Riverine Environment Analysis for the Little Swanport Catchment


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Cover Photograph: *The Little Swanport River downstream Green Tier Creek during low and high flow conditions.*

The Department of Primary Industries and Water provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.

The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

Executive Summary

The rivers and streams of the Little Swanport catchment on the east coast of Tasmania was the subject of a series of environmental assessments undertaken by DPIW during 2004-05 under the State of Rivers program. This document reports on the results of these assessments in the area of hydrology, ecosystem values, geomorphology, water quality and aquatic ecology.

The major findings from these studies relate to the characteristics of geology and hydrology in the catchment, as well as the influence of intensive land use on environmental conditions in the upper catchment. The main outcomes are briefly presented in the following dot points:

- The hydrology of the Little Swanport catchment is highly variable, and one where cease-to-flow periods are a natural characteristic of the flow regime. Like most catchments on Tasmania's east coast, the river system is 'flashy' and responds rapidly to rainfall events. Current water use in the catchment does not significantly affect the pattern and frequency of flooding, but low flows in the upper reaches of the river are higher than normal due to irrigation runoff.
- Interrogation of the Conservation of Freshwater Ecosystem Values (CFEV) database shows that highest conservation priority has been awarded to river reaches in the middle and lower sections of the catchment, while a number of high priority wetlands are located in the upper catchment.
- Water quality assessments show that salinity and nutrient loss from agricultural land are major issues in the upper catchment, where a large percentage of the drainage system is extremely modified by land use practices. In many of the tributaries this is exacerbated by the ephemeral nature of the flow regime. The loss of riparian vegetation along large parts of the upper river system results in high summer water temperatures and extreme variations in dissolved oxygen. During high flows following rainfall turbidity is greatly elevated and the transport of nutrients into the river system is significant. This is ameliorated downstream by inflow from tributaries with substantially better water quality.
- A similar picture is provided by AUSRIVAS assessments, although the degree to which impairment of the aquatic community is a result of land management or the variability of the flow regime is uncertain. In general, river health was poorest at sites where habitat was extremely modified or degraded.

The report highlights the impact of agriculture on the river system in the upper catchment and the need for riparian remediation in this area if environmental condition is to be improved. While salinity of rivers and streams in the upper catchment may be a reflection of the local geology and the character of the groundwater resources, it is likely that the removal of vegetation in this part of the catchment has exacerbated this condition.

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A GLOSSARY OF TERMS

Baseflow

Flow in a stream is a function of inputs from overland flow, subsurface flow and groundwater. During periods when there is no contribution of water from overland flow, river flow is composed of water from deep subsurface and groundwater sources and is termed ‘baseflow’.

Box and Whisker Plots

One common method of examining data collected at various sites is to plot the data from each site as a ‘box and whisker’ plot. These 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 ends of the whiskers show the extremes of the data and together enclose 95% of the data.

Catchment

The land area which drains into a particular watercourse (river, stream or creek) and is a natural topographic division of the landscape. Underlying geological formations may alter the perceived catchment area suggested solely by topography (limestone caves are an example of this).

Discharge

The volume of water passing a specific point during a particular period of time. It usually refers to water flowing in a stream or drainage channel, but can also refer to waste water from industrial activities.

Diurnal Variation

‘Diurnal variation’ is a term that is used to describe the cyclical pattern of change that occurs within a daily timescale. Water temperature variation is a typical example of a parameter that varies ‘diurnally’, with lowest temperatures occurring in the hours before dawn and the highest temperatures occurring around the middle of the day. Many water quality parameters that are influenced by biological processes also tend to vary on a diurnal basis.

Dissolved Oxygen

Oxygen is essential for all forms of aquatic life and many organisms obtain this oxygen directly from the water in the dissolved form. The level of dissolved oxygen in natural waters varies with temperature, turbulence, photosynthetic activity and atmospheric pressure. Dissolved oxygen varies over 24 hour periods as well as seasonally and can range from as high as 15 mg/L to levels approaching 0 mg/L. Levels below 5 mg/L will begin to place stress on aquatic biota and below 2 mg/L will cause death of fish.

Ecosystem

An environment, the physical and chemical parameters that define it and the organisms which inhabit it.

Electrical Conductivity (EC)

Conductivity is a measure of the capacity of an aqueous solution to carry an electrical current, and depends on the presence of ions; on their total concentration, mobility and valence. Conductivity is commonly used to determine salinity and is mostly reported in microSiemens per centimetre (µS/cm) or milliSiemens per metre (mS/m) at a standard reference temperature of 25^{o} Celsius.

Eutrophication

The enrichment of surface waters with nutrients such as nitrates and phosphates, which cause nuisance blooms of aquatic plants and algae.

Faecal Coliforms (also known as 'thermotolerant coliforms' - eg. *E.coli*)

Faecal coliform bacteria are a sub-group of the total coliform population that are easy to measure and are present in virtually all warm blooded animals. Although measurement of this group is favoured by the NHMRC (1996) as suitable indicators of faecal pollution, it is recognised that members of this group may not be exclusively of faecal origin. However their presence in samples implies increased risk of disease. Pathogenic bacteria are those which are considered capable of causing disease in animals.

General Ions

General ions are those mineral salts most commonly present in natural waters. They are primarily sodium, potassium, chloride, calcium, magnesium, sulphate, carbonates and bicarbonates. Their presence affects conductivity of water and concentrations variable in surface and groundwaters due to local geological, climatic and geographical conditions.

Hydrograph

A plot of flow (typically in a stream) versus time. The time base is variable so that a hydrograph can refer to a single flood event, to a combination of flood events, or alternatively to the plot of all flows over a month, year, season or any given period.

Macroinvertebrate

Invertebrate (without a backbone) animals which can be seen with the naked eye. In rivers common macroinvertebrates are insects, crustaceans, worms and snails.

Median

The middle reading, or 50^{th} percentile, of all readings taken.
i.e. of the readings 10, 13, 9, 16 and 11

{Re-ordering these to read 9, 10, 11, 13 and 16}

The median is 11.

The **Mean** (or Average), is the sum of all values divided by the total number of readings (which in this case equals 11.8).

Nutrients

Nutrients is a broad term which encompasses elements and compounds which are required by plants and animals for growth and survival. In the area of water quality the term is generally used with only phosphorus and nitrogen species in mind, though there are many other 'nutrients' that living organisms require for survival.

pH and Alkalinity

The pH is a measure of the acidity of a solution and ranges in scale from 0 to 14 (from very acid to very alkaline). A pH value of 7 is considered 'neutral'. In natural waters, pH is generally between 6.0 and 8.5. In waters with little or no buffering capacity, pH is related to alkalinity which is controlled by concentrations of carbonates, bicarbonates and hydroxides in the water. Waters of low alkalinity (< 24 ml/L as CaCO3) have a low buffering capacity and are susceptible to changes in pH from outside sources.

Riparian Vegetation

Riparian vegetation are plants (trees, shrubs, ground covers and grasses) which grow on the banks and floodplains of rivers. A 'healthy' riparian zone is characterised by a homogeneous mix of plant species (usually native to the area) of various ages. This zone is important in protecting water quality and sustaining the aquatic life of rivers.

Suspended Solids

Suspended solids are typically comprised of clay, silt, fine particulate organic and inorganic matter and microscopic organisms. Suspended solids are that fraction which will not pass through a 0.45 μm filter and as such corresponds to non-filterable residues. It is this fraction which tends to contribute most to the turbidity of water.

Total Nitrogen

Nitrogen in natural waters occurs as Nitrate, Nitrite, Ammonia and complex organic compounds. Total nitrogen concentration in water can be analysed for directly or through the determination of all of these components. In this report, Total Nitrogen (TN) has been calculated as the sum of Nitrate (NO_x) + Nitrite (NO_x) and Ammonia (NH_4^+).

Total Phosphorus

Like nitrogen, phosphorus is an essential nutrient for living organisms and exists in water as both dissolved and particulate forms. Total phosphorus can be analysed directly, and includes both forms. Dissolved phosphorus mostly occurs as orthophosphates, polyphosphates and organic phosphates.

Turbidity

Turbidity in water is caused by suspended material such as clay, silt, finely divided organic and inorganic matter, soluble coloured compounds and plankton and microscopic organisms. Turbidity is an expression of the optical properties that cause light to be scattered and absorbed rather than transmitted in a straight line through the water. Standard units for turbidity are 'nephelometric turbidity units' (NTU's) standardised against Formazin solution.

Units and Conversions

mg/L = milligrams per litre (1000 milligrams per gram)
μg/L = micrograms per litre (1000 micrograms per milligram) e.g. 1000 μg/L = 1 mg/L
μS/cm = Microsiemens per centimeter
m^3/s = cubic metre per second (commonly referred to as a 'cumec')
ML = 1 million litres (referred to as a 'megalitre')

Acronyms

ANZECC - Australian and New Zealand Environment and Conservation Council
ARMCANZ - Agricultural and Resource Management Council of Australia and New Zealand
DPIW - Department of Primary Industries and Water
NHMRC - National Health and Medical Research Council
NHT – Natural Heritage Trust (formerly the National Landcare Program)

Australian Water Quality Guidelines as per ANZECC (2000)

As part of a National strategy to 'pursue the sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development' the Australian and New Zealand Environment and Conservation Council (ANZECC) has been developing guidelines for water quality for a range of Australian waters. Since 1992, a document titled 'Australian Water Quality Guidelines for Fresh and Marine Waters (1992) ' has been available for use as a reference tool for catchment management plans and policies. Since 1995, these guidelines have been under review and have now been superseded by new and more rigorous guidelines (ANZECC, 2000). Where possible, these new guidelines have had a more regional focus. This new approach has changed the emphasis of guideline setting, suggesting a 'risk assessment' approach which utilises the concept of increased risk with increasing departure from 'safe' levels.

The revised guidelines also restate the principle that guidelines are only to be used in the absence of local data, and that where local data can be obtained, they should be used to develop local water quality standards. For some water quality parameters, this approach has been taken, with data from Tasmanian systems (where available) being used to develop guidelines for use within Tasmania

The ANZECC 2000 default trigger values are classified into two categories for rivers in south-east Australia, based on altitude. These categories are lowland rivers, defined as rivers below 150m elevation, and upland rivers, those above 150m. However, due to Tasmania's mountainous landform, relatively small catchment sizes and the coastal nature of many of our low altitude rivers and streams, this definition may be less appropriate for Tasmanian rivers than for other south-eastern states. Therefore this report has used the most stringent set of default trigger values, those applicable to upland rivers, to assist with a professional assessment of each river.

The default trigger values (Table 1) are the concentrations of key performance indicators below which there is a low risk that adverse biological effects will occur. These physical and chemical triggers are not designed as threshold values; rather, they are designed to be used in conjunction with professional judgement to provide an initial assessment of a water body (ANZECC 2000). If these values are exceeded a potential risk exists and further site-specific investigations are recommended.

Table 1: ANZECC 2000 default trigger values for electrical conductivity (EC), turbidity, pH, dissolved oxygen percentage saturation (DO), total nitrogen (TN), nitrate and nitrite (NO_x), ammonium (NH_4^+), total phosphorus (TP) and dissolved reactive phosphorus (DRP) for slightly disturbed ecosystems in Tasmania**.**

Ecosystem Type	EC (µS/cm)	Turbidity (NTU)	pH*	DO	TN (mg/L)	NO_x (mg/L)	NH_4^+ (mg/L)	TP (mg/L)	DRP (mg/L)
Upland River	30-350	2-25	6.5-7.5	90-110	0.480	0.190	0.013	0.013	0.005

* values for humic rich Tasmanian rivers are 4.0-6.5

ANZECC 2000 Microbiological Guidelines

Primary contact

The median bacterial content in samples of fresh or marine waters taken over the bathing season should not exceed:

150 faecal coliform organisms/100mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 600 organisms/100mL);

35 enterococci organisms/100mL (maximum number in any one sample: 60–100 organisms/100mL).

Pathogenic free-living protozoans should be absent from bodies of fresh water. (It is not necessary to analyse water for these pathogens unless the temperature is greater than 24°C.)

Secondary contact

The median bacterial content in fresh and marine waters should not exceed:

1000 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 4000 organisms/100mL);

230 enterococci organisms/100 mL (maximum number in any one sample 450–700 organisms/100mL).

National Health and Medical Research Council - Drinking Water

For drinking water, guidelines published by the National Health and Medical Research Council (NHMRC, 2004) suggest that no *Escherichia coli* or thermotolerant coliforms should be present in water used for drinking.

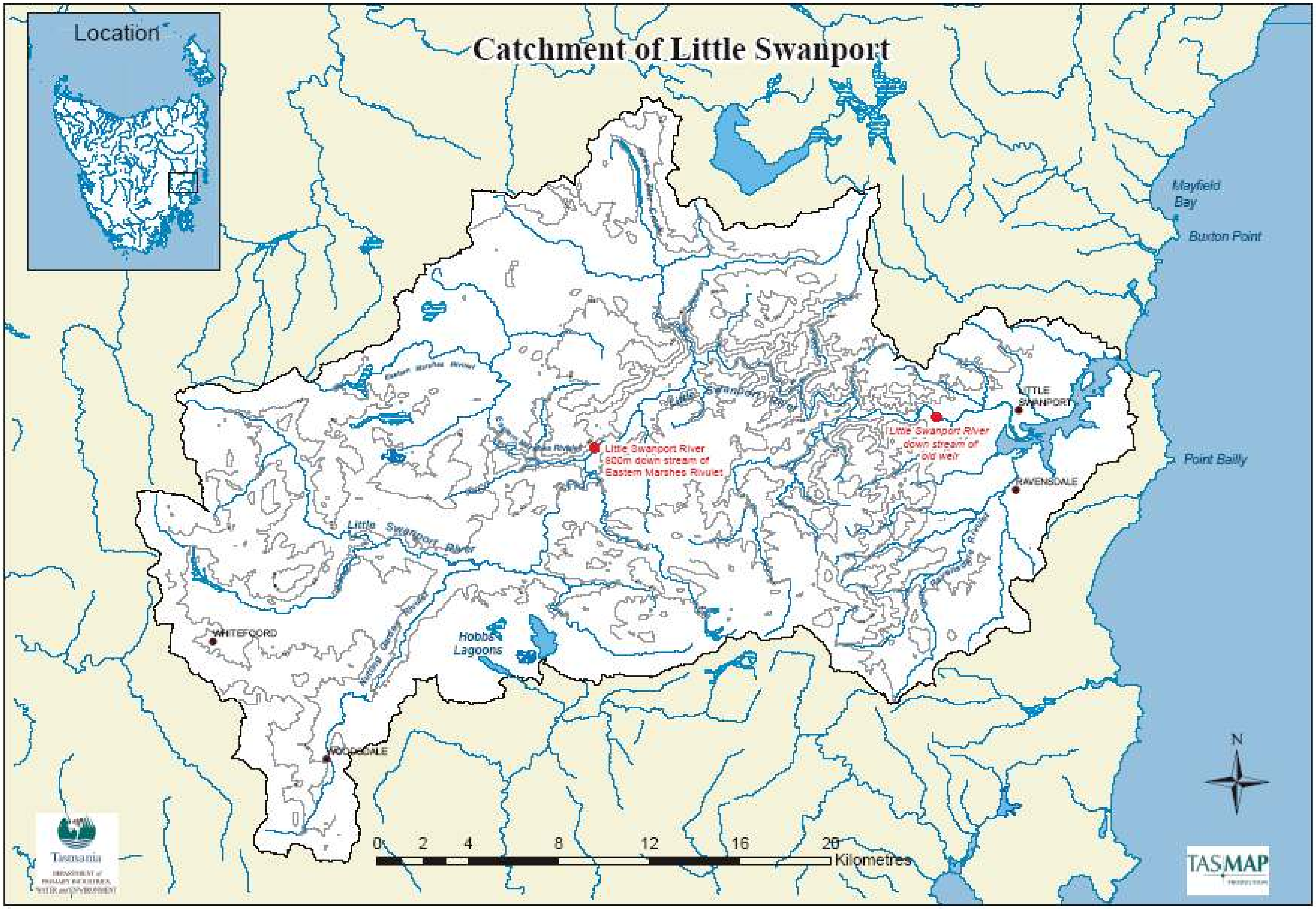

Figure 1: Location map of Little Swanport Catchment displaying hydrometric stations.

1. Introduction

1.1 Projects undertaken in the Little Swanport Catchment

The Water Assessment Branch of the Department of Primary Industries and Water (DPIW) has undertaken a number of projects to help understand the environmental processes operating in the river systems of the Little Swanport Catchment. Together these studies have provided an assessment of the current status of the catchment allowing DPIW in consultation with the Little Swanport Catchment Water Management Planning Consultative Group to produce a Water Management Plan for the catchment.

The purpose of the plan is to provide a framework for managing the catchment's water resources in accordance with the objectives of the Water Management Act 1999, and the State Policy on Water Quality Management 1997. The plan is a statutory plan that affects everyone who uses water in, or from the catchment.

The plan includes environmental and other objectives and supporting provisions for licensing, allocations, transfers, restriction management and review of the plan. The plan also contains statutory requirements and assessments relating to the water needs of the catchment ecosystem, the effects of the plan on water quantity and quality, the capacity of the water resource to meet demand, and the likely effect of the plan on water users and their businesses.

In preparation for this plan the Water Assessment and Planning Branch undertook several projects to address the following issues:

- Water quality in the catchment – including salinity and nutrients
- River health in the catchment – using macroinvertebrates and fish fauna
- Holistic environmental flows for all major water-dependant ecosystem components
- Catchment hydrology – including the effects of farm dams on catchment water yield
- Impact of climate change on catchment water yields

During this process the Water Assessment and Planning Branch have produced the following reports, all of which are available on the DPIW website: www.dpiw.tas.gov.au.

- Pinto, R. (2001). *Environmental Water requirements for the Little Swanport River*. Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart Technical Report WRA 01/08.
- DPIWE (2003). *Little Swanport Catchment, Water Resource Information Package*. Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart.
- DPIWE (2004). *Progress Report on Water Assessment and Monitoring Projects in the Little Swanport catchment*. Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart.
- SKM (2004). *Little Swanport River Catchment, Water Balance Model and Scenario Assessment.* Sinclair Knight Merz, Armadale.
- DPIWE (2006). *Little Swanport Catchment Water Management Plan 2006*. Water Policy and Planning Branch, Department of Primary Industries and Water, Hobart.

The three main scientific areas that were investigated to help further our understanding of the ecological systems operating in the Little Swanport Catchment are water quality, river health and environmental flows. The Holistic Environmental Flows project is completed and a draft report has been produced (DPIWE, 2005). The water quality and river health aspects are the focus of this report.

Water quality monitoring commenced in September 2003 and was completed in December 2004, while river health assessments were conducted in spring 2003 and autumn 2004. Monitoring for both water quality and river health still occurs at the hydrometric sites and will continue to do so for the foreseeable future. Some data obtained after December 2004 is included. At these hydrometric sites, continuous water flow, electrical conductivity, turbidity, temperature, dissolved oxygen and monthly sampling for nutrients are measured. Pesticide flood sampling is also taking place at the lower Little Swanport River site until at least 2008. All water quality and flow measurements are available on the DPIW website at: http://water.dpiw.tas.gov.au

1.2 Water quality monitoring methodology

1.2.1 Background

Water quality was monitored at twenty-five locations in the Little Swanport Catchment (Table 5) and (Figure 2). Samples were collected during the time of lowest tide height in each month to coincide with sampling performed in the estuary by The Tasmanian Aquaculture and Fisheries Institute (TAFI) (TAFI, 2004). Sampling commenced in September 2003 and concluded in December 2004.

1.2.2 Sampling design

Sampling frequency for each parameter was either monthly, quarterly or biannually, depending on the cost of analysis and the information provided by the data (Table 2). In-stream probes were placed at 5 sites in the Little Swanport catchment to collect continuous data providing information on diurnal changes and the effects of flow on water quality. Two automatic flow triggered flood samplers were also installed at the Little Swanport gauging stations to monitor changes in water quality during flood events. Analysis of data collected from these flood samplers together with data provided by the gauging station will allow for the calculation of nutrient loads.

The physio-chemical parameters tested in the field include pH (compensated for temperature), electrical conductivity (corrected to reference temperature 25 ^{o}C), water temperature, turbidity (nephelometric turbidity units, standardised against Formazin) and dissolved oxygen. All other parameters are collected in the field and analysed in a NATA registered laboratory. All water quality monitoring was conducted in accordance with the DPIW Water Quality Sampling Protocols and Standards (DPIW 2005).

1.2.3 Data analysis and interpretation

The water quality results colleted from the Little Swanport monitoring project are presented in a variety of ways depending on the type of data collection. Monthly samples, which consist of physical, chemical and nutrient data, are interpreted through the use of box and whisker plots, displaying the 5^{th}, median and 95^{th} percentile for each parameter or are presented in tabular format. Quarterly surveys for ionic parameters are also presented in this way. Summer and winter catchment surveys for selected parameters are presented as column graphs for comparison between seasons and as tabular data summary's. Flood events, which were collected from the two hydrometric stations and contain physical, chemical and nutrient water quality information are presented in a variety of methods depending on the amount of samples.

All continuous water quality data from in-stream permanent and portable probes are presented as a line graph, to highlight trends across flow types and trends between individual parameters and as box and whisker plots. Line graphs are also used to present data from the in-stream probes to show diurnal water quality variations between sites.

Modelled flow data has been used to provide a context for water quality changes where appropriate. This data is derived from a water balance model of the Little Swanport catchment constructed by Sinclair Knight Merz (SKM, 2005) and has been well calibrated with historical stream flow data from the old gauging station 3 km upstream Tasman Highway. This data has been used to produce a daily flow time series over 100 years.

Not all data collected is presented in this report. All raw water quality data is available on the WIST web site: http://water.dpiwe.tas.gov.au.

Table 2: Measured water quality parameters and sampling frequency

Parameter	Sampling frequency	Unit
Electrical Conductivity (EC)	Monthly	µS/cm
Temperature	Monthly	°C
PH	Monthly	
Turbidity	Monthly	NTU
Dissolved Oxygen (DO)	Monthly	mg/L
Dissolved Oxygen (DO)	Monthly	%
Ammonia Nitrogen (NH^3)	Monthly (10 Sites) & Quarterly	mg/L
Nitrate Nitrogen (NO^3)	Monthly (10 Sites) & Quarterly	mg/L
Nitrite Nitrogen (NO^2)	Monthly (10 Sites) & Quarterly	mg/L
Total Nitrogen (TN)	Monthly (10 Sites) & Quarterly	mg/L
Total Phosphorus (TP)	Monthly (10 Sites) & Quarterly	mg/L
Dissolved Reactive Phosphorus (DRP)	Monthly (10 Sites) & Quarterly	mg/L
Silica (Molybdate Reactive)(SiO^2)	Monthly	mg/L
Total Dissolved Solids (TDS)	Quarterly	mg/L
Total Suspended Solids (TSS)	Quarterly	mg/L
Apparent Colour	Quarterly	mg/L
Total Alkalinity	Quarterly	mg $CaCO^3$/L
Total Hardness	Quarterly	mg $CaCO^3$/L
Chloride (Cl)	Quarterly	mg/L
Floride (F)	Quarterly	mg/L
Total Sulphate (SO^4)	Quarterly	mg/L
Total Calcium (Ca)	Quarterly	mg/L
Total Potassium (K)	Quarterly	mg/L
Total Magnesium (Mg)	Quarterly	mg/L
Total Sodium (Na)	Quarterly	mg/L
Total Aluminum (Al)	Biannually	mg/L
Total Arsenic (As)	Biannually	mg/L
Total Cadmiun (Cd)	Biannually	mg/L
Total Cobalt (Co)	Biannually	mg/L
Total Chromium (Cr)	Biannually	mg/L
Total Copper (Cu)	Biannually	mg/L
Total Iron (Fe)	Biannually	mg/L
Total Mangenese (Mn)	Biannually	mg/L
Total Nickle (Ni)	Biannually	mg/L
Total Lead (Pb)	Biannually	mg/L
Total Zinc (Zn)	Biannually	mg/L
Total Coliforms	Biannually	100mls
Faecal Coliforms	Biannually	100mls
Faecal Streptococci	Biannually	100mls
Escherichia coli	Biannually	100mls

1.3 River health monitoring methodology

1.3.1 Background

Careful management of our waterways and catchments is crucial to maintain and improve river health. This in turn is dependent on good decision-making that requires detailed information on the condition of our rivers and waterways. The complexity of influences on the aquatic environment means that measurement and characterisation of the biota is crucial to understanding anthropogenic and natural disturbances on aquatic communities.

Aquatic macroinvertebrates (such as insects, crustaceans, snails and worms) are very useful indicators in biological monitoring. The basically sedentary nature and relatively long life cycles of macroinvertebrates, allows elucidation of spatial and temporal changes caused by pollution and/or disturbance. In addition, the taxonomy of many macroinvertebrate groups is well known and the responses of many species to different types of pollution have been established. As a result aquatic macroinvertebrates act as continuous monitors of the water they inhabit and can provide an effective means of assessing the ecological condition of river and streams, both in instantaneous and in trend terms.

The National River Health Program (1993-2002) provided a nationally coordinated approach to assessing the ecological condition of Australia's river systems. A major aim of the program was to develop and implement a standard methodology for monitoring benthic macroinvertebrates in freshwater streams using Rapid Bioassessment (RBA) techniques, thus allowing faster and less expensive evaluation of ecological health than would be possible using quantitative methods.

The most comprehensive assessment of river health within Tasmania was undertaken from 1994 to 2001 under the Monitoring Health Initiative (MRHI), the First National Assessment of River Health (FNARH) and Australia Wide Assessment of River Health (AWARH) which were components of the National River Health Program (NRHP). One of the major outputs of these sub-programs was the development of AUSRIVAS (Australian River Assessment System), which consists of a standardised protocol for assessing river health using macroinvertebrates and a suite of habitat- and season-specific mathematical models.

1.3.2 Biological Methods

Macroinvertebrate sampling was carried out in the Little Swanport catchment in spring 2003 and autumn 2004, with the aim of assessing the ecological health of rivers and streams. Twenty-five sites were selected as being free from obvious point source pollution but being otherwise as representative of the upstream reach as possible.

The sites were sampled using the rapid biological assessment methods developed for AUSRIVAS and outlined in Davies (1994) and Krasnicki *et al*., (2001). Separate macroinvertebrate samples were collected within a 100m reach of the river from both the riffle and edgewater habitat, where available, using a 250mm mesh net. Samples were collected from riffles by disturbing 10m of the substrate to dislodge animals that were swept into a net by the current. The edgewater sample was collected by sweeping the net along a 10 metre section of the lateral margins of the river and in backwaters and pools which have slow currents or no flow. The contents of the net were then emptied into a tray and sorted in the field according to standardised live sorting protocols (DPIW, 2004) attempting to ensure that as broad a range of taxa as possible was collected.

The samples were preserved in 70% ethanol and transported to the laboratory for further identification. All macroinvertebrates were identified to family level except in the following cases: Chironomidae (midges) were identified to sub-family level Oligochaeta (worms), Hirudinea (leeches), Acarina (mites) and Turbellaria (flatworms) were identified to order and class level. For the sake of simplicity, the term ‘family’ will be used to describe identifications to these other levels.

1.3.3 Physico-chemical and Environmental Methods

Water quality measurements including; temperature, pH, dissolved oxygen, electrical conductivity, turbidity and alkalinity were collected at each site. Observations were also made on the vegetation along the river banks (riparian zone) and aquatic habitat (substrate, depth) (Table 3). In addition detailed observations were made on a large number of habitat variables (landuse, erosion, pollution, presence of weed species, etc.) to allow more descriptive assessments of stream quality.

Table 3: Environmental variables measured at each site

Substrate	Stream and Banks	Map Based Physical Attributes
% Bedrock	% Riffle area	Distance from source
% Boulder	% Run area	Altitude (m)
% Cobble	% Pool area	Catchment area (km^2)
% Pebble	Stream width (m)	Latitude
% Gravel	Bank width (m)	Longitude
% Sand	Bank Height (m)	Stream Class
% Silt	Stream depth (cm)	Bedslope
% Clay		
% Algal cover	**Water Quality**	**Riparian Vegetation**
% Detritus cover	Temperature (^{o}C)	% Cover overhanging vegetation (shading)
% Silt cover	Conductivity (µS/cm)	% Cover trailing bank vegetation
% Moss cover	pH	% native vegetation cover
	Dissolved oxygen (mg/L)	% exotic vegetation cover
	Turbidity (NTU)	Width of riparian zone (m)
	Alkalinity (mg/L $CaCO_3$)	

1.3.4 Macroinvertebrate Data Analyses

The data were analysed using multivariate analysis: a powerful tool that presents complex ecological data as easily interpretable displays. Multivariate analyses were conducted on the edgewater habitat and riffle habitat separately and performed using the PRIMER v.5 computer program. An association matrix was calculated on the basis of similarities between samples summarising biotic relationships into a coefficient measuring distances between sites, based on community composition. In this study, association matrices were calculated using the Bray-Curtis dissimilarity measure, which is widely used in ecology and is considered to be robust.

Initially, the sites were classified into groups using cluster analysis. In this study, the classification technique known as flexible unweighted pair-groups with arithmetic averaging (UPGMA) was used. This is a hierarchical agglomerative clustering technique that classifies the sites, using all the information on all the taxa, grouping the two most similar sites into a group, then the next most similar and so on, until all the sites are classified. The resulting classification is presented as a dendrogram.

Data were then examined using ordination techniques, which essentially represent multi-dimensional data in a reduced number of dimensions for ease of interpretation. Multidimensional scaling (MDS) is an ordination technique that presents biotic relationships as a ‘map’ in which similar sites are close together and dissimilar sites are widely separated. This procedure can reveal relationships between macroinvertebrate communities and environmental variables. Ordination, which emphasises continuous variation in the data can reveal trends or gradients more clearly than classification methods which attempt to find clear breaks in the data which may not be there. In this study two dimensional ordinations were used for ease of interpretation, since calculated stress values – indicating 'goodness of fit' were acceptable.

1.3.5 AUSRIVAS

Development of the AUSRIVAS models is outlined in Krasnicki et al.,2001 and Coysh et al., 2000. AUSRIVAS assessments of river condition are based on the collection of a representative sample of the macroinvertebrate community at a site. Over 216 minimally disturbed sites (reference sites) were sampled across Tasmania to establish a reference site database from which to build the AUSRIVAS models. Sampling was undertaken twice per year (in autumn and spring) from two separate habitats (riffle and edgewater). Riffle habitats are defined as areas of flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10 cm. Edgewater habitats consist of slow flowing or still waters adjacent to the bank, preferably with overhanging or emergent vegetation, undercut banks, root mats or other suitable habitat providing cover and refuge for macroinvertebrates.

The AUSRIVAS models essentially predict the aquatic macroinvertebrate fauna that would be expected to occur at a site in the absence of environmental stress such as pollution or habitat degradation. One of the main outputs of the models is a list of macroinvertebrate taxa and the probability of each taxon occurring at a test site. The model outputs are expressed as a ratio: the number and type of macroinvertebrates actually collected at a site to the number and type of macroinvertebrates that were "expected' to be found. This ratio is expressed as the observed number of taxa/expected number of taxa (O/E scores). The O/E scores represent the percentage loss of taxa at a test site compared to reference sites and provide a measure of biological impairment of the test site.

To simplify interpretation and to aid management decisions, AUSRIVAS presents O/E scores as bands representing different levels of biological condition (Table 4). The widths of the bands are based on the O/E scores for each individual model.

Table 4: Division of O/E scores into bands or categories for reporting.

Band Label	OE Scores	Band Name	Comments
X	O/E greater than 90th percentile of reference sites used to create the model.	Richer than Reference	More families than expected Potentially biodiverse site Possible mild organic enrichment Continuous irrigation flow in a normally intermittent stream.
A	O/E within range of central 80% of reference sites used to create the model.	Similar to Reference	Index value within range of the central 80% of reference sites
B	O/E below 10th percentile of reference sites used to create the model. Same width as band A.	Significantly Impaired	Fewer families than expected Potential mild to moderate impact on water quality, habitat or both, resulting in the loss of families
C	O/E below band B. Same width as band A.	Severely Impaired	Considerably fewer families than expected
D	O/E below band C down to zero.	Impoverished	Loss of families due to moderate to severe impact on water and/or habitat quality. Very few families collected Highly degraded Very poor water and/or habitat quality

Sites that fall within the central 80% of reference site O/E values about the mean (ie 10th to 90th percentiles) are considered to be equivalent to reference (band A). The next two bands (B and C) have the same band width as band A, but the width of band D will vary, depending on the variability of the reference O/E scores. A site with an O/E score greater than the 90th percentile is judged to be richer than reference and is allocated to band X. Allocation to band X should result in further assessment to determine whether the site has naturally high diversity or is subject to an impact such as mild nutrient enrichment.

1.4 Site selection

Due to the topographical nature of the catchment, the majority of intensive farming and subsequent irrigation occurs in the upper and middle reaches on the Little Swanport River. Sites for AUSRIVAS and water quality were selected across the catchment at all major tributaries and areas of significance. During this process of site selection all previous studies by the Water Resources Division and information collected by local Waterwatch groups was used to pinpoint areas of significance. Sites were selected above and below all major tributaries of the Little Swanport River and around areas where water quality changed significantly. Site selection was limited in parts due to access difficulties in the lower reaches of the river, where the river is constrained by steep valleys and extensive vegetation.

A total of 35 sites across the catchment were selected, 25 of these sites were utilised for spring 2003 and autumn 2004 AUSRIVAS sampling and 25 for water quality sampling between October 2003 and December 2004 (Figure 2, Table 5). Two hydrometric stations were also opened during the Little Swanport study. Both stations were commissioned during 2004 and are currently ongoing. These stations are used to measure the water level at a site on the river. Through river gauging at different flow levels these are converted into flow of water in the river. At both stations, temperature, electric conductivity, turbidity and dissolved oxygen (top site only) in-stream water quality probes were also installed. The first of these sites is located 800m below the confluence of Eastern Marshes and Little Swanport River and is below all major agricultural and irrigation areas. The second site is 3km above the Tasman Highway at the bottom of the catchment below all major tributaries and at the site of the old stream gauging site that was operational from 1971 to 1990.

Figure 2: Location map of the Little Swanport catchment showing water quality and AUSRIVAS sampling sites.

Table 5: Location of study sites.

Code	Stream	Name	Easting	Northing	Water Quality	AUSRIVAS
LSWA01	Little Swanport River	Little Swanport River 3km u/s Tasman Hwy	574000	5312600	yes	Spring 03 & Autumn 04
LSWA02	Little Swanport River	Little Swanport River at Deep Hole	570167	5312821	yes	Spring 03 & Autumn 04
LSWA03	Little Swanport River	Little Swanport River downstream Green Tier Creek	564142	5315479	yes	
LSWA04	Little Swanport River	Little Swanport River upstream Green Tier Creek	563836	5315295		Spring 03 & Autumn 04
LSWA05a	Little Swanport River	Little Swanport River d/s Eastern Marshes Rivulet	561287	5313387		Spring 03 & Autumn 04
LSWA05b	Little Swanport River	Little Swanport River d/s Eastern Marshes Rivulet	559045	5311312	yes	
LSWA06	Little Swanport River	Little Swanport River u/s Eastern Marshes River	558500	5310500	yes	Spring 03 & Autumn 04
LSWA07	Little Swanport River	Little Swanport River at Pine Hill	557269	5309262		Spring 03 & Autumn 04
LSWA08	Little Swanport River	Little Swanport River at Stonehenge	556612	5308032		Spring 03 & Autumn 04
LSWA09	Little Swanport River	Little Swanport River u/s Pages Creek	556088	5305799	yes	Spring 03 & Autumn 04
LSWA10	Little Swanport River	Little Swanport River at Swanston Rd	552222	5306324	yes	Spring 03 & Autumn 04
LSWA11	Little Swanport River	Little Swanport River at McGills Marsh	548000	5307400		Spring 03 & Autumn 04
LSWA12	Little Swanport River	Little Swanport River at lower Inglewood Rd	546168	5308362	yes	Spring 03 & Autumn 04
LSWA13	Little Swanport River	Little Swanport River at Charlies Mount	546144	5309297		
LSWA14	Little Swanport River	Little Swanport River at upper Inglewood Rd	545621	5310556	yes	
LSWA15	Little Swanport River	Little Swanport River above 'Longacres'	543880	5312438	yes	
LSWA17	Pepper Creek	Pepper Creek at Deep Hole	570105	5312610	yes	
LSWA18	Pepper Creek	Pepper Creek at Swanston Rd	568500	5311800		Spring 03 & Autumn 04
LSWA19	Green Tier Creek	Green Tier Ck at Wiggins Rd	563228	5315074	yes	Spring 03 & Autumn 04
LSWA20	Green Tier Creek	Green Tier Creek at Snug Rd	561800	5318800	yes	Spring 03 & Autumn 04
LSWA21	Rocka Rivulet	Rocka Rivulet	567850	5319650	yes	Spring 03 & Autumn 04

LSWA22	Eastern Marshes Rivulet	Eastern Marshes Rivulet at Swanston	558500	5310500	yes	Spring 03 & Autumn 04

Table 5: cont.

LSWA24	Eastern Marshes Rivulet	Easter Marshes Rivulet at Lemont Rd	550800	5315800	yes	
LSWA26	Pages Creek	Pages Creek u/s Little Swanport River	556088	5305799	yes	Spring 03 & Autumn 04
LSWA28	Pages Creek	Pages Creek at Big Lagoon	557375	5303930	yes	Spring 03 & Autumn 04
LSWA29	Nutting Garden Rivulet	Nutting Garden Rivulet at Stonehenge	553778	5305893	yes	
LSWA30	Nutting Garden Rivulet	Nutting Garden Rivulet at Sth Rhodes	552000	5304900		Spring 03 & Autumn 04
LSWA31	Nutting Garden Rivulet	Nutting Garden Rivulet at Tinpot Marsh Rd	550400	5302700	yes	Spring 03 & Autumn 04
LSWA32	Crichton Creek	Crichton Creek at Inglewood Rd	549109	5306857	yes	Spring 03 & Autumn 04
LSWA33	Ravensdale Rivulet	Ravensdale Rivulet at Tasman Hwy	577300	5309700	yes	Spring 03 & Autumn 04
LSWA34	Lisdillon Rivulet	Lisdillon Rivulet at Tasman Hwy	582200	5317900	yes	Spring 03 & Autumn 04
LSWA35	Buxton River	Buxton River at Tasman Hwy	582600	5320600	yes	Spring 03 & Autumn 04