadly falls into two main parts.

Background information and context are provided in chapters 2 to 4, with a description of the catchment (Chapter 2), a description of the power developments in the catchment (Chapter 3), and an outline of the operation of the Hydro Tasmania system in the catchment (Chapter 4).

Aquatic environmental issues in the Derwent Catchment are discussed in chapters 5 to 8. These issues are divided into water quality (Chapter 5), biological issues (Chapter 6), geomorphological issues (Chapter 7), and issues related to multiple uses and community values (Chapter 8).

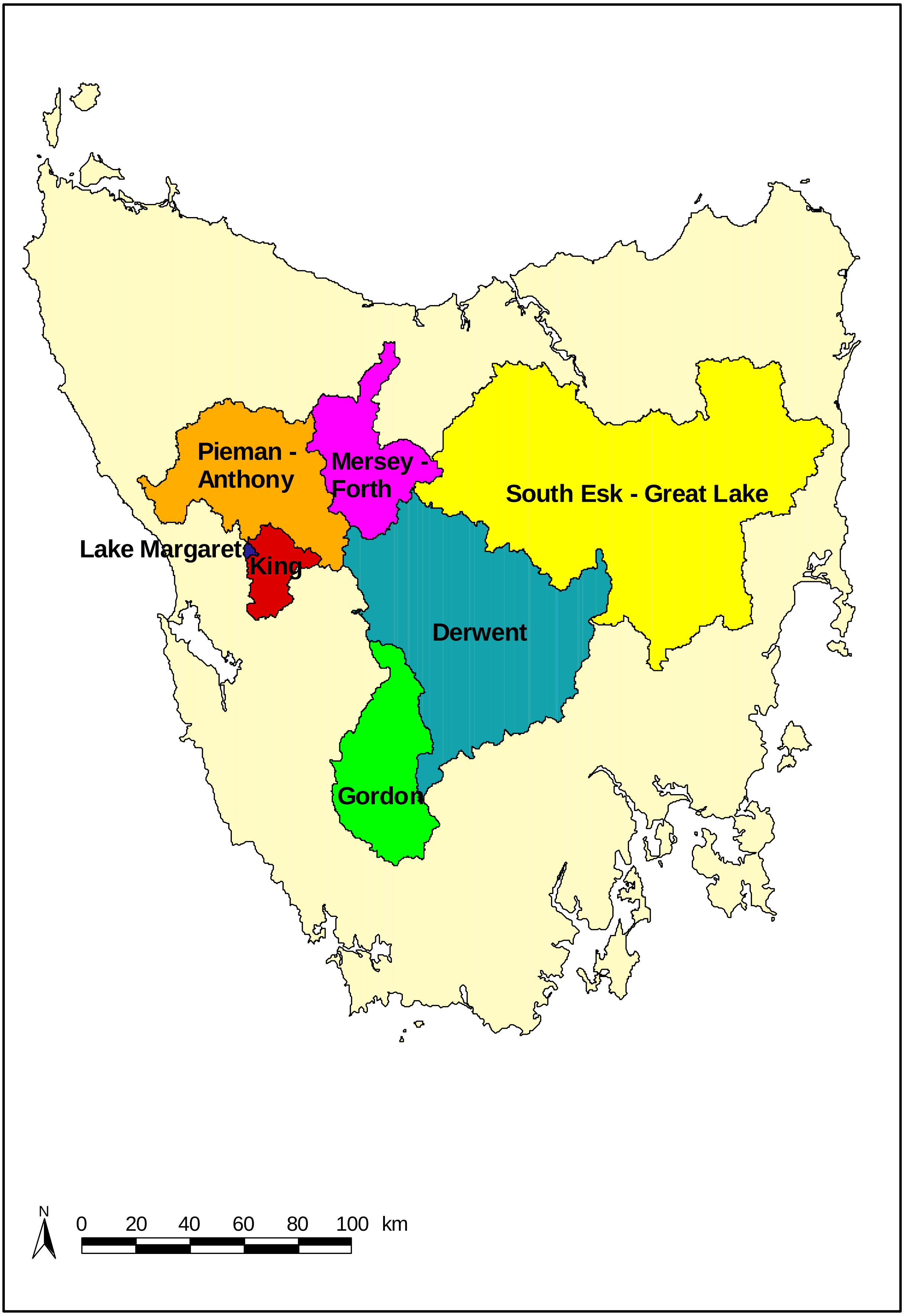
A summary of this report is provided in Chapter 9.

As already stated, this document is the second of a series of six Environmental Review documents. An Environmental Review has already been carried out and a report has been publicly released for the South Esk – Great Lake Catchment, and similar documents will be produced for the Gordon, Mersey – Forth, King, and the Pieman – Anthony and Lake Margaret catchments. The six Hydro Tasmania catchments in the State are shown in Map 1.1. The other documents in this series will follow a similar format, and be released to the public as they are completed.

1.3 Uses of This Document

This document is intended to provide the reader with an overview of catchment features and aquatic environmental issues relevant to Hydro Tasmania operations for the Derwent Catchment. It does not attempt to record every detail of information available, but rather to make the reader aware of the information that exists, provide some summary information, and indicate where to find further details. This document summarises the extent of information known to Hydro Tasmania at the time of writing. It is expected that members of the community will be able to add additional information on impacts and issues relevant to Hydro Tasmania-affected waterways in this catchment.

The information contained in this report is current as of June 2001 and will provide a benchmark against which any future updates of this report can be compared. Input of any additional information is welcomed for inclusion in future updates of this document.



Map 1.1 Hydro Tasmania Catchments

2. CATCHMENT DESCRIPTION AND LAND USES

2.1 Overview

The Derwent Catchment (as shown in Map 2.1) covers an area of approximately 8,800 km^2 in south-east and central Tasmania. The main tributaries of the Hydro Tasmania controlled sections of the Derwent River are the Clarence, Little Pine, Nive, Pine, Shannon, Dee, Florentine, Ouse, Broad and Clyde rivers. The Great Lake Catchment is also included in Map 2.1, as prior to development of the Poatina Power Scheme, the Great Lake Catchment drained into the Derwent, and water may still be directed into the Derwent Catchment from Great Lake for irrigation purposes. An area of the upper Franklin catchment is also shown to the west of Lake St. Clair, as the pickup from this area is also diverted into the Derwent Catchment. These diversions will be discussed in greater detail in Chapter 3.

The Derwent River is the second longest river in Tasmania, after the South Esk. It originates at Lake St. Clair and flows south-east over a distance of approximately 187 km to New Norfolk, where it is subject to tidal influence and becomes the Derwent Estuary. The Derwent River and a number of its main tributaries have been dammed by, or diverted to, 21 storages for the generation of hydro-electricity. The diversion of the Great Lake Catchment to the South Esk Basin, has resulted in a 10% reduction in water yield in the Derwent Catchment, an annual average of between 620 and 730 Mm^3.

2.2 Climate

Tasmania is situated between latitudes 41° and 43° S. The State experiences a cool maritime climate, being positioned on the northern edge of the 'Roaring Forties', a moist, westerly air stream that dominates climate conditions.

Precipitation in the Derwent Catchment is variable, with annual averages ranging from around 500 mm in the vicinity of Lake Meadowbank, to over 1200 mm in areas of the upper catchment. Rainfall in this area is highest during July and August due to the influence of westerly low pressure systems, and the driest period occurs in January and February. Snow may fall at any time of year at higher altitudes in the north and west of the catchment, however, it is most common from July to September. Average temperatures vary across the catchment as shown in Table 2.1.

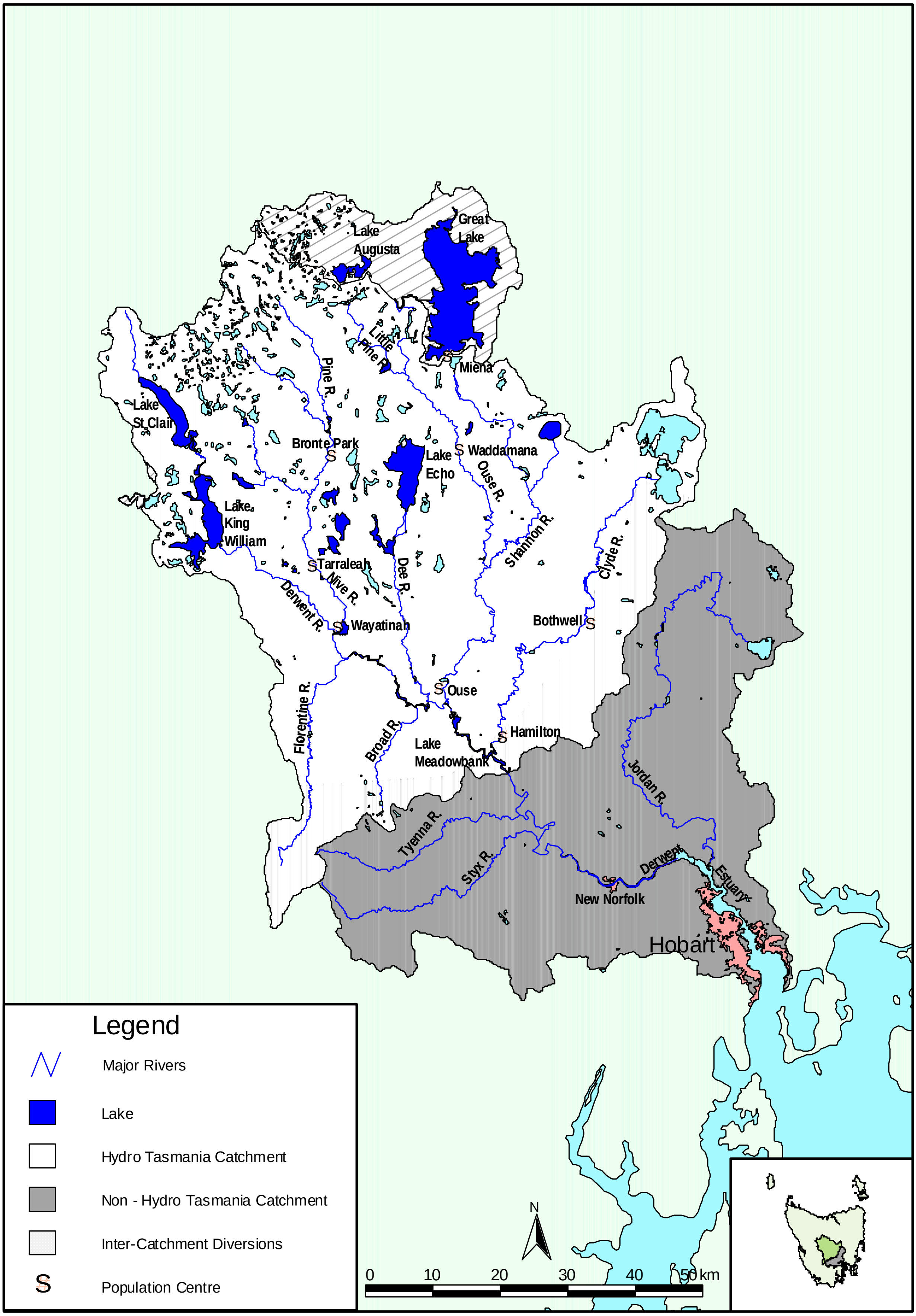
Table 2.1 Average temperatures at locations in the Derwent Catchment

Location	Average Summer Temperatures (°C)	Average Winter Temperatures (°C)
Butlers Gorge	5.5 – 18.7	0.4 – 7.9
Miena	4.2 – 16.3	-1.8 – 5.4
New Norfolk	9.8 – 23.9	1967

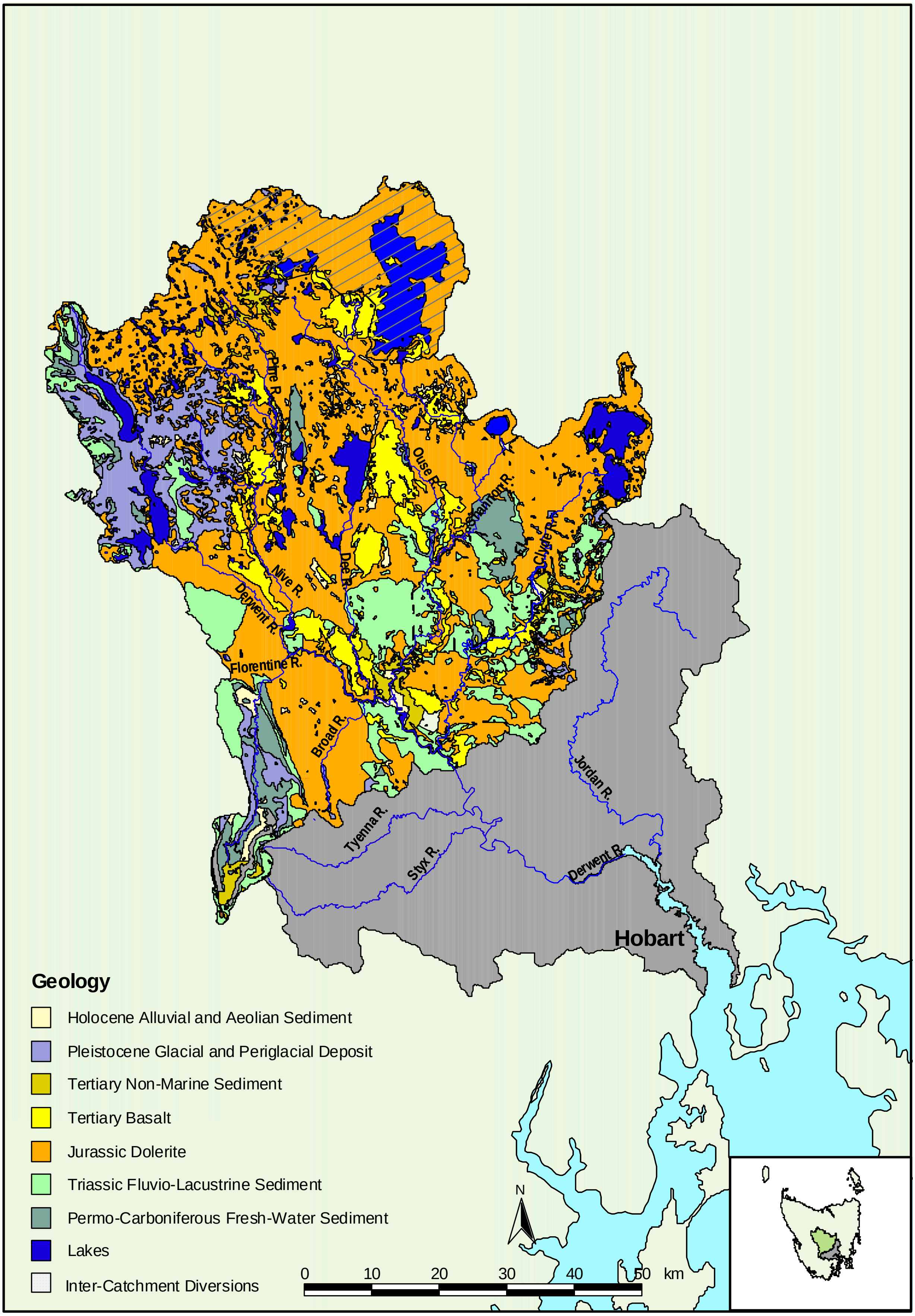
2.3 Geology, Topography and Soils

Detailed descriptions of geology, topography and soils in the Derwent Catchment are given in Pemberton (1986; 1989), Davies (1988) and Burrett and Martin (1989). An overview of the geology of the Derwent Catchment is provided in Map 2.2.

The Derwent Catchment is an area of varying relief, ranging from rolling agricultural land of the Southern Midlands, to the more rugged highland areas of the Central Plateau and Mt. Field Range.



Map 2.1 The Derwent Catchment



Map 2.2 Geology of the Derwent Catchment

In the upper catchment on the Central Plateau, basement rocks have a restricted occurrence and are of Precambrian, Cambrian, Ordovician and Silurian age. They are overlain by Carboniferous, Permian and Triassic sediments of the Parmeener Supergroup, which outcrop in the west and south of the Central Plateau region. These sediments have been intruded by vast sheets of Jurassic dolerite, which cover the majority of the area. Restricted occurrences of Tertiary basalt appear on the Central Plateau east, south and west of Lake Echo. Quaternary glacial and periglacial deposits cover large areas of dolerite in the north-west of the catchment.

The middle and lower catchments also have basement rocks of Precambrian, Cambrian, Ordovician and Silurian age, but these do not outcrop in the catchment. They are overlain by sediments of the Parmeener Supergroup which are dominantly Triassic, with areas of Permian and isolated Carboniferous outcrop. These sediments have been intruded by large sheets of Jurassic dolerite, with some occurrences of Tertiary basalt.

Soils in the Derwent Catchment reflect the underlying geology. Soils formed on Jurassic dolerite at altitude are generally yellowish-brown and gradational, characteristically rocky and with a high permeability. In the middle and lower catchments, soils formed on dolerite are deeper, usually black-brown and gradational or duplex in nature. Sediments of the Parmeener Supergroup form uniform sands and duplex soils. The uniform sands are normally associated with sandstones facies, while grey-brown duplex soils form on sandstone and mudstone-dominated areas and are prone to erosion. Duplex black or red-brown soils form on basalt and are generally clayey. Quaternary deposits usually form uniform sandy soils with undifferentiated siliceous profiles (Burrett and Martin, 1989).

2.4 Vegetation

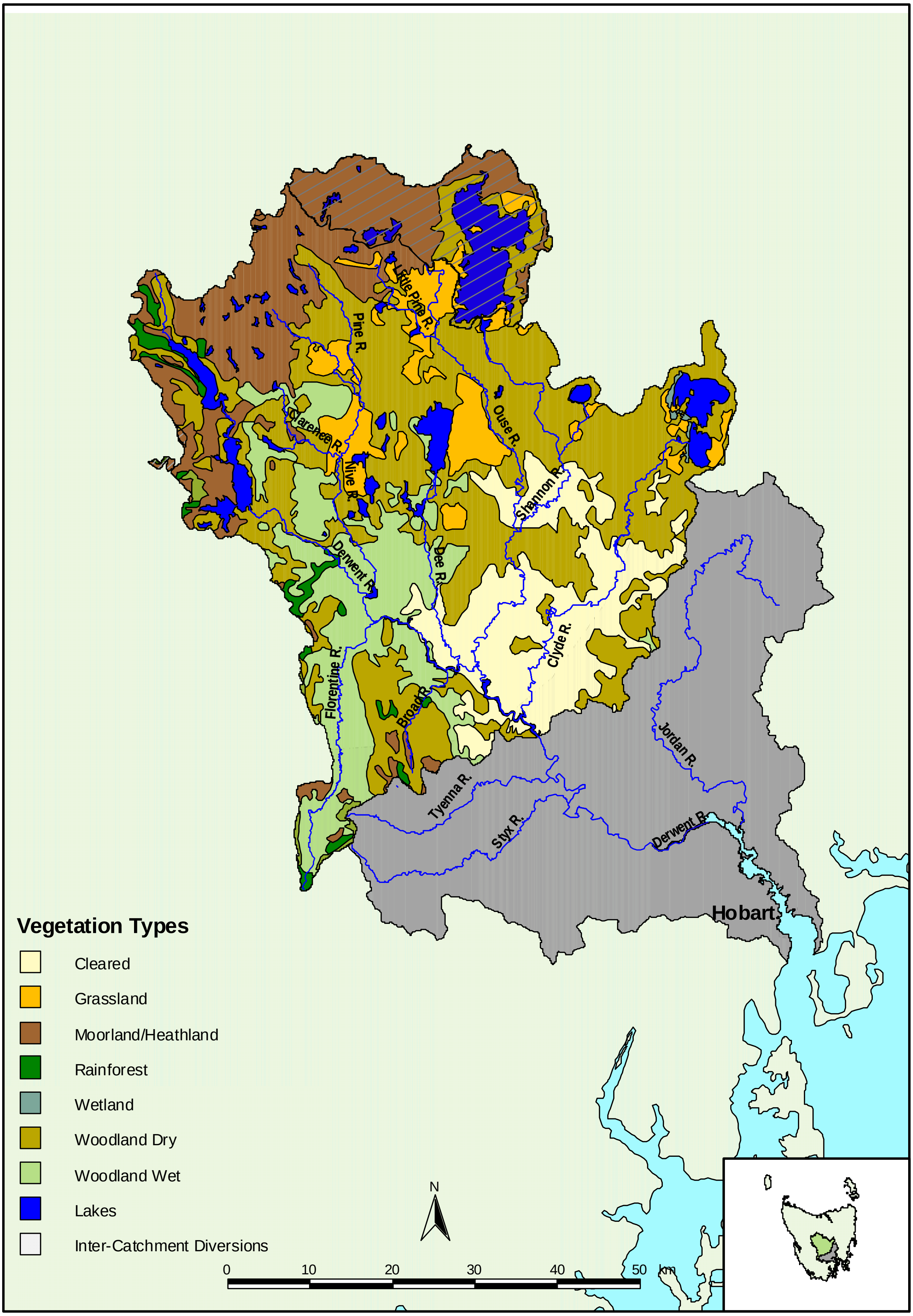
Much of the natural vegetation in the south-east of the Derwent Catchment has been cleared for agriculture and this area is now mostly used for grazing or cropping. However remnant uncleared pockets of grassy woodland, coastal grassy forest and dry sclerophyll forest remain in some locations. The major vegetation types in the catchment are shown in Map 2.3.

The predominant vegetation in the western area of the catchment is tall wet eucalypt forest, and in the north-east the vegetation is dominated by a mix of wet Eucalypt forest, montane grassy forests, buttongrass moors, wet scrub, rainforest and alpine and subalpine complexes. In the higher areas around Mt. Field *Eucalyptus coccifera* forest dominates with patches of alpine complexes, rainforest and buttongrass moor occurring. The middle catchment is dominated by sclerophyll forest, interspersed with large areas of grassland. The high altitude area of the upper catchment consists of large areas of Eastern alpine complex, Drys Bluff and Western Central Plateau subalpine complexes, high altitude tussock grassland and *Eucalyptus coccifera* forest (Kirkpatrick and Dickinson, 1984).

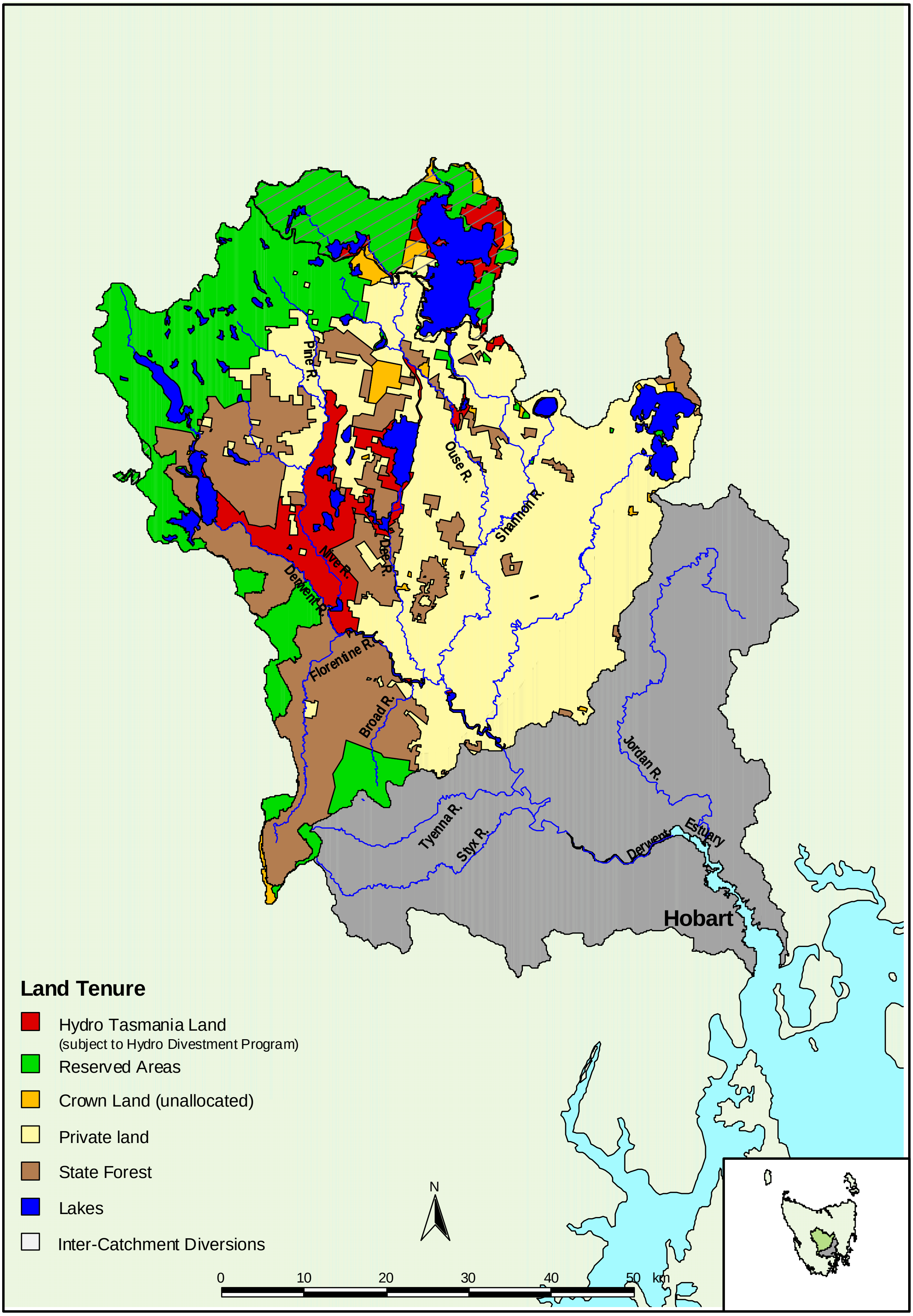
2.5 Land Use

The primary land uses in the Derwent Catchment are agriculture and forestry, with National Parks and other wilderness reservations in some of the highland areas. Urban land use and land used in association with the generation and distribution of electricity make up a small proportion of the Derwent Catchment. Other land uses in the catchment include wilderness recreation and tourism (eg. fishing, bushwalking) and fishing shack use.

Map 2.4 shows the land tenure in the Derwent Catchment. Private land tenure is generally indicative of agricultural land use and some private forestry. Land clearing on private land in the central eastern part of the catchment has been extensive. Agricultural land use occurs predominantly in the catchments of the Clyde and Ouse rivers and along the Derwent River Valley between Ouse and New Norfolk. Sheep and cattle grazing is the main agricultural activity, with smaller areas cultivated for crops such as vegetables, hops, poppies and oil seed crops. Agriculture in the highland regions of the catchment is restricted to grazing of sheep and cattle, mostly on native vegetation, due to the rocky soils and extreme weather conditions. Aquaculture is also present in the catchment, with hatcheries situated in the upper catchment at Wayatinah Lagoon and the Florentine River, and also in the lower Derwent, on the Tyenna and Plenty rivers.



Map 2.3 Vegetation in the Derwent Catchment



Map 2.4 **Land Tenure in the Derwent Catchment**

Significant areas in the western part of the catchment are taken up by State Forests. Forestry operations include harvesting of native forests and increasingly, eucalypt and pine plantations. While forestry is the principal land use in these areas, non-commercial, multiple use activities such as recreational pursuits are often permitted in these forests until harvesting takes place.

Reserved areas (National Parks, State Reserves and Protected Areas) are also largely forested or covered in heath or scrub. The Walls of Jerusalem National Park and Cradle Mountain – Lake St. Clair National Park, which are within the Tasmanian Wilderness World Heritage Area (WHA), cover the north-west corner of the catchment, and the Franklin-Gordon Wild Rivers National Park and the South West National Park extend into the west and south-west of the catchment respectively. The Mt Field National Park is located within the south-west region of the Derwent Catchment. The Central Plateau Conservation Area also extends into the catchment in the north. The main land uses in these areas are recreation and wilderness conservation.

Land vested in Hydro Tasmania is located mostly in the central catchment in the vicinity of Bronte Lagoon, Bradys Lake and Lake Binney, and adjacent to Hydro Tasmania structures such as the Tarraleah canals, and in the middle to lower Derwent Catchment in the Liapootah/Wayatinah area.

3. DESCRIPTION OF POWER DEVELOPMENTS

This chapter provides a history of power development in the Derwent Catchment, and a description of the existing system.

The hydro-generation system in the Derwent Catchment is shown in Map 3.1 and the overall layout of the catchment and power developments is shown in Appendix 2. Water from almost the entire Derwent Catchment is utilised for power generation and the hydro-electricity generating system is quite complex. However, these developments can be grouped into four main systems: upper Derwent, Nive-Dee, lower Derwent and the Ouse-Shannon. The upper Derwent, Nive-Dee and lower Derwent are currently used for electricity generation, while the Ouse-Shannon part of the system no longer has any power stations and the storages in this part of the scheme now provide irrigation and riparian water.

3.1 History of Power Developments

A brief history of the hydro-electric development in the catchment is given below, taken from Lupton (2000), Scanlon (1995), French (1994) and Sloane and French (1991).

3.1.1 Waddamana and Shannon

The first hydro-electric power development in the Derwent Catchment (and the second in Tasmania) was the Waddamana Power Scheme. The Waddamana development diverted water from Great Lake via Shannon Lagoon and a canal system to Penstock Lagoon, and then down a steep drop to a power station at Waddamana on the floor of the Ouse River valley.

This development was initiated by a private company (the Hydro-Electric Power and Metallurgical Co. Ltd.) and their proposal was approved by the State Parliament in 1909. Construction began in 1910, but was taken over by the State government in 1914, which led to the formation of the Hydro-Electric Department. By 1913, Great Lake had been dammed by the construction of an 8 foot coffer weir across the Shannon River. This weir was replaced in 1915 by a larger, more permanent masonry dam.

Electricity was first generated at Waddamana in 1916. The power station had an initial capacity of 7 megawatts (MW), and this was expanded in stages between 1918 and 1923 to meet increases in the demand for electricity. The level of Great Lake was raised in 1922 by the replacement of the original dam with a 10 metre high concrete multiple arch dam, and Liawenee Canal was completed in 1923, diverting the upper Ouse River into Great Lake. These developments supplemented the supply of water to the Waddamana Power Station and allowed the capacity to be increased to 49 MW.

The Shannon Power Development was constructed between 1924 and 1931 to make use of the fall of water between Great Lake and Penstock Lagoon. This development added another 10.5 MW to the generation capacity. A second power station was built at Waddamana between 1939 and 1949, along with a second canal from the Shannon Power Station to Penstock Lagoon. This power station was known as the Waddamana B Power Station and the original power station at Waddamana was referred to as the Waddamana A Power Station. The Waddamana B Power Station added another 48 MW, giving a total capacity of 107.5 MW.

The two Waddamana power stations and the Shannon Power Station operated together between 1949 and 1964, when the Poatina Power Development was commissioned. The Poatina Power Development diverted the water from Great Lake into the South Esk Catchment, and led to the closure of Shannon Power Station in 1964 and Waddamana A in 1965. Waddamana B remained operational until 1994 (either on stand-by or to make use of riparian releases from Shannon Lagoon). The Waddamana A building was opened by Hydro Tasmania as a museum in 1988.

3.1.2 Upper Derwent

The Tarraleah Power Development was approved by State Parliament in 1934 and various stages of construction were carried out until 1951. This scheme, in addition to providing for the State's future electricity demands, was also seen as a means of addressing Tasmania's unemployment problem.

The upper Derwent Catchment was very inaccessible and before work on the scheme began a road had to be constructed. By 1937 a weir and pump station were constructed at Lake St. Clair and a dam with control gates at St. Clair Lagoon, which allowed the manipulation of water levels in Lake St. Clair and St. Clair Lagoon. The pump station was removed from service in 1993. A small weir on the upper Derwent River and an overland channel, from Butlers Gorge to the Tarraleah Power Station (Tarraleah No. 1 Canal) were constructed to divert the water from the river to the power station. The first three turbines at the Tarraleah Power Station were commissioned in 1938.

Further development of the upper Derwent was carried out in the 1950s, with the construction of Clark Dam to form Lake King William in 1951, and the small Butlers Gorge Power Station. The capacity of the Tarraleah Power Station was expanded gradually, with the fourth, fifth and sixth turbines being commissioned in 1943, 1945 and 1951 respectively.

A second overland channel from below Clark Dam to Tarraleah (Tarraleah No. 2 Canal) was constructed in 1955. An automatic pump station on the Derwent River a few kilometres below Clark Dam, and the Mossy Marsh Diversion (harnessing three tributaries of the Nive River) were completed by 1959, and serve to divert additional water into Tarraleah No. 2 Canal. Clark Dam was later raised 6 metres (in 1964) to create more storage in Lake King William.

Approval by Council was granted in mid 2001 for the development of a mini hydro system at Butlers Gorge. This will utilise the water currently flowing from Clark Dam into the Tarraleah No. 2 Canal. The installed capacity is 2.5 MW.

3.1.3 Nive-Dee

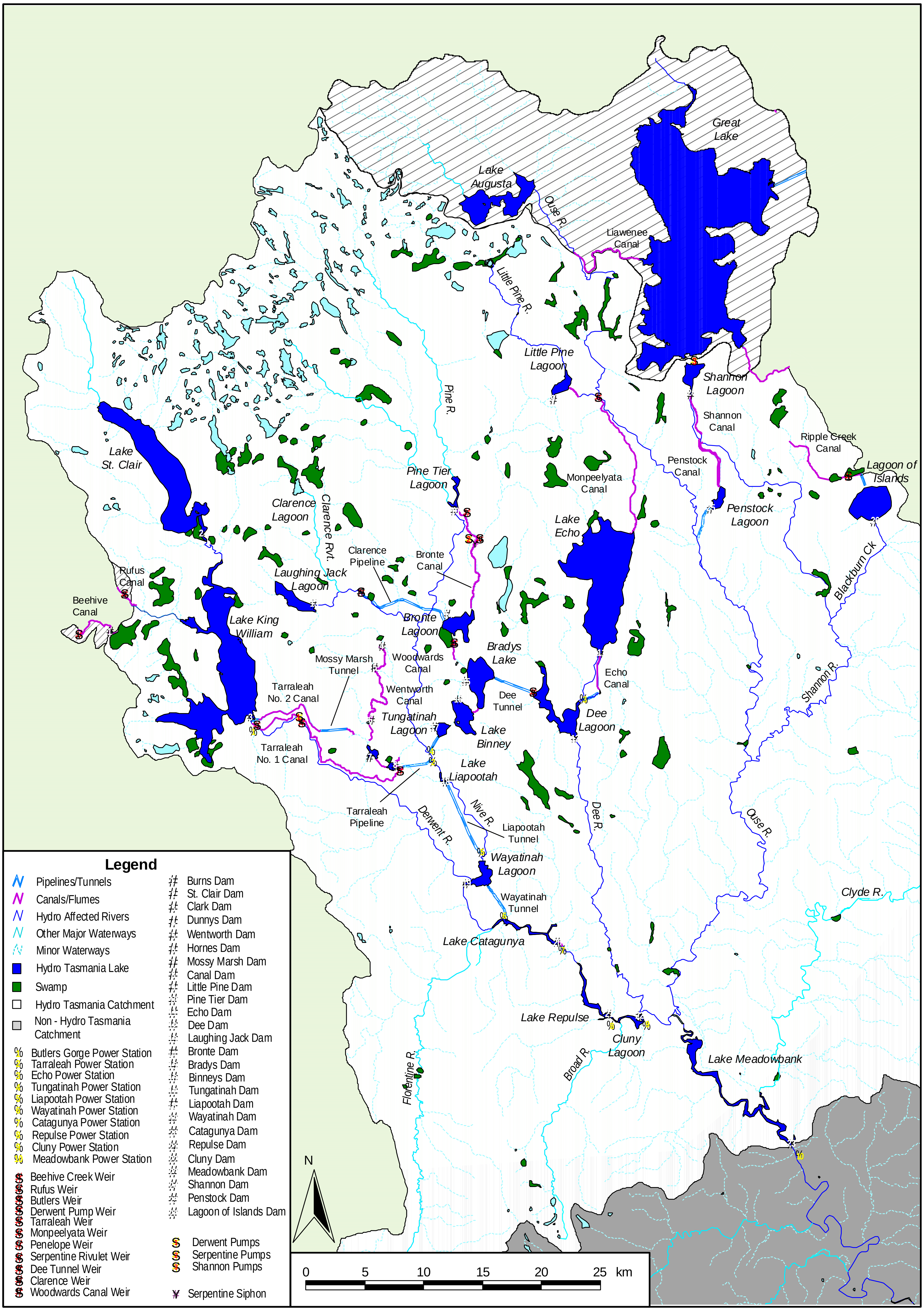
Parliamentary approval for a scheme to develop the catchment areas of the Nive and Dee rivers was granted in 1947 as a result of a rapid increase in the electricity demand in Tasmania. Construction of the western part of the scheme (Nive River) started first and occurred during the early to mid-1950's. Pine Tier, Bronte, Bradys and Binney dams, along with the associated infrastructure: canals (Bronte, Bradys, Binneys and Tungatinah), Serpentine Siphon, Clarence Pipeline and Tungatinah Tunnel and penstocks were completed by 1953. Laughing Jack Lagoon was completed in 1957. Commissioning of the five turbines in the Tungatinah Power Station occurred between 1953 and 1956.

The eastern part of the scheme (Dee River), which also feeds water to the Tungatinah Power Station, was constructed in the mid-1950s. The dam on Dee Lagoon and the Dee Tunnel were completed in 1955, while Echo Dam, and Monpeelyata and Echo canals, were completed in 1956. The Lake Echo Power Station was commissioned in 1956.

3.1.4 Lower Derwent

The lower Derwent was developed between 1956 and 1968. Wayatinah Dam, built just below the junction of the Nive and Derwent rivers (along with a tunnel, pipelines and penstocks) was completed in 1956, and the Wayatinah Power Station was commissioned in 1957. Liapootah Dam was built on the Nive River below the Tarraleah Power Station, and the dam, tunnel and penstocks were completed in 1960, prior to commissioning of the power station in the same year. Catagunya Dam is on the Derwent River below Wayatinah Power Station and was completed in 1962, with the power station also commissioned in 1962.

The proposal to develop the lower three stations on the Derwent River (Repulse, Cluny and Meadowbank) was approved by State Parliament in 1961. The dams were completed in 1968, 1967 and 1966 respectively, and the power stations commissioned soon after in 1968 (Repulse and Cluny), and 1967 (Meadowbank).



Map 3.1 Power Developments in the Derwent Catchment

3.2 Infrastructure in the Current System

The current system operated by Hydro Tasmania in the Derwent Catchment comprises 10 power stations and 21 storages. Electricity is generated using water from almost the entire Derwent Catchment, and a complex system of power developments is in place. As previously stated, the current power developments in the Derwent Catchment can be grouped into three main components of the scheme as it presently exists, the upper Derwent, Nive-Dee system and the lower Derwent, plus the Ouse-Shannon system which now supplies irrigation water and contains redundant water transfer infrastructure.

In the following sections, only the physical characteristics of the Hydro Tasmania infrastructure in the Derwent Catchment are described, the operational characteristics are outlined in Chapter 4.

3.2.1 Power Stations

There are ten power stations currently operating in the Derwent Catchment. These power stations are listed in Table 3.1 below, along with the years they were commissioned, the number and type of turbines they house and their capacity. The actual power output for any year varies according to several factors including rainfall patterns, plant outages and transmission constraints.

Table 3.1 Power Stations in the Derwent Catchment

Power Development	Power Station	Date(s) Commissioned	Turbines	Capacity (MW)
Upper Derwent	Butlers Gorge	1951	1 Francis	12.7
	Tarraleah	1938-1951	6 Pelton	93.6
Nive-Dee	Lake Echo	1956	1 Francis	33.5
	Tungatinah	1953-56	5 Francis	130.5
Lower Derwent	Liapootah	1960	3 Francis	87.3
	Wayatinah	1957	3 Francis	45.9
	Catagunya	1962	2 Francis	50
	Repulse	1968	1 Kaplan	29.1
	Cluny	1967	1 Kaplan	18.6
	Meadowbank	1967	1 Kaplan	41.8

3.2.2 Storages

The primary function of 18 of the 21 Hydro Tasmania-controlled lakes is storage of water for power generation. Two of the remaining three, Shannon Lagoon and Lagoon of Islands are operated by Hydro Tasmania to supply irrigation and riparian requirements on the Shannon and Ouse rivers. The final storage, Penstock Lagoon, is operated in conjunction with the Inland Fisheries Service (IFS) as a recreational trout fishery. A summary of the geometric characteristics of the storages in the Derwent Catchment is given in Table 3.2. Operational characteristics of these storages are summarised in Chapter 4.

Table 3.2 Dimensions of Hydro Tasmania Storages in the Derwent Catchment

Development	Storages	Surface Area at FSL (km^2)	Reservoir Vol. (x 10^6 m^3)	Approximate Max. Depth at Dam (m)
Upper Derwent	Lake St. Clair	28.0	2000.0	165[a]
	Lake King William	41.0	540.0	67
	Tarraleah No. 2 Pond	0.4	0.9	7
Nive-Dee	Pine Tier Lagoon	0.8	7.4	40
	Laughing Jack Lagoon	3.4	25.0	17
	Bronte Lagoon	5.6	19.0	10
	Little Pine Lagoon	2.2	2.9	4
	Lake Echo	41.0	725.0	19
	Dee Lagoon	6.3	40.0	15
	Bradys Lake	6.3	46.0	20
	Lake Binney	4.1	26.0	10
	Tungatinah Lagoon	1.1	5.0	6
Lower Derwent	Lake Liapootah	0.2	1.9	40
	Wayatinah Lagoon	2.4	8.9	24
	Lake Catagunya	2.2	26.0	49
	Lake Repulse	1.5	15.9	42
	Cluny Lagoon	0.8	4.9	30
	Lake Meadowbank	6.2	60.0	43
Ouse-Shannon	Shannon Lagoon	2.2	1.7	4
	Penstock Lagoon	1.3	-	-
	Lagoon of Islands	9.2	37.5	6

[a] maximum depth of Lake St. Clair. Depth at the control weir is approximately 1 metre.

Note: some data not obtainable at time of preparing report

3.2.3 Dams, Weirs and Other Structures

The dams and weirs in the Derwent Catchment are summarised in Table 3.3. There are 23 'referable' dams in the catchment and a numerous smaller weirs and levees. Referable dams are those which are on the register of the Australian National Committee on Large Dams (ANCOLD). These dams are registered for reasons including height, storage capacity and crest length. The full definition and specification of referable dams is given in the Register of Referable Dams in Tasmania (Tasmania Dams Safety Committee, 1991).

There are also numerous hydrological recording weirs and private irrigation and fishing weirs and dams throughout Tasmania. The locations of these structures have not been shown, as a complete list or database has never been compiled. While the majority of these weirs are small and do not retain or divert large volumes of water, they may be impeding or preventing fish passage, which is discussed in section 6.2.

Table 3.3 Hydro Tasmania Structures on Storages and Waterways in the Derwent Catchment

Development	Structure	River	Storage	Length of Crest	Height (m)	Construction	Year Completed	Referable
Upper Derwent	Beehive Creek Dam	Beehive Creek	N/A	19	1.2	Concrete gravity	1969	No
	Burns Creek Dam	Burns Creek	N/A	156	1.5	Clay-cored earthfill	1969	No
	Rufus Weir	Navarre	N/A	23	0.9	Concrete gravity	1969	No
	Lake St. Clair Dam	Derwent	Lake St. Clair	114	0.7	Concrete gravity	1937	No
	Clark Dam	Derwent	Lake King William	338	67	Concrete arch	1949/1966	Yes
	Butlers Weir	Derwent	N/A	107	9	Concrete gravity	1938	Yes
	Derwent Pump Weir	Derwent	N/A	73	-	Earthfill/Concrete	1968	No
	Bakers Creek Weir	Bakers Creek	N/A	4	-	Concrete gravity	1968	No
	Siphon Inlet Creek Weir	Siphon Inlet Creek	N/A	2	-	Concrete gravity	1968	No
	Pickup No.37 Weir	Pickup No.37	N/A	4	-	Concrete gravity	1968	No
	Pickup No.59 Weir	Pickup No.59	N/A	8	-	Concrete gravity	1968	No
	Pickup No.77 Weir	Pickup No.77	N/A	2	-	Concrete gravity	1968	No
	No.5 Creek Weir	No.5 Creek	N/A	5	-	Concrete gravity	1968	No
	Pickup No.93 Weir	Pickup No.93	N/A	3	-	Concrete gravity	1968	No
	Dunnys Dam	Dunnys Creek	Dunnys Pond	106	-	Concrete-faced rockfill	-	No
	Wentworth Dam	Wentworth Creek	Wentworth Pond	94	-	Concrete-faced rockfill	-	No
	Hornes Dam	Hornes Creek	Hornes Pond	107	8	Concrete-faced rockfill	1958	Yes
	Mossy Marsh Dam	Mossy Marsh Creek	Mossy Marsh Pond	15	4	Concrete gravity	1955	No
	Tarraleah No.2 Pond Dam	Wilsons Creek	Tarraleah No.2 Pond	732	8	Earthfill embankment	1949	Yes
	Tarraleah Weir	Wilsons Creek	N/A	-	-	-	-	No
Nive-Dee	Little Pine Dam	Little Pine	Little Pine Lagoon	191	6	Concrete gravity	1955	Yes
	Pine Tier Dam	Nive	Pine Tier Lagoon	195	40	Concrete gravity	1953	Yes
	Penelope Weir	Penelope Creek	N/A	-	-	Rockfill embankment	-	No

Table 3.3 cont'd Hydro Tasmania Structures on Storages and Waterways in the Derwent Catchment

Development	Structure	River	Storage	Length of Crest	Height (m)	Construction	Year Completed	Referable
	Serpentine Rivulet Weir	Serpentine Rivulet	N/A	131	3.8	Rockfill embankment	1971	Yes
	Clarence Weir	Clarence	Clarence Lagoon	101	7	Concrete gravity	1953	Yes
	Laughing Jack Dam	Powers Creek	Laughing Jack Lagoon	170	17	Concrete-faced rockfill	1957	Yes
	Bronte Dam	Woodwards Creek	Bronte Lagoon	311	10	Clay-cored rockfill	1953	Yes
	Bradys Dam	Bradys Creek	Bradys Lake	805	20	Rockfill embankment	1953	Yes
	Binneys Dam	Big Marsh Creek	Lake Binney	1262	10	Rockfill embankment	1953	Yes
	Tungatinah Dam	Nive Marsh Rivulet	Tungatinah Lagoon	716	7	Rockfill embankment	1952	Yes
	Echo Dam	Dee	Lake Echo	305	19	Earthfill embankment	1956	Yes
	Dee Dam	Dee	Dee Lagoon	274	15	Earthfill embankment	1956	Yes
Lower Derwent	Liapootah Dam	Nive	Lake Liapootah	110	40	Concrete gravity	1960	Yes
	Wayatinah Dam	Derwent	Wayatinah Lagoon	549	24	Rockfill embankment	1957	Yes
	Catagunya Dam	Derwent	Lake Catagunya	282	49	Concrete gravity	1962	Yes
	Repulse Dam	Derwent	Lake Repulse	433	42	Concrete arch	1968	Yes
	Cluny Dam	Derwent	Cluny Lagoon	204	30	Concrete gravity	1967	Yes
	Meadowbank Dam	Derwent	Lake Meadowbank	265	43	Concrete buttress	1966	Yes
Ouse-Shannon	Shannon Dam/Weir	Shannon	Shannon Lagoon	130	6	Rockfill embankment	1974	Yes
	Penstock Lagoon Dam	N/A	Penstock Lagoon			Rockfill embankment		No
	Lagoon of Islands Dam	N/A	Lagoon of Islands	320	7	Rockfill embankment	1964	Yes

Note:some data not obtainable at time of preparing report

3.3 General Hydrology of the Current System

Figure 3.1 is a schematic diagram which shows the general hydrology of the hydro-generation system in the Derwent Catchment.

Figure 3.1 **Schematic Representation of Power Developments in the Derwent Catchment**

3.3.1 Upper Derwent

The upper Derwent system utilises the water from the upper Derwent River, from the headwaters of the Franklin River and from the Mossy Marsh Diversion, which redirects a number of small tributaries of the Nive River.

The Derwent River originates at Lake St. Clair, a large, deep glacial lake in the Central Highlands of Tasmania. Lake St. Clair is the most upstream of two hydro storages in the upper Derwent system. The level of Lake St. Clair was raised by a small dam, and can be manipulated by a regulating weir. It is a supplementary storage that collects water from its immediate catchment and delivers it into Lake King William via the regulating weir and a short reach of the Derwent River.

Lake King William is the head storage for the upper Derwent system. It is an instream storage on the upper Derwent River, created by Clark Dam. Lake King William is fed by water from its immediate catchment, from Lake St. Clair, and from the diversion of three small headwater streams in the Franklin catchment, which are diverted into Lake King William via the Navarre River. The uppermost of these is Rufus Creek, followed by Beehive Creek and Burns Creek.

Rufus Creek is diverted by a small weir into Rufus Canal. The canal also picks up local run-off and small drainages and discharges into the Navarre River, which flows into Lake King William.

Beehive Weir is a very small structure which diverts water from the creek of the same name into Beehive Canal. The canal runs into the pond created by Burns Dam, which also picks up water from Burns Creek and the local catchment. This water flows from Burns Dam, via Burns Canal, and into King William Creek, a tributary of the Navarre River, which delivers this water into Lake King William.

Water stored in Lake King William is released through the Butlers Gorge Power Station at the foot of Clark Dam. Butlers Gorge Power Station discharges into a short reach of the Derwent River, where it is then diverted into the Tarraleah No. 1 Canal by Butlers Weir. As Butlers Gorge is a small power station, some water from Lake King William is also released via a bypass outlet in the dam to the Tarraleah No. 2 Canal. Lake King William may spill water into the Derwent River at Clark Dam. Butlers Weir may also spill water down the Derwent River, and this water may then be picked up at the Derwent Pump Station.

The Tarraleah canals transfer the water from Lake King William to the Tarraleah Power Station. The Tarraleah No. 1 Canal is 19.75 km long. As well as receiving the water from Butlers Gorge Power Station, diverted into it by Butlers Weir, Tarraleah No. 1 Canal also picks up water from inflowing streams along its route. The canal is siphoned underneath Mossy Marsh Creek and then continues to the head pond above the Tarraleah Power Station, where it converges with the Tarraleah No. 2 Canal.

Water going into the 11 km long Tarraleah No. 2 Canal bypasses Butlers Gorge Power Station and is transferred to the canal via a venturi, which dissipates the energy. A mini hydro system to utilise the water currently flowing from Clark Dam into the Tarraleah No. 2 Canal has recently been approved by Council. Tarraleah No. 2 Canal also picks up water from inflowing creeks along its route, and from the Derwent River via the Derwent Pump Station. The Derwent Pump Station is about 6 km downstream of Clark Dam, and is intended to pick up any inflows to the Derwent River below the dam, and also water that has spilt over Butlers Weir. The pump station has a 2.9 cumec capacity and delivers the water into the canal via a rising main. The Tarraleah No. 2 Canal goes through the Mossy Marsh Tunnel (2.5 km) into Mossy Marsh Pond, which also picks up the Mossy Marsh Diversion (see below). The water is then transferred into a pump pond, which regulates the movement of water from the Tarraleah No. 2 Canal into the head pond.

The Mossy Marsh Diversion system comprises the relatively small Dunnys, Wentworth and Hornes dams. Dunnys Dam is the uppermost structure in the diversion and transfers water from Dunnys Creek into Dunnys Canal via an underground pipe from the dam. Wentworth Dam captures water from Wentworth Creek and transfers it into Wentworth Canal (7.5 km long), via an aquaduct. Further down the diversion is Hornes Dam which diverts the water from Hornes Creek and Wentworth Canal into another canal which then flows through a marsh and into Mossy Marsh Pond where it joins with water from Tarraleah No. 2 Canal.

The Tarraleah No. 2 Pump Pond picks up the water from the Tarraleah No. 2 Canal and the Mossy Marsh Diversion. The water is then pumped into the head pond, where it converges with water from Tarraleah No. 1 and feeds into the Tarraleah Power Station. It was built to control the release of water into the head pond which has a limited capacity due to spatial constraints. There is also a spillway on the pump pond which allows water to overflow into the Nive River above Lake Liapootah via a canal and creek.

The Tarraleah Power Station is the second (and last) power station in the upper Derwent system. It is located at the intersection of the upper Derwent and Nive-Dee systems, on the opposite bank of the Nive River from Tungatinah Power Station. It receives all the water from the upper Derwent system as described, via the Tarraleah canals.

3.3.2 Nive-Dee System

The modified Nive-Dee hydro-generation system is the most complex part of the Derwent Catchment, in that there are several sub-catchments and inter-basin transfers. The system utilises water from the Nive, Dee, Clarence, Little Pine, Pine and Ouse rivers. There are nine storages and two power stations in the Nive-Dee system.

Lake Echo, Little Pine Lagoon, Dee Lagoon and Echo Power Station

Lake Echo is the head storage for the Nive-Dee system. The lake is an instream storage on the Dee River and it receives water from Little Pine Lagoon (a diversion storage for Lake Echo) and pickup in the Ouse River, via the Monpeelyata Canal.

Little Pine Lagoon was formed by a dam across the Little Pine River, with the intention of diverting water into Lake Echo. Deep Creek Cut is the main outflow from Little Pine Lagoon, although water may also spill into the natural waterway, the Little Pine River. Deep Creek Cut diverts the water from Little Pine Lagoon into the Ouse River just upstream of Monpeelyata Canal. This water plus the water flowing down the Ouse River, is diverted into Lake Echo via the canal. If water spills at Monpeelyata Weir, it continues down the Ouse River to Lake Meadowbank on the lower Derwent River.

Water from Lake Echo is diverted through a flume, pipeline and penstocks into the Lake Echo Power Station, which is the most upstream power station in the Nive-Dee system. The Lake Echo Power Station discharges directly into Dee Lagoon. Lake Echo is able to spill at a spillway on the flume just below the dam. Spills enter the Dee River and flow into Dee Lagoon.

Dee Lagoon is the second instream storage on the Dee River and receives water from the Lake Echo Power Station, and spills and pickup from the Dee River downstream of Lake Echo. Other inflows include Mentmore Creek. Water spills at the dam into the natural waterway, the Dee River, which flows into the lower Derwent below Cluny Lagoon. However the majority of the water is transferred from Dee Lagoon via the Dee Tunnel into Bradys Lake to the west.

Bronte Lagoon, Laughing Jack Lagoon, Pine Tier Lagoon

Bronte Lagoon was created by a dam on Woodwards Creek in the Nive catchment, which flooded Woodwards Marsh. Bronte Lagoon receives water diverted from Pine Tier and Laughing Jack lagoons.

Pine Tier Lagoon was created by a dam built on the upper Nive River. It is a long, narrow reservoir, which floods parts of the Nive and Pine valleys. Pine Tier Lagoon receives inflows from the natural catchment of the Nive and Pine rivers, which drain the Western Lakes. Spills from Pine Tier Lagoon flow into the Nive River, however most of the water is diverted into Bronte Lagoon via the Bronte Canal (which incorporates a concrete flume, siphon and open canal). A weir on Serpentine Creek picks up water from the creek, which is then pumped into the Serpentine Siphon via a short rising main. The siphon carries water across the valley between the Bronte Flume and Bronte Canal (10.5 km), which diverts water from Pine Tier Lagoon to Bronte Lagoon.

The creation of Laughing Jack Lagoon flooded a natural marsh and creek system. The lagoon is fed by a number of creeks which drain Mt. Charles, D'Arcys Bluff and Wentworth Hills. The outflow of water from Laughing Jack Lagoon is into Powers Creek, the natural waterway, via a release valve or spill. Powers Creek joins the Clarence River, and at Clarence Weir, this water is fed into the 8.9 km Clarence Pipeline, which transfers the water to Bronte Lagoon. The water from Katrina Creek in the catchment of Lake King William in the upper Derwent system is also diverted into Laughing Jack Lagoon.

Bradys Lake, Lake Binney, Tungatinah Lagoon, Tungatinah Power Station

Bradys Lake was formed by the construction of a dam on Bradys Creek, a tributary of the Nive. The main inflows are from Bronte Lagoon, via Woodwards Canal, and from Dee Lagoon via the Dee Tunnel. Water from Bradys Lake flows into Lake Binney via a short canal. Bradys Lake spills at the dam into Bradys Creek.

Lake Binney was formed by the construction of a dam on a tributary creek of Bradys Creek. Water from Lake Binney is diverted into Tungatinah Lagoon via a short canal.

Tungatinah Lagoon is the last storage in the Nive-Dee system. The water in Tungatinah Lagoon represents all the water from the Nive-Dee system and it feeds into the Tungatinah Power Station via the 800 m long Tungatinah Tunnel.

The Tungatinah Power Station is the second (and last) power station in the Nive-Dee system. It is situated near Lake Liapootah, on the opposite bank of the Nive River from the Tarraleah Power Station. The Tungatinah Power Station is fed from Tungatinah Lagoon, and discharges into the Nive River directly above Lake Liapootah, which feeds into the lower Derwent system.

3.3.3 Lower Derwent

The lower Derwent system is relatively simple, consisting of a cascade series of storages and power stations. It utilises the water from the lower Derwent Catchment (including the lower Nive River) and the Ouse River, and also re-uses the water from the upper Derwent and Nive-Dee systems. The lower Derwent consists of six storages and six power stations.

Lake Liapootah is an instream storage on the Nive River and was created by the construction of a 40 metre high dam. Water from the upper Derwent system (from Tarraleah Power Station) and the Nive-Dee system (from Tungatinah Power Station) converges in the Nive River directly above Lake Liapootah and is the main inflow to the lake. Spills from the lake go into the natural water course of the Nive River, however most of the water from Lake Liapootah is diverted into the Liapootah Power Station via the 6.9 km Liapootah Tunnel. The Liapootah Power Station discharges into the Nive River just upstream of Wayatinah Lagoon.

Wayatinah Lagoon is the next storage below Lake King William to be sited on the Derwent River itself. The lagoon is located at the convergence of the Nive and Derwent rivers. The main inflow is the water from Liapootah Power Station, however a smaller-than-natural flow also comes down the Derwent River. Water may spill from Wayatinah Lagoon into the Derwent River above Lake Catagunya. Water from Wayatinah Lagoon is diverted through the Wayatinah Power Station, via a 1.7 km tunnel and 1.3 km of twin woodstave pipelines and penstocks, and discharges into Lake Catagunya.

Lake Catagunya is an instream storage on the Derwent River. In addition to receiving water from the Wayatinah Power Station, it also receives water from the Florentine River, which is unregulated. Water is directed through a flume from Lake Catagunya into Catagunya Power Station at the foot of the dam, or may spill at the dam into Lake Repulse.

Lake Repulse is also an instream storage on the Derwent River, and receives water from Lake Catagunya. Water from Lake Repulse passes into Cluny Lagoon, via the Repulse Power Station at the foot of the dam, or via the spillway.

Cluny Lagoon, an instream storage on the Derwent River, receives water directly from the Repulse Power Station or from spill over Repulse Dam. Water leaves Cluny Lagoon via Cluny Power Station, which discharges into the Derwent River above Lake Meadowbank, or by spills over Cluny Dam.

Lake Meadowbank is the most downstream storage in the Derwent Catchment. Water flows into Lake Meadowbank from the Cluny Power Station, and the Dee, Clyde and Ouse rivers. The Clyde River is not regulated by Hydro Tasmania, but is regulated at Lake Crescent by the IFS and Clyde Water Trust, and managed for irrigation. Water from Lake Meadowbank is directed through the Meadowbank Power Station at the foot of the dam, or it may spill over the dam into the Derwent River. The Derwent Estuary is downstream, starting at New Norfolk and ending south of Hobart.

3.3.4 Ouse-Shannon System

The Ouse-Shannon system is no longer used for power generation and the three hydro power stations that previously utilised the water in this catchment (Shannon, Waddamana A and Waddamana B) have been decommissioned (section 3.1.1). However alterations to the hydrology of the catchment as a result of hydro-electricity generation infrastructure remain.

There are three Hydro Tasmania-controlled storages in the catchment, used primarily for irrigation and fishing (Shannon Lagoon, Lagoon of Islands and Penstock Lagoon), and various relict water transfer infrastructure, including Waddamana No. 1 and No. 2 canals.

Shannon Lagoon is located in the Shannon catchment, just south of Great Lake. The primary function of Shannon Lagoon, in terms of Hydro Tasmania’s operations, is to supply irrigation water to the Shannon and Ouse catchments. Shannon Lagoon picks up water from its immediate catchment and as it only has a limited storage capacity, water is transferred from Shannon Lagoon to Great Lake during wet periods for longer term storage. Water is released into the lagoon from Great Lake when extra water is required to meet downstream irrigation and riparian obligations. Water can exit Shannon Lagoon via two routes. The majority of water leaves the lagoon down a canal via a sluice gate. The canal has now been redirected back into the original bed of the Shannon River about 300 metres downstream of the dam. If FSL is attained, water may also leave via a spillway into the original channel of the Shannon River.

The Shannon River at the site of the old Shannon Power Station is directed via a bypass canal into either the Shannon River, or via operation of radial gates, can be redirected into the Waddamana No. 2 Canal. Local pickup which flows into the Waddamana No. 1 Canal is diverted, by a cut between the two, into the Waddamana No. 2 Canal, which flows into Penstock Lagoon.

Penstock Lagoon is located in the Ouse catchment below Shannon Lagoon. The lagoon retains pickup from its local catchment and water also enters the lagoon from the Waddamana No. 2 Canal. Water previously exited Penstock Lagoon via penstocks which led to the now decommissioned Waddamana A and Waddamana B power stations. It now leaves the lagoon via a control structure and travels down a natural drainage line into the Ouse River.

The Lagoon of Islands is located in the Shannon catchment near Woods and Arthurs lakes (which are part of the South Esk – Great Lake Catchment). There is some local pickup from several small creeks including Mary Creek. Hydro Tasmania and the IFS dammed and manage the Lagoon of Islands to provide storage for summer riparian and irrigation needs and to improve the recreational fishery in the lagoon. Ripple Canal diverts water from Ripple Creek, Noels Creek, Forest Marsh and Jacks Marsh into the Lagoon of Islands. Water exits the lagoon via a valve in the dam, flows down Blackburn Creek and then into the Shannon River.

A recently installed valve on Arthurs Flume allows the release of additional water down the Ripple Creek catchment for flushing flows into the Lagoon of Islands. A sluice gate at Jacks Marsh gives the ability to control flows in the Ripple Canal, and divert them into Jacks Creek, which drains into the upper Lake River in the South Esk – Great Lake Catchment.

4. SYSTEM OPERATIONS

A description of the location and physical characteristics of the hydro-electricity system in the Derwent Catchment was given in the previous chapter. This chapter provides a description of the system operating patterns and restrictions for storages, power stations and downstream of other infrastructure.

4.1 Hydro Tasmania's Operating System

Currently, the electricity generation system for mainland Tasmania consists of a network of 51 dams and 27 hydro-electric power stations. In addition there is one thermal power station located at Bell Bay, in the north of the State, which can be used to supplement the hydro generating system if there is a water shortage. The storages and power stations in the Derwent Catchment are operated in conjunction with the rest of the state-wide system to meet two objectives. These are:

1. to operate a secure power system in order to meet requirements in terms of energy and quality of supply; and

2. to operate the integrated hydro power system efficiently while satisfying hydrological, electrical, social and environmental constraints.

To meet these objectives, detailed system planning is undertaken. In planning the operation of the system, various constraints apply, including safety, electrical and hydraulic, maintenance, irrigation, environmental, commercial and recreational considerations.

4.2 Storages

Hydro Tasmania's storages above power stations can be categorised into three sizes: major, medium and minor. These categories are based on the life cycle of the storages, that is, the typical time taken to fill or empty the storage under normal weather conditions. These storages are referred to as 'inter-annual', 'inter-seasonal' and 'run-of-river' respectively. In addition, there are a number of 'diversion' and 'irrigation' storages that Hydro Tasmania operates in conjunction with the power station storages.

Most of the minor storages supply run-of-river power stations and these can cycle (fill or empty) over a period of hours to days. Medium storages are usually the top lakes of a run-of-river chain of storages and power stations ('head' storages), and can cycle over a monthly or seasonal basis. Major storages cycle over a period of decades, there are no major storages in the Derwent Catchment. The long-term system security depends on the major storages being utilised during dry periods when the run-of-river stations cannot be used due to a lack of stored water.

Spills from storages occur when the water exceeds full supply level (FSL) and cannot be released via the power station. Spills bypass the turbines of a power station and therefore represent a loss of generation revenue. Consequently the Hydro Tasmania system is managed to reduce the incidence of spills, and priority of power station operations within the schedule is determined largely by the proximity of the storage to spilling.

Two medium storages, Lake Echo and Lake King William are the head storages for the Derwent hydro-generation system. These lakes are used to store water on an inter-seasonal basis and are generally drawn down over the drier summer and autumn months when less water is available in the run-of-river storages. The capacity of inter-seasonal storages is maximised prior to the wet winter and spring so that a maximum amount of water is captured in the wet season.

Tungatinah Lagoon and all the lakes in the lower Derwent system are run-of-river storages. These lakes have a relatively small storage capacity and are used for electricity generation during periods when the flow in the river is sufficient. Lake levels in run-of-river storages tend to fluctuate over periods of hours or days according to the amount of precipitation and inflow.

The majority of the remaining lakes are diversion storages, which are not directly above a power station and have the function of diverting water to increase the flows in lower parts of the scheme. Some of the storages (Laughing Jack Lagoon and Tarraleah No. 2 Pond) have a main function of regulating the release of water to prevent spill occurring further down the scheme.

Summary operational statistics for storages in the Derwent system are given in Table 4.1.

Table 4.1 Operational Characteristics of Hydro Tasmania Storages in the Derwent Catchment

Sub-Catchment	**Storages**	**Power Station**	**Operating Range** (m)	**FSL** (m)	**NMOL** (m)	**Intake Depth** (m below FSL)	**Storage Type**
Upper Derwent	Lake St. Clair	N/A	2.1	736.72	734.58	N/A	Inter-seasonal
	Lake King William	Butlers Gorge	29.5	719.94	690.52	55.5	Inter-seasonal
	Tarraleah No. 2 Pond	N/A	3.0	647.39	644.35	N/A	Regulated release
Nive-Dee	Pine Tier Lagoon	N/A	2.6	670.56	667.91	N/A	Diversion
	Laughing Jack Lagoon	N/A	9.6	762.00	752.40	N/A	Diversion /Regulated release
	Bronte Lagoon	N/A	3.7	665.98	662.33	N/A	Diversion
	Little Pine Lagoon	N/A	1.5	1007.36	1005.84	N/A	Diversion
	Lake Echo	Lake Echo	13.7	846.43	832.87	15.4	Inter-seasonal
	Dee Lagoon	N/A	0.3	655.62	655.32	N/A	Diversion
	Bradys Lake	N/A	4.3	651.20	647.12	N/A	Diversion
	Lake Binney	N/A	4.2	651.20	646.94	N/A	Diversion
	Tungatinah Lagoon	Tungatinah	4.6	651.20	646.63	6.5	Run-of-river
Lower Derwent	Lake Liapootah	Liapootah	3.5	341.83	338.33	9.7	Run-of-river
	Wayatinah Lagoon	Wayatinah	3.0	231.03	227.99	5.5	Run-of-river
	Lake Catagunya	Catagunya	1.5	169.16	167.64	5.1	Run-of-river
	Lake Repulse	Repulse	3.0	124.96	121.92	10.0	Run-of-river
	Cluny Lagoon	Cluny	4.9	97.84	92.96	10.0	Run-of-river
	Lake Meadowbank	Meadow-bank	6.1	73.15	67.06	10.0	Run-of-river
Ouse-Shannon	Shannon Lagoon	N/A	0.7	1017.66	1016.97	N/A	Irrigation Storage
	Penstock Lagoon	N/A	0.6	919.85	919.25	N/A	Out-of-use storage
	Lagoon of Islands	N/A	2.0	760.40	758.34	N/A	Irrigation Storage

4.2.1 Lake Level Duration Curves

Lake level duration curves are provided for eighteen storages in Figures 4.1 to 4.4. These plots show the frequency of occurrence of specific lake levels. The *y*-axis shows the range of lake levels (expressed as elevations in metres above sea level - mASL) and the *x*-axis shows the percentage of time a particular lake level is exceeded. The plots all have the normal minimum operating level (NMOL) and approximate full supply level (FSL) marked on the *y*-axis, as well as any lake level agreements (LLA). The plotted line indicates the percentage of time that the lake surface was at a particular level during the period of record.

Upper Derwent System

According to the plot in Figure 4.1a, Lake St. Clair spends the majority of the time cycling throughout the active storage range. The lake level exceeds NMOL for approximately 90% of the time. The lake is above FSL for approximately 7% of the time, which may indicate that the lake is spilling. The period of record extends from 1937 to 1998, so the level of the lake being below the NMOL for 10% of the time can be explained by the operation of pumps at Lake St. Clair (these stopped operating in the early 1990s) that allowed Hydro Tasmania to draw the lake below its NMOL. The operation of Lake St. Clair has recently been modified and as the period of record for the plot in Figure 4.1a extends before that time, this plot is therefore not representative of the current operation of the lake.

Lake King William (Figure 4.1b) seldom approaches NMOL (690.52 mASL), spending approximately 99% of the time in the top three quarters of the active storage range, above 697 mASL. The lake level is within 2.5 metres of FSL (719.94 mASL) for approximately 20% of the time.

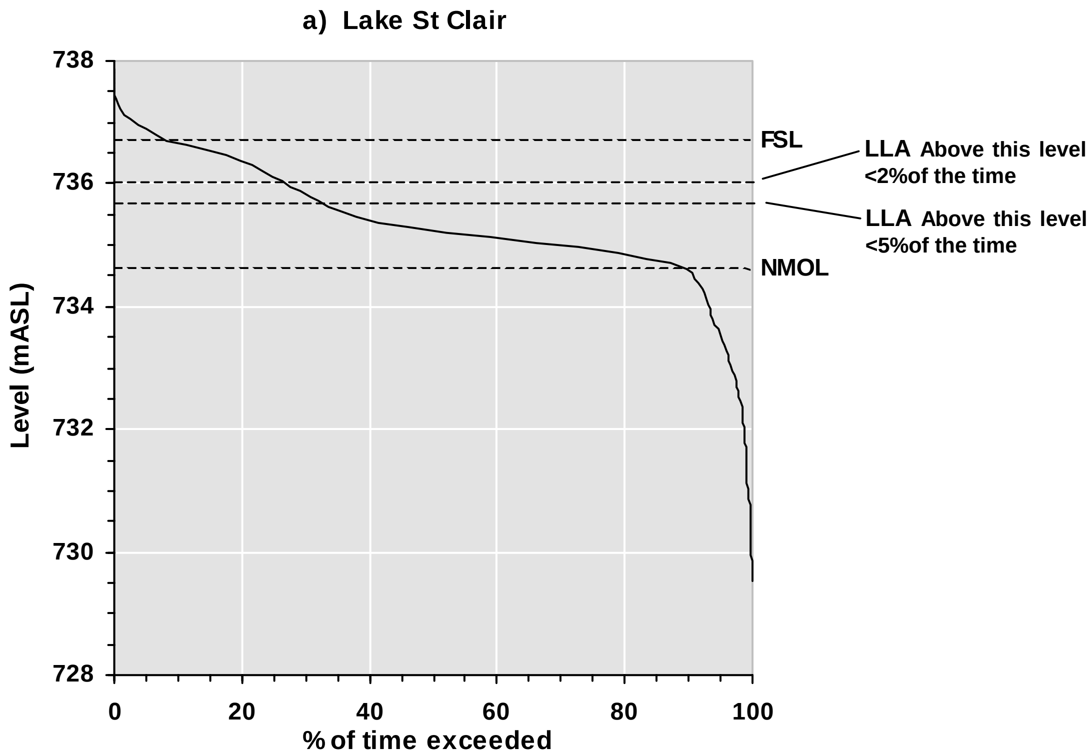


Figure 4.1 Lake Level Duration Curves for Hydro Tasmania Storages in the Upper Derwent System

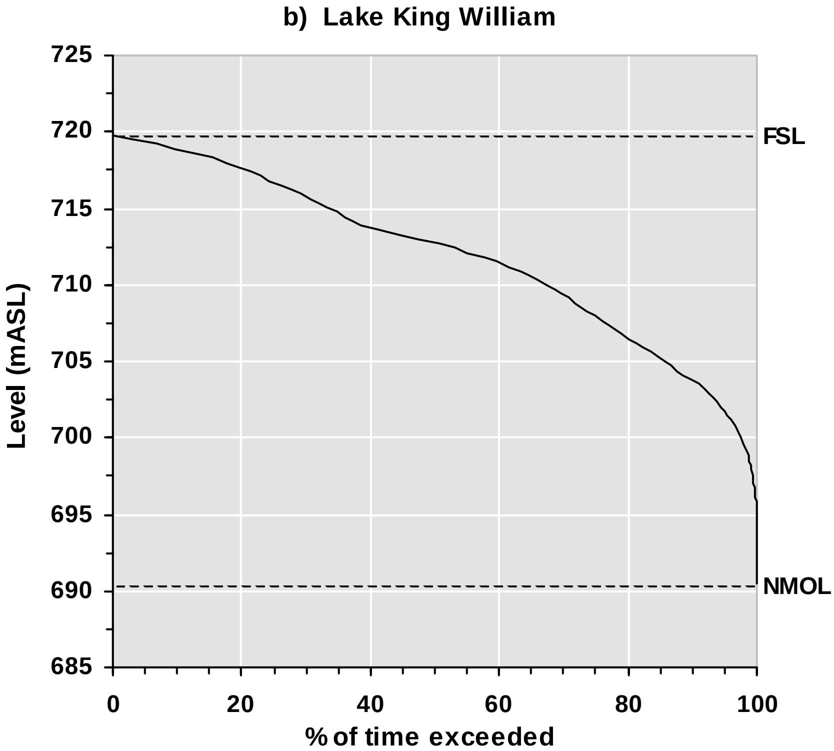


Figure 4.1 cont'd Lake Level Duration Curves for Hydro Tasmania Storages in the Upper Derwent System

Nive-Dee Power Development

Little Pine Lagoon (Figure 4.2a) cycles throughout the active storage range from NMOL (1005.84 mASL) to FSL (1007.36 mASL) for the majority of the time, and exceeds the FSL for approximately 8% of the time, which indicates that the lake was probably spilling. The period of record for this plot is from 1957 to 1998. Little Pine Lagoon us managed under a Memorandum of Understanding with the IFS to keep the water level higher than 1006.33 m for the duration of the fishing season.

Lake Echo (Figure 4.2b) spends approximately 75% of the time in the top half of the active storage range (ie. above 839.5 mASL). However the lake level does cycle throughout the active storage range from NMOL (832.87 mASL) to FSL (846.43). The period of record for the plot is from 1952 to 1998.

The level of Dee Lagoon (Figure 4.2c) exceeds the FSL (655.62 mASL) for approximately 7% of the time which indicates that the storage is spilling during this time. The FSL has been exceeded by up to 2 metres at times, probably during major floods. The operating range of Dee Lagoon is very narrow and the level fluctuates through the range from FSL to NMOL (655.62 to 655.32 mASL). The median lake level (exceeded for 50% of the time) for the period of record (1956-1998) is 655.4 mASL.

Pine Tier Lagoon (Figure 4.2d) fluctuates in level throughout the operating range, however the lake is spilling for approximately 10% of the time, as indicated by the level exceeding the FSL (670.56). The median lake level in Pine Tier Lagoon is approximately 668.75 mASL, which indicates that the lake spends 50% of the time in the top two thirds of the active storage range. The period of record for this plot is 1953-to 1998.

The level of Laughing Jack Lagoon (Figure 4.2e) shows a very even cycling in the lake level throughout the active storage range. The median level in the lagoon is 657.6 mASL, which is approximately midway through the active storage range. During the period of record (1957-1998), the lagoon was spilling for approximately 4% of the time, as indicated by the plotted line exceeding the FSL (762.00 mASL). The level of the lake was below NMOL for approximately 8% of the time as the NMOL was raised in 1995 from 750.42 mASL to its current level of 753 mASL.

Bronte Lagoon (Figure 4.2f) spends more time in the upper half of the operating range overall, with the median level being 663.5 mASL. The level does move from NMOL to FSL (662.33 to 665.98 mASL), however the lagoon spends little time near NMOL, being above 663 mASL for 95% of the time. The level of the lagoon is above FSL for approximately 4% of the time, which indicates spill. The period of record for this plot is 1953 to 1998.

In Tungatinah Lagoon (Figure 4.2g), the median lake level is approximately half way through the operating range. The lagoon cycles throughout the operating range, although it seldom approaches NMOL (646.63 mASL), exceeding 647.4 mASL for 95% of the time. The period of record for this plot is from 1953 to 1998.

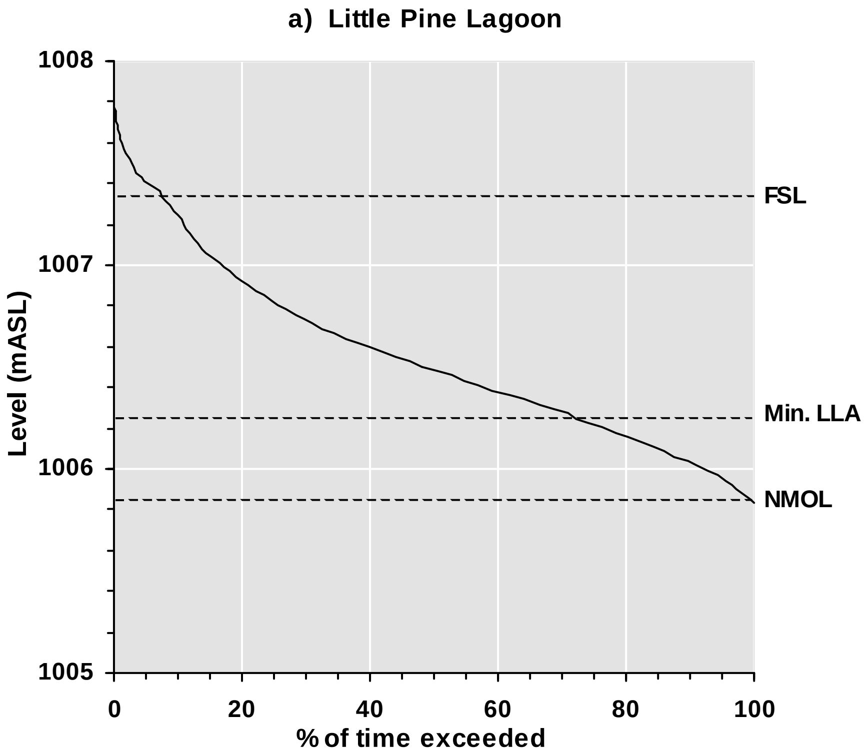
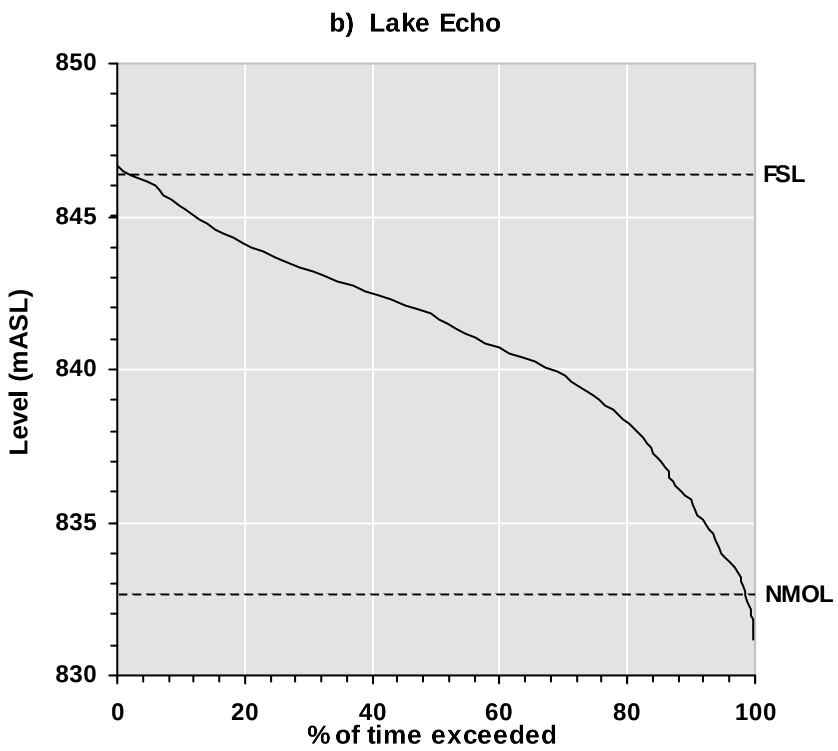


Figure 4.2 Lake Level Duration Curves for Hydro Tasmania Storages in the Nive-Dee Power Development



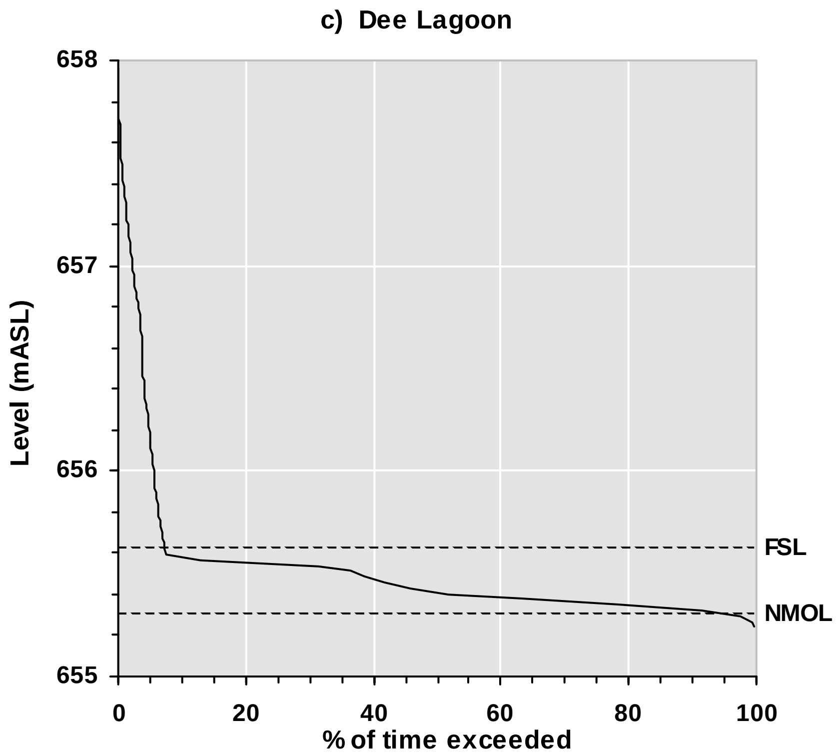
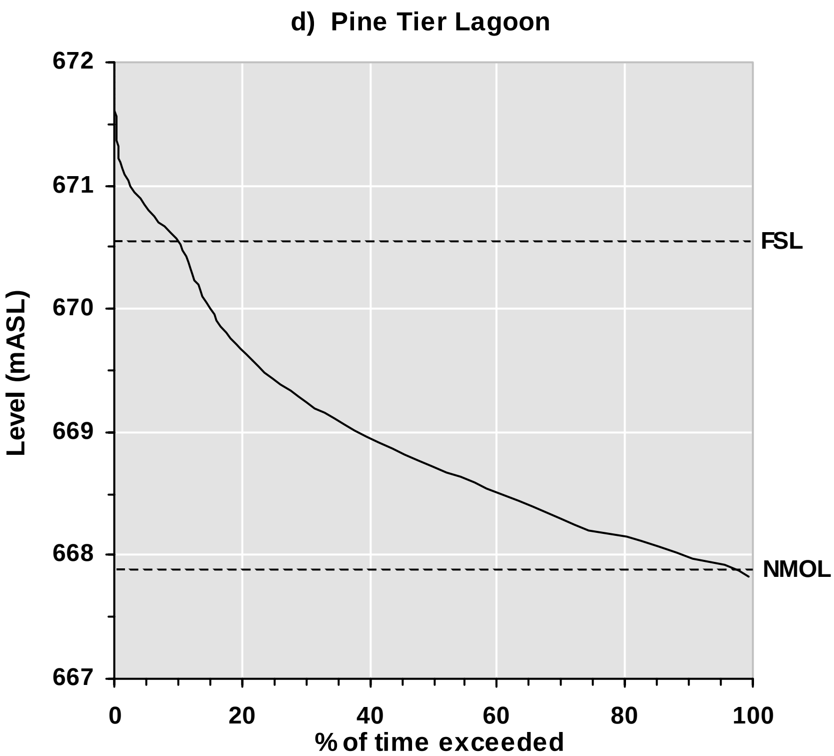


Figure 4.2 cont'd **Lake Level Duration Curves for Hydro Tasmania Storages in the Nive-Dee Power Development**



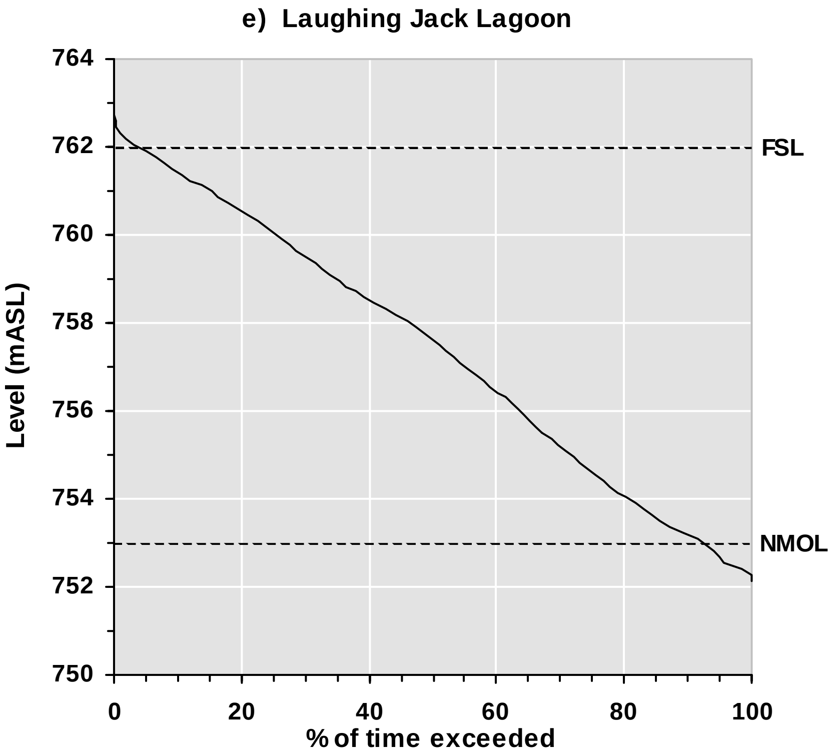
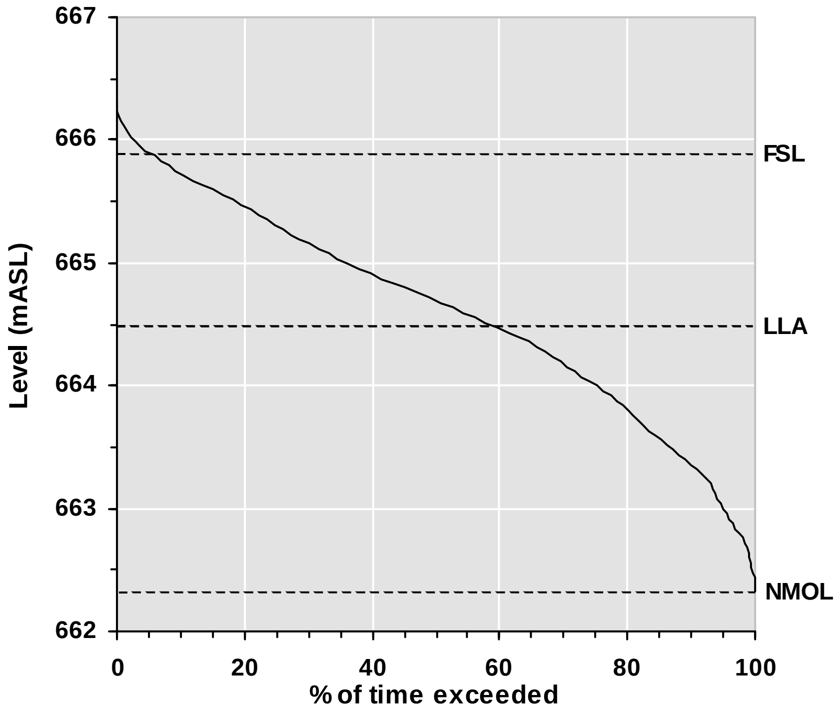


Figure 4.2 cont'd Lake Level Duration Curves for Hydro Tasmania Storages in the Nive-Dee Power Development

f) Bronte Lagoon



g) Tungatinah Lagoon

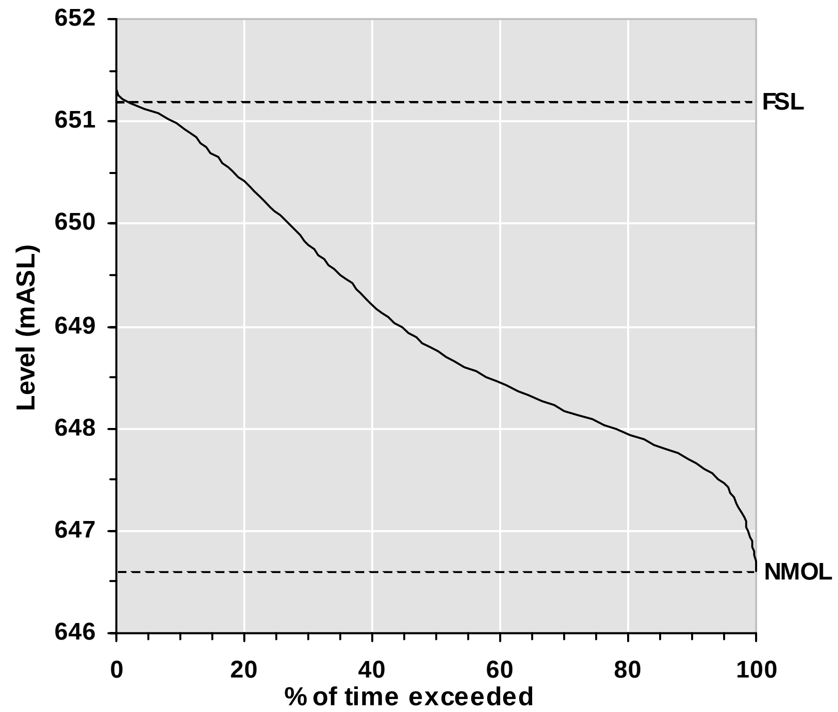


Figure 4.2 cont'd **Lake Level Duration Curves for Hydro Tasmania Storages in the Nive-Dee Power Development**

Lower Derwent System

Lake Liapootah (Figure 4.3a) spends 95% of the time in the top half of its operating range, and has never approached NMOL (338.33 mASL) during the period of record (1967-1998). The median level of the lake is 341.6 mASL, close to the FSL of 342.83 mASL. The lake is at a high level for most of the time as it receives all the water from both the upper Derwent and Nive-Dee systems via Tarraleah and Tungatinah power stations.

The water level in Wayatinah Lagoon (Figure 4.3b) is in the top half of the operating range, or above FSL (231.03 mASL) for the majority of the time. The level of the lake exceeds the FSL for approximately 13% of the time. The lagoon spends little time close to the NMOL (227.99 mASL), being within one metre of the NMOL for only 7% of the time. Wayatinah Lagoon has a median level of approximately 230.3 mASL for the period of record (1990-1998).

Lake Catagunya (Figure 4.3c), Lake Repulse (Figure 4.3d), Cluny Lagoon (Figure 4.3e) and Lake Meadowbank (Figure 4.3f) all show a similar pattern of lake level fluctuation, spending the majority of the time near or above their FSLs. Lake Catagunya (period of record from 1967 to 1998) does spend some time at or below the NMOL (167.64), however the other lakes do not approach NMOL. The period of record for Lake Repulse and Cluny Lagoon is 1968 to 1998 and for Lake Meadowbank, 1967 to 1998. The FSLs for these lakes are exceeded, which indicates that these storages are spilling during this time.

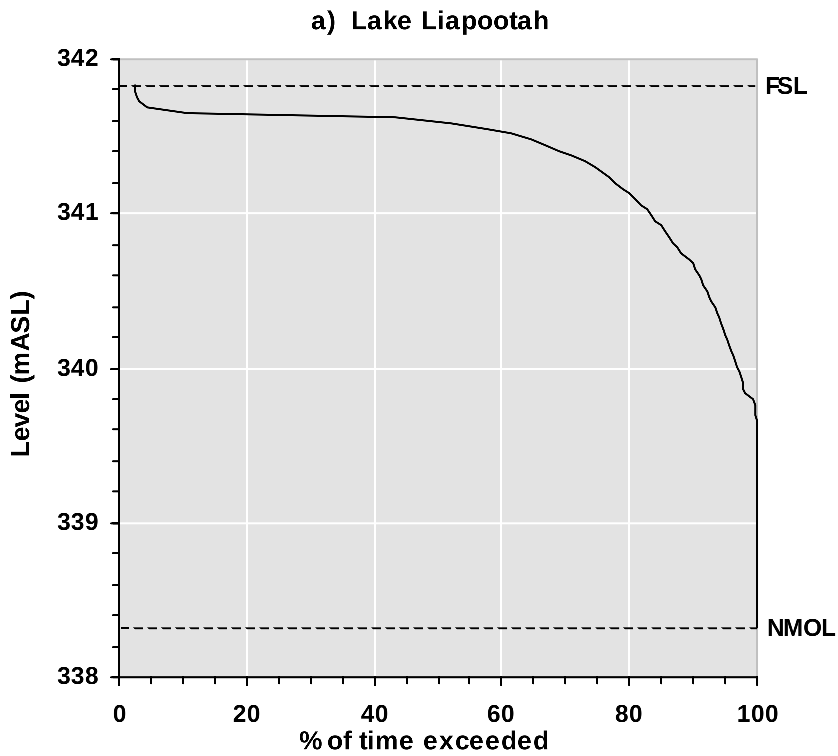
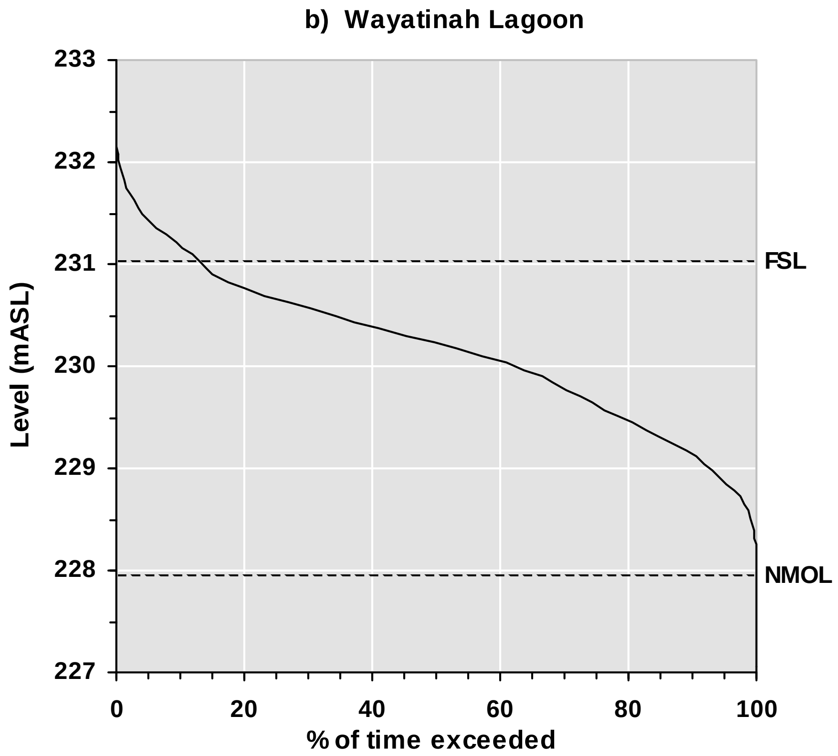


Figure 4.3 Lake Level Duration Curves for Hydro Tasmania Storages in the Lower Derwent System



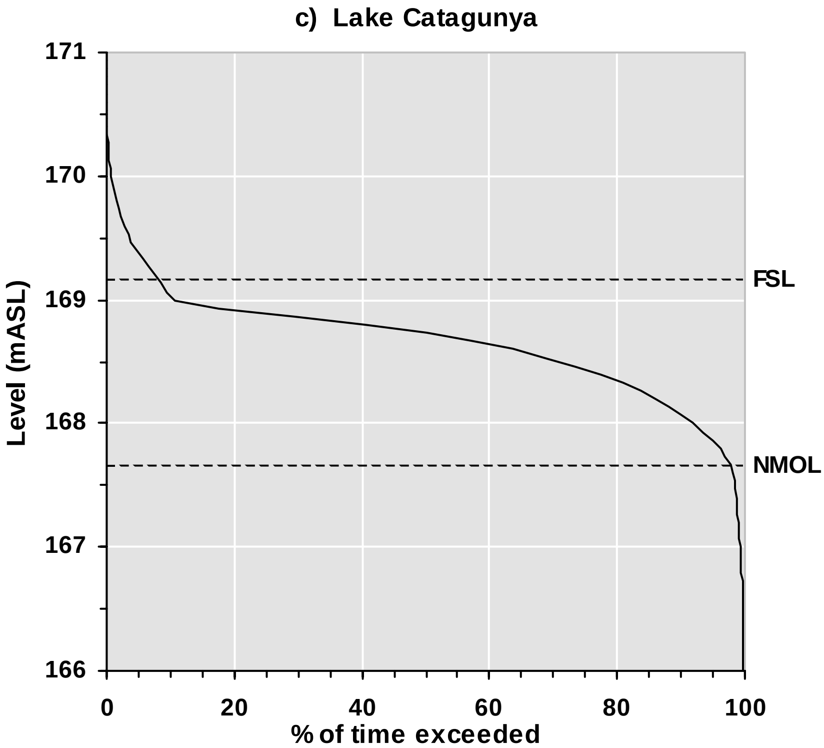
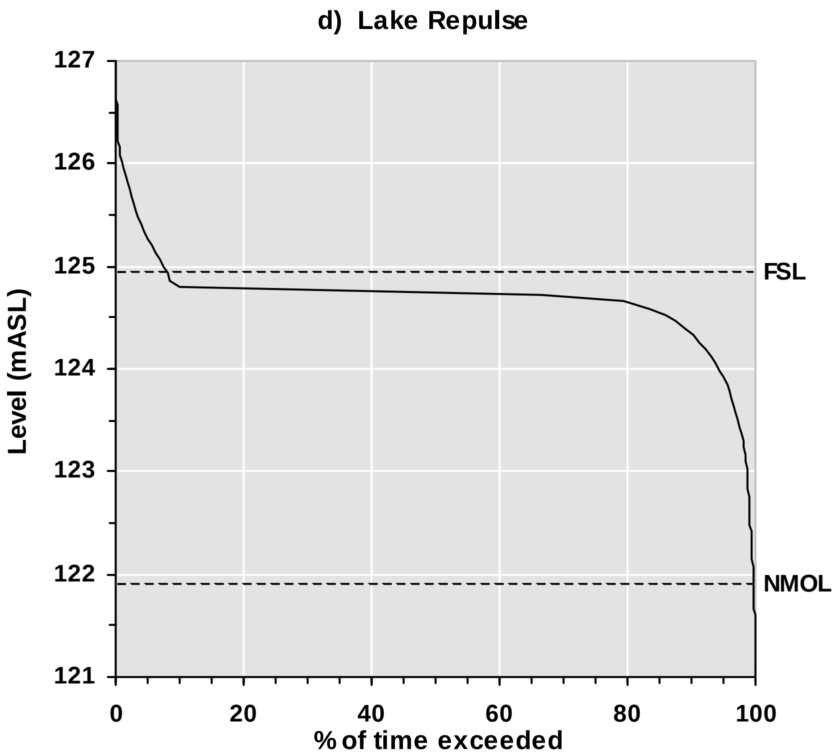


Figure 4.3 cont'd **Lake Level Duration Curves for Hydro Tasmania Storages in the Lower Derwent System**



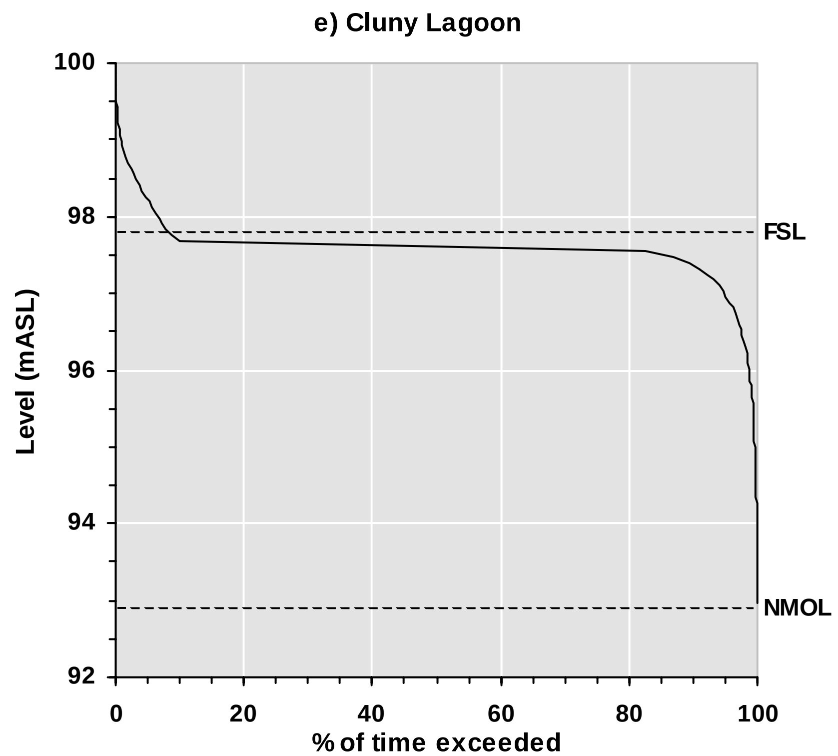


Figure 4.3 cont'd Lake Level Duration Curves for Hydro Tasmania Storages in the Lower Derwent System

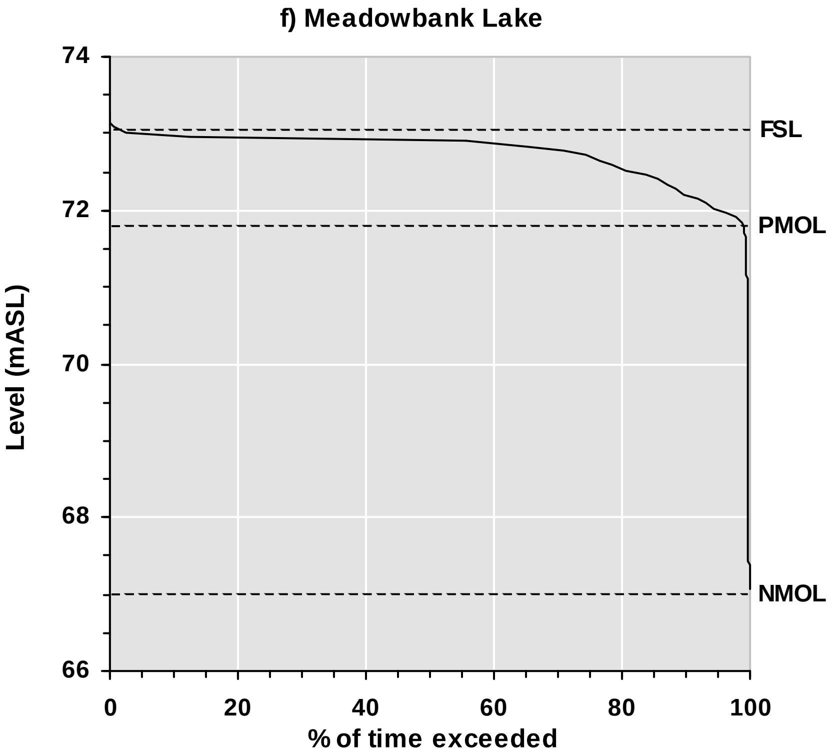


Figure 4.3 cont'd **Lake Level Duration Curves for Hydro Tasmania Storages in the Lower Derwent System**

Ouse-Shannon System

Shannon Lagoon (Figure 4.4a) cycles throughout the operating range. The median level is 1017.35 mASL, which is roughly mid-operating range. The lagoon exceeds FSL for 10% of the time which indicates that the lagoon is spilling. The lagoon is below the NMOL for a small percentage, approximately 2% of the time. The period of record for this plot is from 1967 to 1998.

Lagoon of Islands (Figure 4.4b) cycles throughout the operating range, but also drops below NMOL (758.34 mASL) for 10% of the time. The lagoon spends approximately 50% of the time in the lower quarter of the active storage range, with a median level of approximately 758.9 mASL. The period of record for the plot is from 1964 to 1998. Since the mid-1990s, the lagoon has been managed to a maximum water level of 759.4 m for the purpose of promoting water plant growth and reducing wave erosion on the windward shore.

The level in Penstock Lagoon (Figure 4.4c) was above the NMOL for approximately 73% of the time during the period of record (1967 to 1998). For much of this time, the Waddamana stations were shut down and flow was diverted to Poatina Power Station. The high proportion of time (27%) spent below NMOL is because the NMOL was much lower when the Waddamana power stations were operating. It was raised with the closure of the power scheme in 1994. The median level is approximately 919.4 mASL, which is just below the minimum lake level agreement, which has been in place since 1995. The level exceeds the FSL for approximately 7% of the time, which indicates that the lake is spilling during this time.

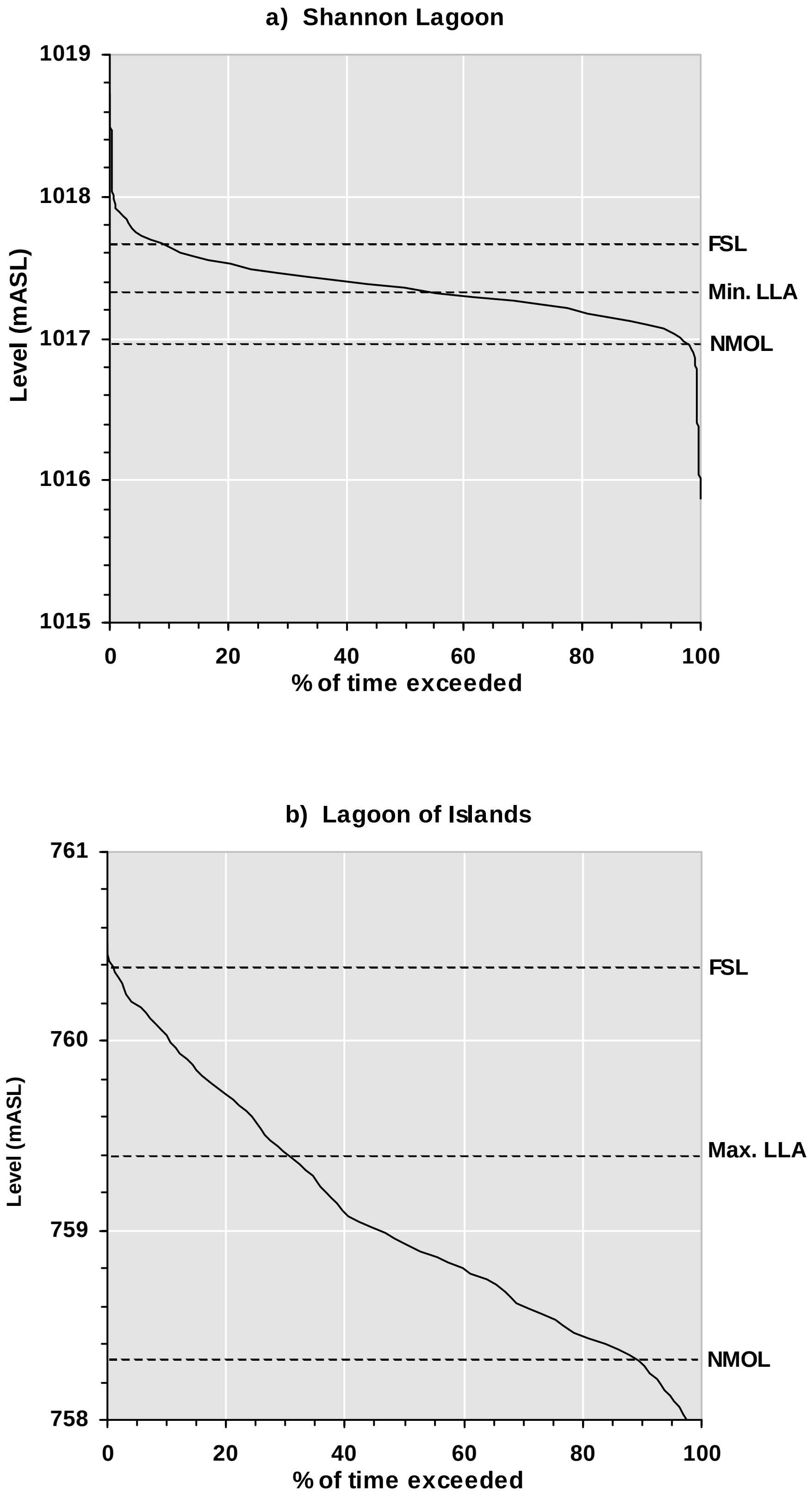


Figure 4.4 Lake Level Duration Curves for Hydro Tasmania Storages in the Ouse-Shannon System

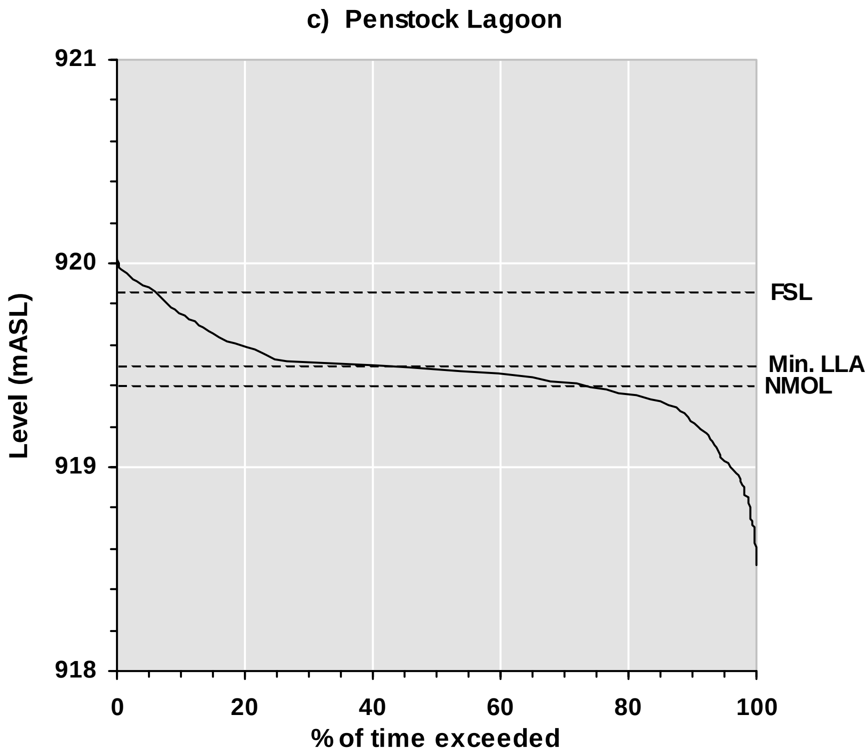


Figure 4.4 cont'd Lake Level Duration Curves for Hydro Tasmania Storages in the Ouse-Shannon System

4.2.2 Average Monthly Lake Levels

The plots in Figures 4.5 to 4.8 show the average monthly lake levels for four Hydro Tasmania storages in the Derwent Power Scheme. These storages represent different patterns in average monthly lake levels. The *x*-axis indicates the months and the *y*-axis indicates the lake level in mASL. The mid-point for each month is the median value, using all values obtained in a given month over the entire period of record. The minimum and maximum values for each month were obtained by taking the highest and lowest single values for each month over the entire period of record.

The smaller run-of-river and diversion storages generally display similar patterns of seasonal lake level fluctuations. The average monthly lake levels in Bronte Lagoon (Figure 4.5) are similar to those displayed in Wayatinah Lagoon, Pine Tier Lagoon, Little Pine Lagoon and Tungatinah Lagoon. These lakes all tend to be at their highest during July or August. This is a wet time of year and these storages are operated on a run-of-river or a diversion basis, whereby the inflows are almost immediately diverted or transferred through the power station. The average monthly lake levels are lowest during the drier periods of year.

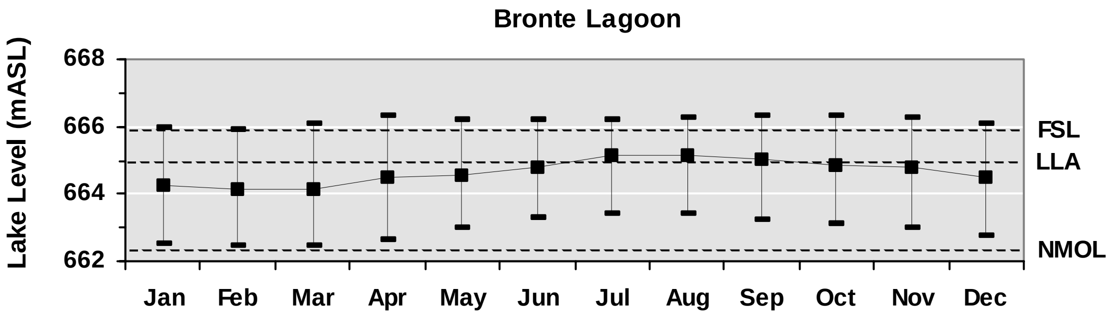


Figure 4.5 Average Monthly Lake Levels in Bronte Lagoon

Dee Lagoon, Lake Catagunya, Lake Repulse, Cluny Lagoon and Lake Meadowbank (Figure 4.6) all display very little seasonal variation and the average monthly lake levels are relatively constant.

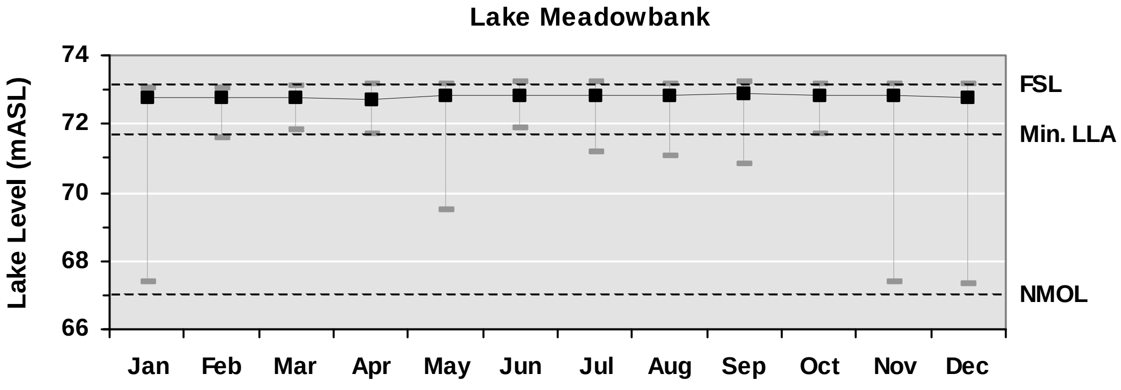


Figure 4.6 Average Monthly Lake Levels in Lake Meadowbank

Lake Echo is an example of the way in which an interseasonal storage fluctuates. Figure 4.7 shows fluctuations in lake level on a seasonal basis. The lake is higher in September and October following the winter and spring rains, and is lowest in April, following the drier summer period. This is a typical pattern for an inter-seasonal storage such as Lake Echo and Lake King William, as water is stored over the wetter times of year in preparation for the lake to be utilised in the drier periods when there is less water available in the run-of-river storages.

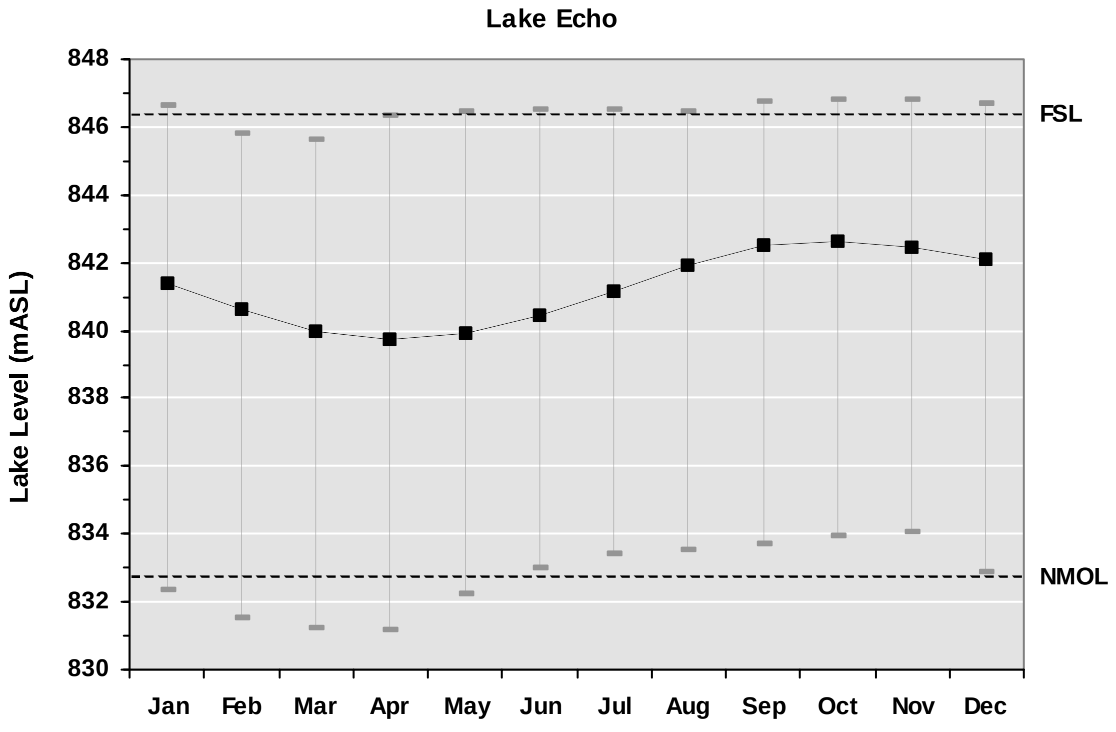


Figure 4.7 Average Monthly Lake Levels in Lake Echo

Shannon Lagoon and Lagoon of Islands (Figure 4.8) fluctuate over small ranges. Shannon Lagoon shows very little variation in seasonal lake levels as the range is largely controlled by pumping excess water into Great Lake. However the average monthly level in Lagoon of Islands is now higher from July to November, leading up to the irrigation season. The level is then drawn down over the irrigation season.

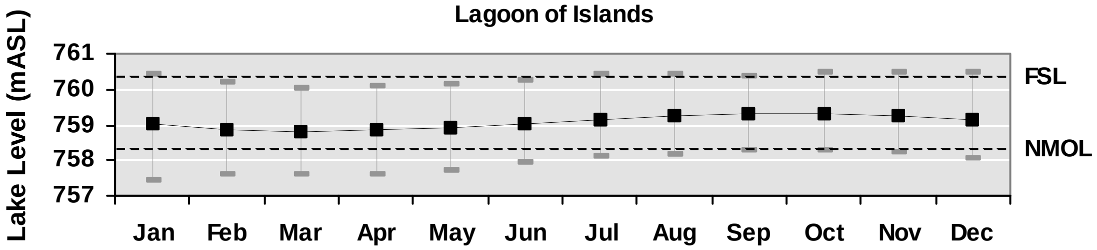


Figure 4.8 Average Monthly Lake Levels in Lagoon of Islands

4.2.3 Lake Level Agreements and Restrictions

Lake St. Clair

As Lake St. Clair is in the Tasmanian Wilderness World Heritage Area, Hydro Tasmania uses water from Lake St. Clair in accordance with the Tasmanian Wilderness World Heritage Area Management Plan (Tasmanian Parks and Wildlife Service, 1999b). This contains a Water Management Strategy which aims to minimise shoreline erosion, maximise revegetation, and enhance the aesthetics of the lake shore environment. Hydro Tasmania has undertaken to modify its operating rules to achieve the following targets:

- The lake level will be maintained above 736.0 m less than 2 % of the time
- The lake level will be maintained above 735.6 m less than 6% of the time

Hydro Tasmania may use the water from Lake St. Clair beyond the limits set down in this strategy, after consultation with, and taking into account the views of the National Parks and Wildlife Advisory Council. At times of flooding and extreme weather conditions, the Corporation will lower Lake St. Clair to full supply level as soon as safe and practicable, thereby minimising shoreline erosion.

Hydro Tasmania limits discharge from Lake St. Clair according to an operating rule, to limit erosion in the Derwent River downstream.

Bronte Lagoon

Hydro Tasmania has an informal agreement with the IFS, whereby Hydro Tasmania attempts to maintain a level of approximately 664.5 metres above sea level (mASL) for the duration of the fishing season. A water level trial was undertaken in 1992, with a target of approximately 665.0 ± 0.3 mASL during the angling season, with a view to reviewing water level management. No new agreement was reached because the outcome of any changes could not be modelled long term and the impact on Hydro Tasmania identified. However, the current practice is to operate the lake at this level whenever possible throughout the fishing season.

Laughing Jack Lagoon

In 1995, the NMOL of Laughing Jack Lagoon was raised from 750.42 to 753.0 mASL as part of a lake level agreement with the IFS. The IFS constructed a weir inside the dam to ensure a minimum level in the lagoon for the recreational fishery. When the level of the lagoon was drawn down, fish would become stranded between the weir and the main dam. The new NMOL keeps the level of the lagoon above the smaller weir to prevent this occurring.

Little Pine Lagoon

Hydro Tasmania has formalised an agreement to maintain Little Pine Lagoon above 1006.33 mASL for the fishing season (August to April) for recreational fishing and ecosystem requirements.

Shannon Lagoon

Shannon Lagoon is operated, for recreational fishing requirements and turbidity mitigation, in the range 1017.3 mASL to 1017.55 mASL. Excess water is pumped into Great Lake.

Lagoon of Islands

Lagoon of Islands has a maximum operating level of 759.4 mASL as set in an informal agreement with the IFS. This is to promote the growth of strapweed (*Triglochin procera*). The strapweed locks up nutrients and therefore helps to maintain water quality. The lower maximum level also protects the dune system on the windward shore from wave erosion.

Penstock Lagoon

Penstock Lagoon is currently operated for water quality and recreational fishing requirements to a minimum level of 919.4 mASL during the summer months. IFS has the ability to seasonally control water levels in the lagoon.

Lake Meadowbank

Meadowbank crest gates operate as inflows vary, to maintain the water level in the reservoir within 150 mm of full supply level where possible. Gate operation is automatic, with the gate position being determined by the storage level and change in flood inflow. Once the gates are fully deployed, the water level in the lake will rise and fall with the natural variability of the flood.

Lake Meadowbank is normally operated between the FSL of 73.15 mASL and the planned minimum operating level (PMOL) of 71.86 mASL. This is done so that the lake is maintained at a level whereby irrigation off-takes will remain submerged. The level of Lake Meadowbank will not be drawn below PMOL without prior notice being given (eg. notification by newspaper advertising).

4.3 Power Stations

4.3.1 Scheduling of Power Station Operations

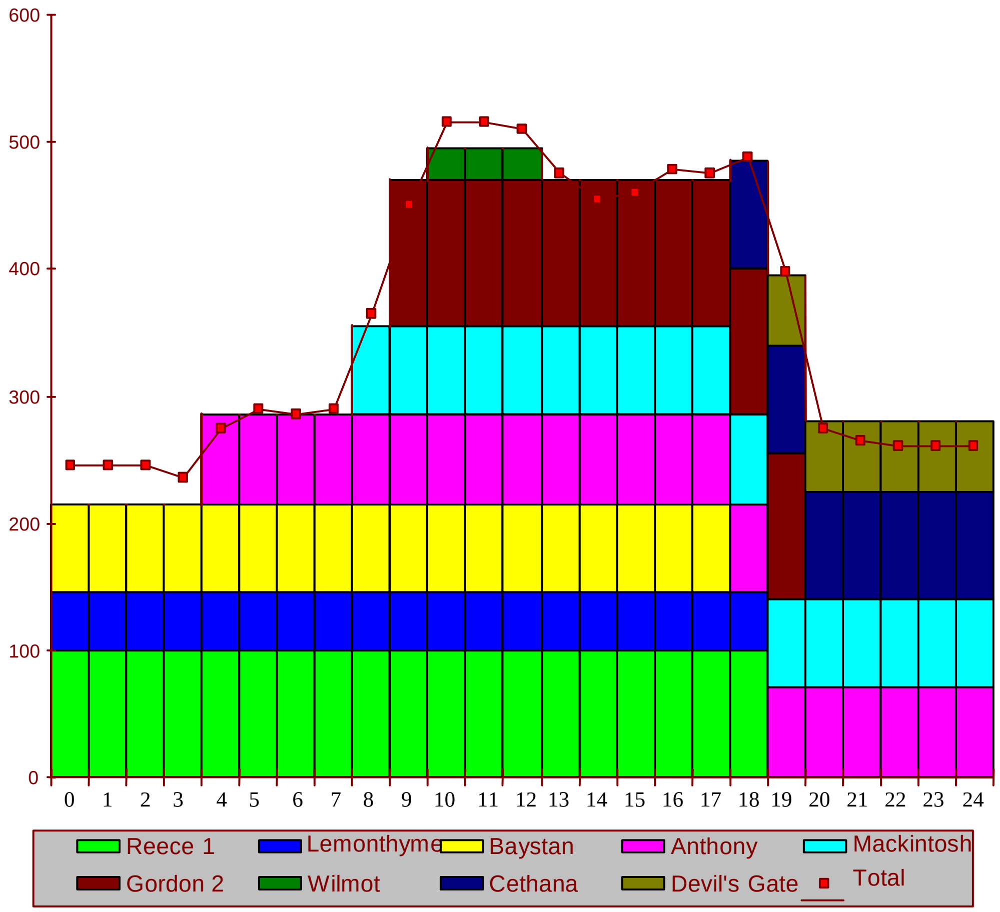
Power stations are not operated continuously. The operational schedule for the network of Hydro Tasmania power stations is determined by the following (in priority order):

- Use any storage on spill - this is water that would otherwise spill and therefore bypass turbines.
- Use catchment pickup draining into run-of-river storages - these run-of-river storages have limited capacity and are therefore more likely to spill if not utilised.
- Storage release.

Release of water from dams is prioritised by the size of the storage. Small storages are utilised first to maximise their storage potential. Medium storages are scheduled next and are prioritised according to their immediate probability of spill. The major storages are last on the priority list because they are unlikely to spill and can provide the reserve energy when water is not available within the rest of the Hydro Tasmania system.

To efficiently operate the system with the required level of security, the system load needs to be estimated in advance. Terms related to load on the system are illustrated in Figure 4.9. These include base load, step load, deficit load, frequency and peak power. Figure 4.9 illustrates a representative 'load curve' as used by Hydro Tasmania to schedule power station operation. Time (24 hours) is shown on the *x*-axis and load (in MW) is shown on the *y*-axis. 'Peak load' occurs in the morning and early evening, and is shown by the two peaks in the graph.

Certain power stations are scheduled to provide 'base load', the load that is constantly required during the day, shown at the bottom of the load curve (Figure 4.9). If there is sufficient rainfall to utilise the run-of-river storages, water will be drawn from them to generate base load. Power stations operating in base load generate a constant load all day, and longer if sufficient water is available.



The load above base load is divided into steps of differing magnitude during different periods of the day (Figure 4.9). This is known as ‘step load’. Specific power stations are turned on for set periods of the day, running at their efficient load (or full gate if the storage is close to spill). Power stations operating in step mode are generally turned on at some point during the day, generate power at a constant load for a certain number of hours (eg. 6-18) and then turn off. Discharge from power stations operated to generate step load will change significantly at specific times of the day.

‘Deficit load’ is the additional load above step load that constitutes the remainder of the daily load curve. It is supplied by power stations operating in deficit or frequency mode. These power stations vary their generation within a particular range (somewhere around their efficient load if possible) to meet fluctuations of the daily load curve. Discharge from these power stations is variable over very short time periods.

‘Efficient load’ relates to an operating level associated with the most efficient power generation. In some cases, power stations have multiple turbines, in which case there are different efficient loads depending on how many turbines are in use. Power stations can operate at ‘full gate’ which discharges the maximum amount of water at a lower power generation efficiency.

4.3.2 Power Station operations in the Derwent Catchment

The Butlers Gorge and Tarraleah power stations are typically run as fairly continuous base load stations for most of the year, as they have a constant water supply from Lake King William. The base load of Butlers Gorge feeds on to base load at Tarraleah via the Tarraleah No. 1 Canal, with additional water from the Tarraleah No. 2 Canal.

The Lake Echo Power Station is usually run on efficient load, generating during the summer, autumn and sometimes early winter (turned off when the heavy rains begin). It is not generally operated in spring. The Tungatinah Power Station is a peaking station and runs on step load for most of the year. It runs on full load when there is a good water supply, so the loads are higher in winter than in summer.

The operation of the Liapootah Power Station is dependent on inflows from the Tarraleah and Tungatinah power stations, and so may be run as either base or step load. Lake Liapootah discharge feeds into the cascade of power stations downstream. Wayatinah and Catagunya power stations, being multiple-machine stations are both step loaded. Repulse, Cluny and Meadowbank power stations are following stations to Wayatinah and Catagunya, and are operated as single-machine step loads to maintain lake levels at about 0.1-0.2 m below FSL.

Table 4.2 gives the discharge from the power stations in the Derwent Catchment when operating at maximum discharge capacity (full gate). The values are for FSL (values vary according to lake level).

Table 4.2 Maximum Power Station Discharge

Power Development	Power Station	Maximum Discharge (Full Gate) (cumecs)
Upper Derwent	Butlers Gorge	32.0
	Tarraleah	39.5
Nive-Dee	Lake Echo	21.8
	Tungatinah	52.5
Lower Derwent	Liapootah	100.0
	Wayatinah	92.2
	Catagunya	133.0
	Repulse	133.0
	Cluny	140.0
	Meadowbank	168.3

4.3.3 Power Station Operating Constraints

Butlers Gorge Power Station

Butlers Gorge Power Station is run as much as possible to minimise spilling water at Clark Dam, which then bypasses Tarraleah and Liapootah power stations and goes into Wayatinah Lagoon. However, the operation of the power station is restricted by the capacity of Tarraleah No. 1 Canal (25.8 cumecs) which will spill if too much water is directed into it. Therefore, generation from Butlers Gorge Power Station is maintained at about 8 MW which is equivalent to a flow of between 17-20 cumecs. If discharge from the power station was the same as the canal capacity, the canal would spill as a result of inflows along its route.

Cluny Power Station

If the Ouse River has less than approximately 10 cumecs of flow during the irrigation season, the Cluny Power Station is not shut down unless there is a sufficient volume of water backed up behind Brock Weir on the Derwent River, to allow for ten hours of irrigation pumping into the Lawrenny irrigation works.

Meadowbank Power Station

Hydro Tasmania has a formal agreement with Norske Skog and an informal agreement with Hobart Water to maintain a freshwater flow in the Derwent River below Meadowbank Dam that is sufficient to prevent the salt wedge from migrating upstream to their respective intakes (section 4.4.1). This may mean generating at Meadowbank Power Station at 6-7 MW to maintain the flow or opening a riparian valve in the dam when the machine is off load. Large discharge variations are prohibited from Meadowbank Power Station for downstream river safety reasons.

4.4 Other Hydro Tasmania Infrastructure

Other infrastructure with spillways and outlets that is associated with Hydro Tasmania's operations of the waterways in the Derwent Catchment is listed in Table 4.3.

Table 4.3 Structures with Spillways and Riparian Outlets in the Derwent Catchments

Power Development	Structure	River	Storage	Outlet Capacity (cumecs) [Diameter (mm)]	Spillway Capacity (m^3/s)
Nive-Dee	Little Pine Dam	Little Pine	Little Pine Lagoon	0.04 [150]	283
	Pine Tier Dam	Nive	Pine Tier Lagoon	0.08 [150]	1508
	Penelope Weir	Penelope Creek	N/A	N/A	-
	Serpentine Rivulet Weir	Serpentine Rivulet	N/A	N/A	242
	Clarence Weir	Clarence	Clarence Lagoon	0.12 [150]	135
	Laughing Jack Dam	Powers Creek	Laughing Jack Lagoon	N/A	28
	Bronte Dam	Woodwards Creek	Bronte Lagoon	N/A	56
	Bradys Dam	Bradys Creek	Bradys Lake	N/A	61
	Binneys Dam	Big Marsh Creek	Lake Binney	N/A	N/A
	Tungatinah Dam	Nive Marsh Rivulet	Tungatinah Lagoon	N/A	N/A
	Echo Dam	Dee	Lake Echo	N/A	93
	Dee Dam	Dee	Dee Lagoon	0.08 [150]	195

Table 4.3 cont'd Structures with Spillways and Riparian Outlets in the Derwent Catchments

Power Development	Structure	River	Storage	Outlet Capacity (cumecs) [Diameter (mm)]	Spillway Capacity (m^3/s)
Upper Derwent	Beehive Weir	Beehive Creek	N/A	N/A	8.5
	Burns Dam	Burns Creek	N/A	N/A	11
	Rufus Weir	Navarre	N/A	N/A	-
	Lake St. Clair (Control) Dam	Derwent	Lake St. Clair	N/A	N/A
	Clark Dam	Derwent	Lake King William	N/A	687
	Butlers Weir	Derwent	N/A	N/A	-
	Derwent Pump Weir	Derwent	N/A	N/A	-
	Hornes Dam	Hornes Creek	Hornes Pond	0.03 [150]	23
	Mossy Marsh Dam	Mossy Marsh Creek	Mossy Marsh Pond	N/A	-
	Tarraleah No.2 Pond Dam	Wilsons Creek	Tarraleah No.2 Pond	N/A	41
	Tarraleah Weir	Wilsons Creek	N/A	N/A	-
Lower Derwent	Liapootah Dam	Nive	Lake Liapootah	N/A	2405
	Wayatinah Dam	Derwent	Wayatinah Lagoon	- [300]	3115
	Catagunya Dam	Derwent	Lake Catagunya	N/A	3594
	Repulse Dam	Derwent	Lake Repulse	N/A	3964
	Cluny Dam	Derwent	Cluny Lagoon	- [1140]	4243
	Meadowbank Dam	Derwent	Lake Meadowbank	19.8 [1520]	5239
Ouse-Shannon	Shannon Lagoon Dam	Shannon	Shannon Lagoon	0.23 [610]	127
	Penstock Lagoon Dam	N/A	Penstock Lagoon	N/A	-
	Lagoon of Islands Dam	Blackmans Rivulet	Lagoon of Islands	2.83 [1067]	48

Note: some data not obtainable at time of preparing report

Pump stations in the Derwent Power Scheme include Derwent Pumps (2.9 cumec capacity), Shannon Pumps (0.9 cumec capacity), Tarraleah No. 2 Pumps and Serpentine Pumps. These flows are indicative only. Canal capacities (in cumecs) are as follows: Tarraleah No. 1 (25.6), Tarraleah No. 2 (8.5), Monpeelyata (14.2), Echo (23), Bronte (46.8), Woodwards (56.8), Bradys (51.7), Binneys (51.7), Catagunya (132).

4.4.1 Other Operating Constraints and Provisions

Shannon River

Hydro Tasmania may release water from Shannon Lagoon into the Shannon River during the irrigation season to comply with statutory requirements in the *Electricity Supply Industry Restructuring (Savings and Transitional Provisions) Act 1995*. This requires Hydro Tasmania to make irrigation water available to downstream users on the Ouse and Shannon rivers. On occasions when there is insufficient water in Shannon Lagoon to make such releases, supplement water may be discharged from Great Lake.

Arthurs Flume

Hydro Tasmania has recently installed a valve in Arthurs Flume (which is part of the Poatina Power Development) so that water can be released into the Ripple Creek catchment. This can provide flushing flows into Lagoon of Islands to manage water quality as required.

Lagoon of Islands

Water is supplied from Lagoon of Islands to Blackburn Creek, the Shannon River and the Ouse River, for irrigation purposes. This water is diverted into Lagoon of Islands via Ripple Canal, which intercepts and diverts headwater streams of the Shannon River.

Waddamana No. 2 Canal

The radial gates at the top of the Waddamana No. 2 Canal (at the old Shannon Power Station site) may be opened to provide water for trout spawning in the canal, if requested by the IFS.

Lawrenny Irrigation Works downstream of Cluny Dam

A riparian valve with a capacity of 11.3 cumecs in Cluny Dam is opened when the power station is shut down during the irrigation season. This is to ensure that there is sufficient water above Brock Weir for pumping into the channels of the Lawrenny Irrigation Scheme.

Derwent River downstream of Meadowbank Dam

Hydro Tasmania has a formal agreement with Norske Skog to maintain a flow in the Derwent River below Meadowbank Dam that is sufficient to prevent the salt wedge from migrating upstream. This enables Norske Skog to extract 90 sluiceheads (1.08 cumecs) of fresh water from the Derwent River at Lawitta for use in the Boyer paper mill. The agreement with the operator of the Boyer Mill (at the time Australian Pulp and Paper Mills) was made in 1980, and is periodically reviewed and updated.

Hydro Tasmania also has an informal arrangement with Hobart Water, made in 1993, to maintain a minimum flow of 20 cumecs at the Bryn Estyn intake (which is virtually across the river from the Boyer mill intake) to prevent the salt wedge migrating upstream, and ensure a fresh water supply to Bryn Estyn.

4.5 Alterations to Natural Flows Downstream of Hydro Tasmania Infrastructure

Figures 4.10a to 4.10h show discharge duration curves for pre- and post-development periods, downstream of power stations and dams in the Derwent Catchment. These plots show the frequency of occurrence of specific flows below these major structures, and indicate changes to the natural flow regime.

The y-axis shows the discharge in cumecs and the x-axis shows the percentage of time a particular discharge is exceeded. The blue plotted line indicates natural discharges and the red line indicates discharges post-development. These lines represent the percentage of time that discharge was at a particular level over a ten year period. The plots were generated using a mixture of modelled and field-derived data.

In the Ouse River below Liawenee Weir (Figure 4.10a), the median and lower flows have decreased post-dam while the higher flows have increased. The median flow has decreased from approximately 3 cumecs to zero. Flows exceeded approximately 16% of the time have remained at 17 cumecs.

Lower in the Ouse River, approximately 20 km downstream of Lake Augusta (Figure 4.10b), flows have decreased overall. Median flows have decreased from 7.5 cumecs pre-dam to approximately 2 cumecs post-dam, flows exceeded 5% of the time have decreased post-development from 37 cumecs to 10 cumecs. Low flows, exceeded 95% of the time have also decreased slightly. This decrease in flows is a result of the upstream diversion into Great Lake (and the South Esk Catchment) via the Liawenee Canal.

In the Little Pine River immediately downstream of Little Pine Dam (Figure 4.10c), flows have decreased overall post-dam. Higher flows exceeded 10% of the time have decreased from approximately 6 cumecs to less than 0.5 cumecs. Median flows have decreased from approximately 2.5 cumecs to zero cumecs post-dam. Low flows exceeded 95% of the time have also decreased to zero from pre-dam flows of less than 1 cumec. This decrease in flows can be attributed to the diversion of water from Little Pine into Lake Echo via Deep Creek Cut and Monpeelyata Canal.

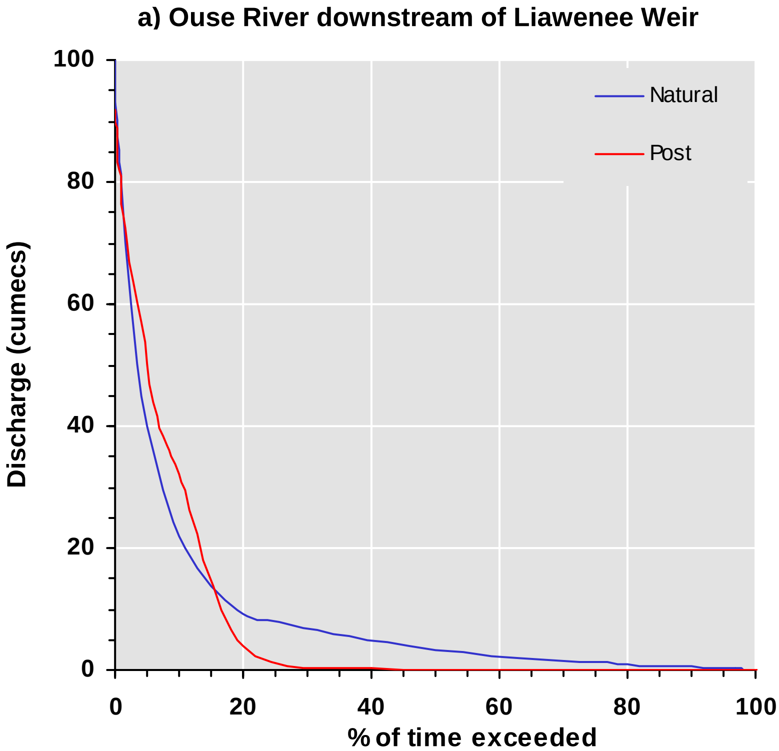
The Nive River immediately downstream of Pine Tier Dam (Figure 4.10d) has also undergone an overall decrease in flows post-dam. The median flows have decreased from 13 cumecs to 2 cumecs. The magnitude of higher flows exceeded 2% of the time has decreased from 100 cumecs pre-dam to 18 cumecs post-dam. Low flows have changed little, and flows exceeded 90% of the time have remained at less than 1 cumec. This decrease in water in the Nive River can be attributed to the diversion of Pine Tier water into Bronte Lagoon via Bronte Canal.

On the Nive River approximately 6 km downstream of Liapootah Dam (Figure 4.10e), flows have decreased post-dam. Median flows have decreased from 10 cumecs to approximately 2 cumecs. High flows exceeded 5% of the time have decreased from 45 cumecs to approximately 4 cumecs. The lower flows, exceeded 90% of the time have decreased from 3 cumecs to zero. The decrease in flows in this section of the Nive River is a result of the diversion of water from Lake Liapootah into the Liapootah Tunnel to Wayatinah Power Station.

The Derwent River immediately downstream of Tarraleah No. 1 Weir (Figure 4.10f) has undergone major decreases in flows in the post-dam period. There is virtually no water in the river immediately downstream of the dam as a result of this diversion.

Further down the Derwent River, approximately 23 km below Clark Dam (above the Nive River) (Figure 4.10g), post-dam flows are somewhat higher than those at the Tarraleah No. 1 Weir, however they have still undergone an overall decrease from natural. Median flows have decreased from 35 to 8 cumecs. The diversion of Derwent water into the Tarraleah canals, including the pumping of water out of the river at the Derwent Pump Pond, has resulted in this decrease in flows.

The Derwent River immediately below Meadowbank Dam (Figure 4.10h) has undergone an overall decrease in flow, due to the diversion of 12% of the catchment to the South Esk Basin. The median flow has decreased from 100 cumecs to 75 cumecs post-dam and high flows (5^{th} percentile) have decreased by 50% from 400 cumecs to 200 cumecs, due to the storage capacity of Lake Meadowbank and upstream impoundments and flow regulation. In contrast, the lower flows (90^{th} percentile) have actually increased from pre-dam flows of 20 cumecs to 40 cumecs post-dam, due to the pattern of power generation at Meadowbank Power Station and the requirement for a minimum discharge of 20 cumecs.



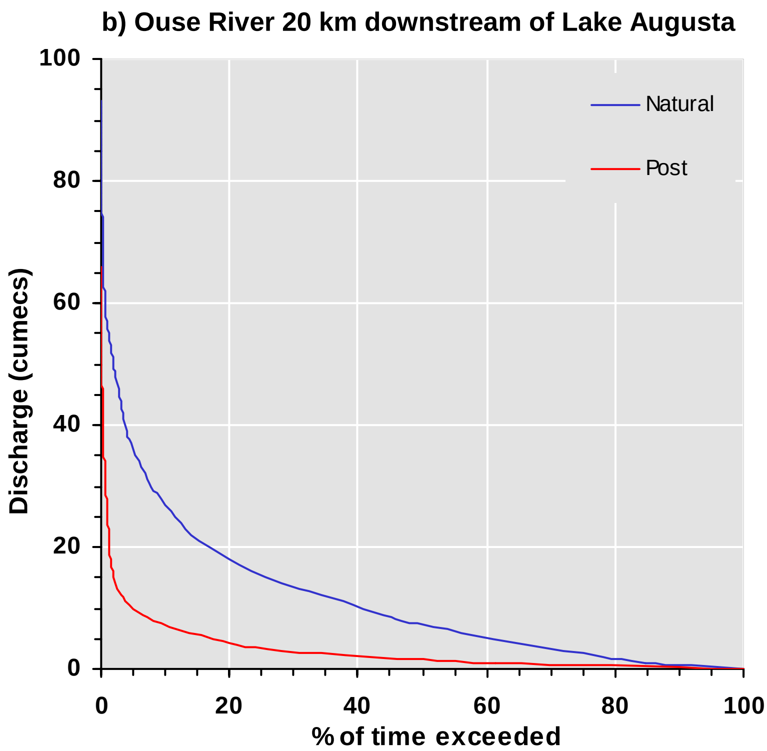
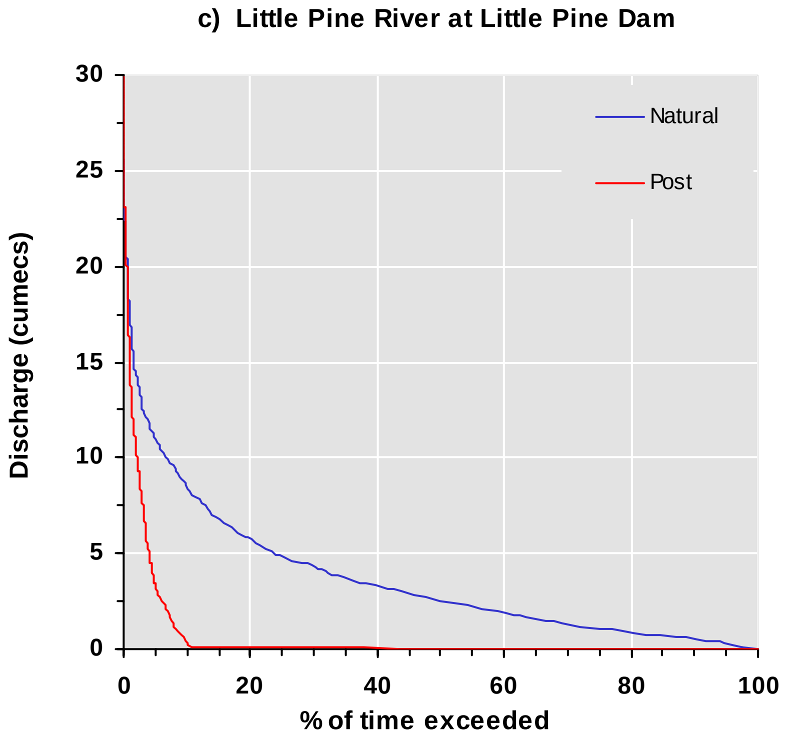


Figure 4.10 Natural and Post Development Flow Duration Curves Downstream of Hydro Tasmania Structures in the Derwent Power Scheme



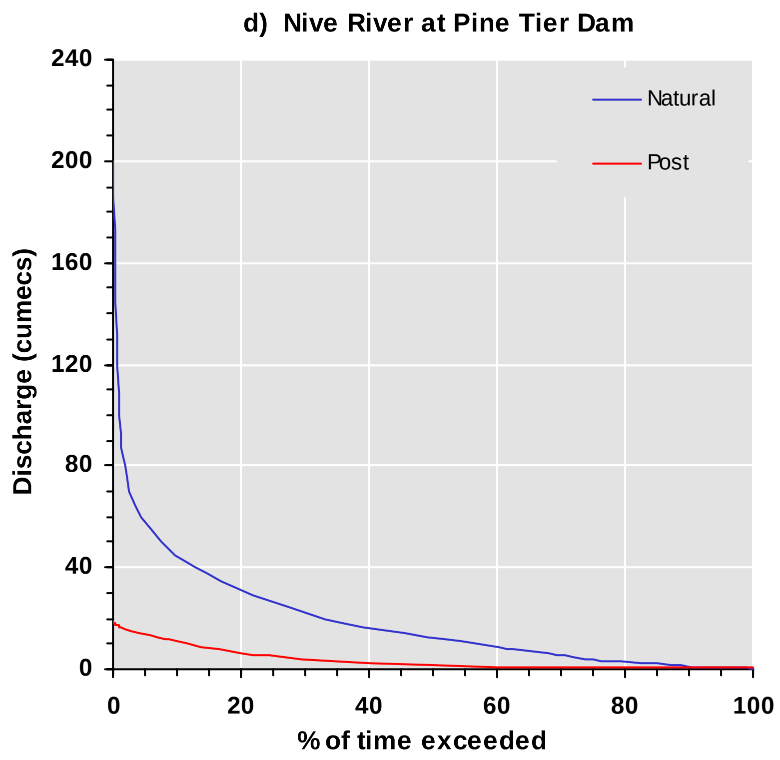
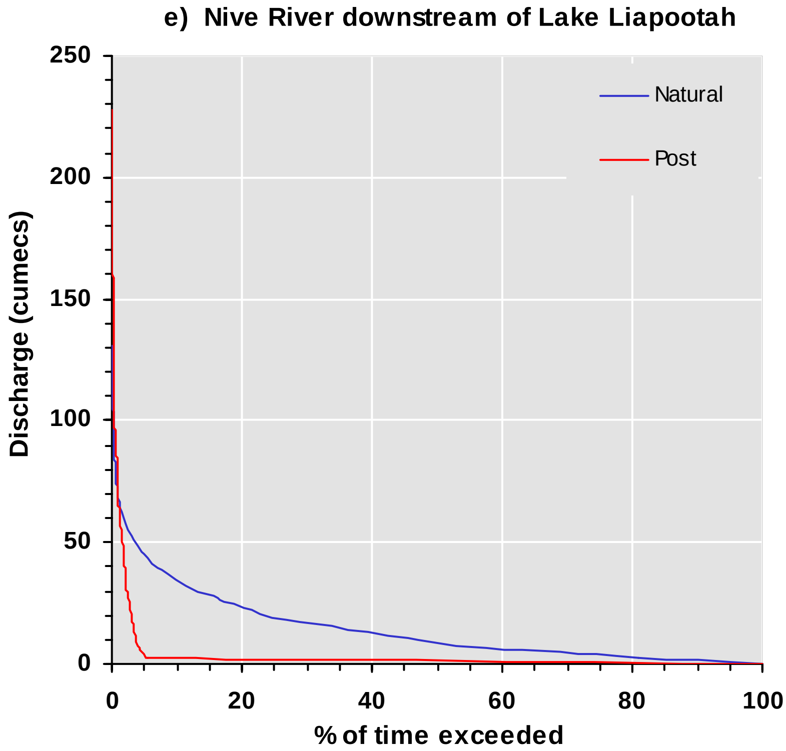


Figure 4.10 cont'd Natural and Post Development Flow Duration Curves Downstream of Hydro Tasmania Structures in the Derwent Power Scheme



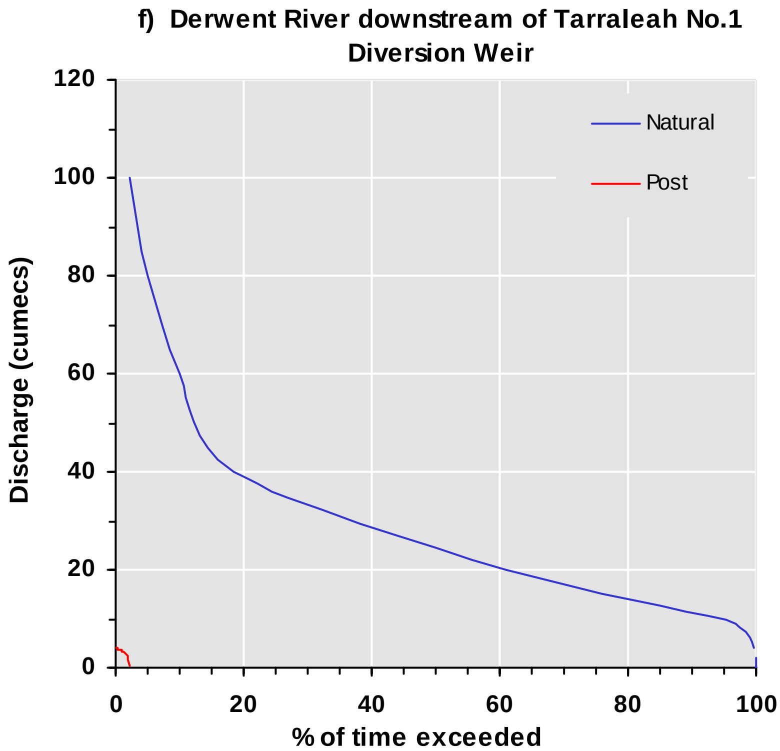
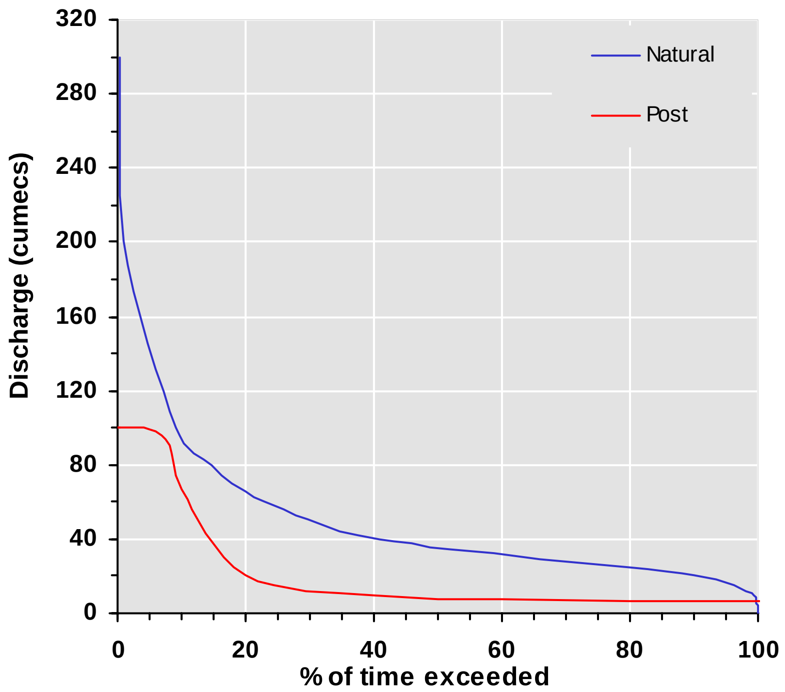


Figure 4.10 cont'd Natural and Post Development Flow Duration Curves Downstream of Hydro Tasmania Structures in the Derwent Power Scheme

g) Derwent River above Nive River



h) Derwent River at Meadowbank Dam

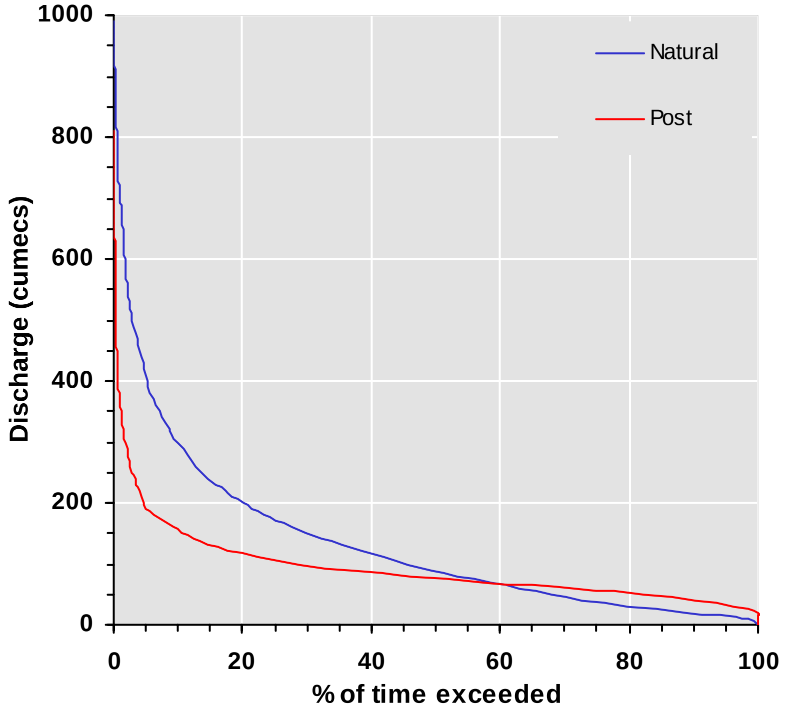


Figure 4.10 cont'd Natural and Post Development Flow Duration Curves Downstream of Hydro Tasmania Structures in the Derwent Power Scheme

4.5.1 Alterations to Seasonal Discharge Patterns

As well as altering percentile discharge values, Hydro Tasmania operations may affect the seasonal patterns of discharge. Under natural conditions, discharge in Tasmanian streams is usually high in winter-spring and low in summer-autumn. Hydro Tasmania power stations may be operated in patterns that are different from this. For example, power stations on larger interseasonal and interannual storages are generally run at higher capacity during the summer months when smaller power stations may be conserving storage. Similarly, reservoirs used for irrigation supply tend to store most of the winter inflows but release larger-than-natural discharges during the summer irrigation season.

4.5.2 Alterations to Short-term Discharge Patterns

Hydro Tasmania operations can have an effect on discharge patterns in the short-term. Relatively sudden surges or recessions in discharge can result from the operation of release valves for riparian or other uses. Power stations that do not operate 24 hours per day will produce pulses in the downstream discharge pattern as the station commences and ceases generation.

5. WATER QUALITY ISSUES

This is the first of four chapters outlining the current state of knowledge on environmental issues in the Derwent Catchment. The four chapters cover known environmental issues relating to water quality (this chapter), biological issues (Chapter 6), geomorphological issues (Chapter 7) and multiple use and community values (Chapter 8). The range of issues in the Derwent Catchment is then summarised in Chapter 9.

This review of water quality in the Derwent Catchment is presented with a generally downstream orientation. The chapter begins with an overview of water quality monitoring that has been undertaken. Water quality in the upper Derwent River, the Nive-Dee sub-catchment, the lower Derwent River and tributaries, and the Derwent River below Lake Meadowbank is outlined in sections 5.2 to 5.5. The chapter then concludes with a summary of the main water quality concerns in the Derwent Catchment.

The information in this chapter was obtained by a desktop study of information from the Inland Fisheries Service Biological Consultancy (IFSBC). This group has been providing consultancy services on water quality and biological issues to Hydro Tasmania since 1991, and their activities and findings have been presented in Annual Progress Reports between 1992 and 1997. In more recent times the IFSBC has provided services to the Waterway Health Monitoring Program (WHMP) which now reports on the condition of Hydro Tasmania waterways. . Other information that has been accessed for this review includes unpublished data from the IFSBC, water quality information from DPIWE and data extracted from Hydro Tasmania's TimeStudio database. No new monitoring or field investigations were undertaken.

5.1 Overview of Water Quality Monitoring

The earliest water quality information available in Hydro Tasmania's TimeStudio database dates from the mid-1960s. No water quality information is readily available that documents the 'pre-developed' condition of the Derwent River and historically there has been little water quality monitoring in the catchment.

More recent information is available from monitoring carried out for Hydro Tasmania by the IFSBC, who have routinely monitored lakes in the Derwent Catchment on a rotating basis since about 1991. Table 5.1 lists the lakes and lagoons in the catchment and indicates when waterways have been monitored by the IFSBC. This monitoring has mostly focussed on nutrient levels in lakes, and fewer samples have been collected from rivers and streams in the catchment. Several Hydro Tasmania lakes have not been monitored through this program in the past, including Lake Binney, Lake Liapootah, Laughing Jack Lagoon and Tungatinah Lagoon. Hydro Tasmania's Waterway Health Monitoring Program will regularly sample these lakes in the future.

Recent water quality data for the Derwent Catchment has also been collected through a Landcare sponsored project managed by DPIWE, the 'Inputs of Nutrients in the Derwent Estuary Catchment' study. That program examined the Derwent River and its major tributaries during 1996 and 1997 (Coughanowr, in prep). The monitoring locations along the Derwent included in that program were at Tarraleah Canal, Derwent River at Glen Dhu, Derwent River below Meadowbank Dam, and Derwent River at Bryn Estyn. The results of the program provide a summary of the downstream nutrient and water quality trends.

Some surface water quality monitoring was also carried out by the Parks and Wildlife Service (PWS) at various locations in Lake St. Clair in 1995/96 (Davies and Driessen, 1997). This work was undertaken as part of a pilot program for surface water monitoring within the Tasmanian Wilderness World Heritage Area, and fulfilled the requirements for ambient water quality monitoring outlined in the WHA Management Plan (PWS, 1999). Sampling sites in Lake St. Clair were located at Pumphouse Point, Cynthias Bay, Echo Point and Narcissus Bay. The data collected included physico-chemical characteristics, nutrient concentrations and levels of faecal bacteria.

Table 5.1 IFSBC monitoring in the Derwent Catchment, 1991 – 2001

Water Body	91 –92	92 - 93	93 - 94	94 - 95	95 – 96	96 - 97	97 - 98	00 – 01
Lake Ada	X			X			X	
Bradys Lake			X			X		X
Bronte Lagoon			X			X		X
Cluny Lagoon		X			X			
Clarence Lagoon	X			X			X	
Dee Lagoon	X			X			X	X
Lagoon of Islands/Ripple Canal	X	X	X	X	X	X	X	
Lake Binney								X
Lake Catagunya		X			X			
Lake Echo	X			X			X	X
Lake King William		X			X			X
Lake Liapootah								X
Lake Meadowbank		X			X			
Lake Repulse		X			X			
Lake St. Clair		X			X			X
Laughing Jack Lagoon								X
Little Pine Lagoon	X			X			X	X
Penstock	X	X	X	X	X	X	X	X
Pine Tier Lagoon			X			X		X
Shannon Lagoon							X	X
Tungatinah Lagoon								X
Wayatinah Lagoon		X			X			

Note: Data from the 2000-2001 program still being compiled.

5.2 The Upper Derwent Catchment above Tarraleah

The western headwaters of the Derwent River are situated within the Cradle Mountain – Lake St. Clair National Park and it would therefore be expected that water quality in Lake St. Clair which is at the top of the Derwent River, would be ‘pristine’. The catchment feeding Lake King William comprises the national park along with Forestry and Hydro Tasmania managed lands, and this water would also be expected to be of a very high quality.

Historic water quality information in Hydro Tasmania’s TimeStudio database provides an overview of water quality in Lake St. Clair and demonstrates the extremely dilute nature of the water body. Very low conductivities and hardness values demonstrate the low ionic strength of the water. One reason for the low conductivity is because of the lake’s position in the centre of Tasmania, largely removed from wind-carried marine aerosols. This is further supported by the low sodium and chloride values. Historic temperature profiles of the lake indicate that there are large seasonal temperature changes within the top thirty metres of the lake (Figure 5.1).

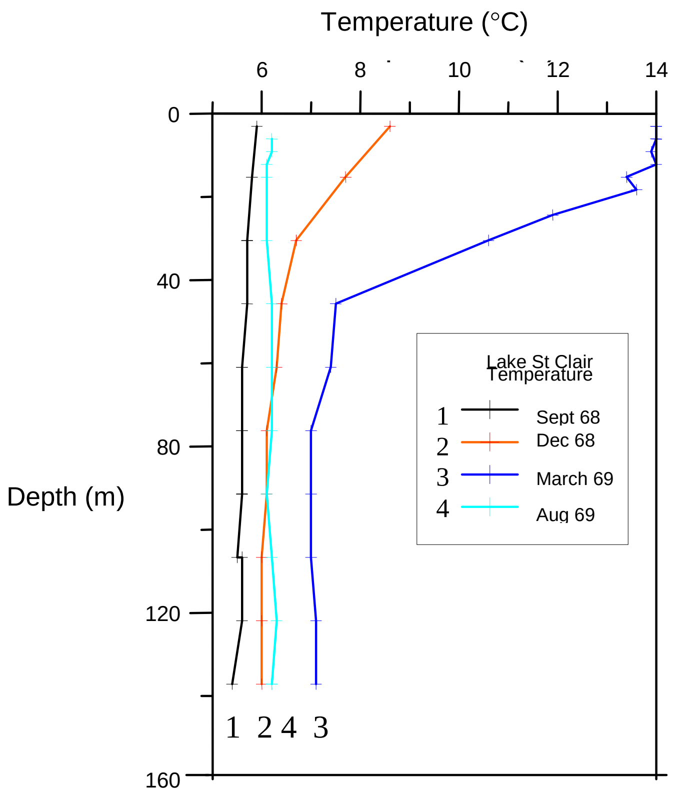


Figure 5.1 **Seasonal temperature changes with depth in Lake St. Clair (Data from Hydro Tasmania's Timestudio Database)**

Recent profiling in the lake under the Waterway Health Monitoring Program (March 2001) has shown that while there is a strong thermocline located at about 20m depth, there is minimal deoxygenation of deeper waters (Figure 5.2).

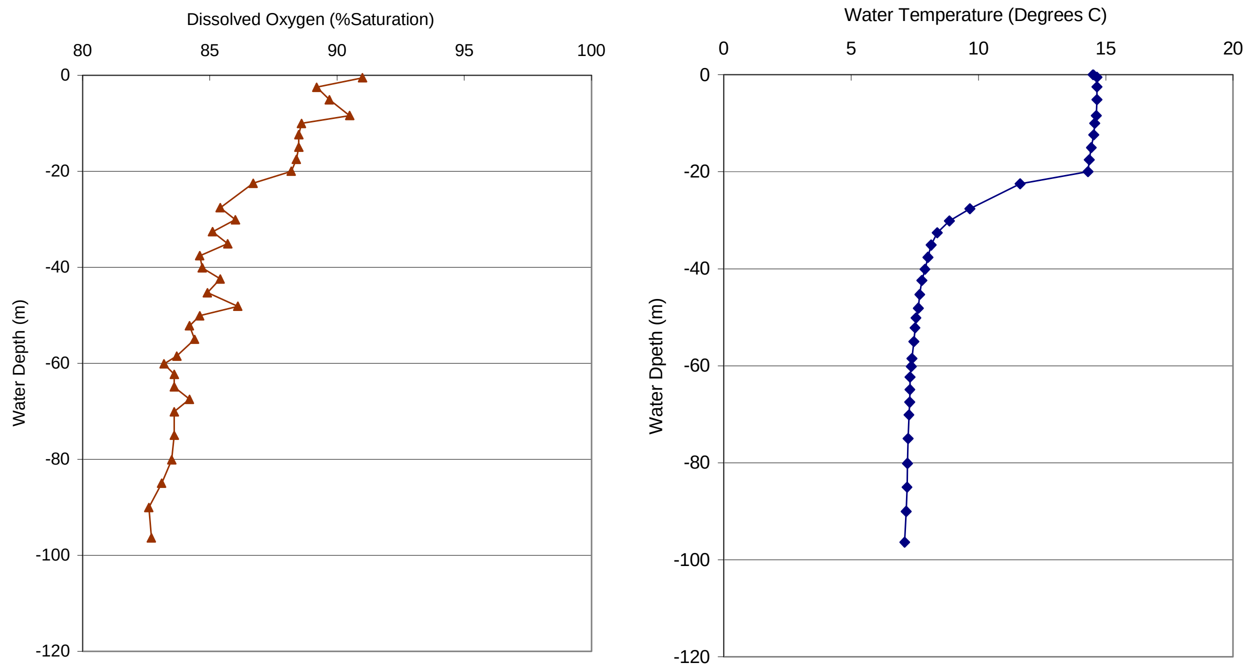


Figure 5.2 **Profiles for Dissolved Oxygen and Water Temperature with Depth in Lake St. Clair**

Monitoring results obtained by the IFSBC from Lake St. Clair during 1992-1993 and 1995-1996 are consistent with the historical data, with Lake St. Clair generally having the lowest concentrations of nutrients and chlorophyll-*a* of all lakes in the Derwent Catchment (Appendix 3). These values are well below the WHMP 1998 indicator values for potential problems relating to nutrients, chlorophyll-*a* and turbidity (Table 5.2).

Table 5.2 IFSBC monitoring results from the 1995-1996 sampling program

	Chl-*a* (µg/L)		pH	Turb.	Cond.	Ammonia	TKN	Nitrate	Total P	Reactive P	Fe	Mn
	mean	max		(NTU)	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Lake St. Clair	0.35	0.8	6.5	0.5	23.7	5	8	15	4	1	62	10
Lake King William	1.07	1.8	6.6	0.9	25.3	6	117	8	4	1	131	10
WHMP Indicator Level	*10*			*10*			*500*		*20*		*1000*	
ANZECC 92	*2-10*					*20-30*			*10-100*			

The data from the PWS pilot program (Table 5.3) provides further evidence that water throughout Lake St. Clair is very dilute, very clear and low in nutrients. Although not presented here, data on bacterial levels around the lake showed that water in the lake generally complied with national guidelines for both primary and secondary contact (NHMRC, 1996), though bacterial levels in Cynthia Bay were found to exceed primary contact guidelines on one occasion when there was strong wave action.

Table 5.3 Surface Water Quality results from Lake St. Clair reported by the PWS Pilot Monitoring Program 1995-1996. (All data reported as median values)

	No. Samples	Turb.	Cond.	Nitrate	Ammonia	TN	Reactive P	Total P
		(NTU)	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L
Pumphouse Point	22	0.3	22.0	15	2	83	1	1
Cynthia Point	22	0.4	22.5	13	2	89	1	1
Echo Point	22	0.35	22.5	11	2	95	1	2
Narcissus	33	0.4	24.5	2	1	87	1	1

Note: Most sites were sampled at 2 or more locations. For the purposes of this report, site data have been grouped

IFSBC results for Lake King William (Table 5.2) also indicate that water within the lake is very dilute and of good quality. Mean chlorophyll-*a* values, turbidity readings and total iron concentrations are higher in Lake King William than in Lake St. Clair, though still very low within the Tasmanian context. The higher values in Lake King William are probably attributable to differences in lake morphology and substrate. Lake King William is also an artificially constructed impoundment, whereas Lake St. Clair is a natural lake whose level has been raised slightly. Past forestry practices in the catchment of Lake King William may also make some contribution to this difference in water quality, however there is no evidence to support this hypothesis at this stage.

The DPIWE water quality results from Tarraleah Canal No.1 (recorded below Butlers Gorge Power Station) confirm the low nutrient status, low conductivity (approx. 20 µS/cm) and low turbidity (<2 NTU) of water discharged from Lake King William (Coughanowr, in prep).

5.3 The Nive and Dee Catchments above Tungatinah

Unlike the Derwent headwaters, land use in the Nive and Dee catchments is not limited to conservation and forestry. A considerable amount of private land has been cleared and is primarily used for broad-acre cattle and sheep grazing.

Historical monitoring data in Hydro Tasmania's database is extremely limited for the Clarence, Nive, Pine and Dee rivers (Appendix 3), with pH and temperature measurements at Gowan Brae on the Nive, and only three water samples in Lake Echo.

More recent data from the IFSBC monitoring program (Table 5.4) indicates that, like the Derwent headwaters, these are also very soft, dilute and contain low concentrations of nutrients. Lake Naomi and Olive Lagoon are situated in the headwaters of the Nive River in the Central Plateau Protected Area, and would be expected to reflect 'natural' conditions. The downstream lakes in the Nive River system: Pine Tier Lagoon, Bronte Lagoon and Bradys Lake are similar in characteristic to the upstream lakes, though turbidity and total iron values are slightly higher. Unpublished physico-chemical profiles collected by the IFSBC in July 1997 indicate that both Pine Tier Lagoon and Bradys Lake were uniform with depth with respect to dissolved oxygen, temperature, pH and conductivity during the winter period.

Table 5.4 Mean IFSBC monitoring results from the 1994-1995 and 1995-1996 sampling program

	Chl-*a* (µg/L)		pH	Turb.	Cond.	Ammonia N	TKN	Nitrate N	Total P	Reactive P	Total Fe	Total Mn
Lake	mean	max		(NTU)	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Lake Naomi	1.00	2.58	6.5	0.8	19	3	150	0.006	<5	<1	<100	<10
Olive Lagoon	0.69	1.63	6.4	0.6	17	4	1 20	0.007	5	<1	<100	<10
Pine Tier	0.383	1.15	6.69	2.0	23	9	142	0.001	4	1	180	10
Clarence Lagoon	0.78	1.73	6.22	1.8	22	1	170	0.01	6	1	190	10
Bronte	0.763	1.95	6.69	4.3	21	6	175	0.002	4	1	360	20
Lake Ada	2.08	7.25	6.92	6.6	24	4	329	0.01	16	2	760	60
Little Pine	3.06	15.3	6.7	3.9	25	3	315	0.001	21	3	430	20
Lake Echo	0.57	1.11	6.8	1.0	28	2	115	0.002	6	<1	120	<10
Dee Lagoon (PS)	0.90	1.49	6.9	1.4	30	2	154	0.001	7	1	150	<10
Dee Lagoon (Mentmore)	2.63	6.71	7.08	4.7	46	4	370	0.007	16	1	670	30
Bradys	0.959	1.90	6.69	2.5	25	5	153	0.002	7	1	220	10
WHMP Trigger Level	*10*			*10*			*500*		*20*		*1000*	
ANZECC 92	*2-10*					*20-30*			*10-100*			

Mean chlorophyll-*a* and turbidity values for Little Pine Lagoon and Mentmore Marsh (Dee Lagoon) are considerably higher than most other lakes in the region (Figure 5.3). The maximum recorded at Little Pine (15.3 µg/L) exceeded the WHMP indicator level. This is attributed to a sample in March 1995. Other high parameter values were measured under extremely windy conditions (October, 1995) that stirred up the lake, resulting in turbidity readings of 14 NTU and higher nutrient levels in the water column (Blühdorn, *et al.*, 1998). Total iron concentrations during the same sampling were also very high (940 µg/L) further demonstrating the impact of wind driven resuspension of sediments on water quality in the lagoon.

The highest chlorophyll-*a* values at many lakes occurred during the March sampling period of 1995 and coincided with elevated results in other water bodies such as Penstock Lagoon and Lake Sorell. During the March sampling, the TKN value was equivalent to the WHMP indicator level (500 µg/L), and the Total P value for Little Pine exceeded the WHMP indicator level of 20 µg/L (IFS unpublished monitoring results).

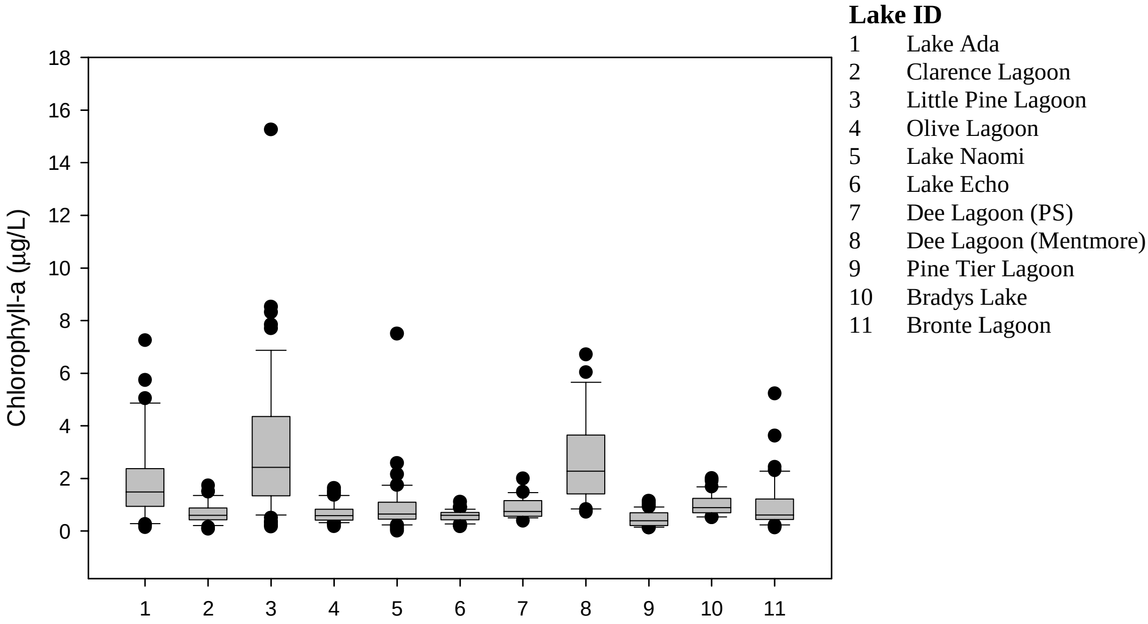


Figure 5.3 Box and Whisker plot showing the chlorophyll-*a* data from lakes in the upper Derwent Catchment

Note: Box plots display the median (or the middle of the data) as a line across the inside of the box. The bottom and top edges of the box mark the first and third quartiles respectively, indicating the middle 50% of the data. The whiskers together enclose 95% of the data and the dots show the extremes.

It is also worth noting that chlorophyll-*a* concentrations in Lake Ada can reach moderately high levels. Although this lake lies within the Conservation Area and is not regulated by Hydro Tasmania or subject to significant land disturbance, it is subject to periods of increased productivity. Like Little Pine Lagoon, Lake Ada is very exposed and subject to wind-driven turbulence, and high chlorophyll-*a* measurements clearly coincide with peaks in turbidity.

Elevated chlorophyll-*a* concentrations at Mentmore Marsh (Dee Lagoon) indicate the greater productivity of this part of Dee Lagoon, where shallower depths and local run-off have combined to produce local eutrophication compared to elsewhere in the lagoon. Conductivity values at this end of Dee Lagoon are also significantly higher than other sites within this lake, and may either by related to the presence of limestone in the catchment of Mentmore Creek or the influence of local run-off.

Lake Echo and most of Dee Lagoon (represented by data from the south-eastern bay) are characterised by low values for all water quality parameters recorded by the IFSBC. Physico-chemical profiles recorded by the WHMP in February, March and May of 1998 in Lake Echo and Dee Lagoon are generally uniform with depth. In the summer months, surface and bottom temperatures varied by a couple of degrees, however there is no indication of reduced oxygen concentrations at depth due to thermal stratification. The lakes also appear to be remarkably homogenous over time as well as depth. The conductivity values in the 2 lakes varied less than 1 µS/cm over the monitoring period (Feb – May, 1998) and pH and dissolved oxygen values remained relatively constant. Occasional high turbidity levels in Dee Lagoon are associated with erosion from Lake Echo Power Station forebay spillway. High turbidity has been recorded at the southern end of Lake Echo as a result of low lake levels and high winds. This water has subsequently been released from Echo Power Station into Dee Lagoon, causing short-term localised turbidity events.

The 1996-1997 DPIWE study monitored Tungatinah Lagoon at the inlet to the power station. This sampling point provides an indication of integrated water quality from the Clarence, upper Nive, and Dee rivers. The approximate ranges of concentrations (n = 6 - 9) were: pH of 6-7; conductivity less than 40µg/L; turbidity 0.5 - 3.5 NTU; total phosphorus of 3 – 9 µg/L; PO_4 of 2 – 4 µg/L; ammonia of 1-8 µg/L, nitrate + nitrite of 2-16 µg/L and total nitrogen of 100-150 µg/L (Coughanowr, unpublished data).

5.4 The Lower Derwent and Tributaries (including the Ouse Catchment)

The waterways that are considered as part of the lower Derwent system include Lake Liapootah and Wayatinah Lagoon, Lake Catagunya, Lake Repulse, Cluny Lagoon and Lake Meadowbank. Although Lake Liapootah and Wayatinah Lagoon are on the Nive River, they are part of the cascade of storages and power stations that make up the lower Derwent system. The major tributaries feeding these lakes are the Florentine, Broad, Dee, Ouse, and Clyde rivers.

5.4.1 Florentine and Broad Rivers

The largest tributary of the lower Derwent system is the Florentine River. This tributary contributes approximately 11% of the total flow at Lake Meadowbank, or about 30% of the Derwent River flow derived below Tarraleah and Tungatinah. The river drains the parts of Mt Field National Park and other crown land managed for forestry. Historic monitoring (Appendix 3) and recent DPIWE results show elevated conductivities in the Florentine River, with values of up to about 400 μS/cm documented by DPIWE (Coughanowr, in prep). The elevated conductivity values and possibly the nitrate values have been attributed to the presence of limestone in the Florentine catchment. DPIWE has also reported that the presence of a fish hatchery near the confluence with the Derwent River results in higher ammonia, total nitrogen and temperature values below the farm, compared to upstream (Coughanowr, in prep).

The Broad River also drains part of Mt Field National Park, entering the Derwent system at the top end of Cluny Lagoon. The Broad flows through Crown land, and its water quality characteristics are similar to the waters above Wayatinah, with low median values for all water quality parameters (Coughanowr, in prep).

5.4.2 Dee, Ouse and Clyde Rivers

The tributaries entering the middle Derwent River from the eastern side differ significantly from the Florentine and Broad rivers, with agriculture a major land use activity. The hydrology of the Dee and Ouse catchments is highly modified, with diversions directing flows into Lake Echo, Dee Lagoon and the Lagoon of Islands. The IFSBC have documented direct relationships between water quality and water quantity in the upper Ouse catchment (Blühdorn et al., 1996). Recent monitoring of the Dee and Ouse rivers upstream of where they enter the Derwent system was part of DPIWE's 'Inputs of Nutrients in the Derwent Estuary Catchment' study (Coughanowr, in prep). The Clyde River was also monitored upstream of Lake Meadowbank. Table 5.5 contains the 10^{th} to 90^{th} percentile ranges for these sites. Higher concentrations were recorded during a flood event when catchment run-off resulted in large increases in many water quality parameter values.

Table 5.5 10 – 90^{th} percentile ranges in water quality parameters from the DPIWE Input of Nutrients to the Derwent Estuary Catchment Study (Coughanowr, in prep)

	pH	**Cond** (μS/cm)	**Turb** (NTU)	**NH_3 – N** (μg/L)	**NO_2 + NO_3** (μg/L)	**Total N** (μg/L)	**PO_4 – P** (μg/L)	**Total P** (μg/L)
Dee River	7.2-8.2	100-600	1-14	2-10	2-16	250-375	4-7	8-37
Ouse River	6.8-7.5	75-225	2-10	2-24	8-35	220-750	4-10	11-55
Clyde River	7.4-8.0	175-325	4-20	2-22	12-50	500-1100	4-12	26-50
ANZECC 92				*20-30*		*100-750*		*10-100*

The values in Table 5.5 compared with those in Tables 5.3 and 5.4 indicate that these tributaries have considerably higher concentrations of nutrients than the upstream tributaries. However, because there is relatively low flow in these rivers compared to the volume of water in the Derwent, the input of these rivers has little overall effect on the water quality of Hydro Tasmania impoundments. Based on ANZECC guideline values (Table 5.5), the Dee and Ouse rivers potentially exceed recommended values for total nitrogen and total phosphorus, with the Clyde results potentially exceeding both these values and also ammonia guidelines. Water quality in the Clyde River is strongly affected by the water released from Lake Crescent, a non-Hydro Tasmania lake in its upper catchment. Severe water quality problems in this lake have been identified, and the IFS and other State government agencies are currently developing appropriate management strategies. Table 5.6 gives mean water quality values for Lake Crescent.

Table 5.6 Mean IFS monitoring results from Lake Crescent between 1991 and 1998.

	Chl-*a* (µg/L)		pH	Turb.	Cond.	Ammonia N	TKN	Nitrate N	Total P	Reactive P	Total Fe	Total Mn
Lake	mean	max		(NTU)	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Lake Crescent	27.7	89.5	7.36	39.4	92	11	1510	11	60	5	2290	71

5.4.3 Upper Ouse Catchment

Within the Ouse catchment, a number of water quality issues have been identified associated with the impoundment and release of water from Shannon Lagoon and the Lagoon of Islands. Hydro Tasmania, through the IFSBC, has investigated water quality in the Lagoon of Islands and in the catchment as a whole.

Lagoon of Islands

Prior to 1964, the present area occupied by the Lagoon of Islands in the headwaters of the Shannon River was a natural marsh with floating mats of reeds and small islands of terrestrial plants (Tyler, 1976a, 1976b). Hydro Tasmania and the IFS dammed the lagoon in 1964 to provide an additional water supply to meet irrigation demand in the Shannon and Ouse rivers, and to develop a recreational trout fishery (Sanger, 1992). The higher water levels resulted in the death of the terrestrial plant communities in the late 1970’s and early 1980’s. In 1984, the Ripple Creek Diversion was constructed to increase yield from the lagoon, and water levels in the lagoon were maintained at a high level during the mid 1980’s (Sanger, 1992). Accompanying these changes was a decline in the condition of fish caught in the lagoon, increasing nutrient concentrations and increasing algal growth and turbidity.

Initial scientific investigations into the problem concluded that the nutrient release associated with the break up of the reed mats and greater input from Ripple Canal was fuelling algal blooms in the storage. Land use practices in the area were also highlighted as contributing to the introduction of biologically available nutrients into the lagoon (Sanger, 1992). Interim management strategies were developed and implemented that aimed to reduce nutrient input and encourage the growth of strapweed (*Triglochin procera*) in the lagoon. It was suggested that increased strapweed growth would stabilise bottom sediments and remove some of the dissolved nutrients from the water column (Sanger, 1992).

These strategies were successful for a number of years, resulting in a decrease in algal activity and a dramatic improvement in fish condition. However in 1996, total nitrogen, total phosphorus, ammonia and chlorophyll-*a* concentrations began to increase. In a review of the monitoring data, Blühdorn *et al.* (1998) suggest these increases could be due to the high water level maintained in the lagoon through 1996. It was also suggested that the strapweed may have reached a successional point where the production of nutrients during its annual winter senescence exceeds the ability of the lagoon ecosystem to absorb them (Blühdorn *et al.*, 1998).

Elevated phosphorus and iron concentrations from Ripple Canal have also been identified as contributing to the worsening water quality in the lagoon. An increase in TP concentration in the lagoon in 1997 has been directly related to an increase in sediment flux from Ripple Canal and is associated with the failure of a trash rack in the canal (Blühdorn *et al.*, 1998). The lagoon has been identified as being phosphorus limited, and this event led to an increase in chlorophyll-*a* concentrations in 1997 (Blühdorn *et al.*, 1998).

Downstream of the Lagoon of Islands, water quality issues associated with release of water from the lagoon into Blackburn Creek and the Shannon River have been identified and investigated by the IFSBC for Hydro Tasmania. Monthly monitoring in Blackburn Creek showed that when discharge from Lagoon of Islands ceased between May and November 1995: flow in the creek decreased from approximately 0.3 - 0.4 m^3/s to between 0.01-0.1m^3/s; chlorophyll-*a* concentrations decreased from 2-4μg/L to ≤1μg/L; iron concentrations increased from ≤ 1000 μg/L to >2500 μg/L; and turbidity increased from <10 NTU to >25 NTU. These water quality changes were found to be localised and not apparent at down stream monitoring sites.

Shannon Lagoon

Wind-induced turbidity has been a water quality issue in Shannon Lagoon for a long time. Turbidity values exceeding 20 NTU were recorded by the IFSBC in 1992. The IFS attempted to stabilise the bed of the lagoon through the establishment of aquatic plants. Unfortunately, the initial trials in the early 1990's were inconclusive, and limited resources resulted in a suspension of the trials.

The seasonal release of water from Shannon Lagoon into the Shannon River also results in downstream water quality issues. Of primary concern are the greatly elevated turbidity and iron levels present in the upper Shannon River during periods of water release from the lagoon. Chlorophyll-*a* concentrations are slightly elevated during periods of release, though the overall concentrations are fairly low (1-3 μg/L during lagoon discharge, <1 μg/L at other times). The overall conclusions from the available data are that the turbidity is largely derived from wind-driven resuspension of lagoon sediments, rather than originating from algal activity.

This is in marked contrast to conditions producing turbidity in Blackburn Creek downstream of the Lagoon of Islands. In Blackburn Creek, turbidity is inversely correlated with lagoon discharge, whereas in the Shannon River there is a direct correlation. This suggests that different 'in lagoon' and 'in stream' processes are controlling turbidity in the two systems.

Penstock Lagoon

With the closure of the Waddamana B Power Station in 1994, the throughput of water in Penstock Lagoon ceased, and water levels were increased. The alterations resulted in significant increases in turbidity and algal growth in the lagoon (Blühdorn *et al.*, 1998).

Modifications to the lagoon and establishment of a target water level in 1995 alleviated the algal problem, although turbidity continued to be a problem (Blühdorn *et al.*, 1995). This was attributed to the wind induced suspension of sediments in the shallow lagoon and, more turbid inflows from Shannon Lagoon. Additional modifications were carried out on the active inflow canal (Waddamana No. 2) to increase inflow to the lagoon and reduce the need for water inputs from Shannon Lagoon, while maintaining an adequate water level (Blühdorn *et al.*, 1998).

During monitoring in 1996-97, chlorophyll-*a* concentrations exceeded the WHMP indicator level (10 μg/L) four out of sixteen times, while the turbidity indicator value (10 NTU) was exceeded on all but one occasion. Nutrient and iron concentrations were high within the lagoon, though low in input waters, suggesting that the lagoon is a significant source of these elements. Later monitoring during 1998-99 showed that conditions had improved, with average chlorophyll-a levels of 5 μg/L. Turbidity was also lower (Hydro Electric Corporation, 1999b). Nutrient concentrations continue to exceed the WHMP indicator levels.

5.4.4 Middle and lower Ouse catchment

Downstream of the Hydro Tasmania-managed lagoons (Shannon, Penstock and Lagoon of Islands), the Ouse catchment is utilised extensively for agriculture. Monitoring of water quality in the catchment by the IFSBC between 1994 and 1996 indicated that although the water quality in the catchment was generally good, there was a general increase in conductivity down the catchment, and nutrient concentrations in the lower river were undesirably high. These results are consistent with the DPIWE monitoring of the lower Ouse River (Table 5.5).

Land use practices are suggested by the IFS as being a major contributor to poor water quality in the lower Ouse River. Boggy Marsh Rivulet, an unregulated catchment containing intensive agricultural activities, was found to have particularly degraded water quality (Blühdorn, *et al.*, 1998).

5.4.5 Lake Liapootah and Wayatinah Lagoon (lower Nive River)

Limited historical water quality data for Lake Liapootah and Wayatinah Lagoon are stored in Hydro Tasmania's TimeStudio database (Appendix 3). The few data available indicate that in the late 1960s, water quality in Lake Liapootah and Wayatinah Lagoon was similar to that of the upper catchment today. Similarly, more recent monitoring results obtained at Wayatinah Lagoon (Table 5.7) show that water quality in the lagoon is very similar to waters upstream (Tables 5.2 and 5.4) . This is not surprising, as there is little new water added to the system between Tarraleah and Wayatinah Lagoon, and the surrounding catchment area is predominantly Hydro Tasmania-managed State Forest.

5.4.6 Lake Catagunya to Lake Meadowbank

Approximately 60% of the total flow in the Derwent system at Meadowbank originates from the upper Derwent Catchment, where the water is characteristically dilute and low in nutrients. In the reaches between Wayatinah Lagoon and Lake Meadowbank, a further 24% of the flow is derived from the major tributaries (the Florentine, Broad, Dee, Ouse and Clyde rivers), with the remainder attributable to small creeks, direct run-off into the lakes, and incident precipitation. As outlined in the section above, these tributaries are subject to different land use pressures and their water quality varies.

Table 5.7 IFSBC monitoring results from the 1995 –1996 sampling program

Lake	Chl-*a* (µg/L)		pH	Turb.	Cond.	Ammonia N	TKN	Nitrate	Total P	Reactive P	Total Fe	Total Mn
	mean	max		(NTU)	µS/cm	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Wayatinah	0.77	1.25	7.0	1.9	32.2	6	147	9	7	<1	200	13
Catagunya	0.87	2.01	7.1	1.6	48.4	6	140	14	6	<1	215	13
Repulse	0.75	1.33	7.0	1.7	52.9	7	143	16	6	<1	237	13
Cluny	0.67	1.24	7.1	1.7	52.5	7	151	16	5	1	242	13
Meadowbank	1.01	2.45	7.1	1.9	62.5	5	168	15	8	2	240	13
WHMP Trigger Level	*10*			*10*			*500*		*20*		*1000*	
ANZECC 92	*2-10*					*20-30*			*10-100*			

The IFSBC monitoring results outlined in Table 5.7 show that in the lakes below Wayatinah Lagoon, there is a slight jump in average conductivity and nitrate values. This is related to the discharge of the Florentine River into Lake Catagunya. Below Lake Catagunya, the results show a small but gradual increase in conductivity, TKN and iron in a downstream direction. However, comparing average values in Lake Catagunya with Lake Meadowbank suggests that downstream changes are minor, and the water exiting Lake Meadowbank is still dilute and of high quality in terms of nutrient concentrations.

5.5 The Derwent below Meadowbank Dam

5.5.1 Tributaries of the lower Derwent

Four major tributaries enter the Derwent River below Meadowbank Dam and above the broadening of the estuary at Hobart: the Tyenna, Styx, Plenty and Jordan rivers. The headwaters of the Tyenna, Styx and Plenty rivers are generally within conservation areas or areas managed for forestry with the lower catchments consisting of private property. Water quality in the Tyenna River is similar to that of the Florentine River, and may reflect limestone inputs (Coughanowr, in prep). The Styx and Plenty rivers have similar water quality to waterways in the upper Derwent, though nitrate concentrations are higher, and probably reflect impacts from local land use practices.

In the Derwent River between Meadowbank Dam and Bryn Estyn, monitoring has shown that the inputs of these tributaries results in a small increase in total phosphorus (TP), total nitrogen (TN), ammonia, and nitrate+nitrite. Bryn Estyn (upstream of New Norfolk) is the site of Hobart Water's extraction/treatment plant, which supplies drinking water to the Hobart metropolitan area.

Because the average combined flow of the Tyenna, Styx, and Plenty rivers is only about 16 m^3/s, compared with an average flow of almost 100 m^3/s at Meadowbank, inflow from these rivers is greatly diluted. It is therefore not surprising that the quality of water at Bryn Estyn compared to that recorded below Meadowbank shows only a minor increase in TP, TN, ammonia and nitrate+nitrite (Coughanowr, in prep).

Downstream of Bryn Estyn the Jordon River enters the Derwent. The Jordan is characterised by fairly high levels of nutrients. However the flow of this river is highly impacted by irrigation extraction, resulting in an average flow of less than 1 m^3/s.

5.5.2 Derwent Estuary

Municipal and industrial discharge points as well as urban and suburban run-off enter the Derwent Estuary. Historically, poor sewage treatment combined with metalliferous and organic-rich industrial discharges have resulted in a highly impacted estuarine environment. A full description of water quality issues in the Derwent Estuary is beyond the scope of this report. However a summary of the status of the Derwent Estuary was published in 1997 in the *'State of the Derwent Report'* (Coughanowr, 1997). More recently, the Derwent Estuary Project has been launched. This is managed by DPIWE and funded through the NHT Coastal and Marine Planning Program. The ultimate aim of the project is to identify 'Protected Environmental Values' (PEV's) for the estuary and develop and implement management plans aimed at achieving these objectives. As a regulator of the major freshwater flow entering the Derwent Estuary, it is important that Hydro Tasmania is aware of, and involved in, this cooperative program.

There are a number of estuarine impacts related to riverine flow regulation. The magnitudes of these impacts are largely undocumented, but include:

- Reduction and changes in discharge patterns due to regulated and diverted flows. About 75% of the catchment is regulated by hydro-generation infrastructure. The effects of this infrastructure may be less than it appears, as the storages and power schemes below Lake King William are 'run-of-river' schemes and discharge patterns grossly mimic natural patterns, at least on a seasonal scale. The diversion of flow from the Dee, Shannon and Ouse rivers would alter the timing of floodwaters from these systems entering the estuary. The diversion of water out of the Derwent Catchment and into the South Esk (through the Poatina Power Station) results in approximately a 10% reduction in total discharge to the Derwent.

- The discharge in the Derwent River directly affects the position and movement of the saltwater wedge within the estuary. Alterations to discharge may affect the dissolved oxygen characteristics of bottom waters in the estuary, the water-sediment interface, and the transport of material within the estuary. Hydro Tasmania currently has an agreement to maintain sufficient flows in the Derwent River below Lake Meadowbank (20-25 m^3/s) to ensure the salt wedge does not interfere with water intake for the Boyer mill.
- The Derwent storages create a chain of sediment traps that prevent the downstream movement of bedload material. The diversion of the Dee, Shannon, and Ouse rivers headwaters reduces the sediment carrying capacity of these rivers, and larger storm events are now required to move the material that was previously transported on a more frequent basis. The reduction of sediment transport to and deposition in the estuary has implications for the rate of burial of contaminated sediments.

5.6 Summary of Water Quality Issues

Water quality in the Derwent Catchment is generally well documented. The only obvious information gap is the lack of pre-development water quality information. Overall, water quality in the Derwent Catchment is very good. There are a number of waterways where water quality is or could potentially become an issue. However, these issues are not necessarily related to Hydro Tasmania operations, but may be linked to other land use practices and environmental influences. Water quality issues that are relevant to Hydro Tasmania operations relate both to its role in releasing water to downstream rivers and users, and also to its role as the recipient of water through inflows to its storages.

The good water quality in the Derwent Catchment is attributable to the large volume of water in the system derived from generally unmodified National Parks, conservation and forestry areas. This large volume of very high quality water provides high dilution rates for the relatively small volume of poorer quality water that enters below Wayatinah, mostly from agricultural and diverted tributaries. The high concentrations of nutrients in the Dee and Ouse rivers appear to be the result of land use practices combined with reduced flows due to headwater diversions. The water in the Clyde River, has higher nutrient concentrations than the Dee or Ouse rivers, and is strongly affected by the quality of water discharged from Lake Crescent.

The main issues related to water quality in the Derwent Catchment include, but may not be limited to the following:

- higher chlorophyll-*a* and turbidity levels in Little Pine Lagoon ;
- high levels of nutrients in the Ouse and Clyde rivers, with the Clyde also indicating high levels of ammonia (note: the Clyde River is not affected by Hydro Tasmania operations);
- elevated turbidity, chlorophyll-*a* and nutrients in Lagoon of Islands, related to inputs from Ripple Canal, and at times downstream in Blackburn Creek and the Shannon River, associated with releases from Lagoon of Islands;
- wind-induced turbidity in Shannon Lagoon and elevated turbidity and iron levels in the upper Shannon River associated with releases from Shannon Lagoon;
- occasional high turbidity levels in Dee Lagoon associated with erosion from Lake Echo Power Station forebay spillway or extreme lake levels in Lake Echo; and
- previously high turbidity and algal growth in Penstock Lagoon.

Map 5.1 shows the waterways in the Derwent Catchment that are influenced by Hydro Tasmania operations, and highlights the key water quality issues throughout the catchment (both for Hydro Tasmania and non-Hydro Tasmania waterways).

Through the Waterway Health Monitoring Program, the IFSBC has provided basic information about surface water quality in the upper Derwent Catchment. This program has provided an understanding of water quality in the lakes, and combined with monitoring results from other catchments, is leading to a better understanding of the processes controlling lake eutrophication, nutrient levels in the lakes, and wind induced turbidity.

Over the past decade Hydro Tasmania and the IFS have had moderate success with managing lakes such as Lagoon of Islands based on monitoring information and water level management. However, recent developments in water quality issues in this lake and others in the Hydro Tasmania system (Woods Lake and Shannon Lagoon) suggest that a greater understanding of the processes acting on the lake is required before appropriate long-term management strategies can be developed. In particular, this will require more information on nutrient cycling and sediment processes.

Hydro Tasmania's Aquatic Environmental Policy sets the framework for the organisation to review its environmental performance. Hydro Tasmania is committed to investigating the influence of its operations on affected lakes and rivers and to reporting on its performance in a systematic and open manner. This allows Hydro Tasmania to make water management decisions based on good scientific information.

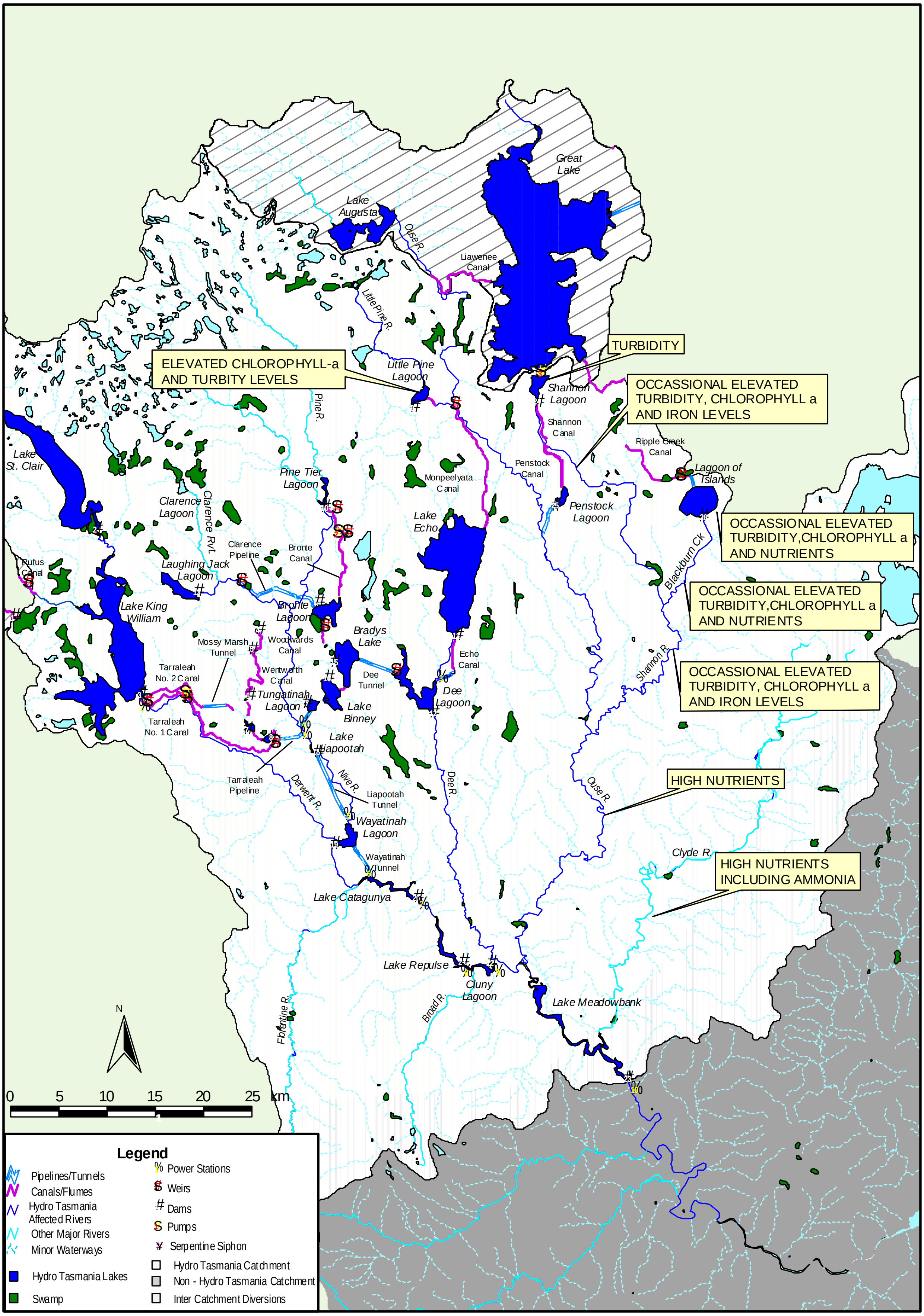
Hydro Tasmania has developed and implemented a Waterway Health Monitoring Program (WHMP) which began in the 1998-1999 financial year, and builds on almost a decade of Hydro Tasmania sponsored water quality monitoring carried out by the IFSBC. The WHMP is based on a routine monitoring program that contains three major elements: water quality, biological assessment and physical condition (Gamble and Locher, 1998).

The water quality component of the WHMP involves monitoring physico-chemical parameters, and is based on three levels of monitoring: routine, investigative and detailed study. The level and frequency of monitoring and the parameters to be monitored are based on an assessment of the waterway characteristics and the current level of knowledge of environmental condition in those waterways.

Most Hydro Tasmania waterways are subject to a routine monitoring program at a minimum. Higher levels of monitoring (ie. investigative monitoring or detailed study) will be implemented for a waterway if the monitoring results show elevations or irregularities in parameters of concern.

Currently in the Derwent Catchment, the IFS and Hydro Tasmania personnel are monitoring Little Pine Lagoon (3 locations), Shannon Lagoon (3 locations), Lagoon of Islands (5 locations) and Penstock Lagoon (3 locations) under an investigative regime. These sites are surface sampled for water quality parameters on 6 occasions throughout the year on every alternate year, and one location at each lake has depth profile data and a nutrient sample taken. All other lakes within the Derwent Catchment are monitored on a less frequent 'routine' program, where lakes are sampled for one year in four.

Hobart Water monitors some basic water quality parameters in the Derwent at the Bryn Estyn water treatment plant on a daily basis (turbidity), and obtains complete water quality analyses, including pesticides and metals, on a quarterly basis. It is critical that water quality at this point in the Derwent River is maintained at a very high standard due to Hobart's reliance on the river for drinking water.



Map 5.1 Overview of Water Quality Issues in the Derwent Catchment

6. BIOLOGICAL ISSUES

This is the second of four chapters that consider the environmental issues related to waterways in the Derwent Catchment. The previous chapter examined water quality, and the following two chapters consider the geomorphological issues and issues related to multiple uses and community values. This chapter outlines biological issues under the headings threatened species (6.1), native fish migration (6.2), and exotic species (6.3). A summary of biological indicators of waterway health is given in section 6.4. A summary of biological issues in waterways throughout the catchment is given in section 6.5.

This review of biological issues consists of a collation of existing information on issues identified in the Derwent Catchment.

6.1 Threatened Species

6.1.1 Threatened Species Classification

This chapter focuses on threatened species as listed by the Tasmanian *Threatened Species Protection Act 1995* which defines threatened in three commonly used progressive categories, based on the International Union for the Conservation of Nature (IUCN) 1994 classification scheme, with adjustments for Tasmanian conditions. These are:

- Endangered (Schedule 3 of the Act).
- Vulnerable (Schedule 4 of the Act).
- Rare (Schedule 5 of the Act).

Other widely applied schemes may also be used, but these do not maintain a purely Tasmanian focus. Of particular interest is the Australian Society for Fish Biology (ASFB) classification scheme.

In addition to the Tasmanian *Threatened Species Protection Act 1995*, there is the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Some threatened species are listed under both acts, indicating their recovery programs are of national importance (eg. the Australian grayling and the great crested grebe).

There are a number of species which are not currently listed on the *Threatened Species Protection Act 1995*, but which have conservation significance. A variety of international, Commonwealth and State agreements and legislation protect international migratory birds. International migratory birds listed under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA) are protected by these international treaties and the *National Parks and Wildlife Act 1970*. Some of these species frequent inland wetlands and thus may be found in Hydro Tasmania managed areas. In addition, Australia is a signatory to the Ramsar Convention, an international treaty to protect critical habitat for international migratory birds. There are 10 Ramsar sites in Tasmania. None of these are located in the Derwent Catchment.

In addition to the above classifications, the Tasmanian Parks and Wildlife Service (PWS) maintains lists of rare or conservation-significant species under the following classifications:

- Indeterminate: Taxa which are likely to fall into the endangered, vulnerable or rare (potentially threatened) category but for which insufficient data are available to make an assessment (require investigation).
- Restricted: Taxa which are not presently in danger but which occur in restricted areas, or which have suffered long term reduction in distribution and/or abundance and are now uncommon.
- Uncertain Status: Taxa whose taxonomy, distribution and/or abundance are uncertain but which are suspected of being restricted.

6.1.2 Threatened Species and Habitats in the Derwent Catchment

A total of 190 threatened species have been identified in the Derwent Catchment through interrogation of the Geo Temporal Species Point Observations Tasmania (GTSPOT) database maintained by DPIWE. Little is known about many of these species, including the degree (if any) of dependence on Hydro Tasmania-affected waterways. Many of these species are known to be fully terrestrial, and therefore are not directly affected by Hydro Tasmania operation of waterways. A discussion of known or likely threatened species issues in the Derwent Catchment is given below.

Galaxiids

Major populations of the Clarence galaxias (*Galaxias johnstoni*) occur in Clarence Lagoon and it is currently known from only six other locations in the Clarence, Derwent and Nive catchments. This species has not been recorded in Hydro Tasmania influenced waterways in recent years, however it was known to inhabit the Clarence River down to Browns Marsh Creek (downstream of Clarence Weir) in the 1930s.

It is listed as endangered under both State and Commonwealth legislation, and has suffered range reductions as it is eliminated by brown trout (Crook and Sanger 1997). It is able to co-exist with brook trout (*Salvelinus fontinalis*) which are also present in Clarence Lagoon (section 6.3.2). Hydro Tasmania does not have any hydrological influence on Clarence Lagoon and is unlikely to impact on this species. Similarly, Clarence galaxias are not known to have any migratory requirements that may be influenced by Hydro Tasmania infrastructure.

The golden galaxias (*Galaxias auratus*) is endemic to Lakes Sorell and Crescent, which are not Hydro Tasmania controlled lakes, and is unlikely to be affected by Hydro Tasmania's operations in downstream areas on the Derwent River. However, it is possible that this species may be found in adjacent areas in the future which may be controlled by Hydro Tasmania. These lakes are currently being managed by the IFS to prevent the spread of European carp (section 6.3.4).

The western paragalaxias (*Paragalaxias julianus*) has also recently been listed as a rare species and included in schedule 5 of the *Threatened Species Protection Act 1995*. Its distribution is given as the lakes of the upper Little Pine, James and Ouse rivers, where it inhabits the rocky margins of these lakes (Fulton 1990).

The Great Lake and Shannon paragalaxias (*Paragalaxias eleotroides* and *P. dissimilis*) have recently been listed as vulnerable species under schedule 4 of the *Threatened Species Protection Act 1995*, as they are locally abundant but have very restricted distributions. Populations occur in Great Lake and Shannon and Penstock lagoons. It is likely that the populations in Shannon and Penstock lagoons have originated from Great Lake. There is a potential threat to these species through intermixing with other galaxiid species and redfin perch via Great Lake and its diversions.

Australian Grayling

The Australian grayling (*Prototroctes maraena*) is a diadromous species and needs unimpeded access from salt water to fresh water to complete its life cycle. It is listed as vulnerable in the *Threatened Species Protection Act 1995* and the *Environment Protection and Biodiversity Conservation Act 1999*. These classifications are due to concerns raised by the extinction of its New Zealand counterpart which has never been fully explained (McDowall, 1996), and to the decrease in available habitat resulting from instream barriers to migration. *P. maraena* occurs in coastal rivers state-wide. The exact spawning area of *P. maraena* is unknown but is assumed to be in freshwater. Larvae are washed downstream and have a marine stage lasting up to 6 months. Juveniles then migrate upstream to inhabit the upper zones of estuaries and clear fresh water streams (McDowall, 1996).

P. maraena has not been recorded in the Derwent Catchment region on the GTSPOT database. However, Forest Practices Board (1998) indicates that the species' distribution includes the lower Derwent Catchment. There are no records of *P. maraena* upstream of Meadowbank Dam and if the species is present in the lower Derwent Catchment, Meadowbank Dam may be acting as a migratory barrier. However the effect that this may have on the regional viability of the species is largely unknown as there has been little research done into its current and probable past distributions or habitat preferences.

Amphibians

There are a total of ten known amphibian species in Tasmania, with two endemics and one species with a restricted range. These species have different habitat requirements, some requiring stream systems, others requiring permanent water. The only listed endangered amphibian in Tasmania is *Litoria raniformis*, the green and gold frog, which does occur in Hydro Tasmania-affected areas in the Derwent Catchment. The green and gold frog appears to prefer permanent water, such as large well-vegetated swamps and dams (Taylor, 1991). In this case, Hydro Tasmania operations may benefit and enhance their habitat; however, frequent large fluctuations in lake levels may not. There are no known occurrences of Hydro Tasmania operations adversely affecting the green and gold frog. There have been incidences of tadpoles stranding at Little Pine Lagoon: however, it is unlikely that the green and gold frog inhabits this water body.

Birds

Four threatened species of birds occur within the Derwent Catchment. These are the wedge-tailed eagle (*Aquila audax fleayi*), the swift parrot (*Lathamus discolor*), the great crested grebe (*Podiceps cristatus*) and the grey goshawk (*Accipiter novaehollandiae*). Of these species, only the great crested grebe and the grey goshawk could potentially be affected by Hydro Tasmania's water management.

The great crested grebe is a highly specialised freshwater bird and lives mostly on lakes, reservoirs, large lagoons and swamps. There have been reports of this species at Lagoon of Islands, Meadowbank Dam and Great Lake during the breeding season and it is assumed that these waterways may have importance for breeding when recognised areas such as Lake Dulverton are dry. It is dependent on large, well-vegetated wetlands for breeding (August to February), and feeds on small fish, tadpoles and aquatic invertebrates. The great crested grebe has nomadic habits and an erratic distribution. When not breeding it prefers areas of greater and more exposed surface water, such as highland lakes and the Derwent and Tamar River estuaries (Green 1995). It is possible that the great crested grebe inhabits waterways such as the Lagoon of Islands, particularly during drought periods, when important habitats such as Lake Dulverton are dry. It is not known if this species breeds in wetlands controlled by Hydro Tasmania.

The grey goshawk is a small hawk dependent on dense mature blackwood swamps for breeding and foraging. It preys primarily on other birds, but small mammals, reptiles and insects are also included in its diet. It has habitat requirements (including prey species) which are dependent on wetland ecosystems, and therefore could potentially be affected by Hydro Tasmania's waterway operations.

Crustaceans

The giant freshwater crayfish (*Astacopsis gouldi*) is endemic to the northern areas of Tasmania. An introduced population has been recorded in the Clyde River which flows into the Derwent River. It is not known if this species has colonised waterways influenced by Hydro Tasmania. Generally, it is found at altitudes lower than 400 m and is most common below 200 m (Forest Practices Board, 1998). This species is long-lived and is extremely susceptible to fishing pressure (which is now illegal), habitat modification and poor water quality, and is listed as vulnerable by the *Threatened Species Protection Act 1995*. *A. gouldi* is found mainly in small streams with substantial riparian shading. It is rarely found in areas that are completely cleared, possibly due to increased water temperatures. As this species is outside its natural range, it is uncertain what management practices should be implemented.

The spiny mountain shrimp (*Anaspides spinulae*) is a rare species of Syncarid crustacean known only from Lake St. Clair and Clarence Lagoon (Horwitz 1990). *Anaspides* spp. are preyed upon by trout and galaxiids which therefore limits their distribution to water bodies without fish populations. Further research into the taxonomy, distribution and ecology is required for this species before it can be listed. Two species of threatened rare amphipods from Great Lake, *Mesacanthotelson setosus* and *Onchotelson brevicaudatus* (the latter is not listed by GTSPOT for this catchment), are now also known to occur in Shannon Lagoon.

Other Invertebrates

One species of threatened freshwater snail, *Phrantela pupiformis,* is recorded for the Derwent Catchment. This is one of 43 hydrobiid species that are considered rare due to their restricted distributions. Many of these species live in very small streams and seeps, and require retention of riparian vegetation and maintenance of water quality. Three species of caddisfly (*Hydrobiosella armata*, *Orthotrichia adornata* and *Oxyethira mienica*) are also listed as rare due to their limited distribution. The larvae and pupae of these species are wholly dependent on freshwater habitats, and may be affected by changes in hydrology and water quality. Some habitat modification is likely to have occurred during flooding of the Derwent lakes, however the distributions of this species prior to hydro-electric development are unknown, and the current effect of Hydro Tasmania's operations on this species has not been assessed.

Flora

Of the 166 listed threatened species of flora that have been recorded by the GTSPOT database for the Derwent Catchment, 9 are aquatic plants and 40 are wetland plants. Compared to the mobility of animal species, plants have restricted ranges and expansion capabilities, which may lead to simpler management strategies. Many of the listed plant species may not be directly impacted by Hydro Tasmania's operational activities. Hydro Tasmania's water management regimes may have most influence on aquatic species, followed by wetland and riparian species. Two examples are given below.

Native wintercress (*Barbarea australis*), a member of the family Brassicaceae, is the only native species of this genus occurring in Tasmania and is listed as critically endangered using the 1994 IUCN criteria. It was thought to be extinct until it was collected at Waddamana in 1982. Extant populations are restricted to riverine vegetation on the Ouse River (4 populations), the Shannon River (1 population) the Clyde River (1 population) and the Nive River (1 population). It occurs near river margins, creek beds and along flood channels adjacent to the river, tends to favour slower reaches, and requires moist soils, in open situations (usually exposed by previous flood action). It is a poor competitor and is highly palatable which, combined with altered flow regimes and exotic species (willow and gorse) invasion, has led to the decline of this species. The major threat to this species is from grazing by domestic stock (Kirkpatrick and Gilfedder, 1998). Manipulations of flow may benefit this species.

There is a unique endemic algae present in a swamp adjacent to Lake St. Clair known as the golden cloud algae (*Chrysonephele palustris*) (Pipes *et al.*, 1989). This species is not listed in legislation, but is classified as a frail endemic by Tyler (1996) and to date has not been found anywhere else in the world. The algae appears sporadically during the summer months, persists for a few days, then disappears again. Water management practices that dewater inhabited waterways, particularly during summer months, may have a negative impact on the survival of this species, although this cannot be confirmed until more is known.

6.2 Native Fish Migration and Dispersal

6.2.1 Background

Migration and dispersal are important parts in the life cycles of native Australian fish and therefore any disruption to these processes may impact on stocks of these species. This is particularly true for Tasmanian fish species, which are often severely restricted in range and are adapted to specific hydrological conditions.

There are a number of dams in the Derwent Catchment which could potentially act as barriers to native fish movements. Meadowbank Dam, being the most downstream dam in the Derwent Catchment could act as a barrier to diadromous species, and dams further inland in the catchments of the Derwent, Nive, Dee and Ouse rivers may affect the movement of native freshwater fish species. Little is known about the barriers presented by numerous small levees and weirs within the catchment.

Whilst dams present obvious barriers to native fish movements, canals, pipelines and inundations may present dispersal mechanisms that did not exist naturally. This interconnection of waterways may result in the introduction of fish and other biota, such as algae, macrophytes and macroinvertebrates, into areas where they were not previously found. However due to a general lack of data prior to hydro-electric development, past distributions are often not known.

Barriers to fish dispersal may also be presented by altered flow regimes or water quality. High river flows may impose a 'velocity barrier' against which fish cannot swim. Reduced flows may lower water levels such that small barriers become insurmountable or the depth of water available for fish passage is not adequate. Low dissolved oxygen levels or extreme temperatures may pose a barrier through which fish may not migrate. Occurrences of this nature have not been documented in this catchment.

Consequently, most issues relating to native fish dispersal relate to the barriers presented by instream structures and associated changes in channel hydrology, and the opportunities for unnatural dispersal through waterway interconnections.

Exotic fish migration and dispersal issues are discussed in section 6.3.

6.2.2 Diadromous species

Diadromous species are those that migrate between fresh and salt water, usually for the purpose of breeding. Many native fish found in waterways influenced by Hydro Tasmania are migratory and are thought to rely on diadromous migration as part of their life cycle. Two of these species (*Galaxias truttaceus* and *G. brevipinnis*) also occur as landlocked populations within Hydro Tasmania-affected waters and can be considered as separate stocks to the diadromous populations. There are several landlocked populations of these two species in the Central Plateau of Tasmania (Humphries, 1989). Table 6.1 lists the native diadromous species found in the Derwent Catchment, their distributions and conservation status.

Table 6.1 Native Diadromous Fish Species occurring in the Derwent Catchment

Species	Common name	Tasmanian distribution	Conservation status	Hydro Tasmania-affected waters
Mordacia mordax	short-headed lamprey	Abundant throughout Tasmania	Not listed in State or Commonwealth legislation	Derwent River and Estuary
Geotria australis	pouched lamprey	Abundant throughout Tasmania, abundance declines with barriers to migration	Not listed in State or Commonwealth legislation	Derwent River and Estuary
Anguilla australis	short-finned eel	Abundant throughout Tasmania. Fishery for adult, elver and glass eels	Not listed in State or Commonwealth legislation	Derwent River and Estuary
Prototroctes maraena	Australian grayling	State-wide except SW coast	Listed as 'vulnerable' in TSPA and EPBC	Downstream of Meadowbank Dam.
Neochanna cleaveri	Tasmanian mudfish	Widespread and common in low elevations around Tasmania (except east coast). Swamp drainage and reclamation threaten populations	Not listed in State or Commonwealth legislation	Widespread

Table 6.1 cont'd   Native Diadromous Fish Species occurring in the Derwent Catchment

Species	Common name	Tasmanian distribution	Conservation status	Hydro Tasmania-affected waters
Galaxias truttaceus	spotted galaxias	Locally abundant throughout Tasmania. Range fragmented by deforestation	Not listed in State or Commonwealth legislation.	Widespread
Galaxias brevipinnis	climbing galaxias	Tasmania wide distribution but contracted due to deforestation and habitat modification. Susceptible to predation by exotics	Not listed in State or Commonwealth legislation	Widespread
Galaxias maculatus	jollytail	Common	Not listed in State or Commonwealth legislation	Lower reaches of Tasmanian coastal streams, with a landlocked population in Lake Meadowbank. Recorded from the Derwent River
Lovettia sealii	Tasmanian whitebait	Tasmanian coasts and estuaries	Not listed in State or Commonwealth legislation	Estuarine and lower reaches of rivers. Recorded from the Derwent River
Retropinna tasmanica	Tasmanian smelt	Lower reaches of coastal streams	Not listed in State or Commonwealth legislation	Lower reaches of rivers. Recorded from the Derwent River
Pseudaphritis urvillii	sandy (tupong or freshwater flathead)	Tasmanian coastal streams	Not listed in State or Commonwealth legislation	Estuarine and lower reaches of rivers. Recorded from the Derwent River

ASFB – Australian Society for Fish Biology;

EPBC – the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*;

IUCN – world Conservation Union

TSPA – the Tasmanian Government's *Threatened Species Protection Act 1995*.

Meadowbank Dam, as the most downstream dam in the Derwent system, is the most likely barrier to diadromous fish migration. An elver trap has been installed below the dam to facilitate the capture and upstream relocation of juvenile eels. It is likely that other migratory species are also inhibited by the dam, however the extent to which unregulated tributaries below Meadowbank Dam provide alternative habitat for diadromous fish species is not known. Passage over this barrier for these species would provide access to major tributaries such as the Clyde and Ouse rivers. Other structures further upstream in the Derwent Catchment may also obstruct fish passage.

Little is known about pre-development distributions of native fish species and therefore, the true effect of the Derwent valley dams and water diversion on fish migration can only be examined retrospectively. Hydro Tasmania's fish migration studies have an on-going program of examining the impacts on native fish species, including a major collaborative study with the IFS on eel populations.

6.2.3 Land-locked species

Native species that form landlocked populations within Hydro Tasmania-affected waters are listed in Table 6.2. These species may undertake within-storage and storage-drainage system migrations for spawning and dispersal which could be disrupted by lake level fluctuations or altered river flows. Artificial barriers to movement may restrict access to spawning sites or may separate populations of rare fish such that genetic viability within the separated populations is compromised.

Introduction of non-endemic galaxiids to any waterway that does not normally contain them is generally considered to have potential risks. Tasmanian galaxiids have adapted to specific ecological niches and their geographical separation has allowed these fish to evolve without competition with similar species. Remixing any previously separated species may compromise the populations of the 'weaker' species as has previously occurred in Lake Pedder. Similarly, predation by such introduced fish may impact detrimentally on threatened invertebrate populations.

The Great Lake paragalaxias and the Shannon paragalaxias (*Paragalaxias eleotroides* and *P. dissimilis*) are lake-bound fish which spawn within the boundaries of a water body. The Shannon River is the original natural outflow of Great Lake, and it is probable that the colonisation of Shannon and Penstock lagoons by both species may have been via this route. The Miena Dam may prevent mixing of these previously linked populations, however it is unknown to what degree fish are able to pass through the dam when the outlet is in operation. It is also unknown how this barrier to mixing is affecting the genetic makeup of the separate populations.

Table 6.2 Land-locked and Riverine Native Fish Species occurring in the Derwent Catchment (adapted from Blühdorn *et al*, 1999)

Species	Common name	Tasmanian distribution	Conservation status	Hydro Tasmania-affected waters
Paragalaxias eleotroides	Great Lake paragalaxias	Great Lake, Shannon and Penstock lagoons	Restricted (ASFB) vulnerable (IUCN) vulnerable (TSPA)	Shannon and Penstock lagoons, (Great Lake)
Paragalaxias dissimilis	Shannon paragalaxias	Great Lake, Shannon and Penstock lagoons	Restricted (ASFB) vulnerable (IUCN) vulnerable (TSPA)	Locally abundant in Shannon and Penstock lagoons (Great Lake)
Paragalaxias julianus	western paragalaxias	Lakes of the upper Little Pine, James and Ouse rivers	rare (TSPA)	(Lake Augusta)
Gadopsis marmoratus	blackfish	Various streams, rivers and lakes around Tasmania.	Not listed in State or Commonwealth legislation. Common in distribution.	Introduced to the Derwent Catchment
Galaxias maculatus	jollytail	Downstream reaches of Tasmanian coastal streams	Not listed in State or Commonwealth legislation. Common in distribution.	Landlocked population in Lake Meadowbank.

ASFB – Australian Society for Fish Biology;

EPBC – the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*;

IUCN – world Conservation Union

TSPA – the Tasmanian Government's *Threatened Species Protection Act 1995*.

NB. Waterways in brackets are not in the Derwent Catchment but are linked

The western paragalaxias (*Paragalaxias julianus*) is found in the highland lakes of the upper Little Pine, James and Ouse rivers. Augusta Dam may prevent local dispersal, although there were no highland lakes downstream of this dam prior to the construction of the Monpeelyata Weir.

The blackfish is a riverine species native to lowland streams in the north of Tasmania, but has been introduced into the North Esk, South Esk, Derwent and Huon catchments. This is a strictly freshwater species and does not undertake large-scale migrations. Its distribution in the Derwent Catchment is unknown.

A landlocked population of jollytail (*Galaxias maculatus*) exists in Lake Meadowbank. This species is said to inhabit only downstream reaches of Tasmanian coastal streams, and it is known to occur at the base of Meadowbank Dam . It may have been moved over the dam through the elver translocation program run by the IFS or through anglers using live-bait upstream of the dam. This species probably inhabited reaches of the Derwent upstream of Meadowbank Dam before construction, although the extent is unknown. It is unknown whether the landlocked population is able to reproduce without access to the estuary as has occurred in other areas (McDowall 1996), or whether it is an ageing population that is not being revitalised.

6.3 Exotic Species

Numerous exotic species exist within the Derwent Catchment, many are terrestrial weeds or diseases that may be spread by vehicle movements. However, these issues are not likely to be affected by the operation of Hydro Tasmania aquatic systems and are not discussed in this document.

The major concerns for exotic aquatic species relate to dispersal via interconnected waterways. Six exotic aquatic/riparian species are of particular concern to Hydro Tasmania and are discussed below.

6.3.1 Redfin Perch (Redfin, European Perch, English Perch)

Redfin perch are an introduced fish species that is highly predatory and therefore presents a threat to many of Tasmania's native fish species. They have strong dispersal tendencies and may form dense, stunted populations of little angling value (Andrews and Jack, 1998).

The upper reaches of the Ouse and Shannon river systems have been surveyed for redfin perch in order to assess the risk of colonisation of Penstock Lagoon, Shannon Lagoon, Little Pine Lagoon and the Western Lakes (Andrews and Jack, 1998). The survey confirmed the presence of redfin perch at Ashton on the Ouse River and at Hermitage, Hunterson and below Christian Marsh Weir on the Shannon River. This pest species is also present in the Lagoon of Islands and Lake Echo.

Redfin are likely to be present in the lower part of Monpeelyata Canal and at Waddamana on the Ouse River, however the lack of suitable habitat has probably slowed their advance in these areas. Surveys of these areas for redfin were undertaken during 1998. However, seasonal factors reduced the effectiveness of the survey and further surveys in spring and summer when fish are more active may produce more comprehensive information. Other rivers and lakes in the Derwent Catchment (eg. upper Derwent, Dee, Repulse, Clyde and Broad rivers) have not been surveyed for redfin perch.

Hydro Tasmania constructed a barrier to fish migration on Liawenee Canal (part of the Poatina Power Development) to prevent upstream dispersal of redfin perch. These fish are suspected but not confirmed to be in Great Lake, and pose a threat to the native fish populations of the Western Lakes and the upper Ouse River which lie within the Tasmanian Wilderness World Heritage Area.

6.3.2 Trout and Salmon

Both brown (*Salmo trutta*) and rainbow (*Oncorhynchus mykiss*) trout are widely dispersed within the Derwent Catchment. Trout are present within all Hydro Tasmania lakes, and brown trout have also invaded, or been translocated to, most of the headwater lakes.

Brook trout (*Salvelinus fontinalis*) are present in Clarence Lagoon, a headwater of the Derwent system. They are eliminated by other trout species but can coexist with the threatened Clarence galaxias and hence are an important species with provides angling value whilst preserving native fish populations. Clarence Lagoon and the Anthony catchment are the only areas in Tasmania that this trout species is present, and some stocking by the IFS is required to maintain this important recreational fishery.

The Atlantic salmon (*Salmo salar*) found in Lake Meadowbank and the Derwent Estuary are probably escapees from fish farms and fish pens. These are not self-sustaining populations, and do not pose a significant threat to populations of native species.

Trout and salmon are important to the Tasmanian economy and often a difficult balance must be drawn in water management between sustaining or improving these fisheries whilst minimising further dispersal and impact on native fish populations. The presence of introduced trout species in Tasmanian waterways is known to have a major influence on the native fish fauna which also inhabit the lakes and rivers. Although information regarding the specific effects of exotic species on native fish in the Derwent Catchment is limited, it is likely that direct predation (especially on juveniles) and competition are two major factors impacting native fish populations.

Recent investigations in the Gordon River catchment have found that brown trout are able to out-compete and displace native species. This is likely to be a result of direct predation and competition for limited resources, but may also be a result of better adaptability to regulated flow conditions. This species also has an advantage over native fish species in that its life-cycle does not require migration to the sea to spawn, as do most native fish (Howland *et al.* 2001).

6.3.3 Cyprinids (Carp, Tench and Goldfish)

Carp (*Cyprinus carpio*) are considered to be the world's most widely distributed fish. Carp thrive in still or slow flowing water, are benthic feeders and their presence has been linked to increased turbidity and resuspension of nutrients, which can contribute to algal blooms. This species would compete with native fish and trout, and is difficult to eradicate once present. Fulton (1990) notes that a successful eradication program was undertaken against the species in 1974, implying that the species was thought to have been removed from Tasmanian waters at that time. However, the discovery of a large population of carp in Lakes Sorell and Crescent (non-Hydro Tasmania lakes in the Derwent Catchment) has led to the creation of a Carp Management Program, administered by the IFS. Currently, carp are not an issue for the management of Hydro Tasmania controlled waterways within the Derwent Catchment. However, the presence of carp in Lakes Crescent and Sorell is of concern due to the possibility of illegal translocation, or escape down the Clyde River which may lead to infestation of Hydro Tasmania controlled waterways.

Tench (*Tinca tinca*) are a native of Europe and were introduced to Australia in 1876 and reported by Fulton (1990) to be firmly established in Tasmania by 1882. They are generally found in slow moving waters and are usually only encountered in large numbers during the spawning period in spring. Tench is not a species favoured as a sport fish in Tasmania and is regarded as a pest.

No information is available with respect to its affects on Tasmanian aquatic ecosystems. Although not confirmed, it is not likely that this species represents a threat to the native fish population through direct predation. Fulton (1990) lists confirmed occurrences in various parts of the Derwent Catchment, particularly the Derwent and Ouse rivers. Some distributional data are held by DPIWE and IFS.

The goldfish (*Carassius auratus*) tends to be widely distributed due to human activity (usually in farm dams) but there have been few reports of feral populations, and none have been reported for the Derwent Catchment as yet.

6.3.4 Willows

Willows are an exotic tree species, which typically occur in riparian areas. They were originally planted as a means of controlling erosion along river banks. Large infestations of willow occur throughout the lower Derwent Catchment, especially in the riparian zones of the Ouse, Nive and Clyde rivers. Illowski (1995) has mapped the distribution of riparian willow and gorse from aerial photographs of the Shannon, Clyde and Ouse, showing extensive willow infestation on the lower reaches of these rivers, with more patchy distribution upstream. There are no reports of willow in the Derwent Catchment upstream of Waddamana.

Several species of willows are found in Tasmania. Of these, *Salix babylonica* (weeping willow) and the hybrid *Salix alba* x *fragilis* (crack willow) occur commonly throughout the State (Rose and Rando, 1988). All willows will propagate vegetatively and some by seed (Cremer *et al.*, 1995), however, it is thought that all crack willow in Tasmania are males and therefore can only propagate asexually. Crack willow, in particular, is notorious for infesting downstream areas via twigs that are broken off during floods, high winds or even stream rehabilitation work.

Willows exclude native riparian vegetation through competition and alteration of habitat. Willow encroachment of river channels, particularly in areas with reduced flows, leads to channel braiding and log jams. Rivers blocked in this manner flood easily and cause excessive erosion in areas of diverted channel flow. High rates of sedimentation are apparent in areas of dense willow infestation leading to burial of riparian plant communities. It has also been postulated that the high seasonal leaf drop from willows during autumn has detrimental effects on aquatic communities that are adapted to a constant nutrient input throughout the year (Parker and Bower, 1996).

6.3.5 Aquatic weeds

The aquatic plant *Elodea canadensis* has a wide-ranging distribution throughout Tasmania and is present in waterways in the Derwent Catchment from the headwaters downstream. *Elodea* is a secondary prohibited aquatic weed introduced from North America. It prefers warm, shallow, slow moving water and forms fast growing, dense beds which out-compete native macrophytes. As a result, the distribution of native instream vegetation is reduced and the habitats available to other aquatic organisms are lessened. *Elodea* is known to clog canals and intake screens to such an extent that regular manual removal is required.

In the Derwent Catchment, *Elodea* has been reported in Little Pine Lagoon, Monpeelyata Weir and Monpeelyata Canal, Shannon Lagoon, Waddamana No. 2 Canal, Penstock, Dee, Bronte and Tungatinah lagoons and the canal between Lakes Brady and Binney. These reports are based on field observations and no comprehensive survey of *Elodea* in Hydro Tasmania waterways has been undertaken to date.

Little is known about the distribution of other aquatic weeds in Tasmania. Alligator weed (*Alternanthera philoxeroides*) and the introduced Bulrush (*Typha latifolia*) may cause localised issues within the catchment, however no coordinated reporting concerning these species is currently being undertaken.

6.4 Biological Indicators

'Waterway health' is a complex concept that is assessed differently depending on the objectives of the assessment, the reasons for monitoring and the desired deliverables (eg. aquatic management plans, state of the environment reports, environmental flow criteria). Health of an ecosystem can be assessed subjectively by expert opinion in various fields, generalised habitat assessment protocols or even on aesthetic values. Objective measures are harder to interpret, but generally rely on the premise that higher species diversity (ie. the number of species compared to the number of individuals) constitutes better ecosystem health. The presence of exotic or weed organisms is considered detrimental to waterway health.

The response of living organisms to abiotic factors is complex and therefore problematic in defining cause and effect relationships. Biological monitoring is probably most useful in providing an 'ecological average' of the environmental conditions existing within an environment of interest and is particularly useful when combined with habitat assessment and channel morphology studies. This is in contrast with abiotic (eg. water quality) sampling that provides only a limited snapshot of the conditions of the waterway at a particular point in time.

The First National Assessment of River Health (FNARH) is an attempt to standardise river health monitoring in which Hydro Tasmania has been actively involved as part of its Waterway Health Monitoring Program (WHMP).

6.4.1 Phytoplankton, macrophytes and attached algae

Sampling of phytoplankton, macrophytes or attached algae is primarily focussed on issues associated with nutrient input and flows, and provides an indication of the level of primary production within the system.

Little is known about the current distribution of aquatic macrophytes within the Derwent Catchment in general. Hydro Tasmania is currently investigating options to fill this information gap through the Waterway Health Monitoring Program.

Recently, work has been carried out to examine the level of attached algae present in some of the waterways within the Derwent Catchment. These data have shown that algal concentrations can vary widely and can be influenced by a variety of factors. Measurement of phytoplankton densities can be done chemically (eg. chlorophyll-*a* concentrations) or through direct counting of phytoplankton cells from water samples. Chemical analysis generally gives only a relative abundance of phytoplankton within a water sample. Counting and visual identification provide more data that may be potentially useful for biological monitoring. Currently chlorophyll-*a* determinations are regularly used, and visual assessment of algal cover is also carried out.

6.4.2 Macroinvertebrates

To date macroinvertebrates have been most widely used as biological indicators, due to their ease of sampling. There are generally high numbers present with reasonable species diversity (variable with degree of impact), and there are many invertebrates with varying sensitivities to environmental factors.

Unfortunately, measurements associated with macro-invertebrate sampling can be prone to misuse and are often used to predict the status of entire ecosystems without any consideration of the upper levels of the food chain. In particular the presence of large carnivores, exotic species and alterations in energy input into the waterway can influence the concept of waterway ‘health’ without being immediately apparent in limited macroinvertebrate sampling. Similarly, sampling true replicates is difficult due to micro-habitat differences and localised differences in (particularly) flow, substrate, depth and instream cover.

The Australian River Assessment Scheme (AUSRIVAS) concentrates on macroinvertebrate indicators and uses the Riverine Invertebrate Prediction and Classification Scheme (RIVPACS) in order to compare invertebrate populations between reference and test sites. Macroinvertebrates are also commonly used in Instream Flow Incremental Methodology (IFIM) analyses of environmental flows. Consequently, macroinvertebrates presently represent the most useful tool for biological monitoring of waterway health.

DPIWE is in the process of compiling numerous reference sites throughout Tasmania and are calibrating RIVPACS models for different zones within the State (Oldmeadow *et al.*, 1998). Models for the north and north-west of Tasmania are almost complete based on autumn and spring samples. Reference sites in the central, eastern and south-eastern areas of the State using the same sampling protocols are being used for the Regional Forest Agreement study which will also generate information for the databases for these regions. Many of the test sites correspond with Hydro Tasmania WHMP sites and additional Hydro Tasmania sites were added for the spring and autumn sampling in 1998/99. These will provide valuable data in assessing the effects on flow regulation on the aquatic environment.

A joint Hydro Tasmania – ESAA funded study into the downstream effects of hydro-electric storages and power stations, completed by Davies, Cook and McKenny (1999), included a number of test and reference sites in the Derwent Catchment. Bioassessment of each test site was carried out by sampling the macroinvertebrate community and then comparing the number and abundance of taxa with those of reference sites. This program used a combination of IFIM and RIVPACS methodologies to investigate environmental flow requirements for Hydro Tasmania-affected waters.

The general findings of the study indicated that macroinvertebrate communities at sites immediately downstream of power stations comprised significantly fewer taxa than at the reference sites. Test sites downstream of dams were also impacted, but to a lesser degree than power station sites. Significant modifications were observed in the macroinvertebrate communities of the Derwent River immediately downstream of Lake St. Clair, the Clarke Dam, and the Repulse, Cluny and Meadowbank power stations. Test sites downstream of Pine Tier Dam on the Nive River and Little Pine Lagoon Dam on the Little Pine River also showed significant losses of taxa. These impacts on macroinvertebrate community composition are primarily associated with changes in flow regimes rather than water quality. However, macroinvertebrate communities of the upper Ouse River downstream of Augusta Dam and the Liawenee Weir were essentially unmodified.

6.4.3 Other Potential Biological Indicators

Zooplankton may be potential biological indicators for lakes as they are the dominant form of invertebrates in the pelagic zone but there are no studies at this stage measuring their presence or abundance.

The species composition of diatoms may also act as a useful indicator, as many diatoms are sensitive to changes in water quality and are widely distributed in lakes and rivers.

Monitoring of fish communities for the purpose of assessing waterway health is generally not conducted due to the logistics of adequate and unbiased sampling in stratified and replicated surveys. In addition to this, the response of fish to subtle environmental variables, particularly in the short term, is largely unknown and therefore poses problems for environmental monitoring programs. Similarly, the effect of exotic species introduction, fishing pressure, and gear selectivity confounds results and need to be accounted for. No dedicated sampling of fish for river health monitoring is taking place within Tasmania, although research programs have been conducted on the mainland (eg. Arthington *et al.*, 1997).

6.5 Summary of Biological Issues

As described in this chapter, there are a number of biological issues in the Derwent Catchment. These issues do not all relate to Hydro Tasmania operations, but may be related to other activities in the catchment, and managed by other organisations. The known issues are summarised under the groupings of rare and threatened species, fish migration and exotic species:

Rare and threatened species issues in the Derwent Catchment include, but may not be limited to, the following:

- a native fish, the Australian grayling (listed as vulnerable) is thought to occur in the lower Derwent River and requires unimpeded access from salt to fresh water to complete its life cycle – barriers such as Meadowbank Dam prevent migration and probably limit the habitat available for this species;
- the western, Shannon and Great Lake paragalaxias are listed under the *Threatened Species Protection Act 1995*. These species have restricted distributions within the upper Derwent Catchment, but are locally abundant; and
- other rare and threatened species associated with aquatic environments which occur in the Derwent Catchment include the grey goshawk, great crested grebe, the green and gold frog and a number of invertebrates and plant species – threats to these species are unknown.

Fish migration issues in the Derwent Catchment include, but may not be limited to the following:

- Meadowbank Dam may be an impediment to both upstream and downstream migration of eels and diadromous fish species (including the 'vulnerable' Australian grayling);
- structures such as weirs and dams may prevent dispersal of land locked fish species within drainage systems (eg. the division of previously mixing populations of Great Lake and Shannon galaxiids by the Miena dam, and it is unknown whether the landlocked population of jollytail in Lake Meadowbank is able to reproduce and be self sustaining, or whether it is an ageing population that is not being revitalised); and
- artificial waterways may provide pathways for the dispersal of native and exotic fish into waterways where they do not naturally occur. Particular threats lie with the inter-mixing of native galaxiid species in the highland regions of the catchment.

Exotic species issues in the Derwent Catchment include, but may not be limited to the following:

- redfin perch are widespread in the Derwent Catchment and barriers need to be maintained to ensure they do not spread into sensitive areas;

- trout are present in most waterways in the Derwent Catchment and are known to prey on native fish species, however trout also provide a valuable fishery, and Hydro Tasmania has informally agreed with the IFS to maintain flows for spawning purposes in Waddamana No. 2 Canal;
- there is extensive infestation of willows in many rivers in the catchment, particularly in the lower catchment areas;
- the aquatic weed *Elodea* (Canadian pondweed) has been observed in many waterways in the Derwent Catchment;
- the presence of carp in Lakes Crescent and Sorell (non-Hydro Tasmania lakes) poses the risk of them escaping into other waterways in the catchment.

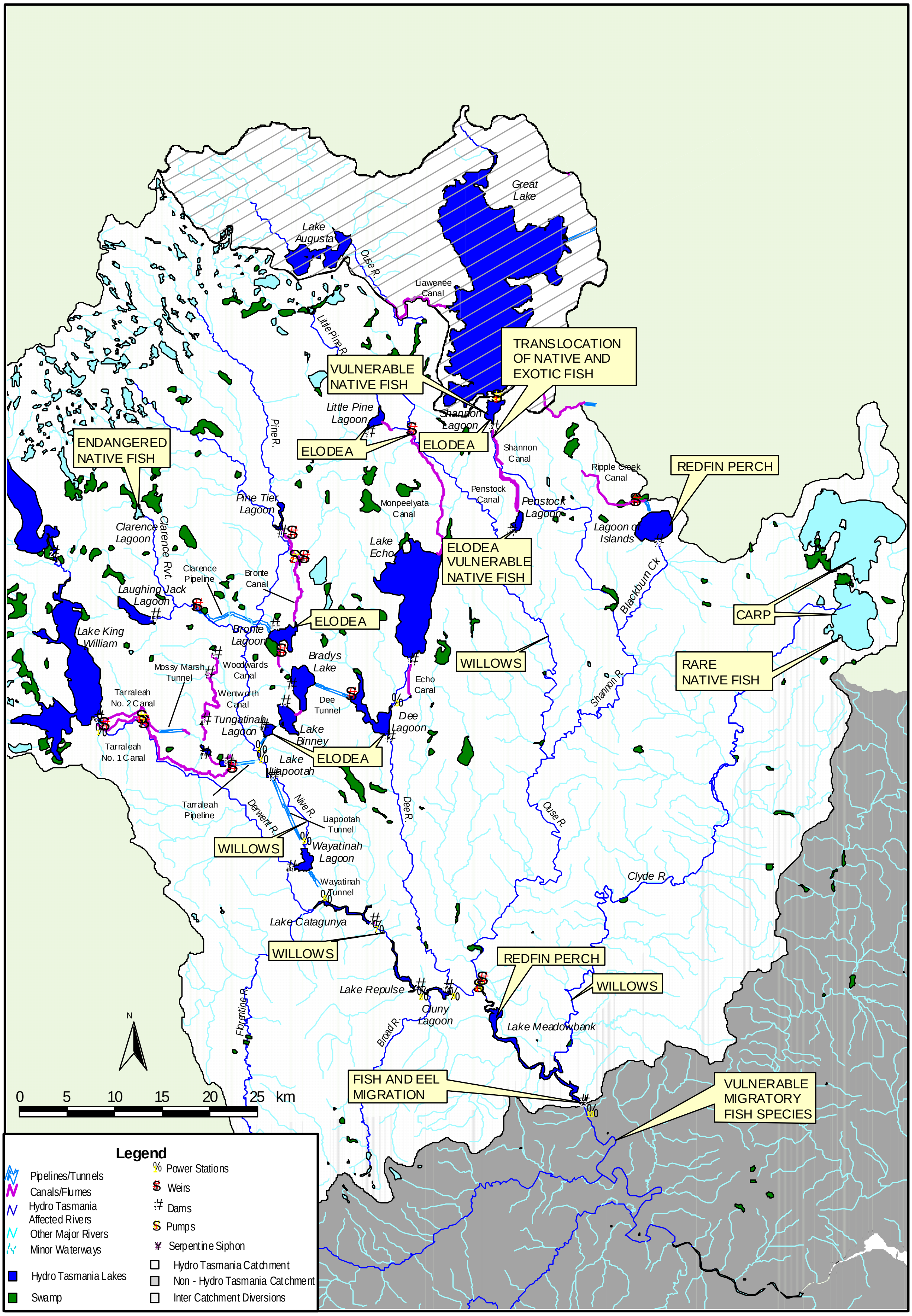
Map 6.1 indicates key issues of a biological nature that occur in the Derwent Catchment. Issues noted are those affected by Hydro Tasmania's water management and those that are relevant to management by other agencies.

Hydro Tasmania's Aquatic Environmental Policy recognises the importance of the biological ecosystem. As stated in this policy, Hydro Tasmania is committed to operating its business (and therefore the waterways that are part of its generating system) in a way that aims to maintain a healthy functioning of aquatic ecosystems. Hydro Tasmania is also committed to investigate the influence of its operations to allow management decisions to be made based on good scientific information.

Hydro Tasmania's Aquatic Environment Program aims to fill many of the information gaps regarding threatened species, exotic invasions and fish migration in the Derwent Catchment Hydro Tasmania has previously run workshops with local experts as part of an internal review on fish migration and threatened species issues in its catchments. This provides Hydro Tasmania with better information on which to assess the effects of its infrastructure and operations.

Hydro Tasmania has undertaken, commissioned or assisted in a number of specific projects to look into biological issues in the Derwent Catchment. In 1998, the upper reaches of the Ouse and Shannon river systems were surveyed for redfin perch in order to assess the risk of colonisation of Penstock Lagoon, Shannon Lagoon, Little Pine Lagoon and the Western Lakes (Andrews and Jack, 1998). Hydro Tasmania co-manages a major collaborative study with the IFS on the sustainability of eel populations in Hydro Tasmania waters, including an assessment on the effectiveness of elver restocking above dams. Hydro Tasmania jointly funded a study with the ESAA to investigate the downstream effects of hydro-electric power stations (Davies, Cook and McKenny 1999).

Comprehensive on-going monitoring of the biological environment and water quality is carried out through Hydro Tasmania's Waterway Health Monitoring Program. Reference sites for the AUSRIVAS program in the Derwent Catchment are currently being compiled by DPIWE and the IFSBC sites are being added to this program for ongoing comparison to assess the biological health of the catchment.



Map 6.1 Overview of Biological Issues in the Derwent Catchment

7. GEOMORPHOLOGICAL ISSUES

This chapter describes the known geomorphic state of waterways in the Derwent Catchment. The water quality issues and biological issues in these waterways were discussed in the previous two chapters, and the following chapter outlines the multiple uses and values of the waterways in the Derwent Catchment.

For the purpose of this report, geomorphology has been defined as the study of land surfaces and the processes which create them. Flow regulation has modified the natural processes which operate in water systems, and in some instances this contributes to geomorphic change. This may take a number of forms including river bank erosion, channel changes, sedimentation, vegetation encroachment, and lake shoreline destabilisation and erosion.

This chapter outlines the general effects that reservoirs and dams can have on the geomorphology of waterways (section 7.1), and discusses the geomorphological issues associated with waterways in the Derwent Catchment that are affected by Hydro Tasmania operations (sections 7.2 to 7.4). These issues are summarised in section 7.5.

Due to a lack of detailed geomorphological studies of the 21 lakes, 8 rivers, 4 creeks and 3 canals under consideration, the assessment presented in this section is of a preliminary nature. It is based on a desktop survey, utilising information gained from interviews, maps, hydrological records, and available literature. In consideration of erosion susceptibilities of lakes, only geology, operating ranges and degree of water level fluctuations were considered. Other factors that are important influences on geomorphology include land use and condition of riparian vegetation. In consideration of river reaches, only the hydrological variations were considered. Where detailed geomorphic assessments have been conducted on a particular waterway, these are summarised in the relevant sub-section.

7.1 Background

7.1.1 Types of Geomorphic Change Associated with Dams

The geomorphic response of rivers in relation to dams is well documented. The nature of these responses has been discussed in detail by Petts (1979, 1984), who concluded that the most significant changes following the damming of rivers are alterations to downstream flow and sediment load. Changes to these two parameters result in adjustments to channel morphology. Rivers may respond to such changes in a number of ways, as summarised by Locher (1997) and presented in Table 7.1.

Table 7.1 The Effects of Regulation on Rivers

Type of Change	Response of River
Flow	• Modified flooding regime • Altered frequency, distribution and variability of flows • More frequent discharge pulses
Sediment Load	• Trapping of bed load sediments in the reservoir • Suspended sediments may settle out in the reservoir • Tributary rejuvenation can increase tributary sediment contribution to streams
Channel morphology	• Degradation which can cause bank instability and/or • Aggradation which can reduce channel capacity, increase lateral erosion, and increase the flooding potential (Simons *et al.*, 1981) • Channel change including width increase or decrease • Channel bed armouring • Lateral migration of bends

Geomorphic changes in lakes may also occur as a result of damming. Inundation of lake shore vegetation and waterlogging of roots may lead to plant death, and consequent destabilisation of lake shores. Lake shoreline erosion may also occur as a result of fluctuating water levels, wind-driven wave splash or wind-driven turbulence, particularly in shallow lakes. In areas where bank materials sitting at water-level are erodible, undercutting and eventual bank collapse may occur. Shoreline erosion (which can also take place in rivers) can occur when water levels are drawn down very rapidly. The pore water pressures in the saturated bank sediments destabilise the recently drained banks and this can cause bank slumping.

7.1.2 The Derwent Catchment

A general description of the Derwent Catchment is given in Chapter 2, including the geology (Map 2.2) and land uses (Map 2.4). These two physical characteristics, combined with the catchment hydrology, play an important role in influencing the nature of geomorphological dynamics in waterways.

The geology of the catchment is a significant factor influencing the erodibility of the substrate. The geology of the upper Derwent Catchment, on the Central Plateau, is predominantly dolerite with basalt present to the south and east of Lake Echo. Glacial and periglacial features are located around the shores of Lake St. Clair, Laughing Jack Lagoon and Lake King William, and erosion-susceptible siliceous sediments are also present around the shore of Laughing Jack Lagoon and on the eastern shore of Lake St. Clair. The upper Derwent River from Lake King William and Cluny Lagoon flows through dolerite dominated geology with patches of basalt and siliceous sediments, while the geology around Cluny Lagoon and Lake Meadowbank is predominantly siliceous sediments. Immediately below Meadowbank Dam, the geology of the Derwent River consists of erodible siliceous and other unconsolidated sediments, which give way to basalt and then unconsolidated sediments towards the Derwent Estuary.

Extensive willow infestation in some rivers in the Derwent Catchment may have a significant effect on channel change in these waterways. In the past, willows were planted on waterways to stabilise shorelines, and have subsequently spread. A reduction in the amount of water flowing down the river allows willows to spread into the stream channel, resulting in channel constriction, sediment build-up, and the potential for increased flooding. The extent of willow spread in the Derwent Catchment has been partially mapped (section 6.3.4).

Hydro Tasmania operations in the Derwent Catchment have resulted in the majority of the rivers in the catchment experiencing significant alterations in flow due to diversions, impoundment and power station discharges. The geomorphological issues associated with water storages and altered flows in rivers in the catchment are discussed in the following sections.

7.2 Nive-Dee System

7.2.1 Lakes

Based on a review of the shoreline geology and lake level fluctuations of the ten Hydro Tasmania lakes in the Nive-Dee sub-catchment (Table 7.2), it is possible that the some of these lakes may suffer be prone to shoreline erosion. The shoreline geology of Little Pine Lagoon, Pine Tier Lagoon, Bronte Lagoon, and Laughing Jack Lagoon, is composed of unconsolidated, alluvial/aeolian and siliceous sediments. This geology is susceptible to wave-induced erosion, and this, coupled with frequent water level fluctuations, may result in these lake shores having a propensity to erode. Lake Echo has a similar erosion-susceptible shoreline geology, however as an interseasonal storage it is not subject to frequent water level fluctuations and is therefore probably less vulnerable to shoreline erosion.

Table 7.2 Erosion Susceptibility of Storage Lakes in the Nive-Dee System

Storage	Operating Range (m)	Typical Water Level Cycles	Geology
Little Pine Lagoon	1.5	Monthly	Dolerite (S); basalt (E), alluvial/ aeolian sediments (NW), unconsolidated sediments (N)
Pine Tier Lagoon	2.6	Monthly	Dolerite; glacial / periglacial (N)
Bronte Lagoon	3.7	Monthly	Dolerite; basalt, alluvial/aeolian sediments (SW)
Lake Echo	13.7	Annual	Dolerite; siliceous sediments (E), unconsolidated sediments (N)
Dee Lagoon	0.3	Monthly	Dolerite; siliceous sediments (NE)
Brady's Lake	4.1	No data available	Dolerite; basalt
Lake Binney	4.2	No data available	Dolerite
Tungatinah Lagoon	4.6	Monthly to bi-monthly	Dolerite; basalt
Laughing Jack Lagoon	9.6	Appears to cycle annually with some monthly fluctuations	Siliceous sediments, glacial/ periglacial (N)

7.2.2 Rivers

Deep Creek and Little Pine River

Water from Little Pine Lagoon is diverted through Deep Creek, which is a short, very steep creek with high velocity rapids. The creek is bounded by erosion-resistant doleritic geology and appears to be very stable.

The diversion of water away from the Little Pine River, downstream of the lagoon has reduced the natural flow. The reduced flow, coupled with the relatively erosion-resistant geology of this reach of Little Pine River, means that it is unlikely that erosion is occurring. Processes associated with reduced flow such as channel contraction, sedimentation and vegetation encroachment may be the dominant geomorphological processes in this part of the Little Pine River.

Nive River

Long reaches of the Nive River experience reduced flows as a result of upstream diversions. It is possible that these reaches (Table 7.3) may be subject to processes such as channel contraction, sedimentation and vegetation encroachment. The effect of the dams on the Nive River on the movement of sediment is not known. The erosion potential for most of the Nive River is relatively low, as the geology consists of dolerite and small patches of basalt. There are, however, some glacial and periglacial features below Pine Tier Lagoon that may be susceptible to erosion.

Table 7.3 Reaches on the Nive River Affected by Dams or Flow Regulation

Reach of Nive River	Effect on Natural Discharge	Approx. Length Affected (km)	Geomorphic or Hydrologic Effects
Nive below Pine Tier Dam	Diversion; spill; riparian release	12 km along the Nive River to Woodwards Creek	Channel adjustment Dewatering
Nive below Woodwards Creek (Bronte Dam)	Diversion; spill	15.3 km along the Nive River from Woodwards Creek to Nive Marsh Rivulet (Tungatinah Dam)	Historical channel adjustment/erosion
Nive below Tungatinah Dam	Diversion; spill	3km along the Nive River to Tungatinah Power Station	Dewatering
Nive below Liapootah Dam	Diversion; spill	5km to Wayatinah	Channel adjustment Dewatering

Dee River

Water is periodically released into the Dee River above Dee Lagoon from the spillway on Echo Flume, immediately below Lake Echo Dam. This reach of the Dee River is approximately 5 kilometres long and it flows into the north-east arm of Dee Lagoon adjacent to the Lake Echo Power Station. The environmental issues associated with spills down this section of the Dee River were investigated by Hydro Tasmania's Environmental Services in January 1999.

The original Dee River channel for the first few kilometres downstream of Echo Dam was wide, marshy and well-vegetated, with a defined main channel. The primary channel is no longer well-defined, and is overgrown with mature woody vegetation and fallen trees. There is clear evidence of channel constriction and vegetation encroachment. At present, the channel appears to be highly stable, with no erosion occurring.

The Echo Power Station forebay has a spillway that is overtopped during emergency shutdowns. Excess water flowing down the flume is diverted over the spillway where it flows down a gully to the Dee River upstream of Dee Lagoon. A substantial volume of sediment has eroded from this gully and has been deposited in three main areas:

- A sediment splay several hundred metres wide composed of coarse graded material at the base of the erosion gully. This has partially buried a small patch of dry sclerophyll forest.
- The Dee River channel has experienced significant sedimentation downstream of the gully erosion. This has led to braiding of the river channel and reduction in water depths.
- The delta at the inflow to Dee Lagoon. The majority of the finer sediments flowing down the river have deposited in the still waters of Dee Lagoon to form a delta of approximately 6 ha.

It was found from a series of test spills down the Dee River channel that when the delta was inundated fine sediment was being resuspended. This sediment subsequently entered Dee Lagoon, locally increasing turbidity levels. In order to avoid these problems, Hydro Tasmania has excavated a bypass channel that diverts water away from the delta into the power station tailrace. This measure has ensured that flooding of the delta is avoided and turbidity is minimised. Additional advantages include improved passage for spawning trout, reduced channel maintenance and reduction in areas of aquatic weeds. As a further measure Hydro Tasmania plans to revegetate the exposed sediments on the delta to ensure long-term stability and visual amenity.

The Dee River continues below Dee Lagoon, downstream of the dam. This reach of the Dee River flows through State Forest for approx 35 km. This reach experiences reduced total flows due to upstream diversions (Dee Lagoon, and Lake Echo), however the hydrology is likely to essentially mimic natural patterns.

Bradys Creek; Big Marsh Creek

The development of Bradys Lake and Lake Binney as storages has dewatered Big Marsh Creek and Bradys Creek, the original drainage channels for these catchments. These creeks now receive only local pickup and occasional spills from the lakes. The doleritic geology of Bradys Creek would be relatively resistant to erosion and due to the reduced flows in these creeks, channel contraction, sedimentation and vegetation encroachment may be the dominant geomorphological processes.

Clarence River

Water from the Clarence River is diverted via a pipeline into Bronte Lagoon, resulting in somewhat reduced flows in the river downstream of the diversion weir. Geomorphological processes in this river are not known, however in some instances, a reduction in flows can lead to channel contraction, sediment build-up and vegetation encroachment.

7.3 Upper and Lower Derwent Systems

7.3.1 Lakes

For the storages in the upper and lower Derwent systems, the shoreline geology, operating range and degree of lake level fluctuation, all of which influence the erosion potential of the lake shores, are summarised in Table 7.4. Lake King William and Wayatinah and Cluny lagoons, and Lake Meadowbank have relatively erosion-susceptible geology, and may be prone to shoreline erosion as a result of wave action. Wayatinah Lagoon, Cluny Lagoon and Lake Meadowbank also have rapid water level fluctuations, which may increase the potential for erosion.

Table 7.4 Erosion Susceptibility of Storage Lakes in the Derwent System

Storage	Operating Range (m)	Water Level Cycles	Geology
Lake King William	29.5	Annual with some monthly fluctuation	Glacial / periglacial; dolerite (S,SE,SW)
Tarraleah No 2 Pond	3.0	No data available	Dolerite, basalt
Lake Liapootah	3.5	Daily	Dolerite
Wayatinah Lagoon	3.0	Monthly	Siliceous sediments; basalt (E)
Lake Catagunya	1.5	Daily	Dolerite
Lake Repulse	3.0	Daily	Dolerite
Cluny Lagoon	4.9	Daily	Aeolian/alluvial; siliceous sediments
Lake Meadowbank	6.1	Weekly to monthly	Siliceous sediments

Lake St. Clair

Since 1998, operating rules have been applied to Lake St. Clair to manage the level of the lake in relation to lake shore erosion. Target water levels are derived from ten years of model simulation of the hydro-electric system (Tasmanian Parks and Wildlife Service, 1999b). The targets may be exceeded in particularly wet years.

The Parks and Wildlife Service has mapped erosion and lake shore deposits at Lake St. Clair, and these are reported in Dixon (1994). The comments below have been extracted from this report.

There is reason to believe that the shoreline erosion at Lake St. Clair is related to water level fluctuations. The majority of the serious erosion damage occurred during extended periods of high water levels before 1967, but the destabilised shoreline is now susceptible to ongoing erosion associated with high water levels. Scarps and sheet eroded areas of the shoreline were found to have had 0.5 metres (up to 1 metre in some areas) of soil and bank sediment removed. Banks were observed to have steepened and retreated in some areas.

Wave action is the primary mechanism by which erosion and shoreline recession has occurred at Lake St. Clair. This wave action has been focussed unnaturally high on the bank profile following artificial raising of the lake level. The wind can disturb the vegetation, organic soil and rootmat cover which exposes the banks to further erosion. Other mechanisms of erosion include alluvial bank erosion by desiccation cracking and subsequent wetting, frost action, wind erosion and visitor impact. The most seriously eroded bank types and those susceptible to further erosion include till, moraine or outwash material. The erosion has involved the scarping and/or undercutting of steeper banks (moraine, till or colluvial material) and the sheet-erosion of the lower angle slopes. This erosion has resulted in tree fall, bank collapse and the removal of a significant amount of bank material. The banks at Cynthia Bay and Narcissus are the most seriously affected.

The evidence that suggests that artificially high water levels are the cause of bank erosion includes: freshly scarped till above the natural level of the lake; overhanging root mats; and in many areas a wave-cut notch has developed about 3 metres above the natural level of the lake. The erosion issue is also significant because the Pleistocene glacial landforms and deposits around the lake have been degraded and these features contribute to the area's World Heritage values.

The Tasmanian Wilderness World Heritage Area Management Plan (Tasmanian Parks and Wildlife Service, 1999b) contains a Water Management Strategy for Lake St. Clair which aims to minimise shoreline erosion, maximise revegetation, and enhance the aesthetics of the lake shore environment. Hydro Tasmania has undertaken to modify its operating rules to achieve the following targets:

- The lake level will be maintained above 736.0 m less than 2 % of the time
- The lake level will be maintained above 735.6 m less than 6% of the time

Hydro Tasmania may use the water from Lake St. Clair beyond the limits set down in this strategy, after consultation with and taking into account the views of the National Parks and Wildlife Advisory Council. At times of flooding and extreme weather conditions, Hydro Tasmania will lower Lake St. Clair to full supply level as soon as safe and practicable, thereby minimising shoreline erosion.

Lake Meadowbank

Hydro Tasmania is undertaking some erosion control works on the lake shore at the lower end of Lake Meadowbank as part of a larger project that is addressing land slip issues in the area. This work will also prevent future sediment inputs to Lake Meadowbank as a result of landslip.

7.3.2 Rivers

Derwent River

Flows in the main stem of the Derwent River are variously impounded, diverted and released from power stations. The regulation of the river will have changed the nature of the its sediment load, and it is likely that the cascade of dams act as sediment traps. Table 7.5 lists the geomorphic effects of these hydrological changes on reaches of the Derwent River.

Table 7.5 Reaches on the Derwent River Affected by Dams or Flow Regulation

Reach of Derwent River	Effect on Natural Discharge	Approx. Length Affected (km)	Geomorphic or Hydrologic Effects
Derwent downstream of Lake St. Clair	Diversion; spill	5 km along Derwent R. to L. King William	Erosion
Derwent downstream of Lake King William	Regulated flow, diversion	1 km along Derwent R. to Butlers Weir	Short reach, channel adjustment, dewatering
Derwent downstream of Butlers Weir	Diversion	6 km to Derwent Pump Weir	Channel adjustment, dewatering
Derwent downstream of Derwent Pump Weir	Diversion	9 km to Mossy Marsh Creek	Channel adjustment, dewatering
Derwent downstream of Mossy Marsh Creek	Diversion; spill	17 km along Derwent R. to Wayatinah Lagoon	dewatering
Derwent downstream of Wayatinah	Diversion; spill; riparian release	6.5 km along Derwent R. to L. Catagunya	Hydrology unknown Channel adjustment
Derwent downstream of Cluny Lagoon	Diversion; spill; regulated flow	8.5 km along Derwent River to L. Meadowbank	
Derwent downstream of Lake Meadowbank	Regulated flow, Diversion; spill; riparian release	43 km along Derwent R. to Derwent Estuary; 57 km along Derwent Estuary	Hydro-dynamics altered

The Derwent River downstream of the Meadowbank Power Station has a continuous discharge, however there are sections of the Derwent River further upstream that are diverted and receive only occasional spills or releases. These reaches may be subject to changes associated with reduced flows, such as channel contraction, sediment build-up and vegetation encroachment.

An operating rule limits discharge between Lake St. Clair and Lake King William to protect this reach of the Derwent River from bank erosion. This rule was implemented many years ago, following historic erosion that occurred downstream of the outlet works on Lake St. Clair.

Hydro Tasmania has carried out erosion control works on the banks of the Derwent River upstream of Lake Meadowbank.

7.4 Ouse-Shannon System

7.4.1 Lakes

There are three storage lakes in the Ouse-Shannon sub-catchment. Their susceptibility to shoreline erosion can be gauged in a preliminary manner by examining the shoreline geology and the operational characteristics (Table 7.6).

Shannon Lagoon and Lagoon of Islands have a shoreline geology composed of unconsolidated alluvial and aeolian sediments. These sediments may be susceptible to wind-driven wave action within the operating range of these storages. In addition Shannon Lagoon can have relatively rapid water level fluctuations which may increase its susceptibility.

There is presently a proposal to rehabilitate Shannon Lagoon to improve the fishery. Among the reasons for the decline in the fishery is the high sediment input from run-off from the unsealed road. Coupled with proposed improvements to the road, Hydro Tasmania has been asked to raise the water level in the lagoon by 30 cm. This request is presently being considered.

Table 7.6 Storage Lakes of the Ouse-Shannon System

Storage	Operating Range (m)	Water Level Cycles	Geology
Shannon Lagoon	0.7	Monthly	Dolerite (SE), alluvial and aeolian sediments (E,W), Unconsolidated sediments (N), basalt (NE)
Lagoon of Islands	2.1	Annual to with some monthly	Unconsolidated sediments (NE), alluvial and aeolian sediments (SW, NW), dolerite (N,S)
Penstock Lagoon	0.4	Seasonal	Dolerite

Regarding the shoreline of the Lagoon of Islands, inspections have identified evidence of erosion on the eastern shore of the lagoon. This windward shoreline, comprising a vegetated lunette system, has been subject, in the past to wave erosion. It has also been degraded from trampling, camping and four-wheel driving, although these activities are no longer permitted. The maximum water level of the lagoon was lowered seven years ago, and erosion caused by high water levels has subsequently been reduced. Wind erosion of the exposed windward faces of the dunes has also occurred as a result of these disturbances.

A major issue with respect to the Lagoon of Islands is the large amount of sediments that are eroded from the banks of Ripple Canal and subsequently entrained and transported to the lagoon (section 7.4.3). Some of this sediment is stored in a delta in Lagoon of Islands, which is currently relatively stable. It is also likely that the bathymetry of Lagoon of Islands has been altered with the loss of floating islands and increased sediment inputs.

7.4.2 Rivers

Shannon River

The Shannon River has been dammed at both Miena and at Shannon Lagoon. Miena Dam impounds the majority of natural flow down the Shannon River. While regulating the Shannon River has altered its hydrology, the reach below Shannon Dam is long and it receives numerous inflows which may assist in mitigating the influence of the dams. Operational changes have restored some of the flow to the river, although it remains highly regulated.

The geomorphic effects of regulation on the Shannon River are largely unknown. Shannon Lagoon appears to be acting as a sediment trap for locally sourced sediments (A. Uytendaal, pers. comm.). The geology of the Shannon River immediately below Shannon Lagoon consists of relatively erosion-resistant dolerite; small patches of basalt and alluvial and aeolian sediments a little further downstream; and siliceous and calcareous sediments below its junction with Blackburn Creek. The alluvial, aeolian and siliceous sediments may be prone to erosion although this has not been investigated. Issues of concern in the Shannon River include the removal of riparian vegetation and willow invasion.

Blackburn Creek

Blackburn Creek receives spills and riparian releases from the Lagoon of Islands. There are 13 km of stream channel between the Lagoon of Islands and the Shannon River. Regulation at the Lagoon of Islands has altered the hydrological regime of the waterway, particularly since there are few other inflows to this section of the creek. The seasonality of flows has changed as a result of increased flows for irrigation in summer, when flows would usually be lower.

Ouse River

The Ouse River receives inflow from Penstock Lagoon, spills and irrigation releases from the Monpeelyata Weir, and spills from Liawenee Weir. The characteristics of the reaches downstream of these structures are outlined in Table 7.7.

Table 7.7 Structures on the Ouse River

Reach	Effect on Natural Discharge	Approx. Length Affected (km)	Geomorphic Effects
Ouse River downstream of Augusta Dam	Diversion; spill; riparian release	6.5 km to Liawenee Weir	
Ouse River downstream of Liawenee Weir	Diversion; spill	20 km to Monpeelyata Weir	Long reach Little water Channel adjustment
Ouse River downstream of Monpeelyata Weir	Diversion; spill	92 km to Derwent River	Long reach Little water Channel contraction

Diversion of headwater flows to other catchments has resulted in an overall reduction in Ouse River flows. This reduction may be linked with channel contraction, sediment build-up and vegetation encroachment. Willow infestation of the stream channel in the Ouse River downstream of Waddamana is an issue, and the reduction in flows is likely to have contributed to this.

The geology of the Ouse River is reasonably resistant to erosion, consisting of Jurassic dolerite with Pleistocene glacial deposits in the south-east region of the Central Plateau, and Jurassic dolerite and Tertiary basalt from Liawenee to Ouse.

Little Pine River

Little Pine River downstream of Little Pine Lagoon has reduced flows as a result of the diversion of water from the river into Lake Echo. The reduction of flows in the river may have led to processes such as channel contraction, sedimentation and vegetation encroachment. Erosion in this river is unlikely to become an issue as the geology of Little Pine River is predominantly dolerite, which tends to be erosion-resistant.

7.4.3 Other Infrastructure

Ripple Canal

Bank erosion in Ripple Canal has been an ongoing problem, and is primarily driven by sub-aerial (within the soil) freeze and thaw processes, which loosen the sediment. Periodic flows then wash the material away to re-initiate a firm bank, which then undergoes another cycle of loosening (Prosser and Rutherfurd, 1998). Stock access to the canal exacerbates the problem by causing additional erosion of the banks (Locke *et al.*, 1998).

A preliminary analysis of bank erosion monitoring over four 70 metre long reaches of Ripple Canal during 1996 and 1997 was carried out by Prosser and Rutherfurd (1998). This analysis found that the overall average erosion of two bare reaches in 1997 was approximately 12 millimetres over 155 days during winter. There were several trends in the location and rate of erosion:

- The greatest rate of erosion was on the lower half of the bank with a slightly lower erosion rate at the very base of the banks;
- There were relatively low rates of erosion on the upper half of the bank and little to no erosion of the very top of the banks.

The lower half of the bank is generally exposed to freezing but receives moderate flows, and these factors may explain why the greatest erosion rate was found in this region. Prosser and Rutherfurd (1998) suggest that the upper bank erodes at a lower rate because flows cannot reach high enough, so the loosened sediment remains *in situ* unless it rolls down the bank. This loosened sediment effectively insulates the underlying firm clay from further freeze and thaw, thus slowing down the processes of erosion. The lower portion of the banks stay under flowing water for most of the winter, and are not exposed to freeze and thaw processes.

In the reaches studied, another trend in erosion is that the left bank of the canal is eroding faster than the right bank. This may be due to increased seepage rate and soil saturation on the left bank, too low to directly remove sediments, but enough to increase the size and extent of needle ice development, which is an important part of the freeze and thaw cycle of sediment loosening (Prosser and Rutherfurd 1998).

Hydro Tasmania previously constructed sediment retention basins at two points in Ripple Canal. However, the size of these basins was not able to be made sufficiently large to settle colloidal particles which continue to be discharged into the Lagoon of Islands (Locke *et al.*, 1998).

In 1997 a trial rehabilitation program was implemented by Hydro Tasmania, which consisted of placing biodegradable matting, grass seed and fertiliser on the banks of two selected reaches. The objective was to ascertain whether or not grass cover would decrease the rate of bank erosion. The rehabilitation was successful, with the net result on the revegetated banks during 1997 being a build up of the banks. This was attributed to expansion of clays as they wetted-up during winter, trapping of debris in the matting and growth of the grass (Prosser and Rutherfurd, 1998). The researchers noted that a moderate cover of grass was useful for rehabilitation because it provided insulation against freeze and thaw, improved cohesion and protected against fluvial scour. Stock access to the canal decreases the ability of grasses to establish (Locke *et al.*, 1998).

On the basis of the revegetation trials, a program to rehabilitate Ripple Canal is currently underway. Revegetation of a substantial section of stream bank with a mixture of grasses (including native species) commenced in March 2001. A technique called hydromulching (Land Solutions Tasmania – Native Rehabilitation) was employed, and initial germination and growth has been encouraging. Stock damage to the canal was also quantified during a site inspection in January 2001, and priority areas for fencing were identified at various points along the canal.

7.5 Summary of Geomorphic Issues

Hydro-electric developments in the Derwent Catchment have resulted in fundamental geomorphic changes to waterways in the catchment. Most of the waterways in the Derwent Catchment have no known geomorphological issues. The historical and current issues that are known include, but may not be limited to the following:

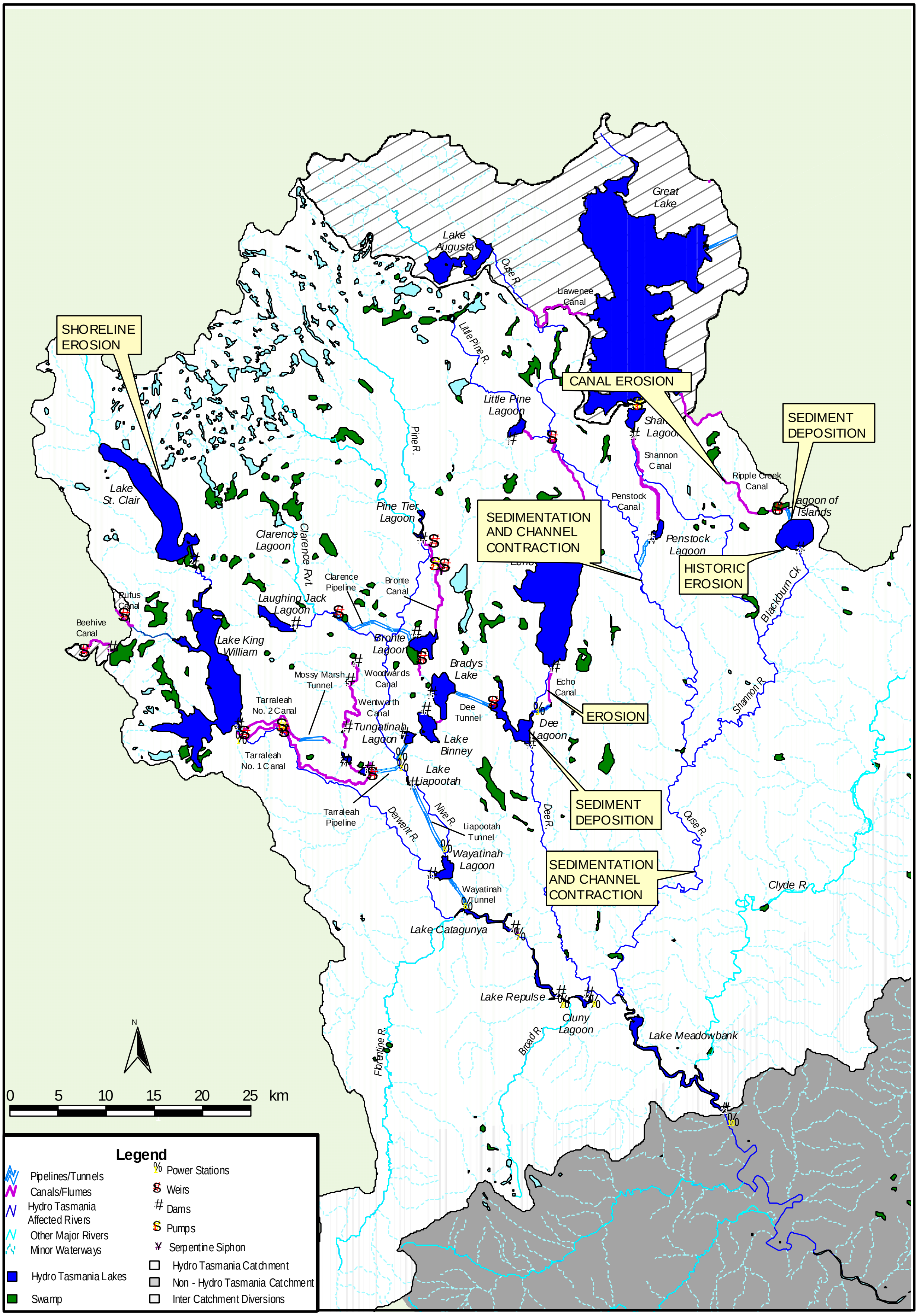
- ongoing bank erosion of Ripple Canal and deposition of these sediments in Lagoon of Islands (trials undertaken from 1996 and phase 1 of treatment undertaken in 2001);
- historic shoreline erosion at Lake St. Clair;
- historic erosion of sediments below the Echo Power Station forebay spillway and the subsequent deposition of these sediments in Dee Lagoon, creating a sediment delta;

- historic erosion of the lunettes at Lagoon of Islands as a result of wave action associated with previously high lake levels; and
- widespread willow infestation in the Ouse, Shannon, Derwent and Nive rivers downstream of diversions and dams potentially encouraging sediment build up and channel contraction.

Map 7.1 shows the waterways affected by Hydro Tasmania operations in the Derwent Catchment with key geomorphological issues noted.

Little is known regarding issues related to the geomorphology of Hydro Tasmania storages, such as lake shoreline erosion. Some of these storage lakes have rapid water level fluctuations and geology that may be susceptible to erosion such as unconsolidated, alluvial and aeolian sediments. There are also information gaps regarding the effect of reduced flows and regulated releases on most of the rivers in the Derwent Catchment.

Hydro Tasmania has undertaken a number of specific geomorphic investigations in the Derwent Catchment through its Aquatic Environment Program. These studies have been in relation to bank erosion of Ripple Canal, shoreline erosion of Lake St. Clair and erosion of sediments below the Echo Flume spillway above the Dee River. To date, the outcomes from these studies have resulted in Hydro Tasmania implementing a lake level management regime at Lake St. Clair, rehabilitation works in the Echo Power Station spillway channel, and rehabilitation works at Ripple Canal.



Map 7.1 Overview of Geomorphic Issues in the Derwent Catchment

8. MULTIPLE USES AND COMMUNITY VALUES

In the previous three chapters, issues relating the water quality, biology and geomorphology of waterways in the Derwent Catchment were outlined. In this chapter, the multiple uses and community values of the waterways in the Derwent Catchment are outlined, and known issues are discussed. This chapter also includes other miscellaneous issues that do not obviously fall into any of the previous chapters. This chapter is subdivided into a number of areas; irrigation and agricultural water use (section 8.1), township and domestic water supply (section 8.2), recreation (section 8.3), fisheries (section 8.4), and cultural heritage (section 8.5). An overall summary of the issues is given in section 8.6. The information in this chapter was obtained by a desktop study of available that involved collating details gained from interviews, legislation and the available literature.

Water uses in the Derwent Catchment are quite diverse and include power generation, irrigation and agriculture, industry use, aquaculture, town water supplies, tourism and recreation. In the western part of the catchment, the land uses are mostly conservation and forestry, and so the water uses differ somewhat from the eastern part of the catchment, which has more agricultural land use.

Water management in Tasmania is principally governed by the *Water Management Act 1999*. This Act repealed the *Water Act 1957* and various other related water management legislation. The purpose of the Act is to further the objectives of the Resource Management and Planning System of Tasmania through promoting sustainable use and development of water resources. The Act is significant in that it provides for the allocation of water for the environment, and focuses on maintaining ecological processes and genetic diversity of aquatic ecosystems. The Act also recognises and protects multiple uses of water, provides for fair allocation of water resources and promotes community awareness and involvement in water management.

Hydro Tasmania operates under a special license under the *Water Management Act 1999*. The purpose of the license is to confirm existing rights and obligations of Hydro Tasmania to other water users. The license also requires an environmental monitoring program designed to assess the environmental impacts or effects of Hydro Tasmania operations.

Hydro Tasmania's special license is based on Hydro-Electric Water Districts, in which Hydro Tasmania has the right to take water. Five Hydro-Electric Water Districts are located within the Derwent Catchment. The River Ouse and River Shannon Hydro-Electric Water Districts fall partly within the catchment, and the River Dee, River Derwent and Lower River Derwent Hydro-Electric Water Districts fall entirely within the Derwent Catchment. Hydro Tasmania has the right to all the water in these catchments apart from certain statutory rights and agreements which give various parties authority to take or use water.

Apart from the *Water Management Act 1999*, other legislation that relates to water management in the Derwent Catchment includes the *Electricity Supply Industry Restructuring (Savings and Transitional Provisions) Act 1995*, which gives statutory rights to some land holders to take water, the *Local Government (Building and Miscellaneous Provisions) Act 1993*, which makes provision for town water supplies and the *State Policy on Water Quality Management 1997*, which has amongst its aims the development of best practice guidelines for releases from impoundments.

Aside from legislated rights or arrangements guiding Hydro Tasmania's water management, there are also a number of informal or formal agreements that Hydro Tasmania has voluntarily entered into. These relate mostly to environmental management and accommodating recreational use and fishing where possible.

8.1 Irrigation and Agricultural Water Use

Riparian land holders on the Ouse River below Waddamana have a statutory right to take water for irrigation, under the *Electricity Supply Industry Restructuring (Savings and Transitional Provisions) Act 1995* and therefore do not require a water license under the *Water Management Act 1999*. Releases to supply this water are made from Lagoon of Islands and Shannon Lagoon and, if necessary, from Little Pine Lagoon.

Members of the Lawrenny Irrigation Scheme, an independent trust set up in the 1840s also have a right under the *Electricity Supply Industry Restructuring (Savings and Transitional Provisions) Act 1995* to draw water from the channels of the scheme, which is supplied from the Derwent River. No licenses are required for this abstraction. Water is supplied to the Lawrenny irrigation channels from the Derwent River. Brock Weir, which is on the Derwent River immediately below the Ouse River junction, backs Derwent River water up into the Ouse River. Brock Pumps draw water from behind the weir and transfer it to a pondage above another weir on the Ouse River. The water from this second weir gravity feeds the Lawrenny Irrigation Scheme. The water is also pumped up 6 metres into a second channel.

There is generally sufficient water available for the Lawrenny Irrigation Scheme without requiring a change to Hydro Tasmania's normal operations. Hydro Tasmania does, however, operate Cluny Power Station to ensure that the water retained behind Brock Weir stays above the pump intake level during the irrigation season.

Under the *Clyde Water Act 1898*, the Clyde Water Trust (riparian landowners on the Clyde River) had rights to take water from the Clyde River. While this Act was repealed by the *Water Management Act 1999*, the rights of the Clyde Water Trust were carried over from the previous Act. However the head storages for the Clyde River, Lakes Crescent and Sorrel, which are not Hydro Tasmania storages, are being managed by IFS to prevent the spread of carp, a pest fish species which is present in these lakes (section 6.3.4). As part of this management, water releases into the Clyde River have been restricted. The Clyde Water Trust were granted a water license to take up to 10,000 megalitres of water from Lake Meadowbank in 2001. The Trust is considering using this water to supplement its existing water supplies.

In addition to the statutory irrigation rights outlined in the previous paragraphs, the Minister of Primary Industries Water and the Environment may issue licenses for irrigation abstraction.

8.2 Industrial Water Use

Hydro Tasmania has an agreement with Norske Skog to maintain a flow in the Derwent River below Meadowbank Dam that is sufficient to prevent the salt wedge from migrating too far upstream. This enables Norske Skog to extract 90 sluiceheads (1.08 cumecs) of fresh water, uncontaminated by salt, from the Derwent River at Lawitta for use in the Boyer paper mill.

8.3 Township and Domestic Water Supply

Water rights for town water supplies are granted under the *Water Management Act 1999*. Councils were granted licenses to abstract 105% of the water allocation taken in the five year period leading up to the passing of the *Water Management Act 1999* for township supply. Hobart Water has a license to take water from the Derwent Catchment under the *Water Management Act 1999*. Hobart Water is owned by the eight councils it supplies and each of these councils has a water district, defined under the *Local Government (Building and Miscellaneous Provisions) Act 1993*.

Hobart Water also benefits from the agreement with Norske Skog as the intake to the Bryn Estyn water treatment plant is virtually across the river from the Boyer mill intake. There is an informal arrangement between Hydro Tasmania and Hobart Water made in 1993, that Hydro Tasmania will maintain a minimum flow at the Bryn Estyn intake to prevent the salt wedge migrating upstream, unless circumstances beyond Hydro Tasmania's control preclude this.

8.4 Recreation

Recreational uses of Hydro Tasmania waterways are diverse. In general, they include recreational angling, boating, water skiing, canoeing, rafting, jet boating and other tourism activities such as wilderness flights and cruises.

Fishing and swimming are major recreational uses in Hydro Tasmania-managed waterways throughout the Derwent Catchment. Trout fishing and boating are also common throughout the catchment. Hydro Tasmania manages the level of some lakes to provide favourable angling conditions. Water skiing is a popular recreational activity on Lake Meadowbank, where the Meadowbank Water Ski Club is based. A competition canoeing and kayaking course is located on Woodwards Canal (sometimes referred to as Bradys Canal), and Hydro Tasmania has special arrangements in place to release water through the course in order to provide a suitable flow during competition events. A jet boat operates on the lower Derwent River at New Norfolk, and a power boat club also uses this reach of the river.

Duck hunting is permitted on Hydro Tasmania lakes in accordance with a negotiated agreement between Hydro Tasmania and the Tasmanian Farmers and Graziers Association (TFGA). The Hydro Tasmania lakes that are open to duck hunting vary from year to year. No operational restrictions are associated with duck hunting.

8.5 Fisheries

The IFS is established under the *Inland Fisheries Act 1995*. This Act defines the jurisdictional boundaries of the inland fisheries and administers fishing licenses and registrations, specifies the powers of fisheries officers and provides for a number of offences and miscellaneous matters. There are provisions in the Act relating to the passage of fish in inland waters, which may influence how Hydro Tasmania may operate some of its structures.

8.5.1 Recreational Angling

One of the largest recreational uses of Hydro Tasmania waterways is trout angling. Hydro Tasmania has made efforts to accommodate angling requirements and a number of lake level agreements with the IFS are currently in place (see section 4.2.4). In some cases, these agreements require a change to optimum hydro-generation practices.

All Hydro Tasmania lakes in the Derwent Catchment are used for trout fishing, as are the Derwent, Ouse and Nive rivers. Table 8.1 gives a relative indication of how much time is spent fishing for trout at lakes and rivers in the Derwent Catchment and also indicates how many fish are caught in the various waterways. The data in Table 8.1 were collected by the IFS from an annual questionnaire mailed to anglers each year. The numbers gleaned from the surveys are thought to be within approximately 30% of the true figures, and should be regarded as indicative only. The data from each waterway are averaged over about eleven fishing seasons between 1985/86 and 1995/96.

Table 8.1 indicates that Bronte Lagoon is by far the most popular Hydro Tasmania storage for fishing in the Derwent Catchment, followed by Little Pine Lagoon, Bradys Lake, Lake Echo and Dee Lagoon. The Derwent River is the most popular river for fishing, followed by the Ouse and then Nive River. The rainbow trout fishery in the Derwent Catchment is important as much larger numbers of rainbow trout are caught in the Nive-Dee lakes than in other areas of Tasmania.

Trout fishing in Tasmania is not only a popular recreational pursuit throughout the State, but also forms part of Tasmania’s tourist industry. Hydro Tasmania recognises the economic benefit this brings to the State, and the importance of maintaining recreational uses of its waterways where possible. As such, Hydro Tasmania manages a number of its storages for trout fishing by maintaining minimum or maximum levels where possible. These storages include Bronte Lagoon, Laughing Jack Lagoon, Little Pine Lagoon, Shannon Lagoon, Lagoon of Islands and Penstock Lagoon.

Hydro Tasmania also maintains spawning channels in some waterways (for instance Waddamana No. 2 Canal) to assist with maintaining the wild trout population.

Table 8.1 Average Annual Fishing Effort and Catch Rate in Derwent Waterways (Data from IFS Angler Questionnaire Database, 1985-1996)

Storage/River	Angler Effort	Angler Numbers	Harvest (brown)	Harvest (rainbow)
Derwent River	16550	2950	11870	510
Bronte Lagoon	14000	3050	15850	2400
Little Pine Lagoon	7600	1900	9650	100
Bradys Lake	5750	1950	4750	950
Lake Echo	4800	1650	8800	700
Dee Lagoon	4650	1600	2000	1350
Lake Binney	4200	1150	3300	300
Penstock Lagoon	3400	1150	2600	400
Lake Meadowbank	3100	1150	2700	150
Pine Tier Lagoon	2500	1050	4550	700
Lagoon of Islands	2500	1050	1150	750
Tungatinah Lagoon	2350	750	1550	150
Laughing Jack Lagoon	2250	800	3000	100
Lake St. Clair	1800	600	2650	500
Lake King William	2000	850	6600	800
Wayatinah Lagoon	1750	450	2200	<50
Ouse River	650	350	900	<50
Lake Repulse	650	200	650	50
Cluny Lagoon	750	250	500	300
Nive River	250	200	150	N/A
Lake Catagunya	250	150	500	50

[a] Angler Effort – Total number of angler days per season
[b] Angler Numbers – Number of individual anglers per season
[c] Harvest – Number of fish caught per season
Note: the statistics for the rivers include the entire length of river – not only Hydro Tasmania-affected reaches
Lakes Catagunya and Repulse only 85/86 and 91/92 to 95/96 seasons
Ouse River only 86/87 to 90/91 seasons
Nive River only 90/91 to 95/96 seasons

8.5.2 Commercial Fisheries and Aquaculture

Short-finned eels form the basis of a commercial fishery in Tasmania, with an annual catch of around 30 tonnes. The fishery encompasses most lakes and rivers in Tasmania, and each of the approximately 10 license holders has a discrete area to fish. The catch is largely exported, with some value-adding such as smoking.

Restocking of Tasmanian waterways by the IFS helps to support the commercial fishery, which has been seen as having sustainability problems. The construction of dams across many waterways in the State has created barriers, which are virtually impassible to migrating fish species, including eels (section 5.3.3.2). The IFS undertakes annual harvesting of elvers (juvenile eels) below Meadowbank Dam and Trevallyn Dam in the South Esk Catchment, for restocking of Tasmanian lakes and rivers. Some elvers are also sold for restocking of interstate waterways.

The Salmon Ponds at Plenty is an historic hatchery and tourist attraction run by the IFS. Salmon and trout species are hatched and reared before being used to restock lakes and rivers around the State.

SALTAS (Salmon Enterprises Tasmania) Fisheries Pty Ltd is one of Tasmania's major salmon trout hatcheries. SALTAS runs hatcheries at Florentine and Wayatinah to provide stock for ocean-based aquaculture farms. A Commercial Agreement exists between Hydro Tasmania and SALTAS regarding the release of water from Lake King William to supply water at Wayatinah, providing that water is available for release when requested. Hydro Tasmania also endeavours to inform SALTAS prior to releases or spills of water from Lake King William that will affect conditions in the river at the hatchery water intake.

There have also been a number of recent proposals for the establishment of other aquaculture ventures in Hydro Tasmania lakes in the Derwent Catchment.

8.6 Cultural Heritage

8.6.1 Aboriginal Cultural Heritage

The primary legislation governing Aboriginal cultural heritage values in Tasmania is the *Aboriginal Relics Act 1975*. This legislation governs the treatment of Aboriginal cultural heritage (any place, site or object made or created by, or bearing the signs of activities of, the original inhabitants of Australia or descendants of such inhabitants, in or before 1876) in Tasmania. It is administered by DPIWE.

The Tasmanian Aboriginal Land Council (TALC) is the representative body for the Tasmanian Aboriginal community and has established protocols and policies with State government agencies, local governments, private developers and other parties. These mechanisms are aimed at ensuring that the Aboriginal community's cultural heritage interests are maintained and protected, and they also assist in ensuring that matters pertaining to Aboriginal heritage are dealt with in an expedient manner.

The section of the Act most relevant to Hydro Tasmania is Section 14(1) of the *Aboriginal Relics Act 1975*. Section 14(1) of the *Aboriginal Relics Act 1975* states:

> Except as otherwise provided in this act, no person shall, otherwise than in accordance with the terms of a permit granted by the Minister on the recommendations of the Director –
>
> (a) destroy, damage, deface, conceal, or otherwise interfere with a relic.

In addition, Section 10 (3) of the Act states:

> A person shall, as soon as practicable after finding a relic, inform the Director or an authorised officer of the find.

Maintaining the integrity of Aboriginal sites is important from two perspectives, these are the cultural significance of the site itself to the Tasmanian Aboriginal community, and the legislative requirements..

For the Aboriginal community, land tenure is an important issue in relation to land that has Aboriginal values attached to it. Where such land is private freehold or managed by government agencies, the Aboriginal community may not have access to the land and may be alienated from it and the cultural values it holds. It is important that the Aboriginal community, through TALC and the appointment of an Aboriginal Heritage Officer, be involved in any Aboriginal cultural heritage surveys on such land so that the correct protocols are followed.

As well as issues related to land tenure, the Aboriginal community is also concerned with the management or protection of particular sites. Such issues are site specific and are dependent on the location and the nature of the site or values. Management issues may not be related to one particular site but may include the landscape, usage of the area and the overall context. Therefore, understanding of overall values of an area is important for management of Aboriginal cultural heritage issues.

It is important to the Aboriginal community that they are consulted through TALC, regarding Aboriginal cultural heritage issues. Consultation with the community may also provide more effective management measures, whereby all aspects can be properly considered. Sites are not rated by the Aboriginal community in terms of their ‘significance’ as all sites are seen as being significant, however there are some sites that may be more important than others in terms of the type of site (for instance art sites versus isolated artefacts). Without community input through an Aboriginal Heritage Officer, this type of assessment can not be made.

From what is known in the Derwent Catchment, it can be speculated that in the upper Derwent region around Lake St. Clair and Lake King William, sites are likely to include rock shelters, quarries and artefact scatters, and in the lower Derwent region, art sites could also be expected. The Derwent and Ouse River valleys would be expected to be quite rich in sites as the river valleys would have been a corridor for movement. Sites may be less common in the region around the Nive-Dee, although it would still be expected that artefact scatters and possibly some quarry sites would be present. This information is speculative, based on what is already known in these areas, and there are likely to be many other sites in existence that have not been discovered.

There is little documented evidence regarding the influence of Hydro Tasmania waterway regulation on Aboriginal site integrity in the Derwent Catchment. The three primary ways in which Hydro Tasmania’s waterway operations could affect Aboriginal sites are inundation, wave sorting and erosion.

Flooding of Aboriginal sites during the creation of water storages is known to have occurred during development of the Derwent Catchment. The number of flooded sites and the extent of impacts are unknown, however it is known that important art sites (the first art sites discovered in Tasmania) were flooded as a result of development of the lower Derwent. Once sites have been inundated management options are limited, although some sites may remain relatively undisturbed under water. When Hydro Tasmania storages are drawn down for maintenance or other purposes, it provides an opportunity for sites to be surveyed and the information they contain to be recorded. Liaison with the TALC on this issue may enable the Aboriginal community to take advantage of these opportunities.

Sites located around lake shores may be subject to wave action and periodic wetting and drying due to fluctuations in water levels. Wave action may disturb site integrity by erosion of the site and exposure of artefacts, and by washing the artefacts up and down resulting in sorting into size classes. Periodic wetting and drying of sites in the littoral zone of lakes may also encourage erosion, exposing artefacts. Siltation of sites may also be an issue for inundated sites and sites on lake shorelines.

Wind-formed sand dunes (lunettes) found adjacent to lakes, such as one near Lagoon of Islands, are potentially rich in Aboriginal sites. These landforms may be affected by lake level fluctuations and wave action. The lunette at the Lagoon of Islands, which borders the south-east and east side of the lagoon, is known to contain Aboriginal sites. The lunette has been degraded by erosion, and this appears to have impacted on some Aboriginal sites, however the extent of impact has not been properly assessed.

While not specifically a water management issue, recreational users of waterways may have significant impacts on Aboriginal sites through vehicle access and fossicking.

8.6.2 Historic Cultural Heritage

Historic cultural heritage of assessed State significance is subject to the *Historic Cultural Heritage Act 1995*. This act forms part of the State’s Resource Management Planning System (RMPS). The Act, through the creation of the Tasmanian Heritage Council, the Tasmanian Heritage Register, heritage areas, heritage agreements and stop work orders and repair notices seeks to promote the identification, assessment, protection and conversation of places having historic cultural heritage significance in Tasmania.

There are no Hydro Tasmania structures currently listed on the Tasmanian Heritage Register, however there are several sites in the Derwent Catchment that are generally considered to have heritage significance, including the Waddamana A Power Station. The power station was decommissioned in 1965 and was opened by Hydro Tasmania as the Waddamana Power Museum in 1988. It is now a significant tourist attraction that contains restored machinery, set in an environment reminiscent of the 1920's.

The Institute of Engineers, Australia (IEA) participates in the identification and recording of industrial heritage sites. In particular these sites are recognised as either National Engineering Landmarks or identified by Historic Engineering Markers. Waddamana A Power Station has National Engineering Landmark status and Tarraleah has an Historic Engineering Marker. Several Hydro Tasmania dams were recently recognised as well, including Catagunya Dam and Laughing Jack Dam in the Derwent Catchment.

The old pump house site on Pumphouse Point, Lake St. Clair is an historic site, managed by the Tasmanian Parks and Wildlife Service (PWS). The Derwent Bridge Hut is an old ex-Hydro Tasmania slab hut built near Lake St. Clair Control Gates. It was previously inhabited by the gate controller, but is now privately owned and managed by the PWS.

8.7 Summary of Multiple Uses and Community Values

As discussed in this chapter, water resources in the Derwent Catchment are used for a range of purposes in addition to the generation of hydro-electricity. These uses include irrigation, commercial fisheries, recreational angling, tourism and other recreational activities such as swimming, water skiing and kayaking. In addition, the land adjacent to the waterways may support other values such as cultural heritage, that could be affected by waterway use.

There are a number of ways in which Hydro Tasmania's operations may affect other uses of water and community values. Issues associated with these uses and values include (but may not be limited to) the following:

- availability of water for irrigation in the Ouse and Shannon rivers and the Lawrenny Irrigation Scheme;
- suitable flows and lake levels for recreational uses, including fishing and boating, in a number of waterways;
- fresh water supply to industry and domestic supply intakes downstream of Meadowbank Dam;
- water supply for trout spawning at Waddamana No. 2 Canal;
- cooperating with aquaculture operations in the catchment;
- fish migration issues in relation to commercially fished species (eg. eels); and
- management of cultural heritage issues.

Map 8.1 indicates multiple uses and community values in the Derwent Catchment. Hydro Tasmania currently has in place a number of operational strategies to manage issues associated with multiple use and community values in the Derwent Catchment. In other areas, management measures or procedures have not yet been developed.

Hydro Tasmania makes a quantity of water available for allocation by the RWSC in the lower Derwent Catchment, and also supplies the Lawrenny Irrigation Scheme with water from behind Brock Weir on the Derwent River. Irrigators on the Ouse and Shannon rivers are also supplied by Hydro Tasmania releases.

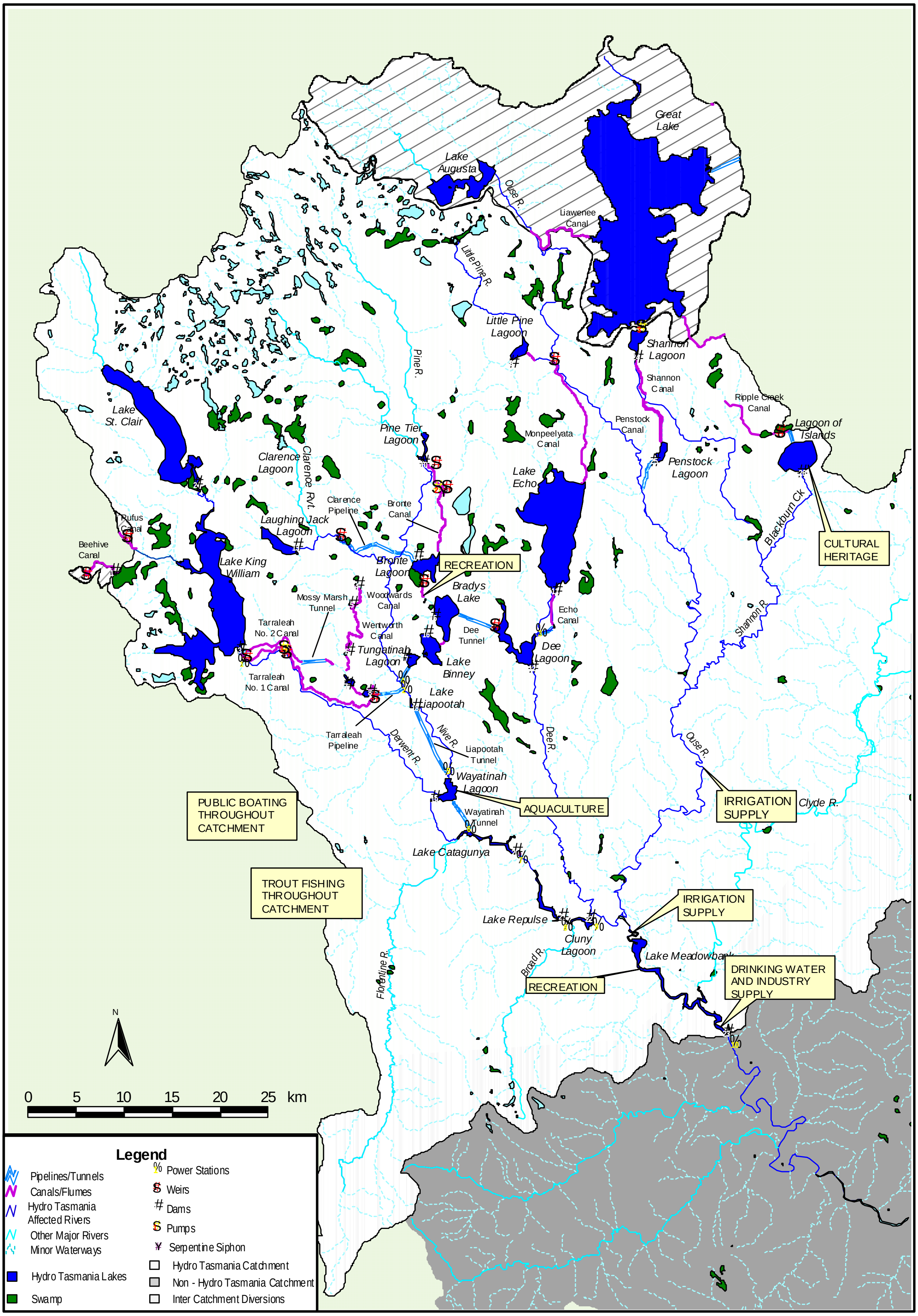
Hydro Tasmania ensures that there is sufficient flow in the Derwent River downstream of Meadowbank Dam to prevent the salt wedge from extending upstream to the Norske Skog intake for the Boyer Mill and the Bryn Estyn water treatment plant intake opposite. Elver harvesting for restocking of Tasmanian waterways is carried out downstream of Meadowbank Dam.

Hydro Tasmania maintains lake level agreements for Bronte, Laughing Jack, Little Pine, Shannon and Penstock lagoons, and the Lagoon of Islands, primarily in relation to trout fishing. Water is sometimes released for kayaking events on the Woodwards Canal whitewater kayak course.

No assessment has been made to date of the likely impact of Hydro Tasmania waterway management on Aboriginal values. However, consultation with the Aboriginal community through TALC is seen as part of normal protocol.

Hydro Tasmania, in its Aquatic Environment Policy recognises the multiple uses of its waterways. The organisation has committed to operate its business in a manner that takes community views and values into consideration, and is prepared to work cooperatively with other government agencies and the community to find practical solutions to water management. This cooperative approach assists Hydro Tasmania in making informed management decisions based on consultation and with community involvement.

Hydro Tasmania has initiated of a review of its water management practices throughout the major catchment areas influenced by its operations. A review of the South Esk – Great Lake Catchment commenced in 1999 and the Derwent Catchment will be the next to be reviewed. The Water Management Review process aims to ensure that Hydro Tasmania has in place practices that are environmentally and economically sustainable, and can link into DPIWE water management plans as appropriate. The review of the Derwent Catchment will take a consultative approach involving stakeholders and DPIWE and it is expected that further issues relating to multiple use and community values will become evident through this process.



Map 8.1 Overview of Multiple Uses and Community Values in the Derwent Catchment

9. SUMMARY AND CONCLUSIONS

9.1 Hydro Tasmania Assets and Operations

The information included in this report describes Hydro Tasmania's infrastructure and operations in the Derwent Catchment, and presents the current state of knowledge on environmental impacts and issues associated with waterways affected by Hydro Tasmania operations.

Utilisation of the waters of the Derwent Catchment for electricity generation dates back to the early 1900s. The Waddamana and Shannon power developments were the earliest in the Derwent Catchment, generating electricity using water from Great Lake. These schemes were phased out following the commissioning of the Poatina Power Station in the 1960s, which meant that the water from the Great Lake Catchment was then diverted north to the South Esk Basin. The upper Derwent system was constructed in various stages from the 1930s to the early 1950s, and the Nive-Dee and lower Derwent systems were developed for electricity generation in the 1950s and 1960s. Hydro Tasmania utilises all the water resources in the Derwent Catchment upstream of the Meadowbank Dam to generate electricity or provide irrigation water. The development of the catchment for hydro-electricity generation, resulted in natural lakes being raised, and the creation of new instream storages. In addition, inter-basin transfers of water were established, including diversions to and from other catchments and diversion between waterways within the catchment. Inevitably, these modifications resulted in some changes to the environment.

9.2 Known Environmental Issues

This report identifies known impacts and issues associated with Hydro Tasmania operations in the Derwent Catchment, and also outlines issues in Hydro Tasmania-affected waterways that are not related to Hydro Tasmania operations. The identified issues are presented under the headings of water quality (Chapter 5), biological issues (Chapter 6), geomorphological issues (Chapter 7) and multiple uses and community values (Chapter 8). These issues are summarised at the end of their respective chapters. In this chapter, identified issues are outlined in relation to each waterway in the Derwent Catchment. This summary is provided in Table 9.1 and depicted in Map 9.1.

9.3 Hydro Tasmania Response to Issues

Hydro Tasmania's Environmental Policy and Aquatic Environmental Policy were written in recognition of the modifications which have been made to the State's water resources, the multiple use nature of these resources and the complexity and variability of issues associated with these waterways. Hydro Tasmania's Aquatic Environment Program aims to put policy statements into practice. It does this on three broad fronts:

1. A Waterway Health Monitoring Program;
2. Targeted investigative studies; and
3. The Hydro Tasmania Water Management Reviews.

The Waterway Health Monitoring Program provides baseline information on the health of Hydro Tasmania-affected waterways. It monitors not only water quality, but also biological indicators and physical condition of streams and lakes. Data and resultant analysis will be publicly available through the annual reports of the Waterway Health Monitoring Program.

Targeted investigative studies in waterways in the Derwent Catchment include the Lagoon of Islands studies, rehabilitation work at Ripple Creek, and work on the Lake Echo spillway erosion. These projects were initiated in response to specific issues identified in the catchment.

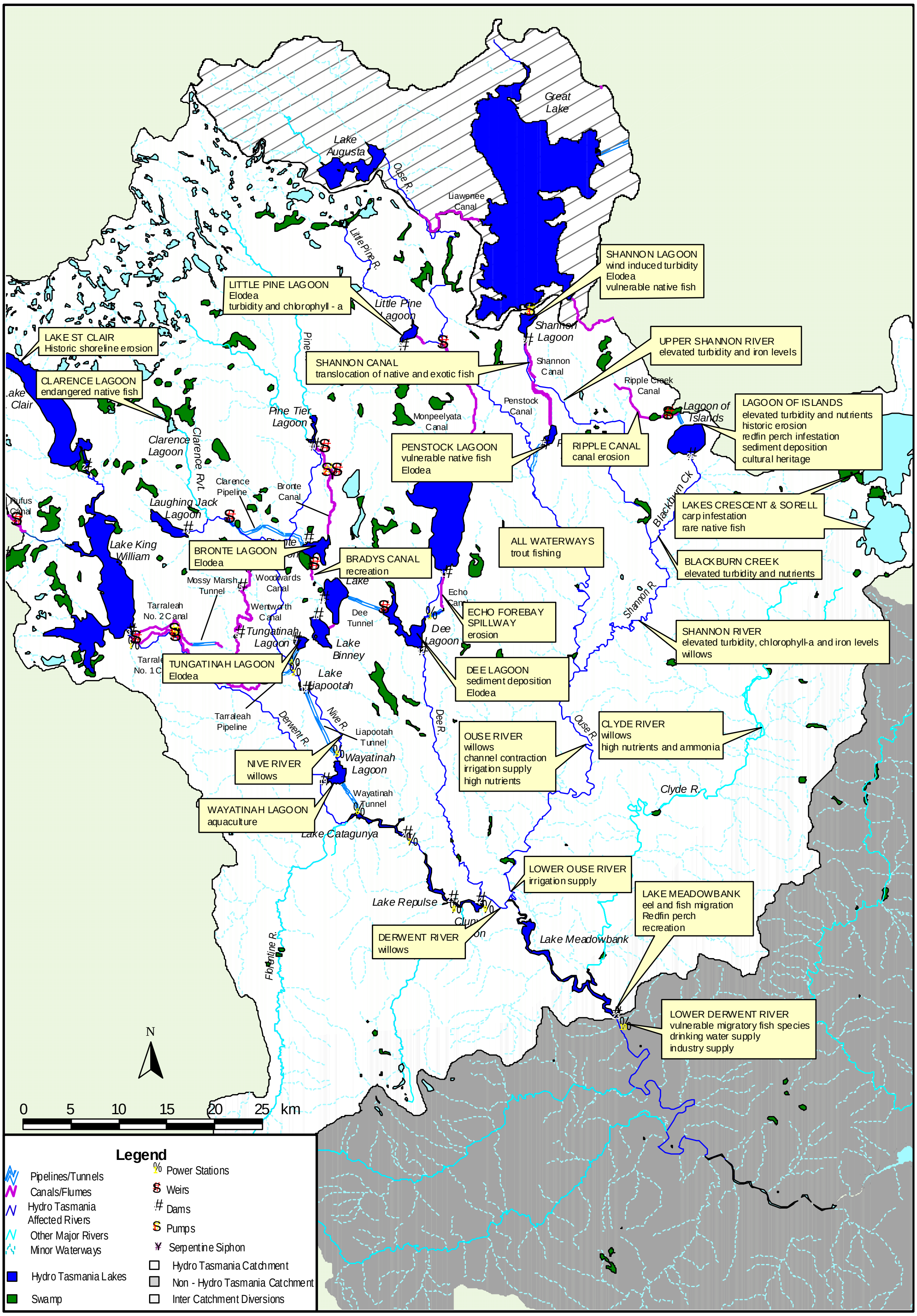
The Hydro Tasmania Water Management Review process is designed to systematically re-assess Hydro Tasmania's water management operations on a catchment by catchment basis, in consideration of issues raised by the general community and information brought forward through the Waterway Health Monitoring Program and targeted investigative studies. The South Esk – Great Lake Water Management Review is underway and the Derwent Catchment is planned as the second to be undertaken. The Water Management Reviews form an important part of Hydro Tasmania's commitment to sustainable management of the water resources under its control. The output from each review will be able to be easily incorporated into a Water Management Plan for the relevant waterways, as allowed for under the *Water Management Act 1999*.

Hydro Tasmania has already demonstrated its willingness to work with stakeholders to achieve solutions and improve the value of its waterways to the community. Lake level agreements are in place for a number of lakes in the Derwent Catchment, operating structures have been installed and operating procedures modified to improve water quality in important fishing waters, such as Penstock Lagoon, flows are released in locations such as downstream of Meadowbank Dam to provide for industrial and domestic supply uses, and Woodwards Canal (sometimes referred to as Bradys Canal) to provide for recreational canoeing.

Table 9.1 Summary of Issues in Hydro Tasmania Waterways in the Derwent Catchment

Waterbody	Known Issues
Shannon Lagoon	Wind induced turbidity; suspension of sediments; *Elodea; Paragalaxias eleotroides; Paragalaxias dissimilis;* Lake level agreement
Lagoon of Islands	Elevated turbidity and nutrients; historic lunette erosion; redfin perch infestation; cultural heritage.
Shannon River	Elevated turbidity and iron levels; willow infestation
Penstock Lagoon	Historic turbidity, algal problems and elevated nutrients; *Elodea*
Derwent River	Historic erosion downstream of Lake St. Clair; Willow infestation; downstream freshwater flows;
Echo Canal	Historic erosion
Dee Lagoon	Sediment deposition; elevated chlorophyll levels (Mentmore Marsh)
Little Pine Lagoon	*Elodea;* Elevated Chlorophyll-*a* and turbidity levels; Lake level agreement
Nive River	Willow infestation
Meadowbank Dam	Eel and fish migration
Monpeelyata Canal	Historic bank erosion
Lakes Crescent and Sorell (non-hydro)	Carp infestation
Laughing Jack Lagoon	Lake level agreement;
Bronte Lagoon	*Elodea;* Lake level agreement
Lake St. Clair	Historic shoreline erosion
Clyde River	Willow infestation
Waddamana No. 2 Canal	Channels for trout spawning
Wayatinah Lagoon	Aquaculture operations
Shannon Canal	Translocation of native and exotic fish
Blackburn Creek	Elevated turbidity and nutrients
Tungatinah Lagoon	*Elodea*
Ouse River	Willow infestation; channel contraction; irrigation requirements;
Clarence Lagoon	Threatened native fish – *Galaxias johnstoni*
Ripple Canal	Canal erosion

Hydro Tasmania fully recognises that aquatic environment issues are inherently complex, that underlying processes and factors need to be carefully discerned and analysed, and that options to address these issues need to be considered in close consultation with users. Solutions should consider community based water management values and goals as well as business needs and objectives. This document is seen as an important step towards achieving this balance.



Map 9.1 Summary of Aquatic Environmental Issues in the Derwent Catchment

GLOSSARY

Term	Definition
Algae	Unicellular or multicellular plants, occurring in water or moist ground, that have chlorophyll but lack true stems, roots and leaves. Microscopic forms also known as phytoplankton.
Alkalinity	Measure of soluble mineral salts which increase the pH of water, in particular calcium carbonate ($CaCO_3$).
Anoxic	Absence or deficiency of oxygen.
Biodiversity (biodiverse)	The number and variety of species in a community.
Biological indicator	A species or organism which is used to grade environmental quality or change.
Chlorophyll-*a*	A green pigment present in photosynthesising biota. The amount present can be measured by spectrophotometer to indicate the amount of algae present in a water sample.
Conductivity	A measure of the ability of a substance to conduct electricity. In water analysis, it indicates the amount of ions present in the water. Also known as electrical conductivity. Measured in µS/cm.
Critical Habitat	An area of land defined under Tasmania's *Threatened Species Protection Act 1995* as critical for the survival of listed endangered flora or fauna.
Cumec	1 cubic metre per second (m^3/s).
Deflation lag	A deflation lag occurs as a result of the removal by wind of fine, loose materials from a deposit of initially mixed grain size, leaving the coarse materials as a lag or residue at the surface.
Diadromous	Fish which migrate between fresh water and salt water environments to complete their life cycles.
Diatom	Algae that have siliceous and often highly sculptured cell walls.
Ecosystem	A community of interdependent organisms together with the environment they inhabit and with which they interact, and which is distinct form adjacent communities and environments.
Efficient Load	The generation load where the amount of energy produced per unit of water passing through the turbine is maximised.
Electrical conductivity	See conductivity.
Endemic	Organism having a distribution limited to a particular geographical area such as an island.
Eutrophic	Applies to waterbodies which are high in plant nutrients, usually through pollution. This often leads to algal blooms that may smother higher plants, reduce light intensity and, through excessive respiration, deoxygenate the water, causing the death of many aquatic animals and higher plants.
Exotic	Not native, introduced, a species not naturally found where it occurs.
Faecal coliforms	A group of bacteria normally abundant in the intestinal tracts of warm-blooded animals including humans, indicators of the contamination of water by faeces.

Fauna	Any taxon of animal, whether vertebrate or invertebrate, in any stage of biological development and includes eggs and any part of such taxon.
Flora	Any taxon of plant, whether vascular or non-vascular, in any stage of biological development and any part of any such taxon.
Full Gate	The maximum flow that can be passed through a turbine.
Full Supply Level (FSL)	The maximum level in a storage at which water can be stored indefinitely, in many cases, equal to the crest level of the spillway.
Galaxiid(s)	Fish that are members of the Family Galaxiidae (includes the genera *Galaxias*, *Galaxiella* and *Paragalaxias*).
Habitat	Part of the environment which is occupied by an organism (plant or animal). A habitat supplies the organism's basic life requirements for survival (eg. food, cover, water).
Halocline	A salinity discontinuity, a zone of marked salinity gradient.
Hardness	A measure of the amount of dissolved mineral salts, the more salts present the harder the water is said to be.
Hyporheic	Pertaining to saturated sediments beneath or beside streams and rivers.
Interstitial	Pertaining to, or occurring within, the pore spaces (interstices) between sediment particles.
Kettle holes	A depression in glacial drift caused by the melting of ice which once formed part of the deposit.
k.y.a	Thousand years ago.
Listed Species	A species of flora or fauna which is listed with the *Threatened Species Protection Act 1995* or any other Commonwealth or State protective legislation.
Macroinvertebrate	Those invertebrates, usually with an aquatic phase, that are greater than 2 mm in size when fully developed. Includes caddisflies, dragonflies, mayflies, chironomids, oligochaetes, molluscs etc.
Meromictic. meromixis	Refers to lakes which are permanently stratified. This occurs when dissolved substances such as ions, create a gradient of density differences with depth, such that the complete mixing and circulation of water masses is prevented.
Mesotrophic	Applied to freshwater bodies which contain moderate amounts of plant nutrients and are therefor moderately productive (see eutropic).
Microbial	Referring to microscopic organisms, usually bacteria.
Monimolimnetic	The stagnant high density deep water layer in a meromictic lake.
Monomictic	A lake having a single period of free circulation or overturn per year, with consequent disruption of the thermocline; may be either cold monomictic or warm monomictic.
Monadnocks	A residual hill of hard rock in an otherwise eroded area.
Native	A species found naturally in Tasmanian waters.
Normal Minimum Operating level (NMOL)	The lowest level that a lake or reservoir can be drawn down to without restricting generation output.

Oligotrophic	A freshwater body which is low in plant nutrients. Oligotrophic water bodies are unproductive and their waters are usually clear as planktonic organisms are sparse.
Periglacial	Applied to the area surrounding the limit of glaciation and subject to intense frost action, and to the living organisms typical of such areas.
pH	Measure of the acidity or alkalinity of a sample: 7 is neutral, less than 7 is more acidic, greater than 7 is more alkaline.
Phytoplankton	Microscopic plants (algae) which are found in water. The basis of aquatic food chains.
Recovery Plan	A plan made for the improvement of conservation status for any species of flora or fauna which is under the threat of extinction.
Scarping	To wear or cut so as to form a steep slope.
Secchi	A method used for estimating the transparency of water by submerging a white disc (Secchi disc) of standard size and recording the depth at which it disappears from view.
Solifluctuation deposits	Deposits resulting from the gradual downhill flow of fragmented surface material, typically over a frozen substrate.
Species	A population or group of individual flora or fauna which interbreed to produce fertile offspring or which possess common characteristics derived from a common gene pool.
Stratification	The vertical structuring of a waterbody into horizontal layers, usually with distinct layers of temperature, oxygen or conductivity.
Taxa/Taxon	A grouping within the classification of organisms, eg. species, genus, order, etc.
Thermocline	A boundary layer in a waterbody in which the temperature changes sharply by at least 1°C.
Threatened	A generic label which covers any species which is listed with the *Threatened Species Act 1995*, regardless of category. A species of flora or fauna at risk of extinction.
Threatening Process	Any process which poses a threat to the natural survival of any native taxon of flora or fauna.
Total Kjedhal Nitrogen (TKN)	A measure of total nitrogen, one of the plant nutrients. High levels in water have been associated with algal blooms.
Turbidity	The cloudiness in a fluid caused by the presence of finely divided, suspended material. Measured using nephelometric turbidity units (NTU).
Type Locality	The exact geographical site at which the type of a species or sub-species was collected.
Wetland Ecosystem	Any areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.
Zooplankton	Microscopic animals (microinvertebrates) found in water. Consume algae and bacteria, and in turn are eaten by macroinvertebrates and fish.

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LIST OF LEGISLATION

Clyde Water Act 1898 (Tasmania – Repealed)

Water Act 1957 (Tasmania – Repealed)

National Parks and Wildlife Act 1970 (Commonwealth)

Aboriginal Relics Act 1975 (Tasmania)

Local Government (Building and Miscellaneous Provisions) Act 1993 (Tasmania)

Inland Fisheries Act 1995 (Tasmania)

Historic Cultural Heritage Act 1995

Electricity Supply Industry Restructuring (Savings and Transitional Provisions) Act 1995 (Tasmania)

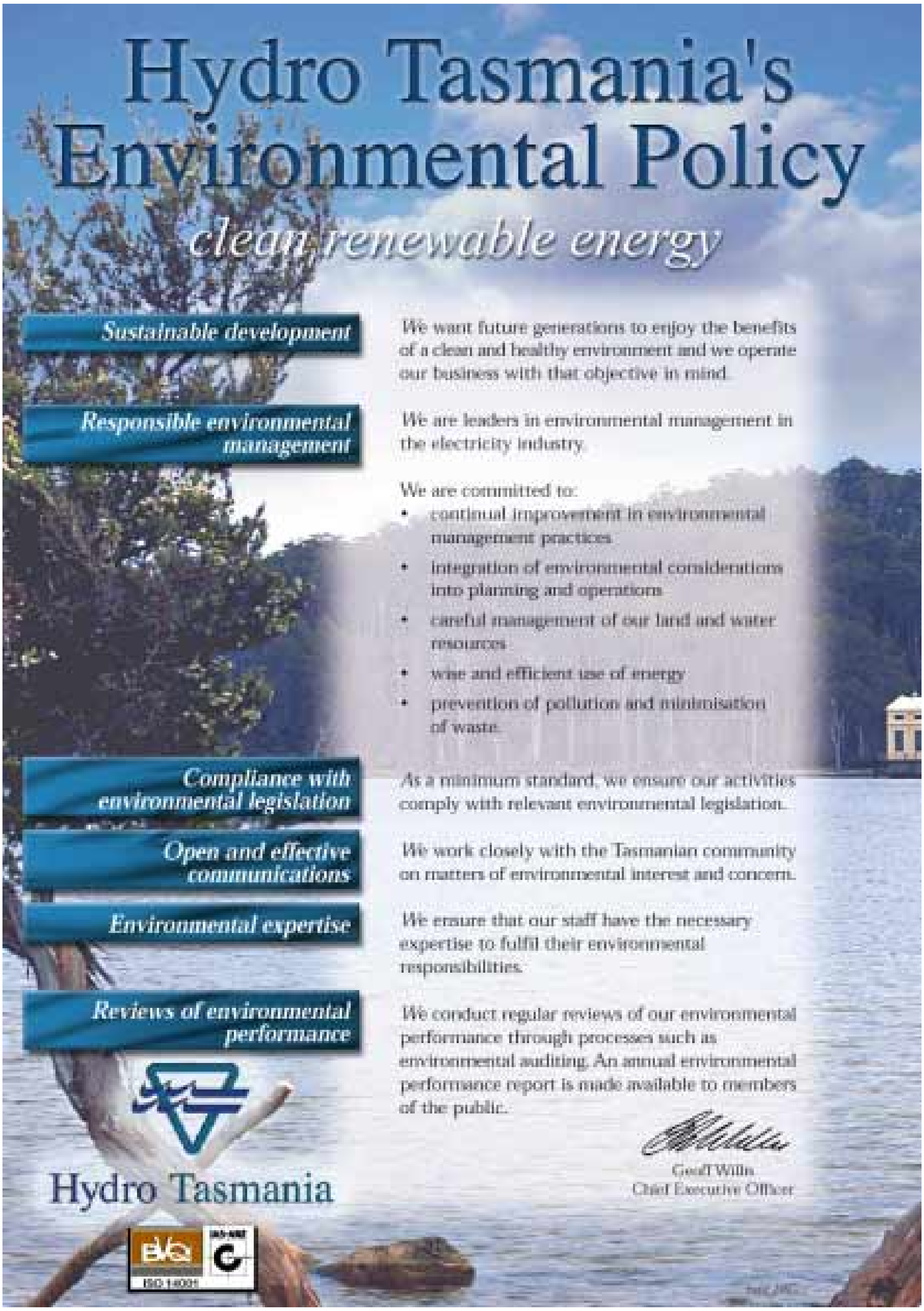
Threatened Species Protection Act 1995 (Tasmania)

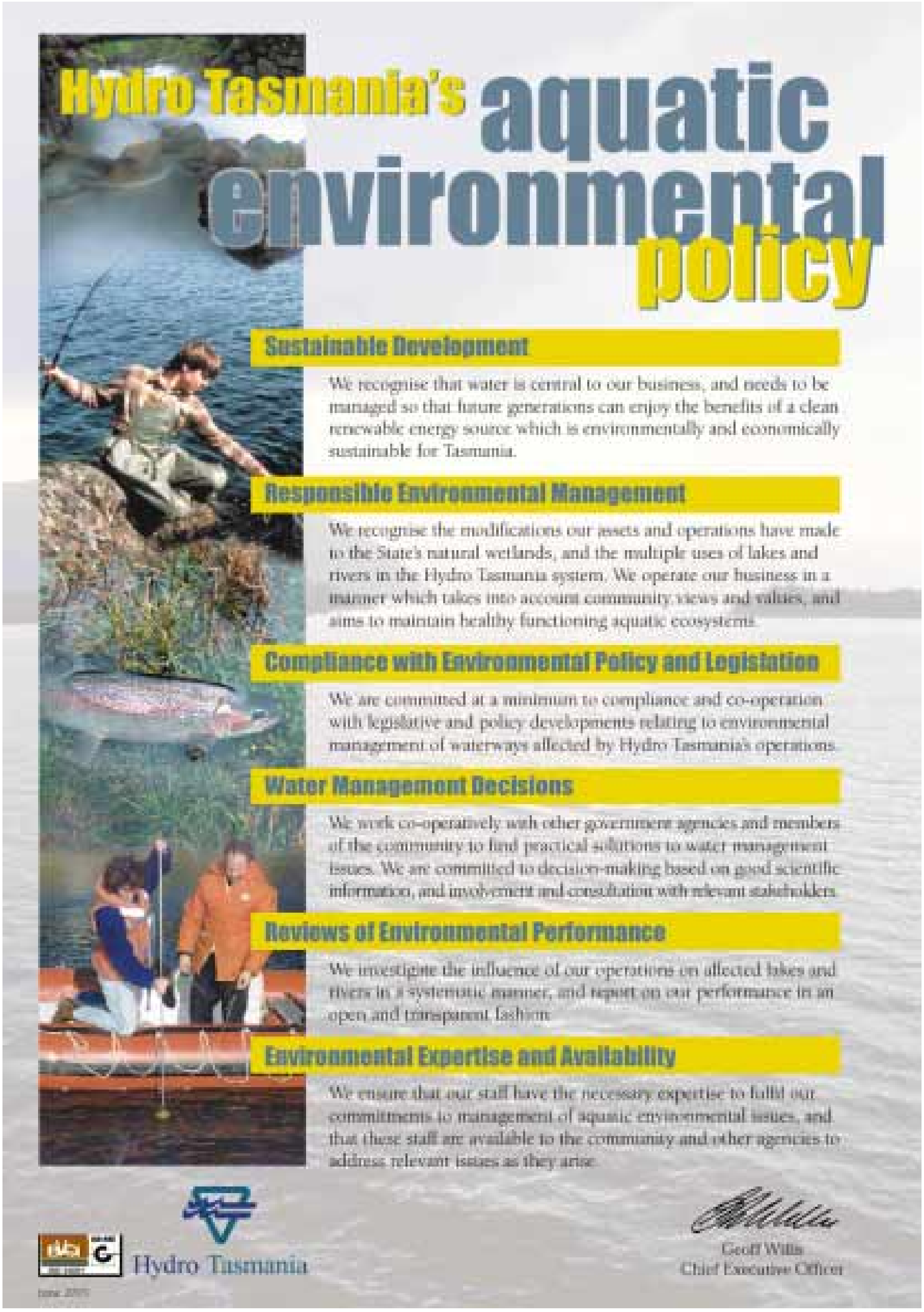
Water Management Act *1999* (Tasmania)

Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)

Appendix 1

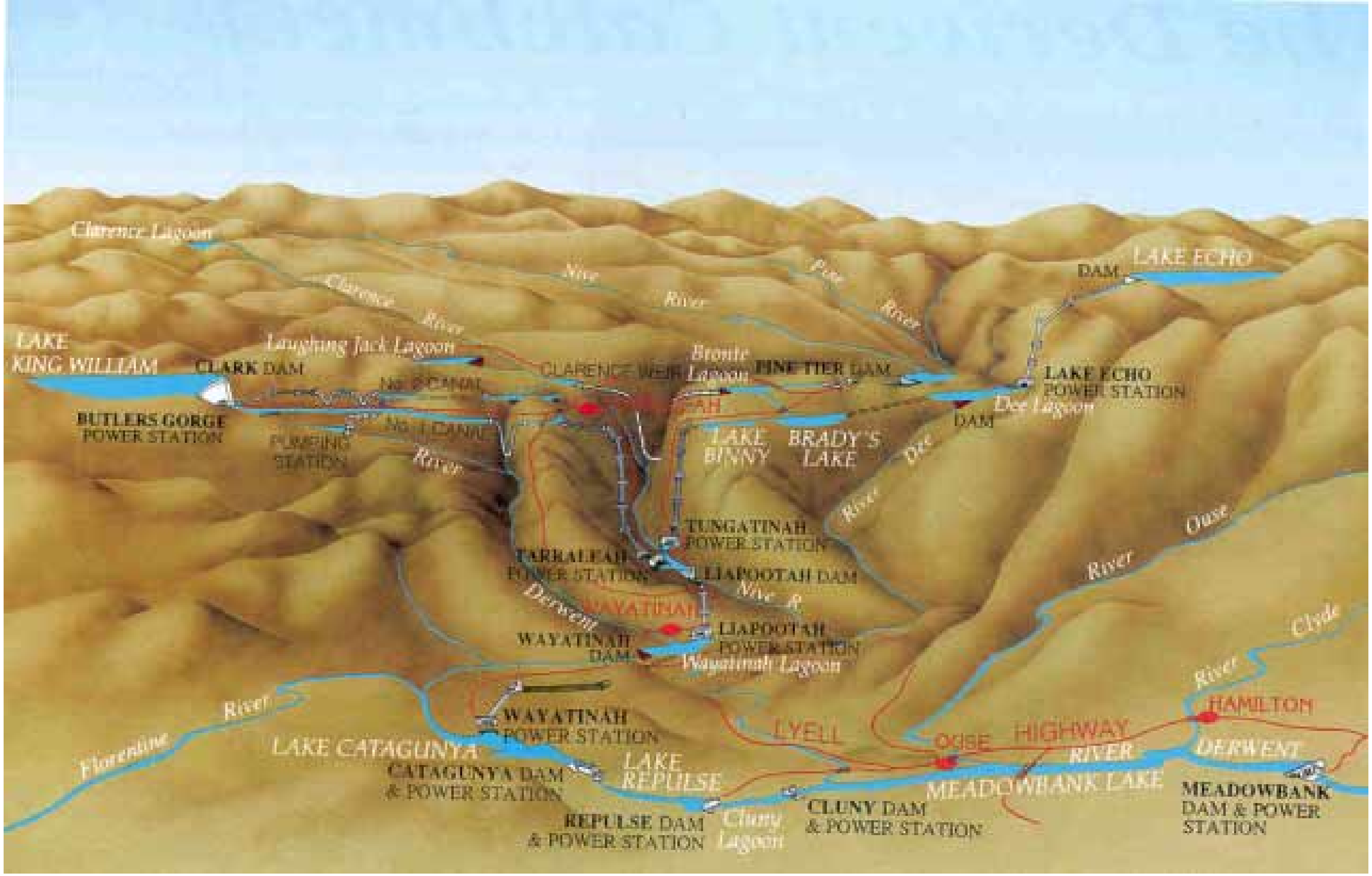
Hydro Tasmania's Environmental Policy and Hydro Tasmania's Aquatic Environmental Policy


Hydro Tasmania's Environmental Policy
clean, renewable energy
Sustainable development
We want future generations to enjoy the benefits of a clean and healthy environment and we operate our business with that objective in mind.
Responsible environmental management
We are leaders in environmental management in the electricity industry.
We are committed to:
• continual improvement in environmental management practices
• integration of environmental considerations into planning and operations
• careful management of our land and water resources
• wise and efficient use of energy
• prevention of pollution and minimisation of waste.
Compliance with environmental legislation
As a minimum standard, we ensure our activities comply with relevant environmental legislation.
Open and effective communications
We work closely with the Tasmanian community on matters of environmental interest and concern.
Environmental expertise
We ensure that our staff have the necessary expertise to fulfil their environmental responsibilities.
Reviews of environmental performance
We conduct regular reviews of our environmental performance through processes such as environmental auditing. An annual environmental performance report is made available to members of the public.
Geoff Willis
Chief Executive Officer
Hydro Tasmania
ISO 14001


Hydro Tasmania's aquatic environmental policy
Sustainable Development
We recognise that water is central to our business, and needs to be managed so that future generations can enjoy the benefits of a clean renewable energy source which is environmentally and economically sustainable for Tasmania.
Responsible Environmental Management
We recognise the modifications our assets and operations have made to the State's natural wetlands, and the multiple uses of lakes and rivers in the Hydro Tasmania system. We operate our business in a manner which takes into account community views and values, and aims to maintain healthy functioning aquatic ecosystems.
Compliance with Environmental Policy and Legislation
We are committed at a minimum to compliance and co-operation with legislative and policy developments relating to environmental management of waterways affected by Hydro Tasmania's operations.
Water Management Decisions
We work co-operatively with other government agencies and members of the community to find practical solutions to water management issues. We are committed to decision-making based on good scientific information, and involvement and consultation with relevant stakeholders.
Reviews of Environmental Performance
We investigate the influence of our operations on affected lakes and rivers in a systematic manner, and report on our performance in an open and transparent fashion.
Environmental Expertise and Availability
We ensure that our staff have the necessary expertise to fulfil our commitments to management of aquatic environmental issues, and that these staff are available to the community and other agencies to address relevant issues as they arise.
Hydro Tasmania
Geoff Willis
Chief Executive Officer

Appendix 2

Generalised relief map of power developments
in the Derwent Catchment


Clarence Lagoon
Clarence River
Nive River
Pine River
DAM
LAKE ECHO
LAKE KING WILLIAM
CLARK DAM
Laughing Jack Lagoon
CLARENCE WEIR
Bronte Lagoon
PINE TIER DAM
LAKE ECHO POWER STATION
Dee Lagoon
DAM
BUTLERS GORGE POWER STATION
PUMPING STATION
River
LAKE BINNY
BRADY'S LAKE
Dee River
TUNGATINAH POWER STATION
TARRALEAH POWER STATION
LIAPOOTAH DAM
Nive R
Derwent
WAYATINAH
Ouse River
LIAPOOTAH POWER STATION
WAYATINAH DAM
Wayatinah Lagoon
Clyde River
HAMILTON
Florentine River
WAYATINAH POWER STATION
LYELL
OUSE
HIGHWAY
LAKE CATAGUNYA
CATAGUNYA DAM & POWER STATION
LAKE REPULSE
RIVER
DERWENT
MEADOWBANK LAKE
MEADOWBANK DAM & POWER STATION
REPULSE DAM & POWER STATION
Cluny Lagoon
CLUNY DAM & POWER STATION

Appendix 3

Historic Water Quality data for the Derwent Catchment from Hydro Tasmania's TimeStudio database

Site		Date	Temp C	Total Chl mg/L	Field Cond uS/cm	Lab Cond @ TRef	pH Lab	pH Field	Filt. Res. mg/L	Hardness mg/L	Nitrate mg/L	Nitrite mg/L	Tot Na mg/L	Tot Ca mg/L	Tot Mg mg/L	Tot Fe mg/L	Tot Mn mg/L	Tot Cl mg/L	Tot SO4 mg/L
UPPER DERWENT - Lake St. Clair to Nive																			
131	Max	4/8/93	15.9	0.78		33.1	8.0	7.1	25.60	10.00	0.04	0.00	3.20	2.20	1.10	0.45	0.01	5.6	1.8
L. St. Clair	Min	26/2/67	5.6	0.21		19.4	6.3	6.2	13.00	4.10	0.01	0.00	1.60	0.70	0.40	0.01	0.01	1.7	0.3
at dam	Average		8.41	0.50		22.23	6.7	6.7	21.16	6.18	0.02	0.00	2.33	1.41	0.65	0.06	0.01	3.9	1.1
	median		6.6	0.515		22	6.6	6.8	21.80	5.65	0.02	0.00	2.30	1.25	0.60	0.04	0.01	3.9	1.1
	n		23	6		13	12.0	13.0	10.00	10.00	6.00	6.00	10.00	10.00	10.00	14.00	16.00	10.0	10.0
87	Max	23/11/93	18		22.6			6.9											
Derwent R.	Min	16/3/84	10		22.6			5.4											
below	Average		13.19		22.6			6.4											
L. St. Clair	median		12.7		22.6			6.5											
	n		13		1			14.0											
123	Max	16/7/98	7.6		39			5.6											
Derwent R.	Min	8/5/90	2.8		39			5.0											
above Nive	Average		5.8		39			5.4											
	median		7		39			5.5											
	n		3		1			3.0											
129	Max	10/11/93	16.5			23.6	7.3	6.6	23.80	5.60			3.00	1.12	0.70	0.23	0.02	3.7	2.1
Tarraleah	Min	31/7/68	4.2			23.6	6.6	5.9	13.20	4.70			2.00	0.70	0.67	0.22	0.01	3.5	0.6
No.1 Canal	Average		8.9			23.6	6.9	6.2	17.80	5.03			2.53	0.87	0.69	0.23	0.01	3.6	1.2
	median		8.45			23.6	6.7	6.2	16.40	4.80			2.60	0.80	0.70	0.23	0.01	3.7	1.0
	n		6			1	3.0	6.0	3.00	3.00			3.00	3.00	3.00	2.00	3.00	3.0	3.0
156	Max	30/9/80	18.5					6.8											
Tarraleah	Min	18/11/66	4					6.1											
No.2 Canal	Average		10.28					6.5											
	median		9.4					6.5											
	n		31					30.0											
NIVE / DEE Above Tungatinah																			
170 - Tungatina L. at dam	1 sample only	12/2/70	18.3			35	7.1	7.1	24.40	9.50			2.40	1.20	1.00	0.26	0.02	3.2	0.5
176	Max	13/2/70	16.1			54	7.0	7.0	28.40	13.00			2.80	2.00	2.00	0.28	0.06	3.9	0.8
L. Echo	Min	16/7/69	4.4			23.9	6.8	6.8	23.00	8.70			1.90	1.30	0.90	0.22	0.01	3.0	0.5
at control	Average		11.2			34.267	6.9	6.9	26.27	10.73			2.30	1.73	1.33	0.25	0.03	3.5	0.7
	median		13.1			24.9	6.8	6.9	27.40	10.50			2.20	1.90	1.10	0.26	0.01	3.6	0.7
	n		3			3	3.0	3.0	3.00	3.00			3.00	3.00	3.00	3.00	3.00	3.0	3.0
180	Max	13/12/90	18.6					7.0											
Deep Ck.	Min	6/12/78	2.6					5.0											
cut	Average		9.85					6.4											
	median		10.5					6.6											
	n		10					10.0											
497	Max	4/9/90	21.5					6.8											
Nive R. at	Min	8/6/67	3					5.2											
Gowan Brae	Average		9.14					6.4											
	median		7.2					6.4											
	n		23					22.0											
579	Max	3/12/69	7.2			31.6	6.8	7.0	36.80	7.70			3.00	1.70	0.90	0.22	0.02	5.5	2.5
L Liapootah	Min	3/8/67	3.3			24	6.5	6.8	21.40	6.60			2.40	1.30	0.80	0.10	0.01	4.2	1.0
	Average		5.64			26.85	6.6	6.9	28.20	7.42			2.58	1.54	0.86	0.15	0.01	4.9	1.4
	median		6.1			25.9	6.6	6.9	25.60	7.60			2.50	1.60	0.90	0.12	0.01	4.8	1.0
	n		5			4	5.0	3.0	5.00	5.00			5.00	5.00	5.00	3.00	5.00	5.0	5.0
MIDDLE DERWENT - below Nive and above Meadowbank																			
190	Max	7/8/69	53.3			34.5	7.1	6.8	59.80	10.40			3.10	2.50	1.00	0.72	0.01	5.5	2.9
Wayatinah L.	Min	20/6/67	5.56			24.7	6.4	6.8	23.40	6.40			2.60	1.30	0.60	0.10	0.01	3.0	1.0
	Average		13.9			28.517	6.8	6.8	33.58	7.93			2.79	1.78	0.85	0.31	0.01	4.6	1.8
	median		7.2			28.05	6.8	6.8	30.10	7.80			2.70	1.75	0.90	0.12	0.01	5.0	1.4
	n		7			6	8.0	2.0	8.00	8.00			8.00	8.00	8.00	3.00	8.00	8.0	7.0
40	Max	25/11/93	11.5		124			7.8											
Florentine R.	Min	4/8/77	6.2		124			3.8											
	Average		8.29		124			7.0											
	median		8		124			7.6											
	n		11		1			10.0											

OUSE / SHANNON																			
1343	Max	1/9/93	8.2	1000			7.2	7.0	110.00		4.00	0.02	6.00	15.80	6.00	4.49	0.32	9.7	1.0
Ripple Ck.	Min	1/3/88	7.5	1000			5.6	7.0	28.00		2.80	0.01	3.40	2.10	0.52	0.35	0.01	4.7	0.9
below Noels	Average		7.85	1000			6.6	7.0	72.20		3.20	0.01	4.37	7.18	2.60	1.30	0.10	6.0	1.0
	median		7.85	1000			6.5	7.0	87.00		2.80	0.01	3.70	5.50	2.20	0.74	0.01	5.0	1.0
	n		2	1			7.0	2.0	5.00		3.00	3.00	3.00	5.00	5.00	7.00	5.00	5.0	2.0
838	Max	1/9/93	11.6	1000		23	7.3	8.4	200.00	14.80	1.20	0.02	4.60	4.60	2.40	23.10	0.11	6.2	2.0
Ripple Ck.	Min	23/5/88	1.8	1000		23	6.4	6.8	43.00	14.00	0.01	0.01	2.40	2.30	0.90	0.37	0.01	4.4	0.7
Diversion	Average		7.83	1000		23	7.0	7.4	77.14	14.40	0.17	0.01	3.50	3.23	1.35	3.07	0.03	5.1	1.2
	median		8.95	1000		23	7.0	7.1	60.00	14.40	0.05	0.01	3.50	3.30	1.25	0.89	0.02	5.1	1.1
	n		4	1		1	8.0	4.0	7.00	2.00	12.00	12.00	2.00	8.00	8.00	16.00	16.00	8.0	6.0
849	Max	12/7/93	11.5				6.9	7.7	74.00	14.40	0.40	0.01	4.60	3.40	1.40	0.90	0.02	6.2	1.0
Jacks' Ck	Min	25/8/88	6.5				6.8	6.5	43.00	14.40	0.01	0.01	4.60	2.80	1.10	0.60	0.01	5.0	0.7
below	Average		9				6.8	7.0	59.00	14.40	0.15	0.01	4.60	3.17	1.20	0.78	0.01	5.4	0.9
Ripple Diversion	median		9				6.8	6.8	60.00	14.40	0.05	0.01	4.60	3.30	1.10	0.80	0.01	5.1	0.9
	n		3				3.0	3.0	3.00	1.00	3.00	3.00	1.00	3.00	3.00	4.00	4.00	3.0	2.0
367	Max	1/9/93	27	3900	175.1	207	8.6	8.3	240.00	91.30	0.90	0.02	16.50	22.50	15.30	5.46	0.50	26.1	11.8
Lagoon of	Min	13/3/67	4.9	1000	102.9	100	6.7	6.6	50.00	40.00	0.10	0.01	4.40	3.20	1.10	0.12	0.01	6.1	0.1
Islands B639	Average		10.37	2800	121.275	141.76	7.6	7.4	181.54	71.44	0.29	0.01	11.30	13.33	6.10	2.41	0.13	15.9	1.3
	median		9.45	3500	103.55	132	7.6	7.4	181.50	73.70	0.18	0.01	11.30	13.15	5.45	2.45	0.07	15.4	0.9
	n		18	3	4	19	27.0	17.0	26.00	10.00	12.00	11.00	15.00	24.00	24.00	28.00	28.00	25.0	21.0
1068 Blackburn	sample 1	1/3/88					7.9		205.00				11.00	15.00	5.70	4.75	0.22	15.9	1.0
Ck. at Lyell Hwy	sample 2	12/3/93	14.2			770		7.4											
791	Max	1/10/97	10.2		246														
Boggy Marsh	Min	30/4/97	1.8		115														
Rivulet	Average		7.33		159.733														
	median		10		118.2														
	n		3		3														
358	Max	1/10/97	22	25000	148.3	135	7.9	7.4	220.00	14.70	0.10		10.20	20.00	15.40	3.36	0.13	37.0	1.4
Ouse River	Min	6/3/66	3	25000	29	82	6.5	5.5	57.00	8.00	0.10		3.20	3.50	1.50	0.18	0.01	5.3	0.5
at Ashton	Average		12.84	25000	103.575	108.33	7.2	6.7	107.30	11.35	0.10		7.20	9.65	6.45	1.50	0.03	15.2	0.9
	median		11.7	25000	118.5	111.5	7.3	6.8	90.00	11.35	0.10		7.70	8.60	5.00	1.03	0.02	12.8	0.9
	n		14	1	4	6	10.0	14.0	10.00	2.00	1.00		4.00	8.00	8.00	8.00	8.00	9.0	7.0
826	Max	10/11/93	19			246	7.5	7.4	150.00				10.90	17.10	16.20	1.50	0.04	37.9	3.3
Ouse River	Min	16/9/88	11			108	6.6	6.0	93.00				8.90	7.60	4.50	0.42	0.01	15.5	0.5
at No.3B	Average		14.22			154.47	7.2	6.9	111.25				9.90	10.95	7.88	0.97	0.03	21.8	1.3
	median		12.6			109.4	7.4	7.1	101.00				9.90	9.55	5.40	0.98	0.03	17.0	0.7
	n		6			3	4.0	6.0	4.00				2.00	4.00	4.00	4.00	4.00	4.0	4.0
27	Max	12/4/88	19.4	15500			7.7	7.6	260.00	144.60	0.10		34.00	26.60	19.00	0.72	0.10	81.6	6.7
Ouse River	Min	26/5/67	12.4	15500			6.7	5.9	87.00	30.10	0.10		4.70	8.20	5.40	0.51	0.01	16.9	0.8
at Ouse	Average		15.4	15500			7.3	6.8	139.07	72.50	0.10		14.58	14.00	9.28	0.64	0.04	33.1	2.7
	median		14.4	15500			7.4	6.8	120.70	42.80	0.10		9.80	9.90	6.40	0.66	0.02	18.0	1.7
	n		3	1			6.0	4.0	6.00	3.00	1.00		4.00	5.00	5.00	4.00	5.00	5.0	4.0
465	Max	25/11/93	22		656		8.4	8.2	440.00										
Clyde R.	Min	3/8/79	4		150		6.6	5.5	106.00										
above Hamilton	Average		12.63		304.839		7.5	7.0	199.71										
	median		13.2		300		7.6	6.9	152.00										
	n		59		31		15.0	49.0	7.00										
366	Max	11/10/88	19		102.9	130	8.3	7.4	487.00	200.00			11.00	37.00	26.00	5.00	0.46	178.0	1.0
Tea Tree Ck.	Min	30/8/71	9		102.9	128	5.8	6.3	81.00	180.00			7.50	11.30	4.10	3.10	0.08	14.4	0.5
	Average		13.3		102.9	129	7.3	6.9	234.33	190.00			9.25	22.20	11.55	4.24	0.23	60.4	0.7
	median		12.5		102.9	129	7.4	6.9	199.00	190.00			9.25	15.00	5.65	4.43	0.15	53.5	0.5
	n		4		1	2	24.0	4.0	24.00	2.00			2.00	5.00	6.00	4.00	3.00	16.0	3.0

LOWER DERWENT and TRIBS - below Meadowbank																		
715 Derwent R. below Meadowbank	1 sample	24/8/77	7		47.8	7.1	7.2	49.60	17.80			3.80	4.60	1.60	0.34	0.01	5.5	0.3
29	Max	29/7/77				7.5		91.00									12.7	
Plenty R. at	Min	22/7/75				5.1		55.20									7.1	
Salmon	Average					6.8		72.30									10.1	
Ponds																		
	median					7.0		72.50									10.3	
	n					8.0		8.00									4.0	
499	Max	25/7/96	20	710		8.2	8.4	185.00										
Tyenna R.	Min	19/6/74	3	40		6.4	5.6	1.00										
at Newbury	Average		9.04	159.225		7.5	7.2	92.38										
	median		8	137.75		7.6	7.3	85.50										
	n		95	28		16.0	74.0	16.00										
7	Max	11/3/85	20	165	48.6	8.3	7.5	62.00	22.50			7.10	5.20	2.30	0.53	0.01	10.0	1.9
Derwent R.	Min	31/5/69	4	37	48.6	6.2	6.2	62.00	22.50			7.10	5.20	2.30	0.53	0.01	10.0	1.9
at	Average		11.52	73.5	48.6	7.1	6.7	62.00	22.50			7.10	5.20	2.30	0.53	0.01	10.0	1.9
Macquarie																		
Plains	median		10	69	48.6	7.1	6.8	62.00	22.50			7.10	5.20	2.30	0.53	0.01	10.0	1.9
	n		51	13	1	30.0	16.0	1.00	1.00			1.00	1.00	1.00	1.00	1.00	1.0	1.0
1133	Max	12/3/93	21		770	7.9	7.4	205.00				11.00	15.00	5.70	4.75	62.00	15.9	1.0
Derwent R.	Min	27/8/75	6.5		770	6.5	7.4	205.00				11.00	15.00	5.70	4.75	0.22	15.9	1.0
at E. Boyer	Average		13.74		770	7.0	7.4	205.00				11.00	15.00	5.70	4.75	26.19	15.9	1.0
	median		13.8		770	7.0	7.4	205.00				11.00	15.00	5.70	4.75	27.00	15.9	1.0
	n		8		1	8.0	1.0	1.00				1.00	1.00	1.00	1.00	12.00	1.0	1.0
405	Max	30/3/82	21			8.3		205.00	27.00	0.90	0.01	4.80	8.80	2.20	1.04	0.02		1.2
Derwent R.	Min	27/2/74	3.5			6.6		28.00	1.00	0.00	0.00	3.50	0.10	0.10	0.13	0.01		0.2
at Bryn	Average		11.33			7.4		56.16	19.24	0.24	0.00	4.09	5.36	1.45	0.35	0.01		0.9
Estyn																		
	median		11.5			7.3		51.00	20.00	0.11	0.00	4.05	5.50	1.50	0.24	0.01		1.0
	n		30			33.0		34.00	7.00	7.00	6.00	8.00	8.00	8.00	8.00	4.00		8.0
1139	Max	4/12/80	19			7.2										43.00		
Derwent R.	Min	27/8/75	6.5			6.3										5.00		
at W. Boyer	Average		12.6			6.9										17.91		
	median		12.8			7.1										13.00		
	n		7			7.0										11.00		
1135	Max	4/12/80	19			7.3										47.00		
Derwent R.	Min	27/8/75	7.5			6.7										7.00		
at Old	Average		12.93			7.0										21.00		
Beach																		
	median		13			7.1										20.00		
	n		7			7.0										11.00		
Jordan R.	Max	4/2/92	22	370	1480	8.3	8.2	1220.00		0.16	0.01							
at	Min	17/8/83	5	370	474	7.4	6.2	366.00		0.16	0.01							
Bridgewater	Average		12.89	370	839.62	8.0	7.1	638.75		0.16	0.01							
	median		14	370	750	8.1	7.0	556.00		0.16	0.01							
	n		29	1	13	7.0	26.0	8.00		1.00	1.00							

CONTACT AND FEEDBACK

THIS IS THE FIRST ENVIRONMENTAL REVIEW DOCUMENT FOR THE DERWENT CATCHMENT. IT WILL BE UPDATED AT INTERVALS AND FEEDBACK ON ITS CONTENT IS WELCOME.

PLEASE CONTACT
HYDRO TASMANIA
ENVIRONMENTAL SERVICES

03 6230 5899

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