WATERWAY ASSESSMENT IN THE WESTERN PORT CATCHMENT:

THE HEALTH OF THE LANG LANG RIVER

Report prepared by

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EXECUTIVE SUMMARY

This study was undertaken to assess the health of waterways in the Lang Lang River catchment and to identify those factors that have the most impact on their aquatic ecosystems. The long-term objective in managing these waterways is to provide a sustainable, diverse and native flora and fauna that would typically occur in an unpolluted urban waterway. This study identifies the major issues that need to be addressed to improve the health of aquatic ecosystems in the Lang Lang River and its major tributaries. It is intended that similar studies will be conducted every 5 to 10 years to assess how the health of these systems change over time. Regular monitoring of this type will also provide feedback about how well these waterways are being managed by landholders and relevant government organisations.

Aquatic ecosystems are influenced by many interrelated factors, particularly water quality, stream hydrology, catchment characteristics, the extent and type of riparian vegetation, and the condition and type of stream bed and banks. A variety of indicators were used in this survey to examine the current condition of these waterways and to identify major factors influencing the biota. Water quality during base flows was surveyed on seven occasions at roughly 21-day intervals, from 12 sites throughout the Lang Lang River catchment.

The physical condition of the Lang Lang River was assessed using the Waterway Condition Monitoring Program methodology.

A broad spectrum of biological indicators was measured in order to provide an assessment of the aquatic ecosystem and also an indication of the major influences on ecosystem health. The diatom (benthic microscopic plants) flora were surveyed from four locations on the Lang Lang River. Macroalgae (such as large, filamentous algae) were surveyed at all sites on one occasion. Aquatic macroinvertebrates were qualitatively sampled from available pool and riffle habitats at all sites, using a rapid bioassessment technique. Fish surveys were conducted using a backpack electrofisher, from five sites on the Lang Lang River and one site on Minnieburn Creek.

A clear advantage of this multidisciplinary approach is that work programs will focus on the most relevant issues. For example, improvement in water quality is not a universal way of improving waterway health. Water quality improvement would only be an *a priori* issue if it enhances ecological values.

Stream health within the Lang Lang River catchment is generally fair to poor. Although quite degraded, several values still exist in the system, such as platypus, native fish and patches of remnant vegetation. Aquatic ecosystem rehabilitation goals in this catchment should seek improved diversity and sustainability of native biota – both in the Lang Lang River system and Western Port.

There are several key stream health issues within the Lang Lang River catchment, in particular, erosion (and subsequent sedimentation in streams and Western Port), poor

stream flows, poor riparian vegetation and lack of in-stream habitat. Other issues include the presence of fish barriers and elevated nutrient loads.

RECOMMENDATIONS

Rehabilitation of Riparian Zones

Riparian vegetation is degraded in large sections of the catchment. This stream-side vegetation is important not only for stream stability but also, for example, habitat (including in-stream habitat from large woody debris), a food resource for many organisms (especially leaf litter) and stream shade (to protect from excessive water temperatures and restrict nuisance algal growth). Continuous riparian vegetation can also play an important role by providing migratory corridors for various terrestrial organisms. It is recommended that reaches with degraded riparian vegetation should be targeted for revegetation through the Stream Frontage Management Program. Stream-frontage management in the catchment would also be beneficial in restricting stock access to waterways and controlling weeds.

Severe willow infestation occurs along some waterways in the Lang Lang River catchment. Willow removal should occur in accordance with the Willow Removal Strategy. Priority areas for removal should be where willows dominate the stream channel and areas in the upper catchment where there is less chance of re-establishment from upstream stands. Where willows are removed, revegetation needs to follow closely in order to avoid exposure of bare banks. Care also needs to be taken where willows may be holding erosion heads. Willow removal must follow the (Melbourne Water) Standard Work Procedure for managing willows.

Minnieburn Creek should be a priority for rehabilitation because it forms an important flow corridor in the upper catchment.

Improve In-stream Habitat

The relatively shorter and more intense flows in the Lang Lang River system during storm events (primarily resulting from forest clearing and channel straightening) are also a concern. Not only do they increase flood risk, as demonstrated by historical management (e.g. levee construction), but they also increase stress on aquatic organisms during storm events, increase erosion rates and result in lower base flows. Options to manage this problem should be explored. Possible options include re-engaging sections of the floodplain, catchment revegetation and construction of riffles (recognising the additional benefits of some in-stream stabilisation works). Riffles could help to reduce stream power and provide refuge for aquatic organisms during storm events. Several riffles have been constructed recently by Melbourne Water as part of stream stabilisation works, which also included the removal of fish barriers. Further works of a similar nature would also be beneficial. In addition to riffles, stream-frontage management (where riparian vegetation progressively provides large woody debris) would also improve in-stream habitat in future decades.

Protection of Flows

This study was conducted during a drought and results demonstrated the importance of steady flows for maintaining aquatic ecosystems in the catchment. A Stream Flow Management Plan needs to be developed for the Lang Lang River catchment that ensures sustainability of this resource for human needs and protection of aquatic ecosystems. The highest priority for flow protection is Minnieburn Creek and other spring-fed reaches of the Lang Lang River. Southern Rural Water is the responsible authority for developing a Stream Flow Management Plan in this catchment.

Removal of Fish Barriers

In order to encourage a diversity of native fish in the catchment, barriers to fish migration need to be removed. Several fish barriers were identified in the lower Lang Lang River. Melbourne Water recently conducted works to remove some of these but further work is required – especially the large barrier at Heads Road.

Protection of Western Port

Further research is required to determine catchment effects on the health of Western Port. This research will help identify priority issues in sub-catchments and develop strategic management programs. One aspect requiring further research, in particular, is seagrass decline. Possible causes of seagrass decline include increased sediment loads and turbidity, elevated nutrients, biocides and surfactants.

Results from the Melbourne Water/EPA Victoria Western Port sediment study (conducted by CSIRO Land and Water, Canberra) will be used to prioritise erosion works in the Western Port catchment, and will provide important information to help understand the reasons for seagrass loss.

In addition, reducing the amount of nutrients and other pollutants being discharged from the Lang Lang River could enhance the health of Western Port. There are several possibilities for dominant nutrient sources in the catchment, including fertilisers, dairy waste, sewage treatment plant discharges and nutrients associated with highly erodible material. Efforts to reduce nutrient levels could involve erosion control, encouraging riparian buffer strips, in-stream revegetation and fostering Best Management Practices on farms.

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1. INTRODUCTION

This study was undertaken in order to assess ecosystem health and water quality within the Lang Lang River catchment. A multidisciplinary approach was employed to not only assess current status of these waterways but also to identify major issues to facilitate the sustainable management of these waterways.

The specific objectives of this study are to:

- Determine the current condition of the Lang Lang River and its major tributaries.
- Identify those physico-chemical attributes that most influence river health.
- Identify those sections of the catchment that contribute to a decline in river health.
- Provide a sound data set for monitoring long-term changes in the river health of the waterway (at roughly 5–10 year intervals).
- Provide recommendations to Melbourne Water regarding how to sustain or improve the condition of these waterways over the next decade.

River health is a term used to describe the overall condition of a waterway. It refers to the water quality and the physical attributes of a waterway, but primarily focuses on the condition of the aquatic ecosystem. A broad range of environmental indicators is used to assess the health of the Lang Lang River catchment. These indicators include: various water quality measurements, metals in sediments, macroinvertebrates, fish, benthic diatoms, macroalgae and an assessment of stream condition (particularly the quality of in-stream habitat). A brief explanation of the reasons why these indicators were selected is presented in the "METHODS" section. Further details regarding how to assess river health are detailed by the River Basin Management Society (RBMS 1997).

A limited assessment of water quality trends in this catchment is also presented. Water quality data have regularly been collected since 1990 from three sites on the lower Lang Lang River as part of the water quality monitoring network.

This study was designed to provide a snapshot of the status of the Lang Lang River catchment. Scientifically rigorous methods are employed to assess waterway health so as to ensure that they can be repeated in future studies and to enable a reasonable assessment to be made of how these systems change over time. Coleman and Pettigrove (1999) discuss the role of this type of report in assisting Melbourne Water's management of waterways.

It is important to recognise the limitations of this study in order to clarify the purposes of this report. This study only provides a snapshot of the condition of the catchment. More extensive monitoring would be required to gather information about how the system changes between seasons and in relation to longer-term fluctuations in the weather. For example, 1997-98 was exceptionally dry; some different issues may have emerged if the weather had been wetter and cooler, such as what occurred in 1995-96. This report is not a concept plan, and therefore does not provide recommendations or action plans about future land uses. Furthermore, the focus of this report is on the health of the waterways. Riparian vegetation is only assessed in relation to how it may influence the waterway's health. Other land management issues, such as the presence of rare plants and associated wildlife, are not considered.

The purposes of this report are, therefore, to generate greater community interest and to facilitate a greater understanding of the various issues that need to be managed. Considerable community interest and awareness of these systems are required to ensure that these waterways and their distinct ecosystems are protected for future generations.

2. STUDY AREA

2.1 General Location and Background

The Lang Lang River catchment is a major drainage system to Western Port. It has a total area of approximately 430 km^2 and is roughly confined to the boundaries of Poowong, Drouin South and Lang Lang. The Lang Lang River itself is about 60 km long.

Headwaters of the Lang Lang River are situated in the Strzelecki Ranges near Poowong – approximately 90 km south-east of Melbourne. From Poowong, the Lang Lang River flows north-west to Athlone, where it meets with a major tributary called O'Mahony Creek (catchment area of approximately 105 km^2). The O'Mahony Creek catchment, which flows from Drouin South, incorporates flows from Minnieburn Creek.

From Athlone, the Lang Lang River flows roughly west, past Heath Hill and Lang Lang, until it reaches Western Port – approximately 75 km south-east of Melbourne. Pheasant Creek, the Little Lang Lang River and Adams Creek are major tributaries downstream of Athlone and have approximate catchment areas of 80, 120 and 30 km^2 respectively.

The catchment falls within the jurisdiction of Bass Coast (headwaters), Baw Baw (middle to upper catchment) and Cardinia (middle to lower catchment) Shires.

Flows in the Lang Lang River are highly seasonal. The majority of floods occur during late winter to early spring, although the catchment does experience severe storms in summer (GHD 1998).

2.2 Land Use

History

The Lang Lang River catchment has undergone significant changes. Prior to European settlement, the Lang Lang catchment was densely forested throughout and contained a series of swamps with thick tea-tree scrub (WPCCG 1984). The Lang Lang River originally followed a meandering course across the plains until it became lost in the southern extension of the Koo Wee Rup Swamp, called the Yallock Swamp, located downstream of the present Lang Lang township. There were no identifiable channels crossing the Koo Wee Rup swamp into Western Port (Ministry for Conservation 1977).

Clearing of the forest commenced in the mid 1800s to establish cattle and sheep runs. By the early 1900s, as European settlement intensified, much of the catchment had been cleared for agriculture, thus resulting in the loss of a rich forest and its diverse flora and fauna (WPCCG 1984).

The Koo Wee Rup Swamp was drained in the 1890s. Draining of this and other swamps in the district was to take advantage of their rich peat soils. The swamp was also seen as endangering the livelihood of early settlers, with water up to a depth of 2 feet (0.61 metres) covering the area and some places being impassible due to dense scrub (WPCCG 1980). Draining of the Koo Wee Rup Swamp produced several straight channels to Western Port. These straight channels increased stream flow power and the river responded by incising into the floodplain (GHD 1998).

The initial Koo Wee Rup swamplands drainage system could not cope sufficiently with floodwaters from the Lang Lang River, so an 18-km drain was constructed in 1915 to replace all, except the upper section, of the meandering river course. The 8-km long straight section of the drain replaced a river loop of 11 km, and has subsequently become a zone of considerable erosion. In 1923, the drain was enlarged to 15 m wide and 3 m deep and extended 1.3 km to replace the remaining river meander. An embankment was also constructed along its northern side and a levee was built to divert overflows at the edge of the plain back into the drain. This levee has been a significant cause of erosion because it concentrates all floodwater power into the drain rather than allowing it to flow over the floodplain where stream power would dissipate (Ministry for Conservation 1980).

Lang Lang River catchment hydrology was significantly altered by the transition from a forest to an agricultural catchment, as rainfall run-off potential increased. Increased run-off during wet weather results in greater and more intense high flows down the catchment, which increases the likelihood of erosion and flooding problems. Compared to the Bunyip River, the Lang Lang River has both higher and lower flows, indicating that it is a comparatively flashy stream with a quick response and low base-flow component (Lakey 1982). Increased run-off through clearing large areas has increased erosion of the catchment, allowing water to cut tunnels and gullies into the soil and generating sediment loads and associated pollutants to waterways. Run-off in the catchment is also intensified by the low porosity soils (GHD 1998).

Recent Land Use

Land use in the Lang Lang River catchment in the early 1970s was approximately 82% agricultural, 9% forest and less than 1% urban/industrial (Shapiro 1975). Today, there is no discernible change in the percentages of the catchment that fall within these generalised land uses (Figure 1).

ACI Raw Materials, Lang Lang, is a major industry in the catchment. This operation extracts and processes sand to meet glass industry requirements in Melbourne. The company leases about 187 ha of land on McDonalds Track, east of Lang Lang. Sand extraction at Lang Lang commenced in 1952 using a 'dry mining' technique, which caused little physical environmental change compared to the 'wet mining' technique that began in 1962 (WPCCG 1979).

2.3 Geology and Soils

Parent materials in headwaters of the Lang Lang River catchment are Jurassic arkose, Tertiary sandstone and basalt, which are typical of the Strzelecki formation (Ministry for Conservation 1980). The geology of the Minnieburn Creek catchment is generally basaltic, punctuated with associated pyroclastics, conglomerates and thin brown coal seams. The soil formations that overlay the Strzelecki formation are typically brown

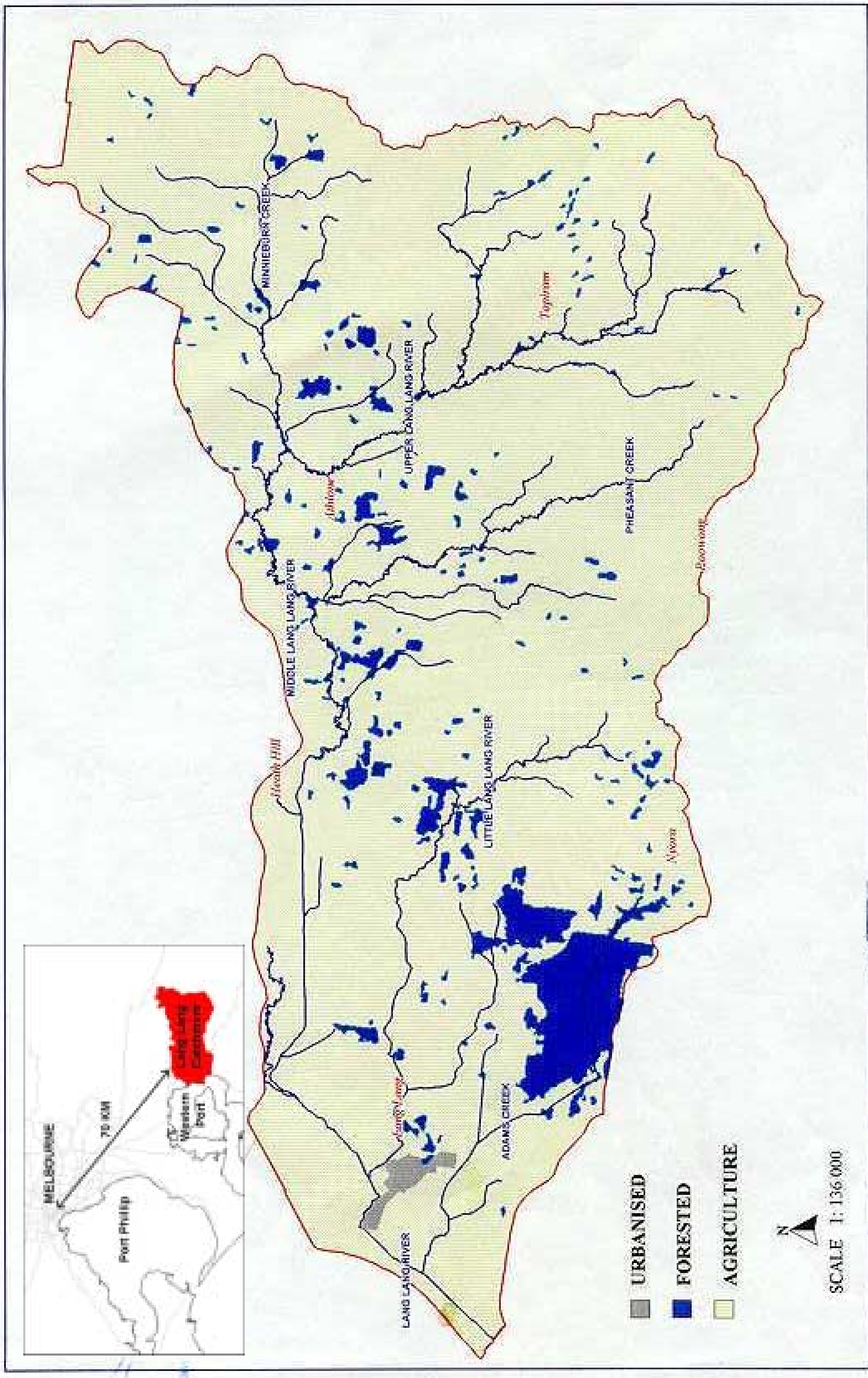


Figure 1: Land use in the Lang Lang River catchment

to yellowing clay loams. Overall, soils throughout the drainage lines of the catchment tend further towards grey clay loams with isolated occurrences of fine sandy clay loams or light clays (WPCCG 1984).

Parent materials in the central section of the catchment are recent marine and fluviatile sediments with sections eroded into buried sand dunes (Ministry for Conservation 1980). The Heath Hill Fault, with its Tertiary ferruginous sand and clays, demarcates the middle and upper sections of the catchment.

The lowest section, which crosses through the old Koo Wee Rup Swamp to Western Port, consists primarily of Quaternary alluvial and aeolian deposits overlaying Cretaceous Strzelecki group formations of sandstone and basalt. Over-bank deposits having been generated from sediment dropout during flood events (GHD 1998).

2.4 Population Size and Distribution

A map of population size and distribution is presented in Figure 2. As expected, the population within the rural Lang Lang River catchment is low compared to many other catchments throughout Greater Melbourne. The most densely populated regions of the catchment are Lang Lang and Nyora townships.

2.5 Status of Sewering in the Catchment

Sewering in the catchment is confined to Lang Lang township, which is serviced by a local wastewater treatment plant that currently treats about 100 ML a year (D. Cliff, South East Water, pers. comm., 1998). The treatment plant is located on Western Port Road, near the South Gippsland Highway and uses lagoon and grass filtration treatment with discharges all treated effluent into Adams Creek. Average inflow to the treatment plant is 219 kL/d (about 95% capacity), with the subsequent outflow to Adams Creek varying according to evaporation rates through the various treatment processes and to absorption levels into the soil used for grass filtration. Outflow, therefore, varies from approximately 80–90% of inflow during winter, to sometimes 0% during the summer (J. Furey, South East Water, pers. comm., 1998).

Currently there is some on-site re-use for irrigation but the majority of treated water is discharged into the creek. South East Water is moving towards 100% re-use on adjacent tree plantations. This is scheduled to commence in the summer of 2000–2001 and will be fully operational after about three years. Initially, effluent re-use was restricted as the treated water was saline; however, conversion of the town water supply from groundwater to the less saline Cardinia Reservoir water will alleviate this complication (S. Muir, South East Water, pers. comm., 2000).

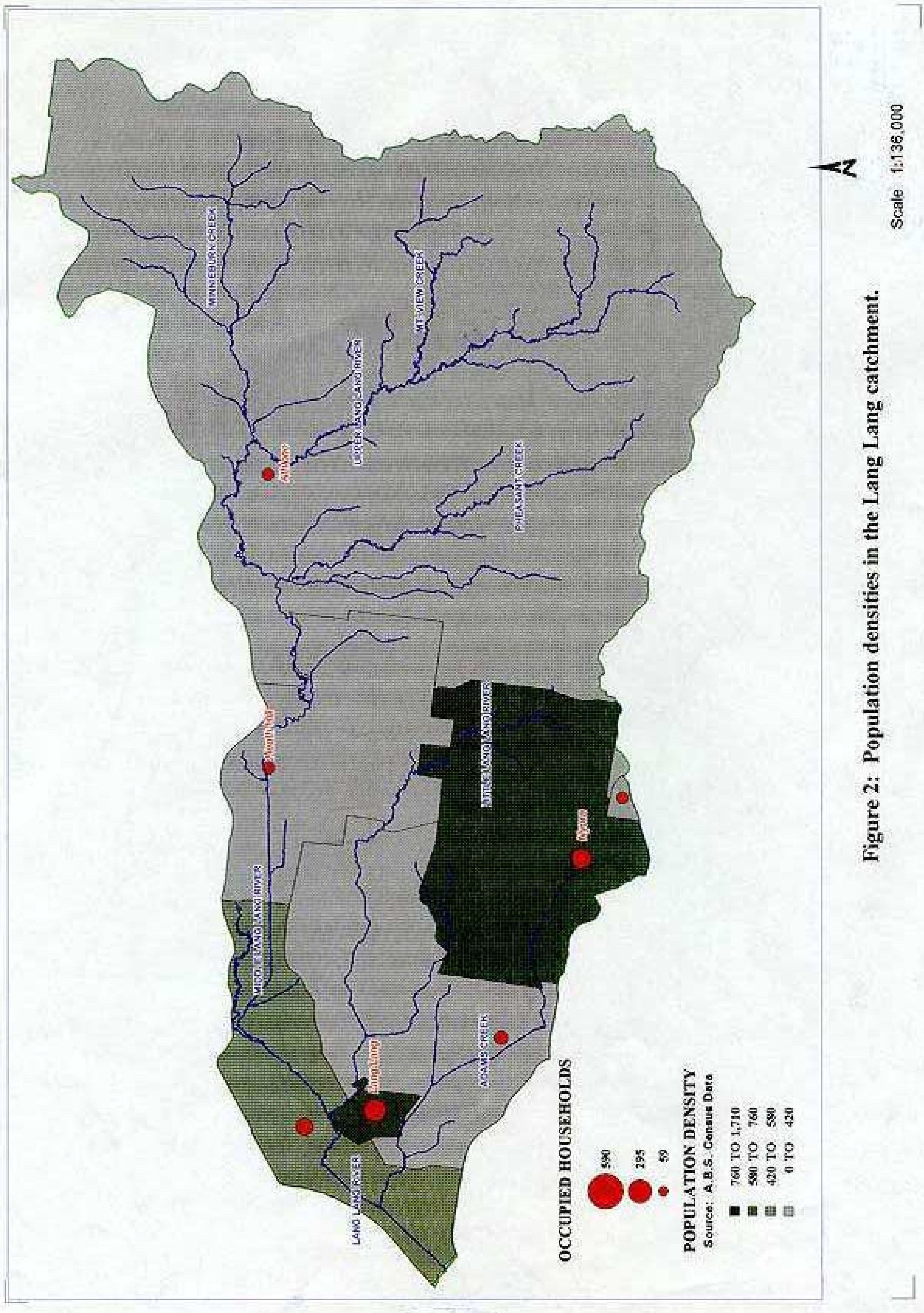


Figure 2: Population densities in the Lang Lang catchment.

2.6 Water Use

Groundwater

Currently groundwater is the primary source of domestic water to the township of Lang Lang. There are two major bores that transfer groundwater via pipeline to a single storage basin with a 3.5 ML capacity. Water is chlorinated within the inlet to the basin before it is dispersed to local residents (D. Cliff, South East Water, pers. comm., 1998). Water tanks are also used as a source of domestic water. A pipeline has recently been constructed from Koo Wee Rup to Lang Lang in order to connect potable water from Cardinia Reservoir to Lang Lang township, hence replacing reliance on groundwater. For this new supply to be operational, a pump station at Koo Wee Rup is required and is expected to be completed in October/November 2000 (S. Muir, South East Water, pers. comm., 2000).

Groundwater is an important complement to surface waters as a source of water for livestock, particularly in arid areas where it is often the only viable water source. Groundwater may discharge to surface waters, such as rivers, streams and coastal water bodies. Groundwater in the Bunyip and Tarago Rivers, adjacent Western Port catchments, has been estimated to contribute up to 70% of surface flows in drought years and 28% in high rainfall years (Lakey 1982).

Waterways within the mid-Lang Lang River catchment are underlain by permeable sediments to a depth greater than 100 m. This section of the catchment is relatively elevated and the water table is at a considerable depth (5–30 m) below waterway surface levels. In the mid-reaches of the catchment, therefore, there is potential for streams to discharge to underlying groundwater. An arbitrary elevation of 20 m AHD has been selected to represent the boundary between the lower and mid reaches, as it is hypothesised that streams higher than 20 m AHD will discharge to groundwater (D. Green, SKM, pers. comm., 2000). In the Lang Lang River, this boundary is roughly midway between Soldiers and Heads Roads. As there is a potential for streams in the mid-catchment to discharge to groundwater, surface water quality in these reaches may influence groundwater quality (D. Green, SKM, pers. comm., 2000).

In upper reaches of the catchment, sediments are predominantly consolidated and relatively impermeable (D. Green, SKM, pers. comm., 2000). There is probably a minor net discharge of groundwater to streams in the upper reaches. Groundwater springs are expected to be present and to be discharging to adjacent waterways at outcrops of basement rock in these areas (D. Green, SKM, pers. comm., 2000). Within the lower reaches (i.e. below 20 m AHD), there is likely to be a hydraulic potential for groundwater to discharge into streams (D. Green, SKM, pers. comm., 2000).

Currently there are insufficient data to quantify the volumes of water leaking from, or discharging to, streams in the catchment. This would require regular surface and groundwater monitoring in different regions of the catchment. It is thought, however, that the volume of stream leakage would be offset by a similar volume of groundwater discharge to the streams (D. Green, SKM, pers. comm., 2000).

Surface Water Diversions
Domestic, irrigation and industrial diversions from the Lang Lang River and Minnieburn Creek are as follows (WPCCG 1984):

Lang Lang River

11	Domestic and dairy annual permits	48 ML
11	Domestic and stock permits	24 ML
1	Industrial permit	5 ML
10	Irrigation permits	490 ML
1	Dairy permit	2 ML
	Riparian rights	50 ML
	Total	**619 ML**

Minnieburn Creek

2	Domestic, stock and dairy permits	7 ML
1	Domestic stock permit	2 ML
1	Dairy permit	2 ML
1	Irrigation and domestic permit	52 ML
28	Irrigation permits	1,084 ML
	Riparian rights	100 ML
	Total	**1,247 ML**

2.7 Public Survey

Quantitative Survey
During June 1998, Melbourne Water commissioned 150 telephone interviews with residents of the Lang Lang River catchment (ResearchWise 1998a). Telephone interviews were about 20–25 minutes each. Respondents living within 2 km of Lang Lang River were selected. The ages of respondents were evenly spread across three age classes; that is, younger than 30 years, 30–50 years and older than 50 years. Residents were asked to comment on their level of satisfaction according to several key aspects such as:

- *waterway access* (e.g. opportunities to walk along waterway, view waterway, signage);
- *safety* (e.g. stability of banks, floodwaters, snakes);
- *appearance* (e.g. natural appearance, condition of vegetation, overall impression);
- *healthiness* (e.g. litter, fish and other aquatic animal habitat, water clarity, presence of scums, odours, amount of flow, extent of native vegetation);
- *wildlife* (e.g. presence of birds, fish and platypus).

The most important issues in the catchment focused on a lack of flows, erosion, litter and a lack of natural habitat. It is likely that the importance of a lack of flow was emphasised due to the recent drought period. Compared to similar surveys conducted in other Melbourne catchments (Mullum Mullum Creek, Diamond and Arthurs Creeks, Merri Creek and Kororoit Creek), flows, erosion and habitat were uniquely problematic in the Lang Lang River.

Bird life, a lack of pollution (but not water clarity) and its suitability for fishing were considered to be the strengths of the Lang Lang River. Weaknesses were a lack of platypus and safety issues such as unstable banks, snakes and the risk of personal injury.

Of all the catchments surveyed, Lang Lang River residents visited their local waterway most frequently (i.e. 62% visit it at least weekly). Lang Lang River is most often viewed from a car, but fishing is a significant use – unlike other catchments surveyed.

Only 26% of respondents considered that the Lang Lang River is well managed compared to an average of 40% across all catchments surveyed. Overall satisfaction with their local waterway was lowest in the Lang Lang River catchment survey (50% were satisfied), with satisfaction most evident in younger respondents and those less familiar with the waterway.

Qualitative Survey

A qualitative survey of Lang Lang River catchment farmers was conducted in conjunction with the telephone surveys (ResearchWise 1998b). Discussion was limited to 12 farmers. The views of these farmers had little in common with attitudes expressed during the telephone interviews.

Farmers were concerned that the Lang Lang River is getting worse, with flow velocities being too high, extensive erosion and decreasing flows over the past 20 years.

A significant issue according to them was the recent removal of willows. They criticised past willow-removal works as being too destructive, not strategic and resulted in a mess of woody debris. Willows were not perceived to be an invasive weed and, in addition, removal was believed to be a major cause of erosion. Little importance was placed on the role of snags as habitat for aquatic life, with farmer values focused on stock water and irrigation. Flooding was also voiced as an important issue. Flooding problems were seen to be related to the abundance of snags and the cause of the erosion problems.

Farmers believed that they were personally responsible for weed control – with Wandering Tradescantia being the primary weed. Extensive algal growth was considered to lower waterway values during summer. Farmers acknowledged the need to be careful about spraying too close to waterways.

3. METHODS

3.1 Stream Condition Assessment

The physical condition of waterways in the Lang Lang River catchment has a major influence on the health of these waterways. Major ways that riparian zones influence waterway condition are by:

- providing shade (which influences the amount of photosynthesis);
- vegetative litter (representing a source of food for aquatic organisms);
- root structures (which affect bank stability) and the modification of channel structure by large woody debris;
- regulating nutrient flux between the stream and the terrestrial habitat along the bank (e.g. Cummins 1993).

Surveys of waterways in the Lang Lang River catchment were conducted by Brizga *et al*. (1997).

The method used to assess stream condition follows that used by (Melbourne Parks & Waterways 1995). In essence, the environmental condition of each segment was assessed by considering the following indicators:

- aquatic structure
- shading
- water quality
- bed stability
- bank stability
- verge/floodplain stability
- bank vegetation
- verge vegetation
- noxious/pest plants.

A combined overall indicator of stream condition is used to give each stream reach a rating.

3.2 Water Quality

A broad spectrum of water quality parameters was surveyed during base flows only. There was a total of 12 water quality sites (refer to Appendix 8.1 for a detailed description plus photograph of each site). Six sites were located on the Lang Lang River, one site on Adams Creek, two sites on the Little Lang Lang River, two sites on Pheasant Creek, and one site on Minnieburn Creek (Figure 3). All of these sites were sampled on seven occasions at approximately 21-day intervals during base flows between 4 December 1997 and 21 April 1998.

Sites were surveyed for dissolved oxygen, water temperature, electrical conductivity, pH, biochemical oxygen demand, total phosphorus, orthophosphate, total Kjeldahl nitrogen, ammonia, oxidised nitrogen, *Escherichia coli* (*E. coli*), suspended solids and

Site	Waterway	Site Description	Map Ref.
LLG01	Lang Lang River	South Gippsland Hwy	ES. 796 C12
ADM02	Adams Creek	South Gippsland Hwy	ES. 824 C1
LLL03	Little Lang Lang River	Western Port/Pioneer Rd, Lang Lang	ES. 796 E13
LLL04	Little Lang Lang River	Martins/Pooles Rd, Lang Lang	ES. 825 D1
LLG05	Lang Lang River	Patullos Rd, Yannathan	ES. 797 C9
LLG06	Lang Lang River	Western Port Rd, Heath Hill	ES. 797 G10
PHE07	Pheasant Creek	Clifton Rd, Athlone	ES. 798 A11
PHE08	Pheasant Creek	Timms Road, Poowong	ES. 826 D5
LLG09	Lang Lang River	Drouin/Poowong Rd, Athlone	ES. 798 D9
MIN10	Minnieburn Creek	Main South Rd, Athlone	ES. 789 H9
LLG11	Lang Lang River	Standfields Road, Poowong North	ES. 826 G3
LLG12	Lang Lang River	Korrumburra/Drouin Rd, Triholm	Mel. 512 U9
PHE13	Pheasant Creek	Houlahans Rd, Poowong	ES. 826 D7

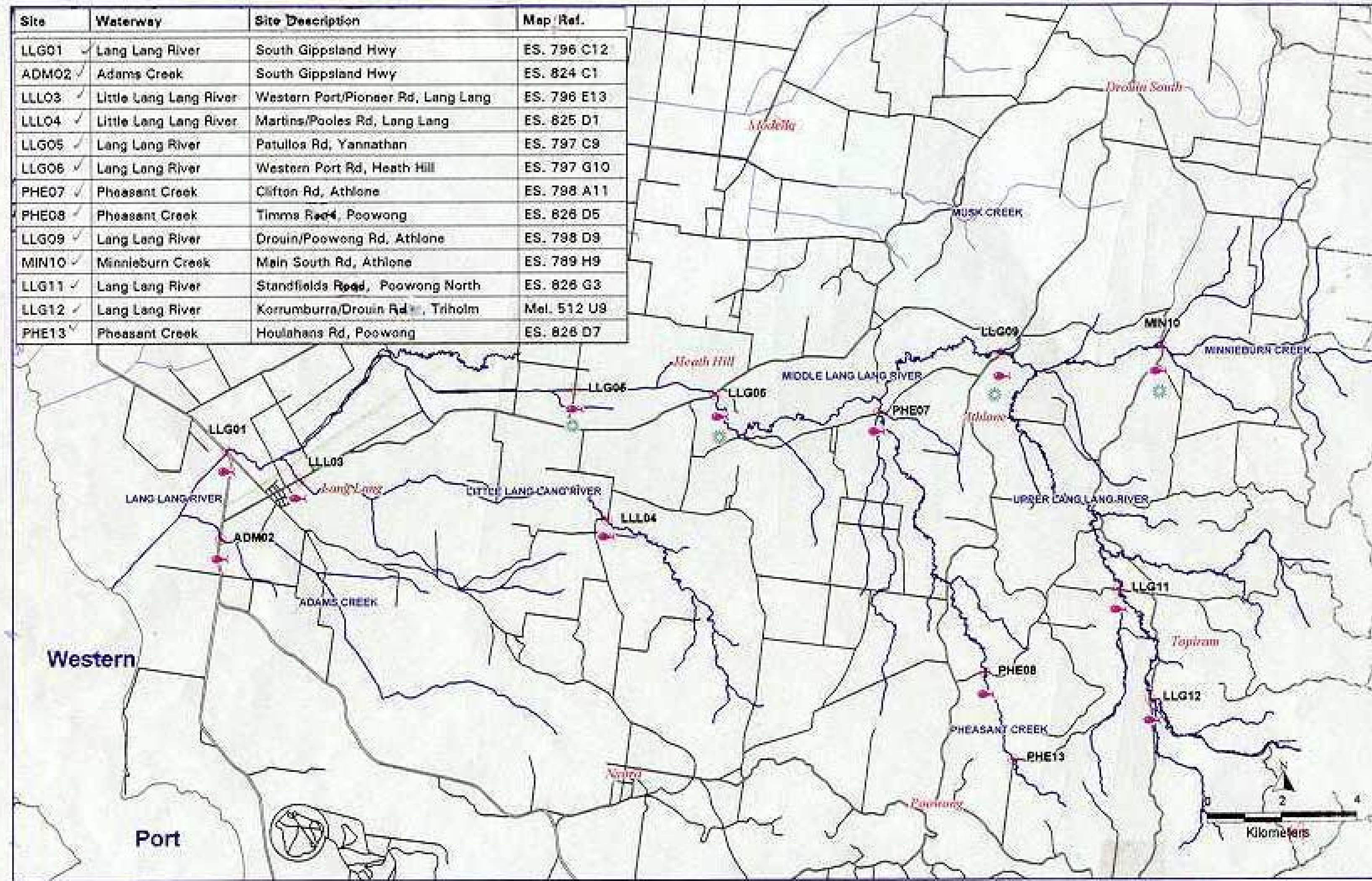


Figure 3: Lang Lang River site descriptions and locations

turbidity. Water samples were analysed by Australian Laboratory Services Pty Ltd (Clayton, Victoria).

Heavy metals are considered to be the most toxic of environmental pollutants (Forstner & Muller 1976). They are generally found in sediments as most of them have low solubilities in water and are bound to sediment particles (Laws 1993). Methods used to collect the sediment samples and analyse the sediment for metals are detailed by Lewin (1997). Samples were analysed to determine concentrations of arsenic, cadmium, chromium, copper, lead, zinc and mercury.

Sediments were also analysed for organics (volatile solids and pesticides) and nutrients (total phosphorus, total Kjeldahl nitrogen and iron) at four sites. Pesticides and their derivatives were sampled in Adams Creek, the Little Lang Lang River and the Lang Lang River at Patullos Road and the Drouin-Poowong Road. Nutrients in sediments were sampled in Minnieburn Creek and the Lang Lang River at Patullos Road, Western Port Road and the Drouin-Poowong Road. Organic and nutrient analyses were carried out on whole samples.

Sediment data for metals and organics are compared to draft Australian and New Zealand Environment and Conservation Council (ANZECC) Interim Sediment Quality Guidelines (ISQG) (ANZECC 1997).

3.3 Diatoms

Diatoms are the most abundant autotrophic organisms in rivers (Round 1993) and, therefore, are an important component of lotic ecosystems. They are a major source of food for protozoa, invertebrates and juvenile fish, and may considerably influence water chemistry (e.g. pH, dissolved oxygen and ion concentrations; Round 1993). Since the early part of this century, it has been known that many diatom taxa have specific ecological requirements, optima and tolerance in respect to a variety of water quality indicators. Such knowledge enables a measure of water quality based upon the composition of a diatom community. Diatoms are considered a valuable intermediate between the infrequent, discontinuous (‘snapshot’) nature of physico-chemical sampling, where short-term events can result in ecologically significant changes not being detected, and the monitoring of higher organisms, which may have a tolerance of brief stresses or effective avoidance behaviour (Reid *et al*. 1995).

Benthic diatom communities were sampled at four sites: Minnieburn Creek and the Lang Lang River at Patullos Road, Western Port Road and the Drouin-Poowong Road. Artificial substrata, with six roughened plastic slides (25 x 75 mm), were used as the basis for sampling. Artificial substrata were chosen because they provide a standardised habitat and colonisation period in order to enable a quantifiable comparison between communities at each site. Disadvantages of artificial substrata are that the flora may, to some degree, be ‘unnatural’ and biased towards diatoms that are fast growing and can attach to flat, smooth surfaces (Round 1993). The plastic slides were roughened in an attempt to reduce the potential bias of smooth surfaces and to prevent sloughing of the diatom films (Round 1993). An important aspect to consider with the use of artificial substrata is that the diatom community will only represent the environmental conditions during the colonisation period.

Colonisation of diatoms on artificial substrata generally takes 2–4 weeks for adequate growth (Round 1993), but colonisation has been known to take up to eight weeks in moderately nutrient-enriched rivers (Biggs 1988). In this study, the substrata remained in the water at each site for six weeks (6 April to 18 May 1998). To provide more reliable results, three substrata were placed at each site. These replicates were situated no more than 10 m apart.

Sampling was restricted to locations with at least moderate flow (generally riffles) and placed so that the slides were parallel with the flow. This was to reduce the likelihood of silt accumulation on the substrata, which could smother the diatom communities.

After the colonisation period, diatoms were scraped into a separate sample jar from each substratum. Removal of diatoms from the slides and the preparation of samples for microscopic analysis followed the methods of Round (1993).

Slides were examined under oil immersion using Nomarsky Differential Interference Contrast at a magnification of x1000. For each slide a random transect was chosen and the first 200 frustules encountered were recorded. Where possible, identification was to species level.

3.4 Macroalgae

'Macroalgae' is a term used to describe algae that are conspicuous to the naked eye. Macroalgae in urban streams are commonly filamentous. Macroalgal biomass and community composition can provide a measure of water quality. Interpretation of macroalgae data is usually broad because it is based on the limited amount of ecological information available.

Macroalgal sampling was conducted on a single occasion at each site (i.e. 8 May 1998). Samples for macroscopically visible growths were taken only. Visibility in turbid streams was improved using a plastic underwater viewing box (approximately 0.5 m long and 20 x 30 cm at the base). Samples were preserved at the time of collection with 5% commercial formalin.

The composition of available algal habitat and its proportion to the total substratum viewed was determined at each site, using a scale from 0 to 5 where: 0, 0% of total site substratum; 1, <10% of total site substratum; 2, 10–35% of total site substratum; 3, 35–65% of total site substratum; 4, 65–90% of total site substrata; and 5, >90% of total site substratum. When algal samples were taken, the cover of each sample type on the various substrata was also estimated (using the same scale as above). At each site, a broad estimate of water surface shading was determined from low, moderate and high.

Identification of macroalgae was performed using a light transmission microscope at a magnification of x400. At least three subsamples were used to identify the species present in each sample. A general abundance value from 1 to 3, based on the method of Entwisle (1989a), was applied to each sample where: 1, isolated plants; 2, not common; and 3, common and easily observed.

3.5 Macroinvertebrates

Macroinvertebrates were qualitatively sampled using a rapid bioassessment technique in accordance with protocols defined in the River Bioassessment Manual (Monitoring River Health Initiative 1994). They were collected from pool and riffle habitats at each site, where both habitats were present. This method aims to collect as many taxa as possible within an *in situ* 30-minutes live sort. Animals picked from the sample were preserved in alcohol and sent to Water Ecoscience Pty Ltd (Mt Waverley, Victoria) for identification. All macroinvertebrates were identified to the lowest possible taxonomic level. Further details regarding this technique and laboratory processing of samples are detailed by Smith *et al*. (1997).

Until recently, no aquatic macroinvertebrate criteria existed in the current Western Port State environment protection policy (SEPP). Invertebrate data, therefore, have been analysed in terms of the number of taxa and major taxonomic groups, and the SIGNAL (Stream Invertebrate Grade Number – Average Level; refer Chessman *et al.* 1997) scores calculated according to the method recommended by EPA Victoria (EPA; 1998). Results have also been compared with Hewlett (1998) and Hardwick and Lewin (1999). EPA Victoria recently released a draft of environmental indicators and objectives for the region (EPA 2000).

The three sites on Pheasant Creek and the upper site on the Little Lang Lang River were only sampled on one occasion, because they had completely dried up by the second sampling event in March 1998. Sites on the Lang Lang River at South Gippsland Highway and the Poowong-Drouin Road were sampled in late October 1997, as part Melbourne Water's biological monitoring program. Remaining sites were first surveyed during early December 1997.

3.6 Fish Surveys

Fish surveys were conducted in five sections of the Lang Lang River and one section in Minnieburn Creek. Each site was only sampled once; however, these results provide a glimpse of the type of fish fauna that inhabit these waterways and helps identify those factors that may influence fish abundance and distribution.

The Marine and Freshwater Resources Institute (MAFRI; Heidelberg, Victoria) conducted the fish surveys with some field assistance from Melbourne Water. Fish were surveyed by means of a method, which would provide an estimate of densities and that could be repeated in further surveys.

The method involved collecting the fish from a 100-m section of stream. Stop nets were positioned at each end of the sampling area and the fish were collected using a portable Smith-Root model 12 backpack electrofisher. Two electrofishing passes were conducted at each site, with the second pass commencing at least 30 minutes after the end of the first. Sampling was conducted during February 1998. All fish and freshwater crays captured were identified and a subsample of 20 individuals of each species was measured for length and weighed. The bulk weight of fish at each site was also measured. A visual assessment of flow type, substratum composition and in-stream habitat was also made, and was used to assist in site and aquatic faunal comparisons. Further details of this method are presented by Raadik and Zampatti (1998).

3.6 Platypus Surveys

The Australian Platypus Conservancy was commissioned to conduct a survey to determine whether platypus occurred in the Lang Lang River catchment.

Two fyke nets, which are also known as eel nets, were set at each site (with one net facing downstream, the other facing upstream) in the afternoon of 17 March 1998. Nets were then monitored throughout the night. Each net is suspended partly out of the water to ensure that platypus have access to air.

Any other animals (i.e. water rats, tortoises and fish) collected in these nets are also recorded. A list of the sites surveyed and their location is presented in Table 1. Williams et al. (1998) presents further details regarding the methods used in this survey.

Table 1: A list of the sites surveyed for platypus by Williams *et al* (1998)

Code	Waterway	Location	ESMAP
LA1	Lang Lang River	Western Port Road	797 G10
LA2	Lang Lang River	Smethurst's property along marked track to Quarry, north of Clifton Road (2 km west of LA4)	798 H/I9
LA3	Lang Lang River	Monk's property, about 1.5 km upstream of LA2	798 B9
LA4	Lang Lang River	Poowong-Drouin Road	798 D9
LA5	Minnieburn Creek	Main South Road	798 H/I9

4. RESULTS

4.1 Stream Condition Assessment

Overall stream condition appears to have changed little in the upper catchments since the former Dandenong Valley Authority carried out the last assessment of stream condition in 1985. The following account of stream condition is primarily derived from Brizga *et al*. (1997). Other contributions are also cited.

Lang Lang River Below Heath Hill

The Lang Lang Cut is subject to continuing minor to moderate bed degradation and localised bank erosion. An erosion head of about 0.5 m is currently located at Soldiers Road. Similar instances of bed degradation are likely throughout the Cut to the estuary. Major stabilisation works are presently being carried out at Patullos Road. Further bed stabilisation work is considered necessary, but a field survey would be needed to define the extent of works. Regeneration and revegetation of the riparian zone with indigenous species should have some priority along the Cut. Willows in the base of the channel are implicated with some of the observed bank slumping and wash-outs. Blackberry growth is dense throughout the reach. Stock trampling causes moderate to severe (but usually localised) bank degradation, and puddling by stock in the bed contributes to water quality concerns.

Substantial improvements have occurred in the stability of the lower river near Heath Hill as a result of the major program of river stabilisation adjacent to Lyons Road. Although these works were observed to be stable, there is still evidence of bed degradation at the upstream end of the works and at least one additional chute (or raising of an existing chute) is recommended.

The rate of bed degradation in the incised section of the Lang Lang River from Heath Hill to the South Gippsland Highway is much slower than it was in the late 1960s to late 1970s (GHD 1998). Main areas of concern identified in the lower Lang Lang River catchment in terms of degradation were:

- the 1-km reach below the drop structure at Patullos Road;
- the area immediately above Patullos Road;
- the reaches extending 1 km upstream and downstream of the junction of the Little Lang Lang River;
- the 1-km reach below the South Gippsland Highway bridge (GHD 1998).

Since 1998, Melbourne Water has conducted stabilisation works in the Lang Lang River upstream and downstream of Patullos Road (1997–98 to 1999–2000), downstream of Heads Road (1998–99), at Heath Hill (1997–98) and between the South Gippsland Highway and Dandenong Leongatha Railway line (1998–99).

Middle to Upper Lang Lang River

Further upstream, concerns for the middle and upper Lang Lang River segments relate to willow infestations, inadequate riparian vegetation, stress from excessive stock grazing and dairy farm effluent. A demonstration site showing the benefits of stock exclusion as a means for bank stabilisation can be seen on the upstream side of Timms

Road. Most tributaries are either touching bedrock or are continuing to incise slowly so that under continual stock pressure, banks are subject to minor to moderate erosion. Riparian vegetation is often completely absent or dominated by willows. Extensive willow infestation occurs in the upper Lang Lang River between Mt View Creek and Olsens Road (Seymour 1987). Good stands of mature river red gums, however, have been identified in sections of the Lang Lang River between Lyons Road at Heath Hill and the confluence with Mt View Creek downstream of Poowong East (Seymour 1987).

O'Mahony and Minnieburn Creeks

The O'Mahony Creek/Minnieburn Creek system appears to have changed little in the past 12 years; an erosion head of about 0.8 m held by a willow tree in a tributary stream on Lardners Track has not altered visibly. Southern tributaries are in a similar condition to the upper Lang Lang River and its tributaries. Northern tributaries are mostly straightened cut drains in gentling, sloping alluvial valley bases. They are subject to minor aggradation and degradation. Stock grazing in the drains is a concern. Riparian vegetation is virtually limited to pasture grasses, although some river red gums have been reported in Minnieburn Creek (Seymour 1987).

Pheasant and Eliza Creeks

The Eliza Creek system suffers from minor to moderate bed degradation and bank erosion in its upper reaches and has poor to very poor riparian vegetation throughout.

Pheasant Creek suffers less from erosion problems, possibly as a by-product of the dominance of willows. Blackberries are very dense in places. In general, the management concerns and needs are similar to those of the upper Lang Lang River tributaries, these being improvements in riparian vegetation, control of stock grazing and better management of dairy farm effluent.

Interesting observations made in this and adjacent waterway systems included some successful revegetation/stabilisation projects and a trend towards localising cattle movements in protected laneways prior to milking. While the latter reduces pressure on paddocks in general and prevents stock accessing the waterways, the laneways inspected were unfortunately located so that drainage of the concentrated droppings was directly to road table drains and then to the waterways themselves, with no filtration.

Little Lang Lang River

The Little Lang Lang River is still subject to minor to moderate bed degradation and bank erosion between Murphys Road and Watsons Road. The channel is subject to meander cuts as well.

Downstream, revegetation and fencing programs appear to be successful, although the channel is still showing some signs of bed degradation. Near Lang Lang township, the creek has been mostly straightened but currently appears to be reasonably stable. Riparian vegetation is dominated by exotics, and stock grazing is contributing to continuing slow erosion of banks. Some important swamp communities have been identified in the lower Little Lang Lang River below Watsons Road, and also in a tributary of the Lang Lang River that flows from Nyora Estate Road into the Lang Lang River upstream of Heath Hill (Seymour 1987).

Adams Creek

Adams Creek has been the subject of extensive bed and bank stabilisation works upstream of Kettles Road to the railway line. These were observed to be stable. Minor bank erosion and some localised drops in the bed occur downstream of the works and these warrant monitoring. Access is extremely difficult upstream of the railway. Aerial photos and observations within ACI Raw Materials, Lang Lang, indicate no stability problems are likely, but the presence of some floating scums indicates some degrading inputs of process materials from the plant may occur from time to time.

Recommendations from a Recent Fluvial Geomorphology Study

A recent internal Melbourne Water report on the fluvial geomorphology of the Lang Lang River (GHD 1998) made the following key recommendations:

- Up to nine rock weirs should be constructed in the channel of the Lang Lang River in the following reaches (with care not to create fish barriers):
  downstream of the railway line
  downstream of Soldiers Road
  upstream of Heath Hill.
- Rock drop structures should be constructed downstream of Heads Road.
- Appropriate works should occur to temporarily store additional floodwaters on the floodplain at:
  the Loop (i.e. natural channel at Heath Hill),
  upstream of Pheasant Creek
  upstream of Athlone.
- Reinstatement of a damaged levee along the Lang Lang River at Camerons Road.
- Progressive revegetation of the Lang Lang River channel banks to assist in erosion protection and habitat renewal.
- A study should be undertaken to assess the potential for reducing storm event peak flows by a reafforestation program as part of the whole catchment management process.

4.2 Water Quality

The following assessment of water quality in the Lang Lang River catchment considers conditions only during base flows. Water quality would significantly alter during storm flows when most contaminants are likely to be transported within waterways (e.g. contaminants washed into a waterway within run-off or from increased erosion/sediment re-suspension associated with elevated flows).

Base-flow samples were collected during drought conditions; therefore, the results may not illustrate what usually occurs in the catchment (Figure 4). Figures 5 and 6 show that flows in the Lang Lang River at Heads Road during the study were lowest between 1980 and 1998. A local farmer near Poowong stated that they were the lowest flows that he had seen in the Lang Lang River since the 1950s. The upper Lang Lang River sites (LLR12 & LLR11), Pheasant Creek, the Little Lang Lang River and Adams Creek were reduced to a series of pools. Pheasant Creek at Clifton Road

(PHE07) was dry for most of the study. Even though the results were likely to be biased as a result of the drought, they provide a unique perspective of this catchment during extreme conditions.

Figure 4: Mean daily flows in the Lang Lang River at Heads Road 1/90 to 6/98

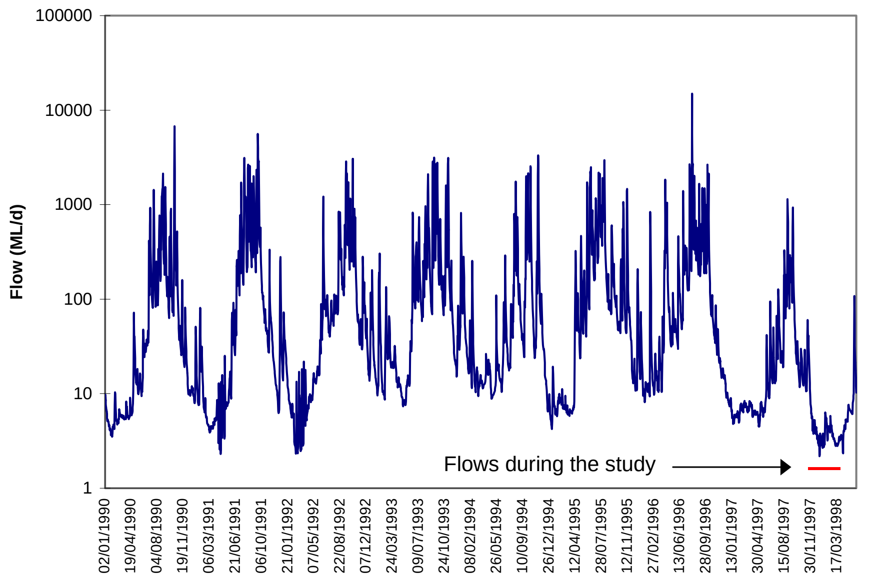
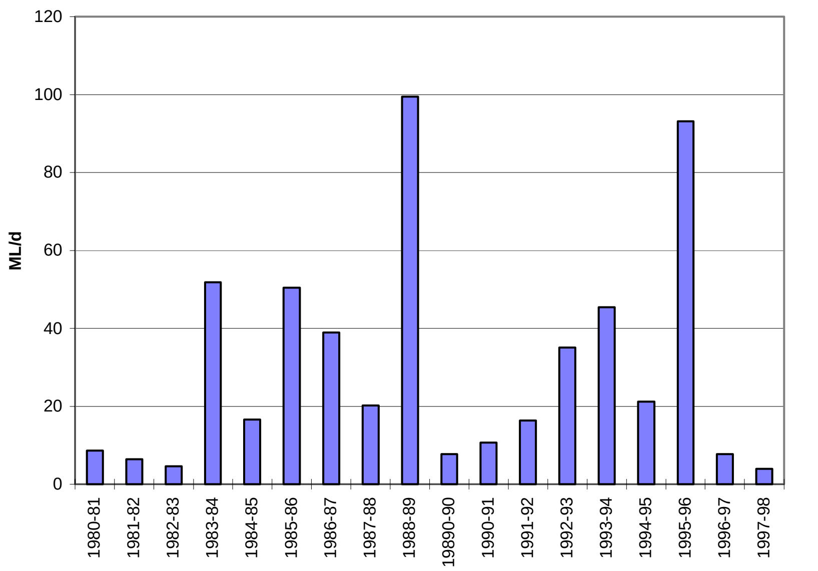
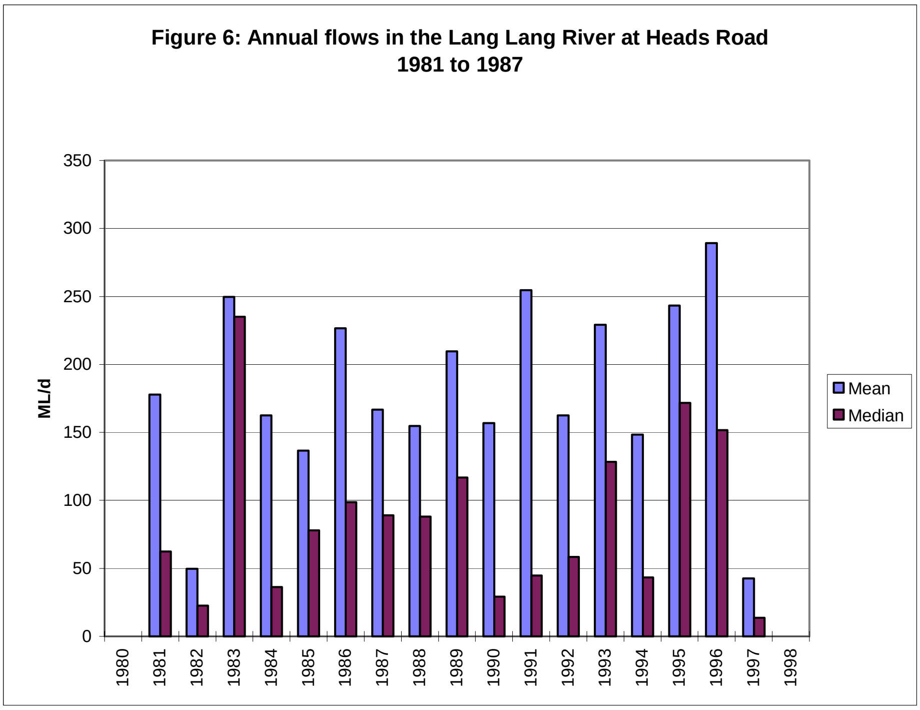


Figure 5: Mean 'December to April' flows in the Lang Lang River at Heads Road 1980-81 to 1997-98





Water quality results are compared to the draft *State Environment Protection Policy (SEPP) Waters of Western Port and Catchment* – which includes the Lang Lang River catchment (EPA 2000). According to this SEPP, the Lang Lang River catchment consists of two segments; that is, the 'Lowlands and Phillip Island' segment and the 'South Eastern Rural' segment. The first segment contains a small section downstream of the South Gippsland Highway, while the South Eastern Rural segment, contains the rest of the catchment.

Where SEPP objectives do not apply to a particular water quality indicator, results are compared to the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992).

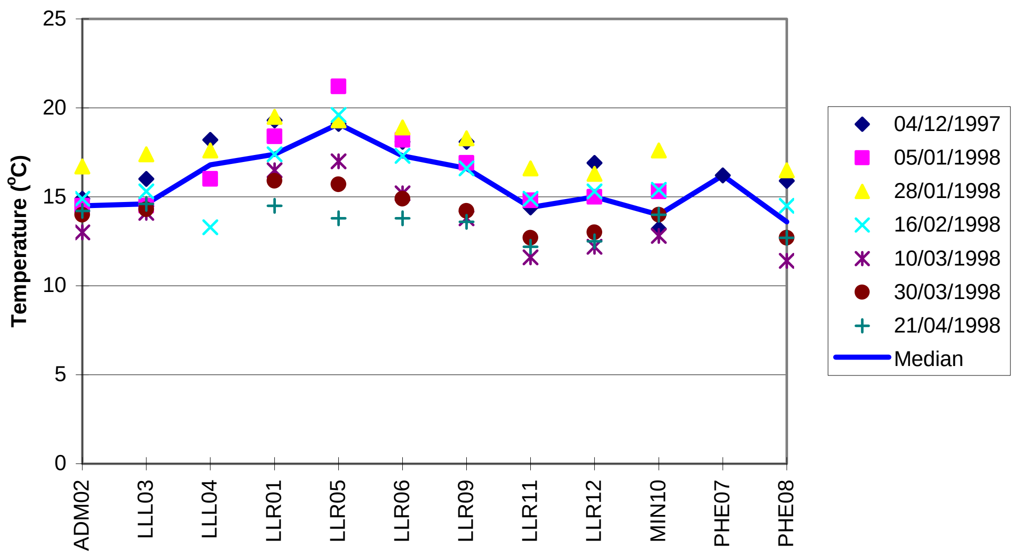
4.2.1 Water Temperature

Water temperature can have a substantial effect on many aquatic organisms. Physiological processes have thermal optima, and alterations to ambient temperatures may affect the exposed species in a variety of ways. However, there are currently too few data to recommend a guideline relating to reductions in temperature (ANZECC 1992).

Water temperatures recorded during base flows in the Lang Lang River catchment are presented in Figure 7. Temperatures ranged from 11.4^{o}C in Pheasant Creek at Timms Road (PHE08) on 10 March 1998 to 21.2^{o}C in the Lang Lang River at Patullos Road (LLR05) on 5 January 1998. These sites also possessed the lowest and highest median temperatures for each site, which were 13.6^{o}C (PHE08) and 19.1^{o}C (LLR05).

In Lang Lang River, water temperature tended to increase between Stanfields Road (LLR11) and Patullos Road (LLR05), then decrease further downstream.

Figure 7: Water temperatures in the Lang Lang River catchment

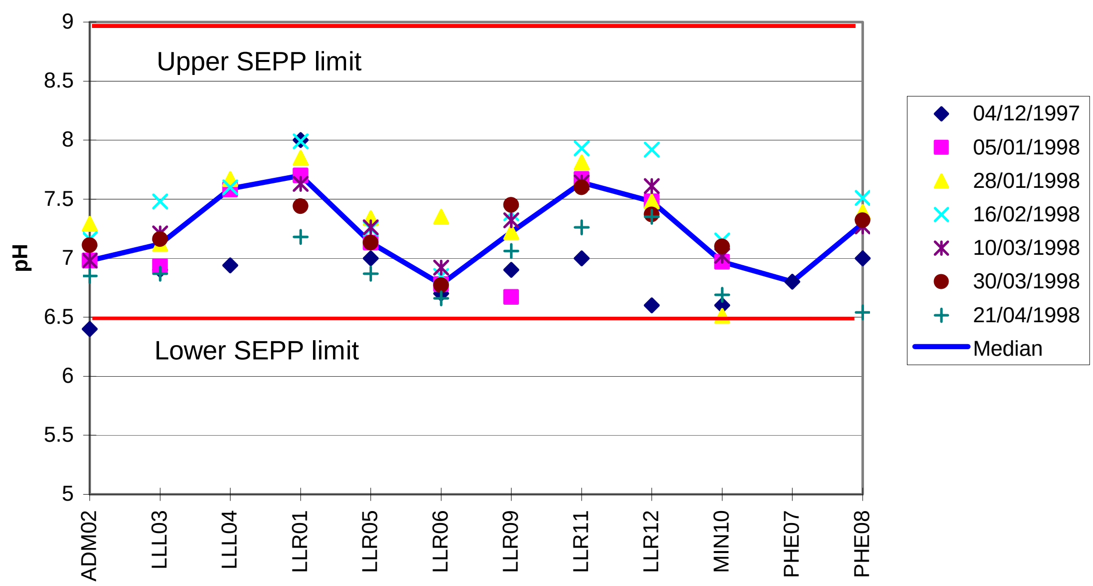


4.2.2 pH

pH results measured during base flows in the Lang Lang River catchment are presented in Figure 8.

The SEPP objective for surface waters within the entire Lang Lang catchment is a pH range between 6.5 and 9.0 (EPA 2000). The only result to exceed this range was 6.4 in Adams Creek on 4 December 1997. The catchment could be classified as neutral to slightly alkaline, with the median pH at each site varying between 6.8 in the Lang Lang River at Heath Hill (LLR06) and 7.7 in the Lang Lang River at the South Gippsland Highway (LLR01).

Figure 8: pH in the Lang Lang River catchment



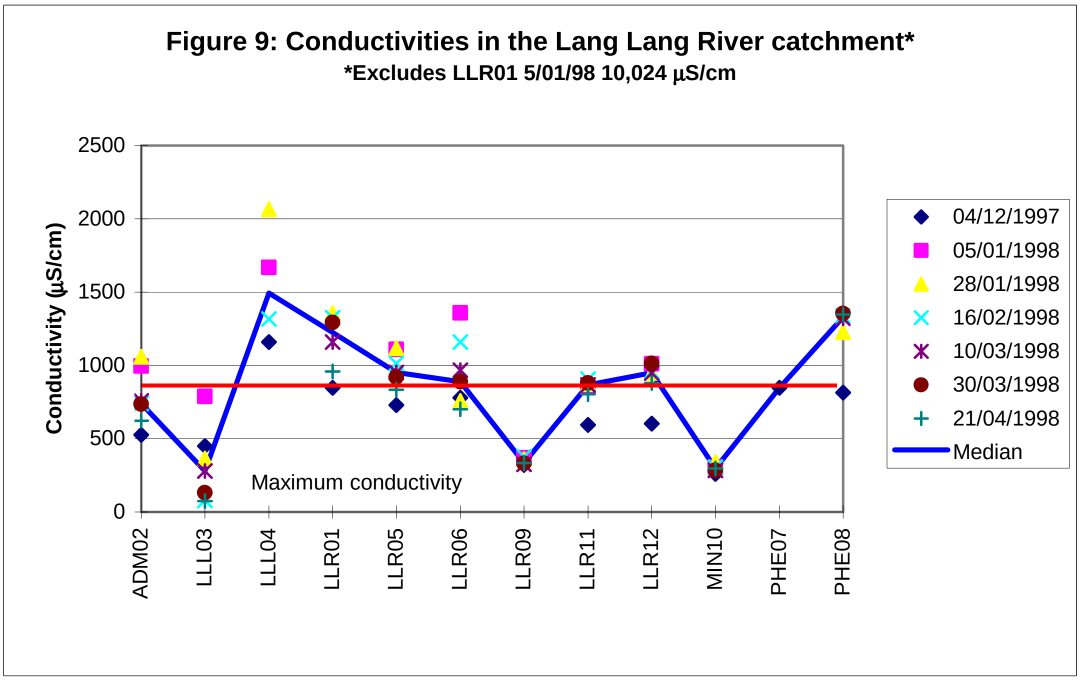
4.2.3 Conductivity

Conductivities measured at each site during this study are shown in Figure 9.

Results ranged from 75 µS/cm in the Little Lang Lang River at the Western Port Road (LLL03) to 2065 µS/cm in the Little Lang Lang River at Pooles Road (LLL04). Median conductivity varied from 280 (LLL03) to 1492 µS/cm (LLL04). The difference in conductivity between the two sites could be a reflection of different evaporation rates, with the former retaining more water and experiencing slightly cooler temperatures (Fig. 7). Inputs from Minnieburn Creek appear to reduce conductivity in the Lang Lang River between Drouin-Poowong Road (LLR09) and Stanfields Road (LLR11).

Conductivity tended to display a downstream increase along the Lang Lang River, although there is an obvious localised reduction at the Drouin-Poowong Road (LLR09). Perhaps the elevated conductivity upstream of Drouin-Poowong Road was a result of pooling and evaporation, or from a comparatively greater proportion of groundwater in the upstream sites due to lower flows.

The SEPP objective for waters in the Lang Lang River catchment is approximately that conductivity <800 µS/cm (i.e. total dissolved solids of <500 mg/L) (EPA 2000). Most sites had a median conductivity that exceeded the SEPP objective. The Lang Lang River at the Drouin-Poowong Road (LLR09), Minnieburn Creek (MIN10), the Little Lang Lang River at Western Port Road (LLL03), and Adams Creek (ADM02) had median conductivities below the SEPP objective.



Summary conductivity data collected from the Lang Lang River between April 1990 and June 1998, as part of the water quality monitoring network, are presented in Table 3. This summary information indicates that conductivity levels determined by the monitoring program are comparable to the results from this study in the Lang Lang River at the Drouin-Poowong Road (LLR09), but are almost half the conductivities determined by this study in the Lang Lang River at Patullos Road (LLR05) and the South Gippsland Highway (LLR01). This is probably a reflection of reduced flows during the study and a subsequent greater contribution to water chemistry attributed to groundwater inputs.

Summary conductivity data collected from the Lang Lang River between July 1975 and December 1981 are presented in Table 2.

Table 2: Summary water quality data collected from the Lang Lang River at Lang Lang between July 1975 and December 1981 (State Rivers & Water Supply Commission 1984)

	n	Lowest	10th Percentile	Median	90th Percentile	Highest
Temp (^{o}C)	76	5.5	9.0	15.0	22.5	25.0
Cond (µS/cm)	76	77	294	623	958	1090
pH	72	6.1	7.0	7.4	7.8	7.9
Turb (NTU)	67	1	4	14	63	150
SS (mg/L)	16	2	2	11	110	290
DO (mg/L)	69	5.0	7.2	9.2	11.1	12.9

Temp, temperature; Cond, conductivity; Turb, turbidity; SS, suspended solids; DO, dissolved oxygen.

Table 3: Summary water quality data collected between April 1990 and June 1998 from the Lang Lang River at Drouin-Poowong Road (LLR09), Patullos Road (LLR05) and the South Gippsland Highway (LLR01)*

Site		Temp (^oC)	DO (mg/L)	DO (%Sat)	Cond (µS/cm)	pH	Turb (NTU)	SS (mg/L)	*E. coli* (org/100 mL)	BOD_5 (mg/L)
LLR09	*N*	48	49	14	49	49	49	49	48	26
	Lowest	7.5	3.3	39	115	6.5	5	1	20	1
	25th Percentile	10.0	6.2	64	350	7.0	10	5	210	1.025
	Median	12.5	7.6	72	392	7.2	15	9	405	1.6
	75th Percentile	16.6	8.5	83	455	7.5	22	23	765	2.4
	Highest	23.3	12.5	91	749	8.3	190	520	58000	12
	Date from	Apr 90	Apr 90	May 96	Apr 90	Apr 90	Apr 90	Apr 90	Apr 90	Apr 90
	Date to	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Aug 95
LLR05	*N*	20	20	ns	20	20	20	20	19	20
	Lowest	7.6	5.0	ns	225	6.7	6	2	50	1.0
	25th Percentile	9.8	6.3	ns	370	7.1	11	7	160	1.3
	Median	12.0	7.3	ns	496	7.2	14	12	350	1.4
	75th Percentile	15.6	8.8	ns	640	7.4	26	31	605	2.9
	Highest	21.0	11.0	ns	890	7.6	100	250	66000	9.8
	Date from	Jun 90	Jun 90	na	Jun 90	Jun 90	Jun 90	Jun 90	Jun 90	Jun 90
	Date to	May 94	May 94	na	May 94	May 94	May 94	May 94	May 94	May 94
LLR01	*N*	76	76	26	79	79	78	79	77	44
	Lowest	8.0	4.5	68	40	6.8	5	2	40	1
	25th Percentile	11.0	6.8	87	471	7.3	11	8	160	1.15
	Median	14.5	8.8	98	636	7.4	20	16	320	1.8
	75th Percentile	18.2	9.8	106	760	7.6	34	42	650	3.45
	Highest	25.3	11.7	127	1700	8.5	360	580	41000	9.2
	Date from	Jun 92	Jun 92	May 96	Apr 92	Apr 92	Apr 92	Apr 92	Jun 92	Apr 92
	Date to	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Aug 95

*Data were collected as part of the Melbourne Water Water Quality Monitoring Program. Temp, temperature; Cond, conductivity; SS, suspended solids; Turb, turbidity; DO, dissolved oxygen; BOD_5, biochemical oxygen demand (5 day test); *n*, number of samples; ns, not specified.

4.2.4 Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) test provides a measurement of the quantities of oxygen consumed during biological oxidation of organic waste matter under controlled conditions. It is possible to interpret BOD data semi-quantitatively in terms of gross concentrations of organic matter, as well as in terms of the amount of oxygen in the stream that is likely to be consumed by organisms feeding on organic material (e.g. Mancy & Weber 1971). There are no draft SEPP or ANZECC objectives for BOD.

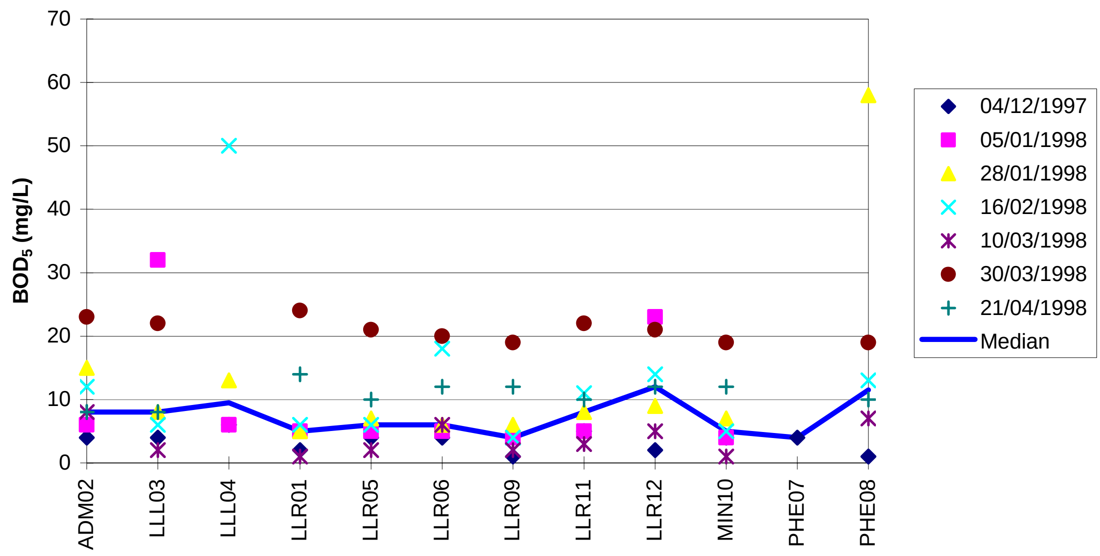
Concentrations of BOD in waters of the Lang Lang River catchment are presented in Figure 10. Values generally varied more between sample runs rather than sample sites. The most significant sample run was on 30 March where results ranged between 19 and 24 mg/L.

The lowest median BOD was 4 mg/L in the Lang Lang River at Drouin-Poowong Road (LLR09) and Pheasant Creek at Clifton Road (PHE07) – although the latter was only sampled on one occasion. Highest median BOD was 12 mg/L in the Lang Lang River at Korumburra-Drouin Road (LLR012). These levels are slightly higher than median values from similar Melbourne Water catchment studies within Greater Melbourne; for example, Andersons/Jumping Creeks (2–7 mg/L), Corhanwarrabul Creek (3–6 mg/L), Watts River (2–4 mg/L) and Mornington Peninsula–Western Port (4–9 mg/L) (Pettigrove & Coleman 1998a, Pettigrove & Coleman 1998b, Coleman & Pettigrove 1998, Hardwick 1998). Results tended to be higher in sites where there was little or no flow (i.e. Upper Lang Lang River, Pheasant Creek, Little Lang Lang River and Adams Creek). Those sites with more steady flows did, however, show results similar to these other Greater Melbourne catchments.

According to criteria for assessing BOD in the *State of the Environment Report 1988 - Victoria's Inland Waters*, the lower Lang Lang River catchment to Athlone (LLR09) had median values classified as moderate, the uppermost Lang Lang River sites and Pheasant Creek at Timms Road were degraded, and Minnieburn Creek was poor (State of the Environment 1998).

BOD measurements during this study were greater at all sites compared to Melbourne Water historical data (Table 2). Historical median BOD values ranged between 1.4 and 1.8 mg/L, whereas, during this study the median BOD values at these sites ranged from 4.0 to 6.0 mg/L.

Figure 10: Biochemical Oxygen Demand (5-day test) in the Lang Lang River catchment



4.2.5 Dissolved Oxygen

The concentration of dissolved oxygen (DO) can have a major impact on the types of organisms that can inhabit the waterway. For example, DO levels below 50% saturation can stress many freshwater fish (Koehn & O'Connor 1990) and, presumably, many macroinvertebrate taxa.

Results for DO at each site are illustrated in Figure 11. Dissolved oxygen levels were typically low throughout the catchment, particularly those sites that had ceased to flow for most of the study. The lowest DO reading was 6% saturation in the Lang Lang River at Korumburra-Drouin Road (LLR12) on 5 January 1998. The highest reading was 128% saturation in the Lang Lang River at the South Gippsland Highway (LLR01) on 4 December 1997.

Median DO concentrations ranged from 14% saturation in the Lang Lang River at Korumburra-Drouin Road (LLR12) to 79% saturation in the Lang Lang River at the South Gippsland Highway (LLR01).

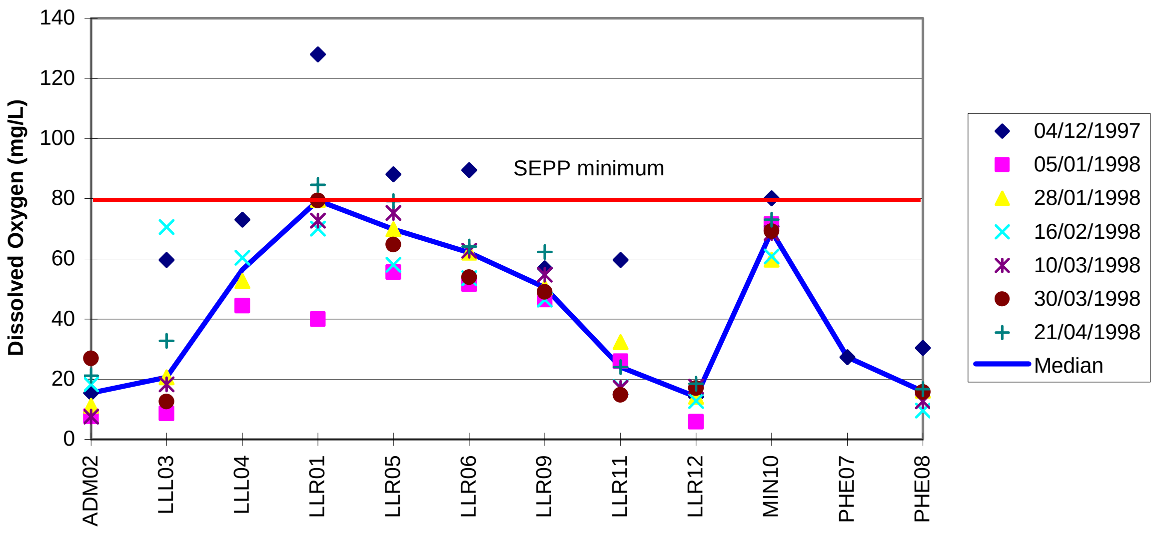
The SEPP objective for waters of the Lang Lang River catchment is that the minimal DO concentration should exceed 80% saturation (EPA 2000). All sites had a median DO concentration below the SEPP objective, with only the three lowest sites in the Lang Lang River having concentrations above the objective on one or two sampling runs.

The Lang Lang River increased in DO from the headwaters (LLR12) to Drouin-Poowong Road (LLR09), which could reflect the subsequent increase in flows. Pheasant Creek at Timms Road (PHE08), where there was water for most of the study, had a median DO concentration of 16% saturation.

Adams Creek had a median DO concentration of 15% saturation. The Little Lang Lang River also had low median concentrations of 21% saturation (LLL03) and 56% saturation (LLL04). The upper site in the Little Lang Lang River (LLL04) was dry during March and April sampling.

During this study, median concentrations of DO in the Lang Lang River at Drouin-Poowong Road (LLR09), Patullos Road (LLR05) and the South Gippsland Highway (LLR01) were lower than the levels depicted in the Melbourne Water water quality monitoring summary data (Table 2). This would be a reflection of the particularly warm and low flow conditions experienced during the study.

Figure 11: Dissolved oxygen concentrations in the Lang Lang River catchment



4.2.6 Nutrients

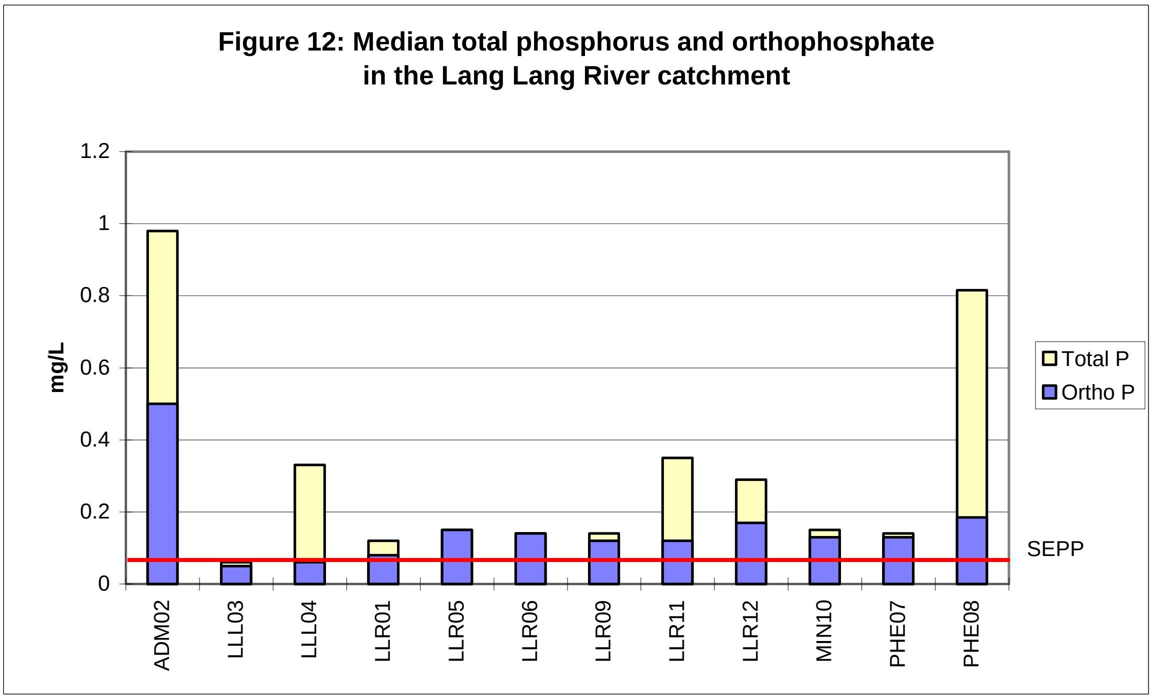
Phosphorus

Median concentrations of total phosphorus and orthophosphate during base flows are presented in Figure 12.

Orthophosphate concentrations ranged from 0.02 mg/L in the Little Lang Lang River at Western Port Road (LLL03) on 4 December 1997 to 1.75 mg/L in Adams Creek (ADM02) on 10 March 1998. These two sites also defined the median orthophosphate range with 0.05 mg/L and 0.5 mg/L, respectively.

Total phosphorus concentrations ranged between 0.04 mg/L in the Little Lang Lang River at Western Port Road (LLL03) on 30 March 1998 and 2.56 mg/L in Adams Creek (ADM02) on 10 March 1998. Similarly, these sites also defined the median total phosphorus range with 0.06 mg/L and 0.98 mg/L, respectively.

The draft SEPP objective specifies a maximum total phosphorus concentration of 0.05 mg/L during base flow for water in the Lang Lang River catchment (EPA 2000). Notably, median total phosphorus concentrations exceeded the nutrient guideline at every site. Except for two samples in the Little Lang Lang River at Western Port Road (LLL03) and one sample in the Lang Lang River at the South Gippsland Highway (LLR01), all sites exceeded this nutrient objective. More significantly, all orthophosphate results during the entire duration of the study exceeded the nutrient objective on their own, except for the Little Lang Lang River and the lowest site in the Lang Lang River (LLR01).



The ratio of orthophosphate to total phosphorus can indicate the relative richness, or bioavailability, of the phosphorus that is present in a stream. As orthophosphate is readily assimilated by organisms, elevated levels of this form of phosphorus usually indicates that there is a locally rich source of phosphorus entering the waterway.

Median ratios of orthophosphate to total phosphorus during base flows at the study sites are presented in Table 4. These ratios show that a high proportion of phosphorus in the Lang Lang River catchment is bioavailable, particularly in the middle to lower section of the Lang Lang River, Minnieburn Creek and the lower sections of Pheasant Creek (PHE07), and the Little Lang Lang River at Western Port Road (LLL03). Ratios were lower where phosphorus levels were especially high (i.e. the uppermost Lang Lang River sites (LLR11 & LLR12), Pheasant Creek at Timms Road (PHE08), the Little Lang Lang River at Pooles Road (LLL04) and Adams Creek (ADM02)).

Table 4: The ratio of median orthophosphate to median total phosphorus in waterways in the Lang Lang River catchment

ADM02	0.51
LLL03	0.83
LLL04	0.18
LLR01	0.67
LLR05	1.00
LLR06	1.00

LLR09	0.86
LLR11	0.34
LLR12	0.59
MIN10	0.87
PHE07	0.93
PHE08	0.23

Nitrogen

Median concentrations of organic nitrogen, ammonia and oxidised nitrogen during base flows are presented in Figure 13.

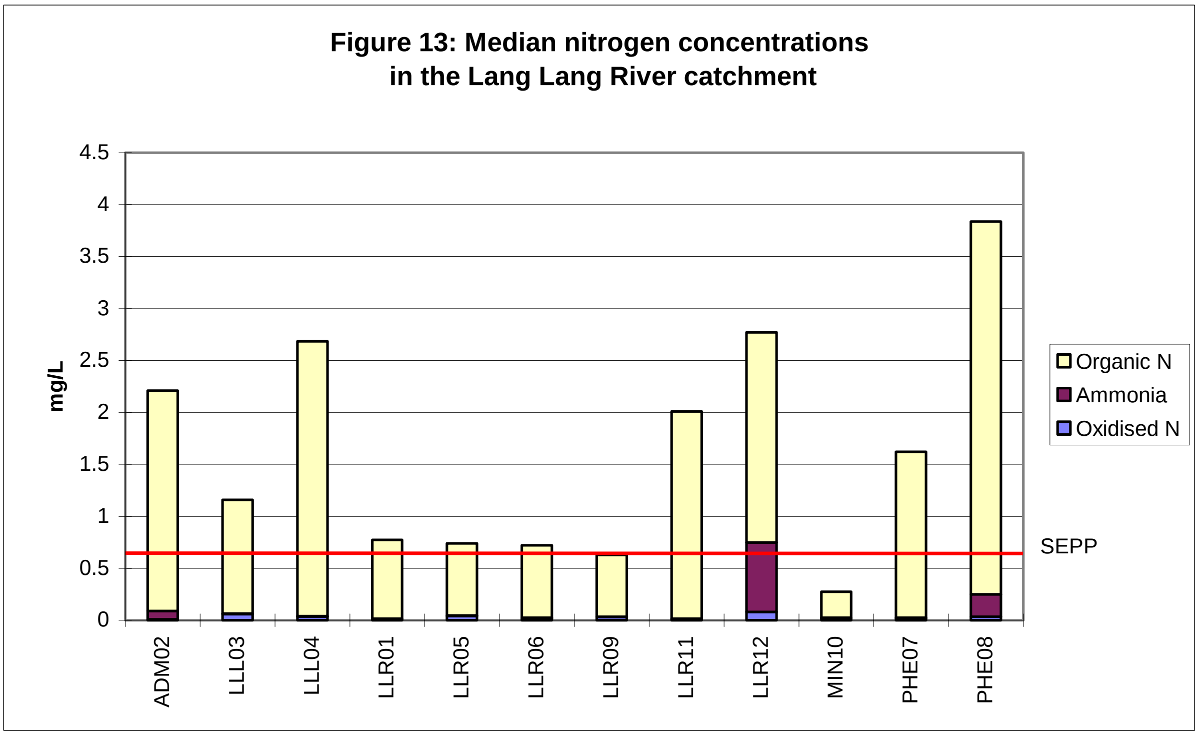
Median total nitrogen concentrations varied between 0.28 mg/L in Minnieburn Creek and 3.84 mg/L in Pheasant Creek at Timms Road (PHE08). Total nitrogen levels seem to be greatest at the sites where there was little or no flow during the study.

At all sites, median total nitrogen concentrations were primarily attributed to organic nitrogen, with the median organic nitrogen concentrations ranging between 0.25 mg/L in Minnieburn Creek and 3.59 mg/L in Pheasant Creek at Timms Road (PHE08).

Oxidised nitrogen levels were low, with median concentrations ranging between 0.01 mg/L (in Adams Creek) and 0.08 mg/L in Lang Lang River at the Korumburra-Drouin Road (LLR12).

Ammonia is a rich form of nitrogen that is readily adsorbed by plants. Elevated levels of ammonia can be acutely toxic to aquatic organisms, particularly fish. Salmonoid fish (e.g. trout) are particularly sensitive to ammonia. There is some general acceptance that undissociated ammonia should not exceed 0.02–0.03 mg/L in Australian waters. Given that the prevailing pH during this survey was between 6.8 and 7.7 (Fig. 8) and the water temperature was between 13 and 19^{o}C, a conservative recommended guideline for total ammonia in the Lang Lang River and associated tributaries would be 1.4 mg/L (ANZECC 1992). A value of up to 2.0 mg/L, however, would be acceptable during cooler water temperatures (below 15^{o}C) that usually occur outside summer. Median ammonia concentrations at all sites were well below 1.4 mg/L. On one occasion each, however, Adams Creek and the Lang Lang River at the Korumburra-Drouin Road (LLR12) exceeded the guideline level. These exceeding concentrations were 1.78 and 2.16 mg/L, respectively.

Similarly to the total phosphorus concentrations, total nitrogen concentrations were significantly higher in sites with little or no flow during the study. Most sites exceeded the draft SEPP objective of 0.6 mg/L for total nitrogen during base flow (EPA 2000). The only sites with median measurements below this objective were the Lang Lang River at Drouin-Poowong Road (LLR09) and Minnieburn Creek (MIN10).



Long-term Nutrient Trends in the Lang Lang River

Summary nutrient data collected from Lang Lang River at Drouin-Poowong Road (LLR09), Patullos Road (LLR05) and the South Gippsland Highway (LLR01) between April 1990 and June 1998, as part of water quality network monitoring, are presented in Table 5. Other summary nutrient data collected between 1975 and 1981 are presented in Table 6. Values for total nitrogen in the summary data are greater in the Lang Lang River at Drouin-Poowong Road (LLR09) and Patullos Road (LLR05). This difference in total nitrogen is largely related to lower organic nitrogen levels, but also significantly lower oxidised nitrogen concentrations during the study. In contrast with the total nitrogen results, total phosphorus results during the study were slightly higher than summary historical results. This seems to be due to a higher concentration of orthophosphate.

An estimated mean nitrogen load from the Lang Lang River catchment, using data from the late 70s to early 80s (primarily EPA data), was 500 kg/d or 6.0 kg/ha per year (Dandenong Valley Authority 1986). This was the highest estimated mean nitrogen load out of 15 major catchments throughout Western Port – with the second highest being Bunyip River (370 kg/d). In terms of load per catchment area, it was the fourth highest, with 15.0, 9.7 and 6.3 kg/ha per year for Kings Creek, North West Main Catch Drain and Watsons Creek, respectively (Dandenong Valley Authority 1986).

Using the same data for the Lang Lang River catchment, an estimated mean phosphorus load was 31 kg/d or 0.4 kg/ha per year (Dandenong Valley Authority 1986). This was the fourth highest mean phosphorus load out of the 15 major Western Port catchments studied – with Bunyip River, Bass River and Yallock Creek having mean phosphorus loads of 66, 53 and 36 kg/ha per year, respectively (Dandenong Valley Authority 1986). In terms of phosphorus load per catchment area, the Lang Lang River was slightly below average, with an average of 0.45 kg/ha per year (Dandenong Valley Authority 1986).

Table 5: Summary nutrient data (in mg/L) collected between April 1990 and June 1998 from the Lang Lang River at Drouin-Poowong Road (LLR09), Patullos Road (LLR05) and the South Gippsland Highway (LLR01)*

Site		**NO_3-N**	**NO_2-N**	**NH_3-N**	**Org-N**	**T-N**	**O-P**	**T-P**
LLR09	*n*	48	49	49	37	49	49	38
	Lowest	0.010	0.000	0.018	0.311	0.000	0.003	0.028
	25th Percentile	0.195	0.012	0.077	0.550	0.806	0.020	0.086
	Median	0.850	0.023	0.100	0.923	1.588	0.032	0.120
	75th Percentile	1.250	0.038	0.100	1.400	2.437	0.060	0.180
	Highest	3.700	0.130	2.300	5.500	6.190	0.120	0.750
	Date from	Apr 90	Apr 90	Apr 90	Apr 93	Apr 90	Apr 90	Apr 93
	Date to	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98
LLR05	*n*	19	19	20	9	9	20	9
	Lowest	0.100	0.003	0.050	0.560	0.900	0.020	0.020
	25th Percentile	0.340	0.020	0.100	0.630	1.062	0.040	0.060
	Median	0.730	0.025	0.100	1.200	2.644	0.060	0.110
	75th Percentile	1.500	0.035	0.100	2.100	3.750	0.105	0.200
	Highest	1.900	0.050	0.200	5.500	6.345	0.180	0.650
	Date from	Jun 90	Jun 90	Jun 90	Apr 93	Apr 93	Jun 90	Apr 93
	Date to	May 94	May 94	May 94	May 94	May 94	May 94	May 94
LLR01	*n*	78	78	78	67	79	78	74
	Lowest	0.010	0.000	0.004	0.287	0.120	0.003	0.025
	25th Percentile	0.113	0.006	0.100	0.670	0.769	0.010	0.060
	Median	0.510	0.010	0.100	1.080	1.644	0.030	0.094
	75th Percentile	1.200	0.034	0.100	1.900	3.305	0.070	0.215
	Highest	4.000	0.100	0.500	5.150	5.787	0.180	1.100
	Date from	Apr 92	Apr 92	Apr 92	Feb 93	Feb 93	Apr 92	Feb 93
	Date to	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98	Jun 98

*Data were collected as part of the Melbourne Water Water Quality Monitoring Program. NO_2-N, nitrite; NO_3-N, nitrate; NH_3-N, ammonia; Org-N, organic nitrogen; T-N, total nitrogen; O-P, orthophosphate; T-P, total phosphorus; *n*, number of samples; ns, not specified.

Table 6: Summary nutrient data collected from the Lang Lang River at Lang Lang between July 1975 and December 1981 (State Rivers & Water Supply Commission 1984)

	No. of samples	Lowest	10th Percentile	Median	90th Percentile	Highest
Total P	15	0.013	0.015	0.050	0.210	0.310
Nox	16	<0.003	0.004	0.465	1.70	2.90
TKN	16	0.10	0.31	0.67	2.1	2.4

Total P, total phosphorus; Nox, oxidised nitrogen; TKN, total Kjeldahl nitrogen.

Figures 14–23 show historical water quality data for total nitrogen, oxidised nitrogen, organic nitrogen, orthophosphate and total phosphorus. These data come from samples collected during routine water quality monitoring between April 1990 and June 1998.

Figures 14–19 illustrate fluctuations in nitrogen concentrations in the Lang Lang River between April 1990 and June 1998. There are no distinct linear trends in the total nitrogen, oxidised nitrogen or organic nitrogen results at either site. This is supported by the Kendall Tau-B coefficient values in Tables 7 and 8. Moving medians of organic nitrogen results (particularly at the Drouin-Poowong Road), however, do show some evidence of a slight decrease over the eight-year period.

Figures 20–23 also show significant temporal fluctuations with phosphorus concentrations in the Lang Lang River. Visually, the total phosphorus results at both sites did not reflect an obvious trend, but the moving median in the Lang Lang River at Drouin-Poowong Road did produce the strongest trend (i.e. decreasing total phosphorus) according to the Kendall Tau-B coefficient values. Visually and statistically, however, the most likely trend in nutrient concentrations in the Lang Lang River between 1990 and 1998 is a gradual decrease in orthophosphate (Figures 22 & 23; Tables 7 & 8).

Figures 24 and 25 are the mean daily flows for corresponding sample dates recorded at continuous gauging station in the Lang Lang River at Heads Road. An analysis of correlation between the individual water quality indicators and flow (Tables 9 & 10) determined that, overall, total nitrogen and suspended solids were most correlated with flow – particularly suspended solids in the Lang Lang River at the Drouin-Poowong Road (r = 0.769).

Table 7: Kendall Tau-B coefficient values for the Lang Lang River at the South Gippsland Highway (LLR01) April 1990 to June 1998

LLR01		
Indicator	**Kendall**	***n***
O-P (mm)	-0.600	69
Org-N (mm)	-0.453	48
O-P	-0.400	78
Total-P (mm)	-0.280	64
Nox-N (mm)	-0.188	69
Total-N (mm)	-0.169	69
Flow	-0.167	77
Total-P	-0.086	73
Flow (mm)	-0.085	69
Org-N	-0.080	57
Nox-N	-0.071	78
E. coli	-0.054	73
E. coli (mm)	-0.004	67
Total-N	0.008	78
SS	0.123	78
SS (mm)	0.283	69

mm, moving median
n = number of observations

Table 8: Kendall Tau-B coefficient values for the Lang Lang River at Drouin-Poowong Road (LLR09) April 1990 to June 1998

LLR09		
Indicator	**Kendall**	***n***
Total-P (mm)	-0.682	27
Org-N (mm)	-0.620	28
O-P (mm)	-0.582	39
Nox-N (mm)	-0.400	39
Org-N	-0.336	37
O-P	-0.284	48
Flow (mm)	-0.262	40
Flow	-0.233	49
Nox-N	-0.228	48
Total-P	-0.219	36
SS (mm)	-0.194	39
E. coli (mm)	-0.166	38
SS	-0.130	48
E. coli	-0.065	44
Total-N	-0.045	49
Total-N (mm)	-0.029	40

mm, moving median.
n = number of observations

Table 9: Pearson's *r* values for water quality indicators and flow for water quality data in the Lang Lang River at the South Gippsland Highway (LLR01) from April 1990 to June 1998

LLR01		
Indicator	**Correlation with flow**	**n**
Total-N	0.678	77
SS	0.546	77
E. coli	0.479	72
Org-N	0.292	56
Nox-N	-0.018	73
Total-P	-0.028	72
O-P	-0.099	73

n = number of observations

Table 10: Pearson's *r* values for water quality indicators and flow for water quality data in the Lang Lang River at Drouin-Poowong Road (LLR09) from April 1990 to June 1998

LLR09		
Indicator	**Correlation with flow**	***n***
SS	0.769	47
Org-N	0.629	48
Total-N	0.538	48
E. coli	0.505	44
O-P	0.370	48
Nox-N	0.339	36
Total-P	0.270	36

n = number of observations

Figure 14: Total nitrogen and moving medians (based on previous 10 samples) in Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998

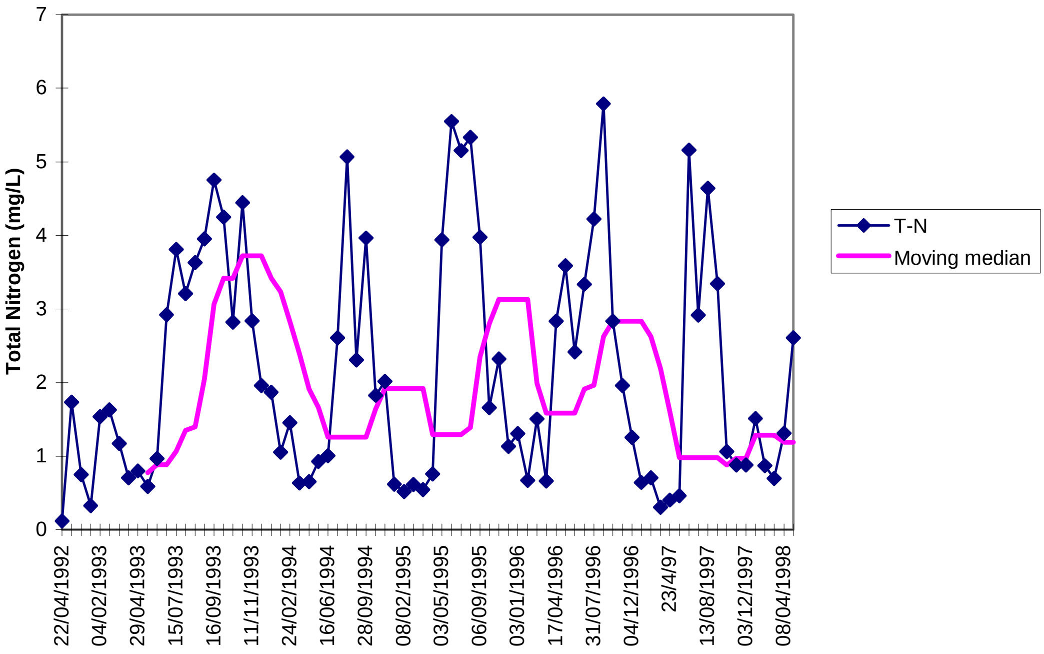
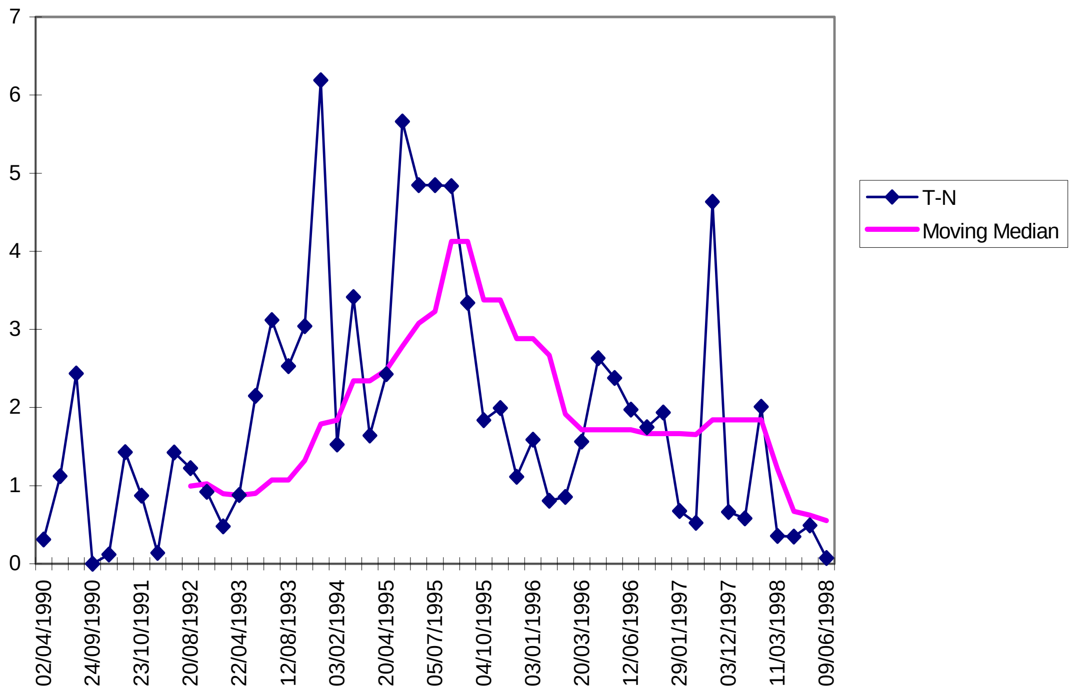


Figure 15: Total nitrogen and moving medians (based on previous 10 samples) in the Lang Lang River at Drouin-Poowong Road (LLR09) between April 1990 and June 1998



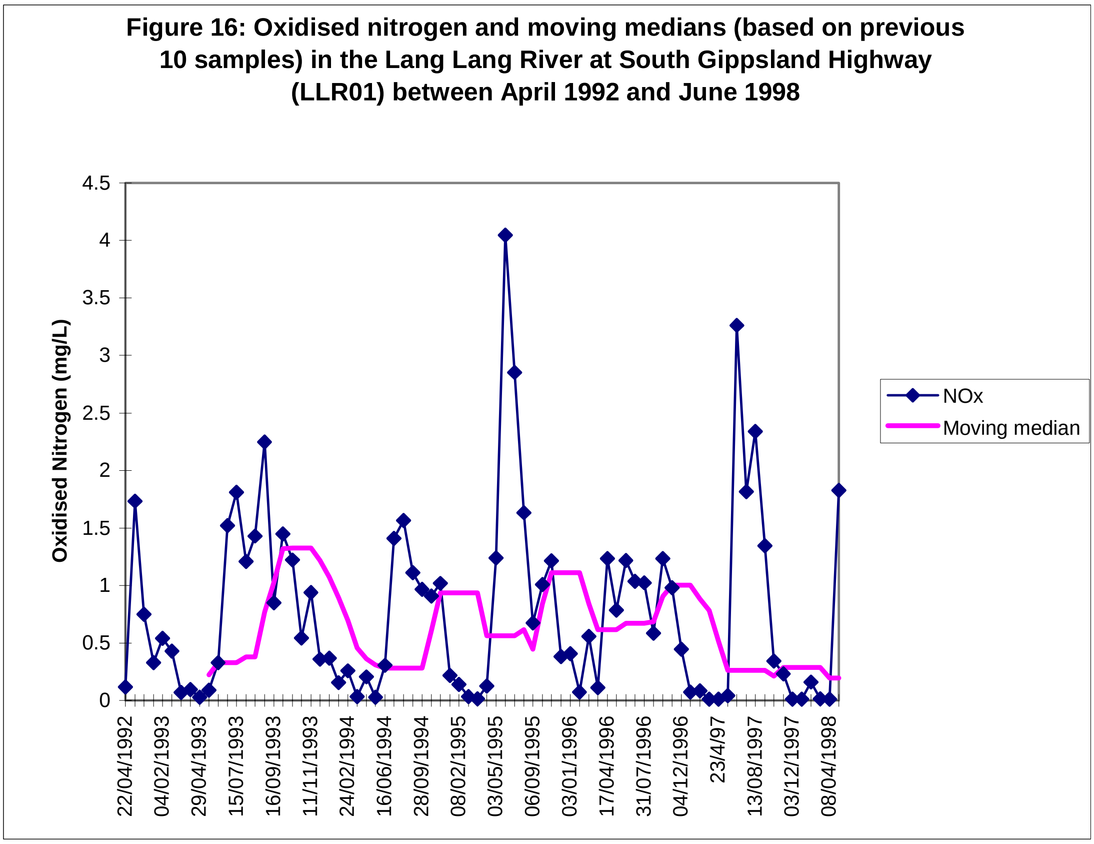


Figure 16: Oxidised nitrogen and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998
Oxidised Nitrogen (mg/L)
NOx
Moving median
22/04/1992
04/02/1993
29/04/1993
15/07/1993
16/09/1993
11/11/1993
24/02/1994
16/06/1994
28/09/1994
08/02/1995
03/05/1995
06/09/1995
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13/08/1997
03/12/1997
08/04/1998

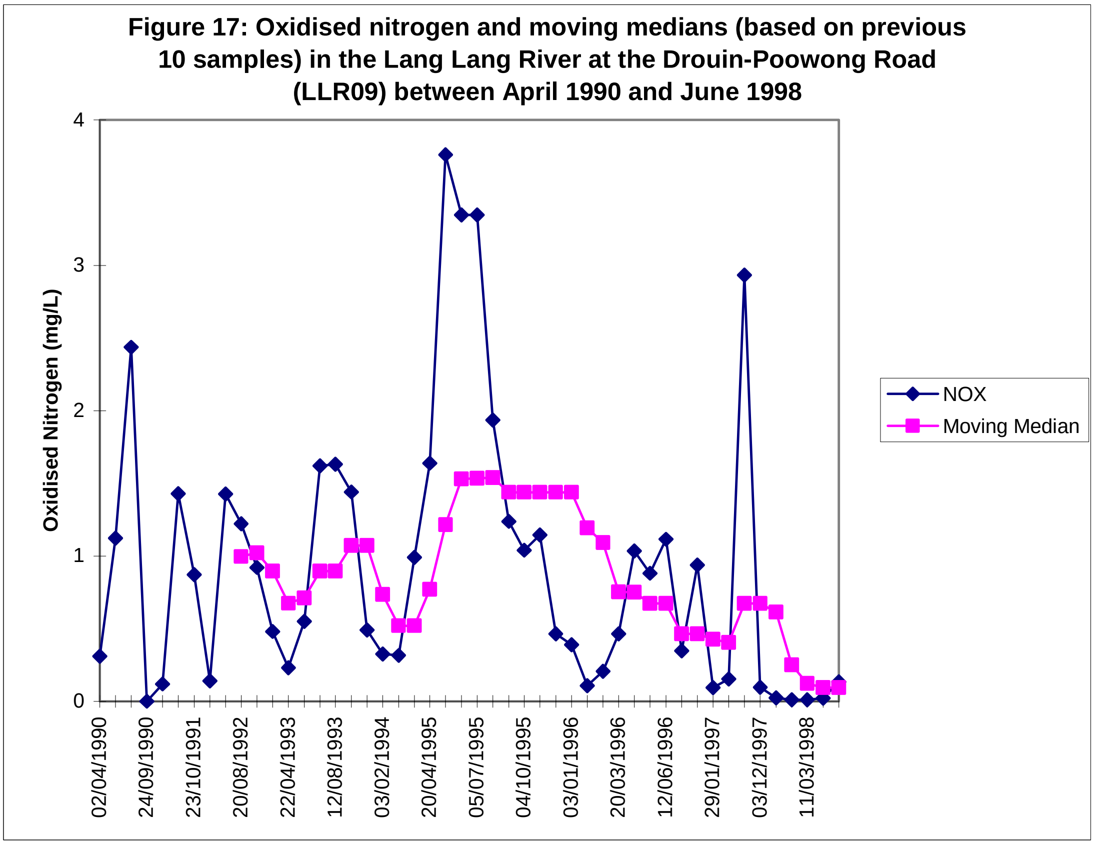


Figure 17: Oxidised nitrogen and moving medians (based on previous 10 samples) in the Lang Lang River at the Drouin-Poowong Road (LLR09) between April 1990 and June 1998
Oxidised Nitrogen (mg/L)
NOX
Moving Median
02/04/1990
24/09/1990
23/10/1991
20/08/1992
22/04/1993
12/08/1993
03/02/1994
20/04/1995
05/07/1995
04/10/1995
03/01/1996
20/03/1996
12/06/1996
29/01/1997
03/12/1997
11/03/1998

Figure 18: Organic nitrogen and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998

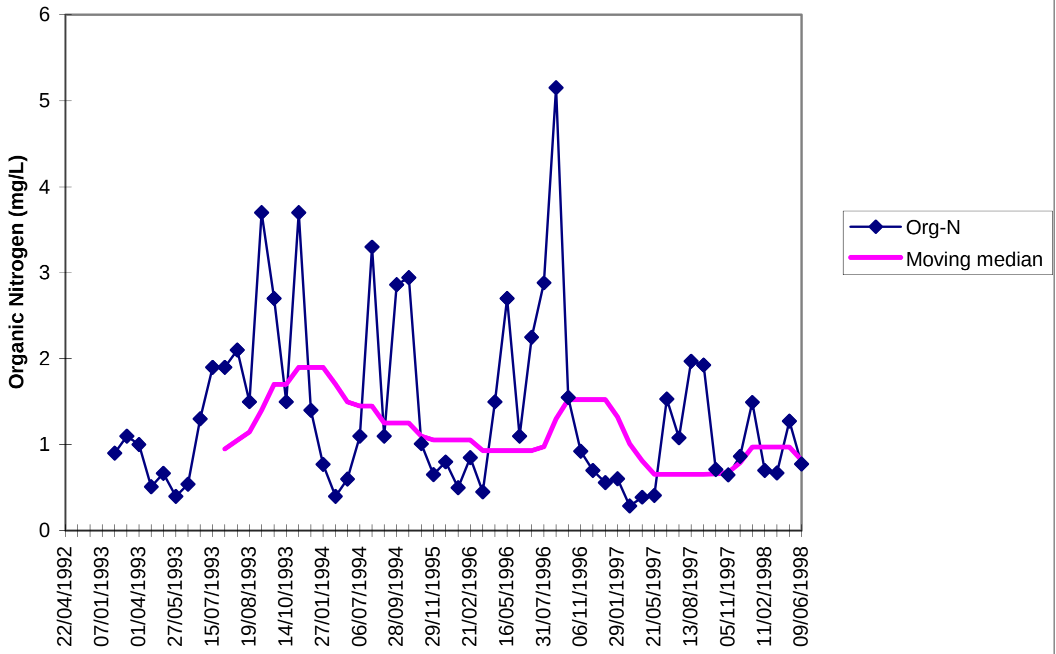


Figure 19: Organic nitrogen and moving medians (based on previous 10 samples) in the Lang Lang River at Drouin-Poowong Road (LLR09) between April 1990 and June 1998

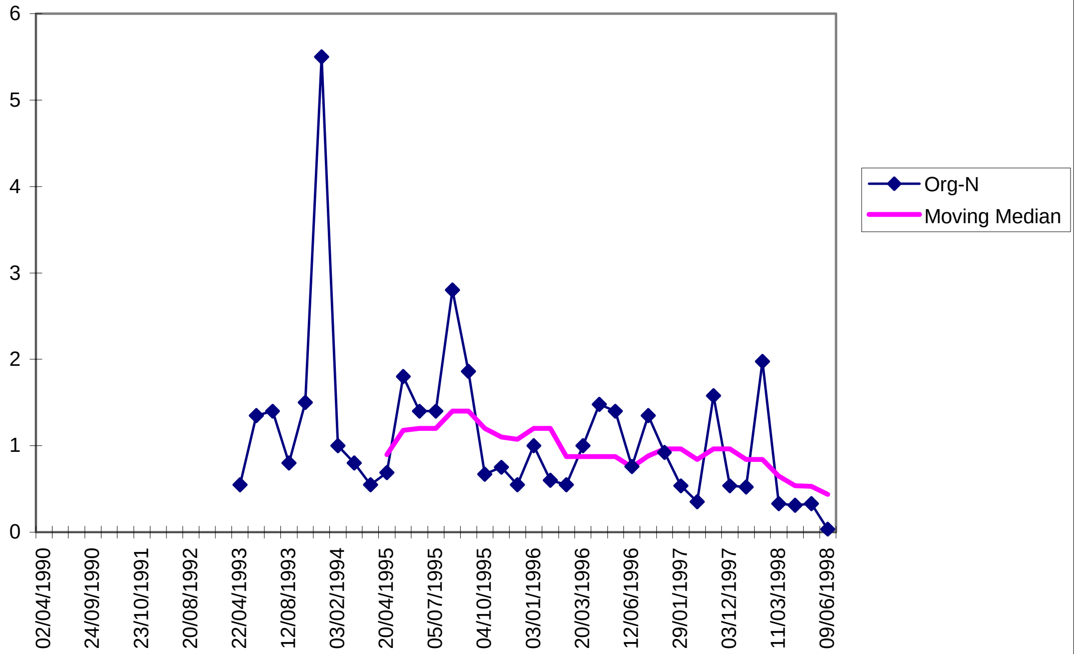


Figure 20: Total phosphorus and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998

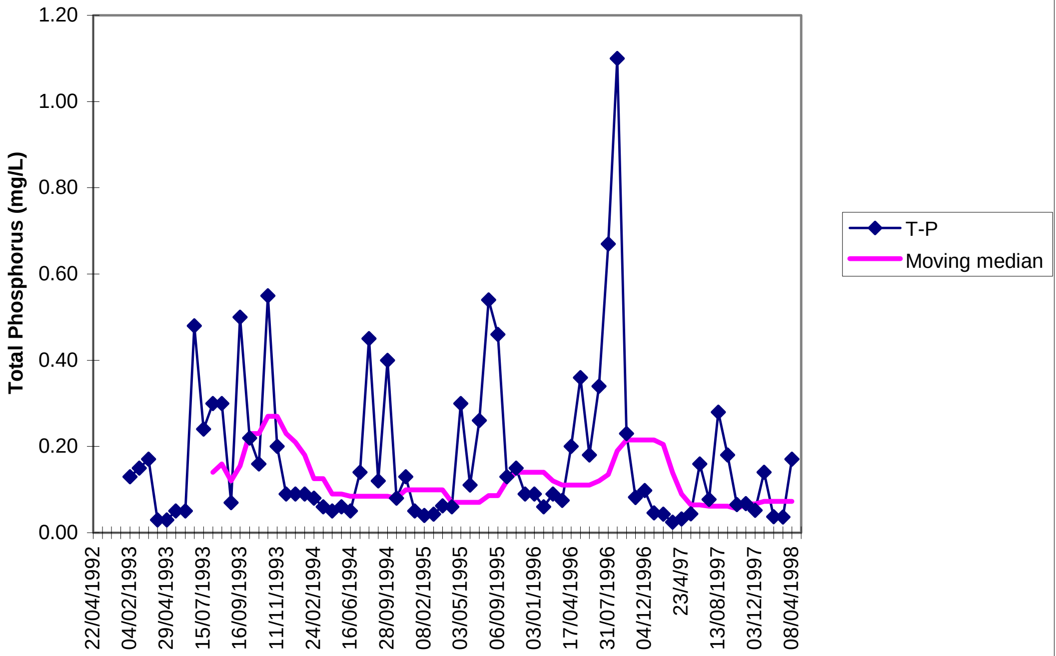


Figure 21: Total phosphorus and moving medians (based on previous 10 samples) in the Lang Lang River at Drouin-Poowong Road (LLR09) between April 1990 and June 1998

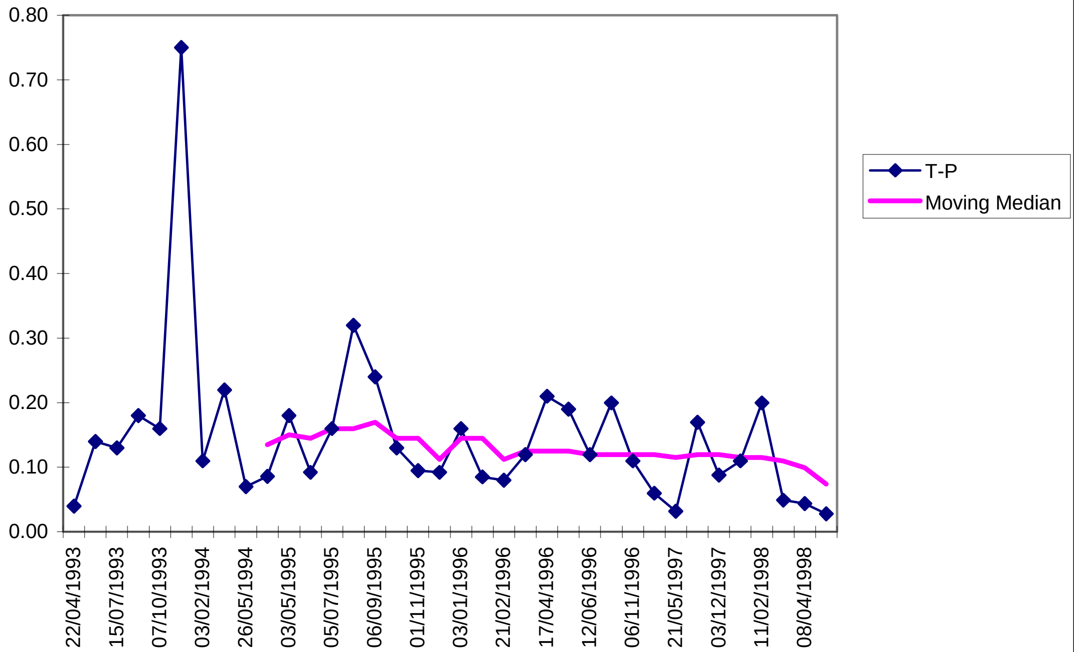


Figure 22: Orthophosphate and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998

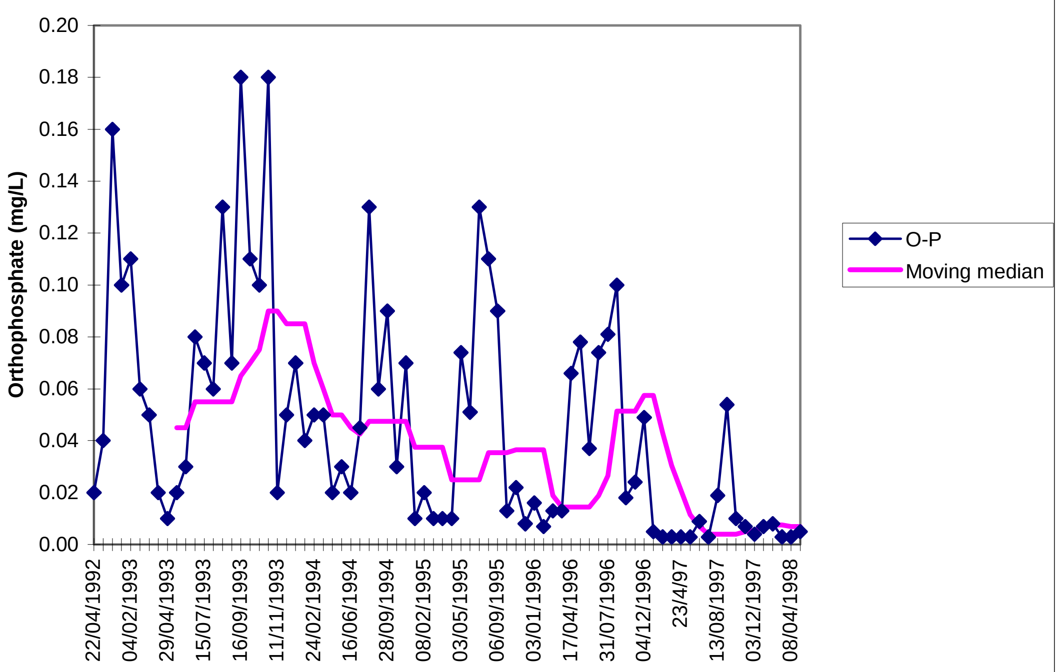


Figure 23: Orthophosphate and moving medians (based on previous 10 samples) in the Lang Lang River at Drouin-Poowong Road (LLR09) between April 1990 and June 1998

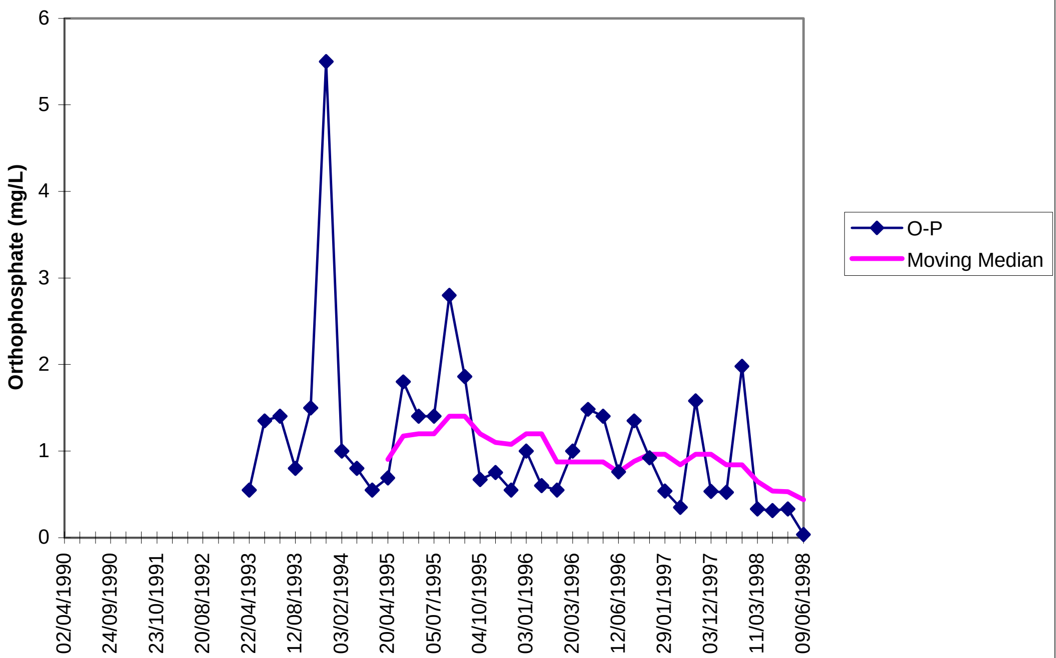


Figure 24: Mean daily flows and moving medians (based on previous 10 samples) for sampling dates in the Lang Lang River at the South Gippsland Highway*

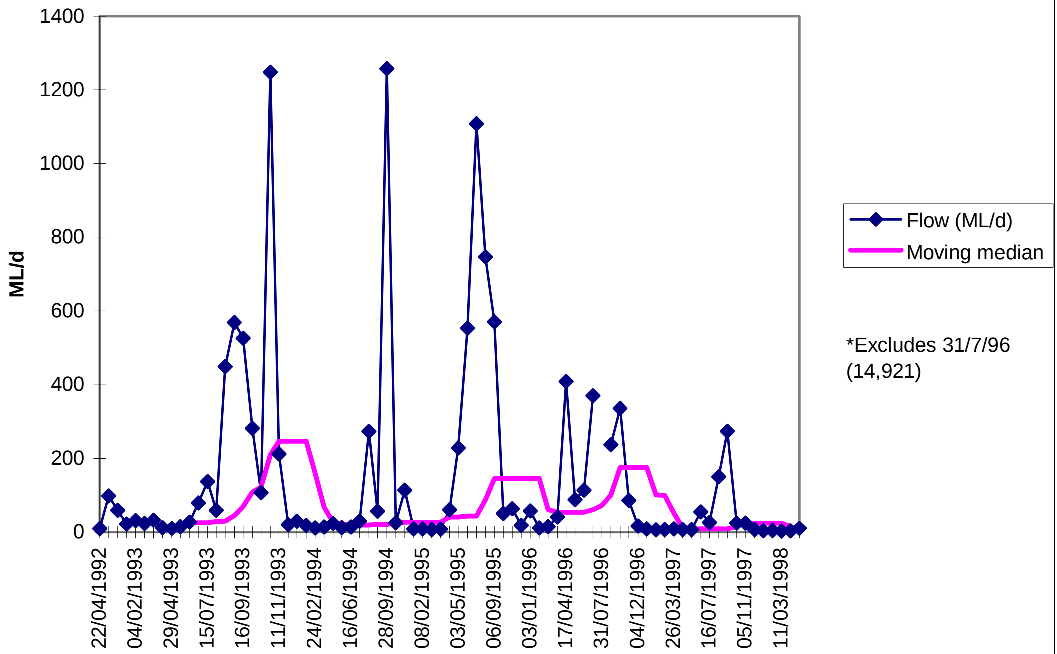
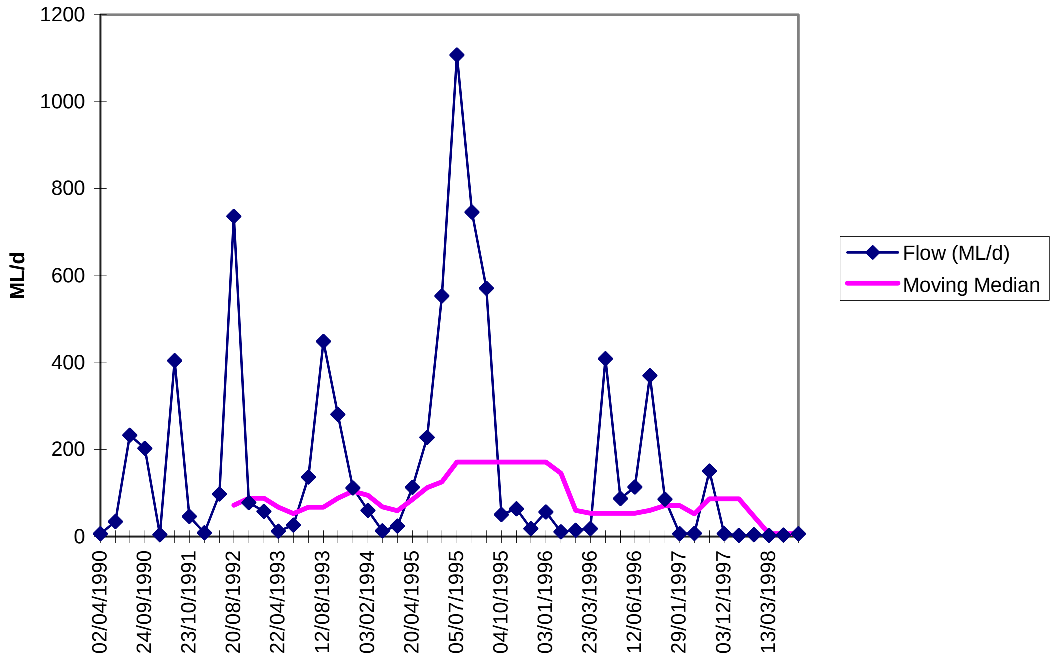


Figure 25: Mean daily flows and moving medians (based on previous 10 samples) for sampling dates in the Lang Lang River at Drouin Poowong Road



4.2.7 *Escherichia coli*

Escherichia coli is widely used to provide an indication of faecal contamination and hence the potential for water to contain pathogenic organisms. The SEPP objective for *E. coli* in the Lang Lang River catchment is that the geometric mean should not exceed 400 organisms/100 mL upstream of the South Gippsland Highway (EPA 2000). This geometric mean can only be based on a minimum of five samples collected during a period of not more than 42 days.

The geometric mean of *E. coli* in the Lang Lang River catchment during base flows is presented in Figure 26. These means are based on seven sampling events conducted during base flows between December and April 1997. Because results are geometric means, these sites are compared to the SEPP objective in order to illustrate their suitability for primary, secondary (e.g. wading and fishing) and passive recreation within the waterway during base flows. Current results, however, do not satisfy the conditions specified by the SEPP to enable a correct assessment of compliance. This is because the samples were not collected randomly during any flows and the time span for comparisons is too long.

The Little Lang Lang River was the only waterway in the Lang Lang River catchment with geometric means that exceeded the SEPP. Geometric means in the Little Lang Lang River were 1,575 organisms/100 mL at Pooles Road (LLL04) and 838 organisms/100 mL at Western Port Road (LLL03). *Escherichia coli* levels were fairly constant throughout the Lang Lang River.

The generally low *E. coli* levels measured during this study are likely to reflect a lack of high flow events (i.e. of washing faecal material into waterways). These results also indicate that if stock were directly defecating into the streams during the study, they were not having a significant regional impact.

Figure 26: Geometric means of *Escherichia coli* levels in the Lang Lang River catchment

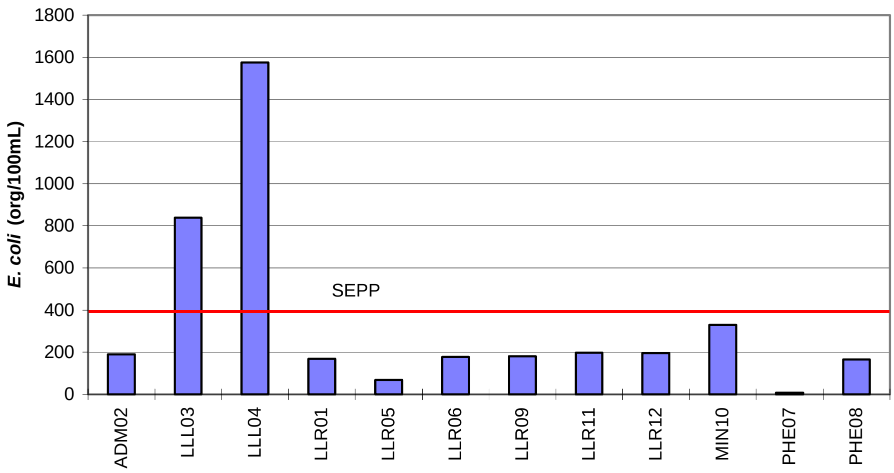


Figure 27: *Escherichia coli* and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998 *

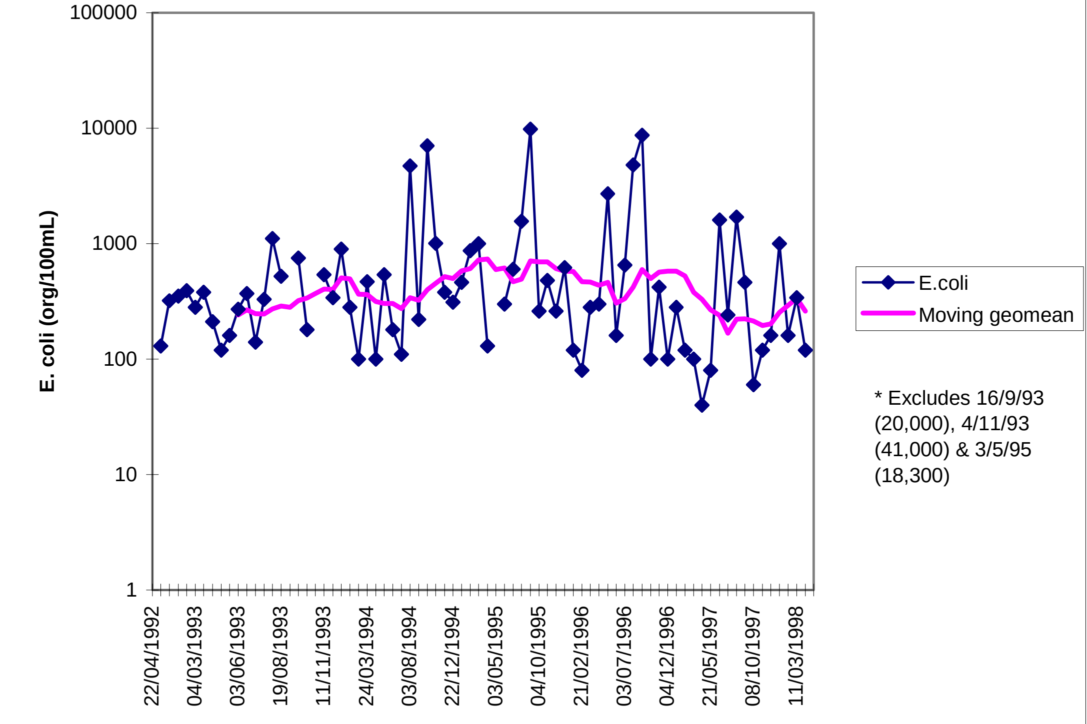
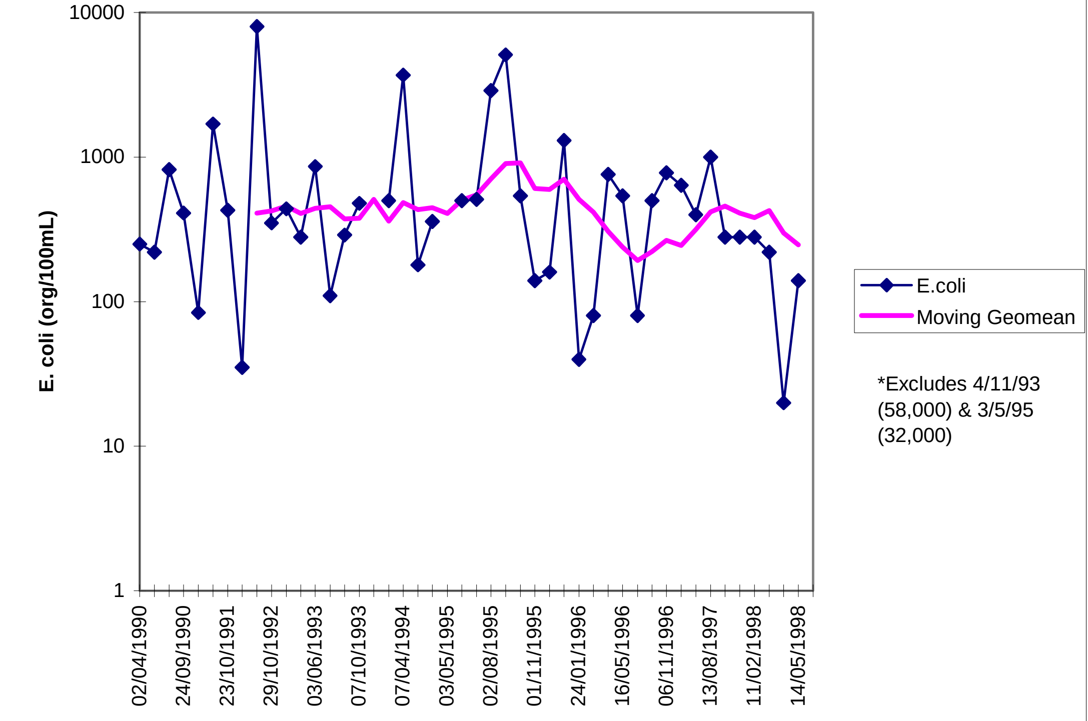


Figure 28: *Escherichia coli* and moving medians (based on previous 10 samples) in the Lang Lang River at Drouin-Poowong Road (LLR09) between April 1990 and June 1998*



Results from this study show slightly lower *E. coli* levels in the Lang Lang River during the study compared to the previous eight years (Table 2). Historical *E. coli* readings from the routine water quality monitoring network between April 1990 and June 1998 are presented in Figures 27 and 28. They show no significant temporal linear trend over the past eight years, and have Kendall values to support this (Tables 7 & 8).

4.2.8 Water Clarity

Suspended solids

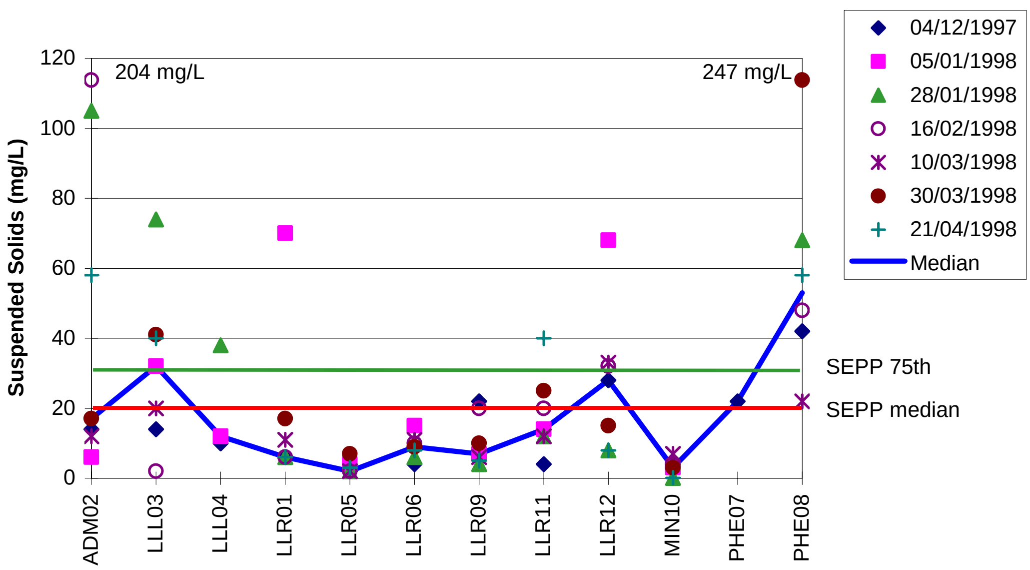
Suspended solids concentrations and their median value for each site during base flows are presented in Figure 29. The draft SEPP objective for waters of the Lang Lang River catchment is in two parts: an annual median of 20 mg/L and a 75th percentile of 30 mg/L. This objective is intended to account for a variety of flows over a 12-month period, whereas these data were only collected during base flows and for a five-month period.

Suspended solids concentrations ranged from <1 mg/L in Minnieburn Creek on two occasions to 247 mg/L in Pheasant Creek at Timms Road (PHE08) on 30 March 1998. Median suspended solids concentrations at each site ranged between 2 mg/L in the Lang Lang River at Patullos Road (LLR05) and 53 mg/L in Pheasant Creek at Timms Road (PHE08). Four sites had a median concentration greater than the SEPP of 20 mg/L and these were the uppermost site in the Lang Lang River (LLR12), the lower Little Lang Lang River site (LLL03) and the two sites in Pheasant Creek (PHE07 and PHE08).

The Lang Lang River complied well between the South Gippsland Highway (LLR01) and Stanfields Road (LLR11). Suspended solids seemed to show a gradual downstream decrease from the headwaters. Minnieburn Creek also performed well, with all results less than or equal to 7 mg/L.

Figure 29: Suspended solids in the Lang Lang River catchment*

***excludes LLL04 16/02/98 560 mg/L**

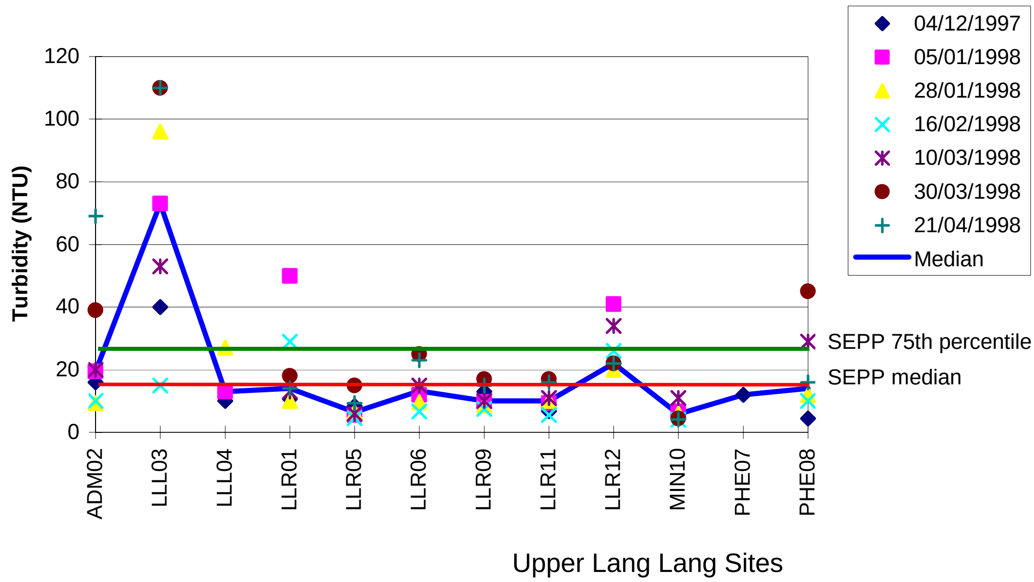


Turbidity

Turbidity levels (in nephelometric turbidity units, NTU) and their median values for each site are presented in Figure 30. The draft SEPP turbidity objective for waters in the Lang Lang catchment above the South Gippsland Highway is also in two parts: an annual median of 15 NTU and a 75th percentile of 25 NTU (EPA 2000).

Figure 30: Turbidity in the Lang Lang River Catchment*

***excludes LLL04 16/02/98 400 NTU**



Lowest turbidity reading during the study was 4 NTU in Minnieburn Creek on 16 February 1998. Highest readings were 110 NTU in the Little Lang Lang River at Western Port Road (LLL03) on 30 March and 21 April 1998. Median turbidity measurements ranged from 6 NTU in Minnieburn Creek to 73 NTU in the Little Lang Lang River at Western Port Road (LLL03). Sites to exceed the median of 15 NTU were Adams Creek (ADM02), the Little Lang Lang River at Western Port Road (LL03) and the Lang Lang River at Drouin-Korumburra Road (LLR12).

Turbidity tended to be low in the Lang Lang River downstream of Drouin-Korumburra Road (LLR12), with no apparent downstream trend.

Historical water clarity data

Suspended solids data collected from the Lang Lang River through the routine water quality monitoring network between 1990 and 1998 are presented in Figures 31 and 32. These graphs show no obvious trend over the past eight years, with the correlation results in Tables 9 and 10 suggesting that flow had a large influence on these results (particularly at Drouin-Poowong Road). The lack of a significant historical trend in suspended solids concentrations is supported by the Kendall Tau-B values, which are shown in Tables 7 and 8.

Figure 31: Suspended solids and moving medians (based on previous 10 samples) in the Lang Lang River at South Gippsland Highway (LLR01) between April 1992 and June 1998

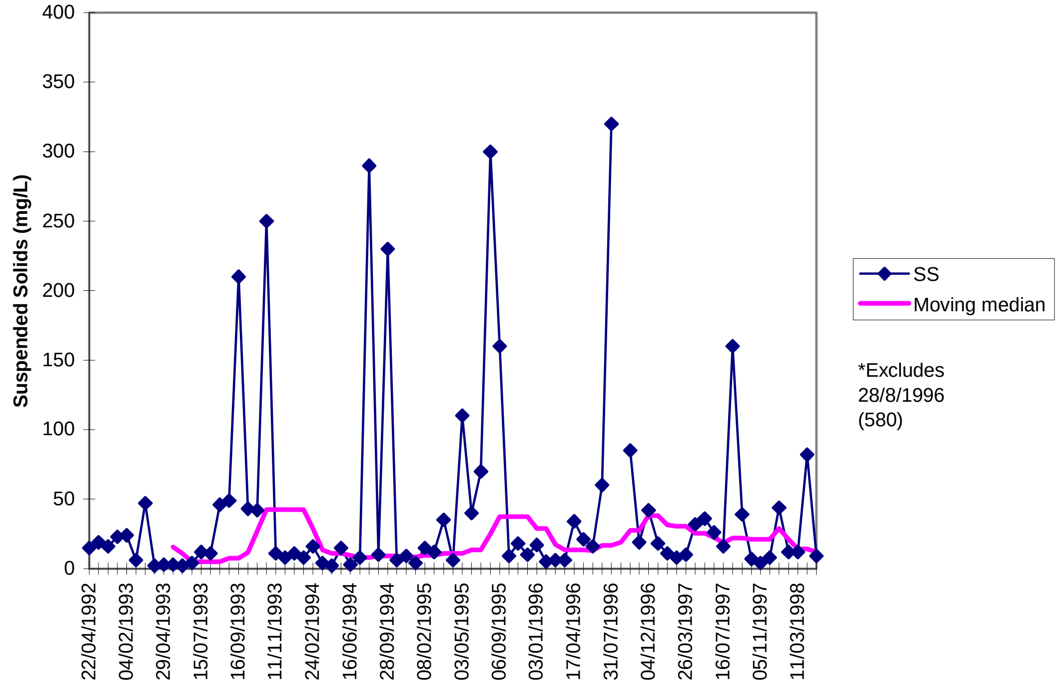
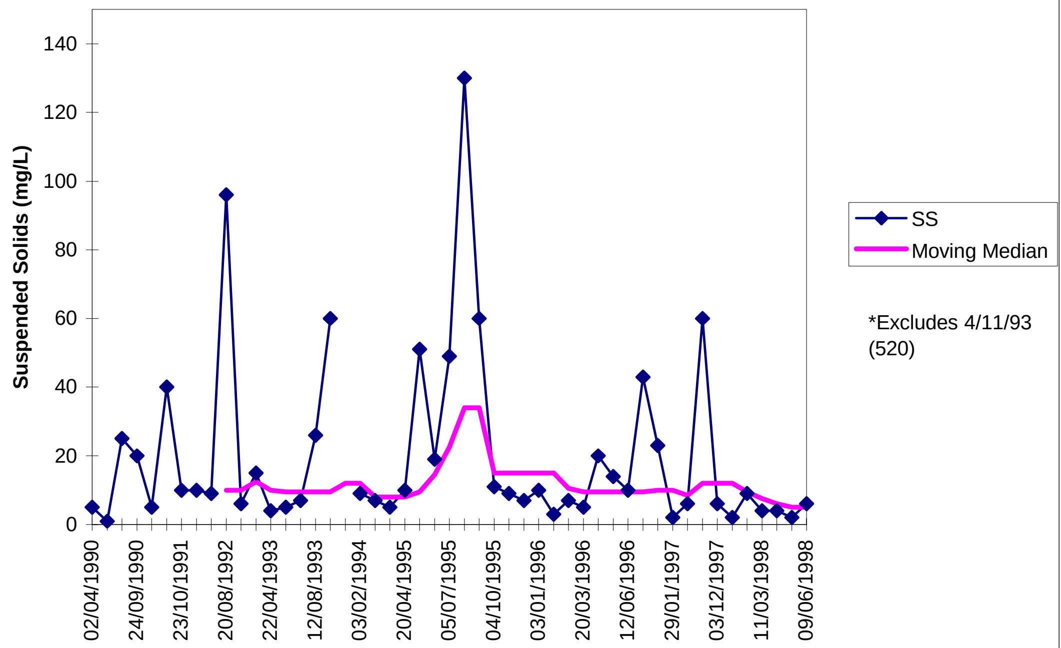


Figure 32: Suspended Solids and moving medians (based on the previous 10 samples) in the Lang Lang River at Drouin-Poowong Rd (LLR09) between April 1990 and June 1998 *



Compared to the summary table of historical water clarity data (Table 2), median measurements during this study were closer to the 25th percentiles in the Lang Lang River at the South Gippsland Highway (LLR01) and Drouin-Poowong Road (LLR09).

Median measurements from this study in the Lang Lang River at Patullos Road were closer to the lowest readings at that site observed over the previous four years. From these comparisons and the correlation values (Tables 9 & 10), the better water clarity experienced during the study would be related to the simultaneous low flows.

A comparison of sediment loads in the Lang Lang River catchment during low and high flows is given in Table 11. These results show significant increases in suspended solids during wet weather, which is supported by Pearson's *r* values given in Tables 9 and 10. Using results in Table 11 for the Lang Lang River at Heath Hill, suspended solids loads were negligible during base flows compared to high flows (i.e. 0.2 tonne/day and 550 tonne/day, respectively) (WPCCG 1984).

An estimated mean suspended solids load from the Lang Lang River catchment, using data from the late 1970s to early 1980s (primarily EPA data), was 21 tonne/day or 250 kg/ha per year (Dandenong Valley Authority 1986). This was the third highest estimated mean suspended solids load out of 15 major catchments throughout Western Port – with greater loads of 38 and 26 tonne/day estimated for the Bass River and Bunyip River catchments, respectively (Dandenong Valley Authority 1986). In terms of load per catchment area, the Lang Lang River was also the third highest, with greater loads of 600 and 310 kg/ha per year for the Bass River and Cardinia Creek catchments, respectively (Dandenong Valley Authority 1986).

The load of sediment from the incised section of the Lang Lang River, which is between Heath Hill and the South Gippsland Highway, is estimated to be about 24% of the total load of suspended solids delivered to Western Port (GHD 1998). About 63% of the sediment delivered to Western Port is suspected to come from the Lang Lang River catchment above Heath Hill (GHD 1998).

Table 11: Comparative suspended solids concentrations (mg/L) during wet and dry weather in the Lang Lang River catchment (WPCCG 1984)

Site	Mean Dry Weather (Three samples)	Mean Wet Weather (Two samples)
Lang Lang River at South Gippsland Highway	12	583
Lang Lang River at Patullos Road	7	391
Lang Lang River at Heath Hill	9 (Flow = 25 ML/d)	424 (Flow = 1300 ML/d)
Tributary at Lyons Road	5	53
Tributary at Clifton Road	8	64
Lang Lang River at Athlone	8	204
O'Mahony Creek	5	24
Minnieburn Creek	6	49
Lang Lang River near Topiram	11	205
Lang Lang River at Waterfall Road	4	125
Branch of Pheasant Creek	ns	42
Branch of Pheasant Creek	4	61
Branch of Pheasant Creek	5	Ns
Branch of Pheasant Creek	4	49

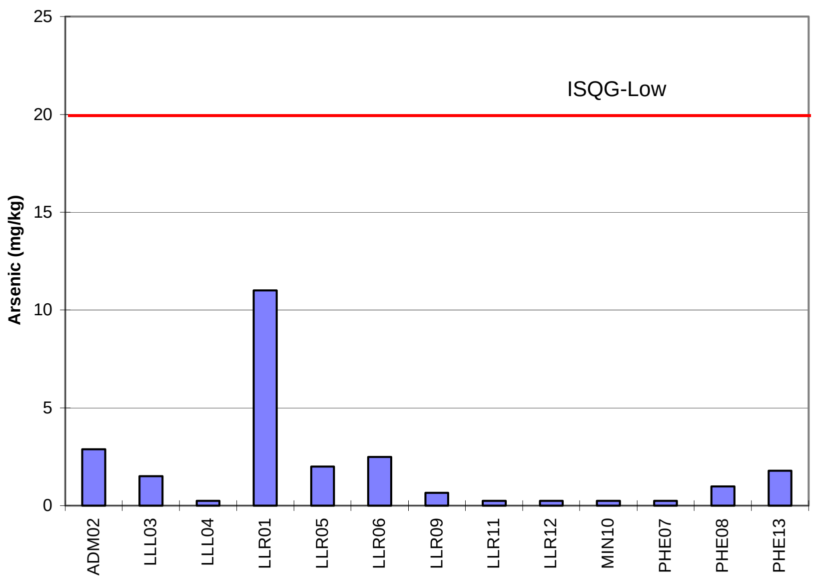
ns, not specified.

4.2.9 Sediment Quality

Arsenic

Concentrations of arsenic in fine sediments collected from the Lang Lang River catchment are presented in Figure 33. All sites were below the ISQG-Low of 20 mg/kg, indicating that arsenic concentrations are likely to be a low risk to ecosystem health. Between 1994 and 1997, only one of eight samples collected from the Lang Lang River at the South Gippsland Highway had an arsenic sediment concentration that was likely to be of moderate risk to ecosystem health (Table 12).

Figure 33: Arsenic concentrations in fine sediments collected from the Lang Lang River catchment



Cadmium

Concentrations of cadmium in fine sediments collected from the Lang Lang River catchment are presented in Figure 34. All results were well below the ISQG-Low of 1.5 mg/kg, with the highest concentration being 0.3 mg/kg in Pheasant Creek at Clifton Road (PHE07). Downstream increases in cadmium concentrations are evident in the Lang Lang River, the Little Lang Lang River and Pheasant Creek.

Historical sediment sampling in the Lang Lang River at South Gippsland Highway (LLR01) and Drouin-Poowong Road (LLR09) show similar cadmium concentrations to those values recorded during this study. During autumn sampling in 1995, however, concentrations of cadmium in fine sediments exceeded the ISQG-Low in the Lang Lang River at South Gippsland Highway (Table 12).

Chromium

Concentrations of chromium in fine sediments collected from the Lang Lang River catchment are presented in Figure 35. All results were well below the ISQG-Low of 80 mg/kg, indicating that the concentrations are likely to be of low risk to ecosystem health.

Table 12: Historical sediment sampling results from the Melbourne Water Toxicant Monitoring Program in the Lang Lang River at the South Gippsland Highway (LLR01) and Drouin-Poowong Road (LLR09) between 1994 and 1997*

Site	Date	As	Cd	Cr	Cu	Pb	Zn	Hg	Ni
LLR01	1/05/94	1.9	0.04	8.3	5.8	3.7	30	0.015	
	1/11/94	5.3	0.02	15	6.8	14	20	0.2	
	1/05/95	20	1.6	32	11	32	32	0.03	
	1/11/95	7.1	0.05	12	4.4	10	30	0.02	
	1/04/96	8.6	0.023	21	9.2	15	30	0.0025	
	1/11/96	13	0.049	27	7.1	12	37	0.044	10
	1/05/97	22	0.03	37	8.7	16	31	0.044	13
	1/11/97	11	0.018	34	9.8	15	35	0.052	13
Median		**9.8**	**0.035**	**24**	**7.9**	**14.5**	**30.5**	**0.037**	**13**
LLR09	1/05/94	0.75	0.13	8.8	8.8	8	53	0.023	
	1/11/94	1.7	0.015	5.2	9.4	18	37	0.05	
	1/05/95	2	1.4	12	20	48	47	0.03	
	1/11/95	2	0.07	5.4	4.3	6.5	34	0.03	
	1/04/96	1.7	0.068	8.4	7.9	9	40	0.0025	
	1/11/96	1.1	0.16	13	8.5	11	52	0.032	6.5
	1/05/97	2.3	0.14	8.9	7.2	9	41	0.029	10
	1/11/97	0.66	0.13	11	9.7	10	50	0.032	10
Median		**1.7**	**0.13**	**8.85**	**8.65**	**9.5**	**44**	**0.03**	**10**

Yellow shading indicates a moderate probability, and no shading indicates a low probability of impacting the aquatic ecosystem (ANZECC 1997). As, arsenic; Cd, cadmium; Cr, chromium; Cu, copper; Pb, lead; Zn, zinc; Hg, mercury; Ni, nickel.

Figure 34: Cadmium concentrations in fine sediments collected from the Lang Lang River catchment

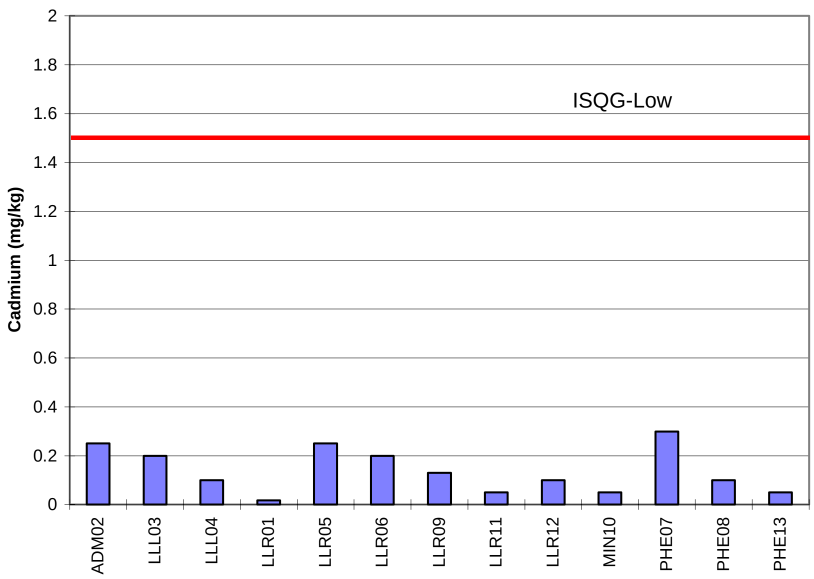
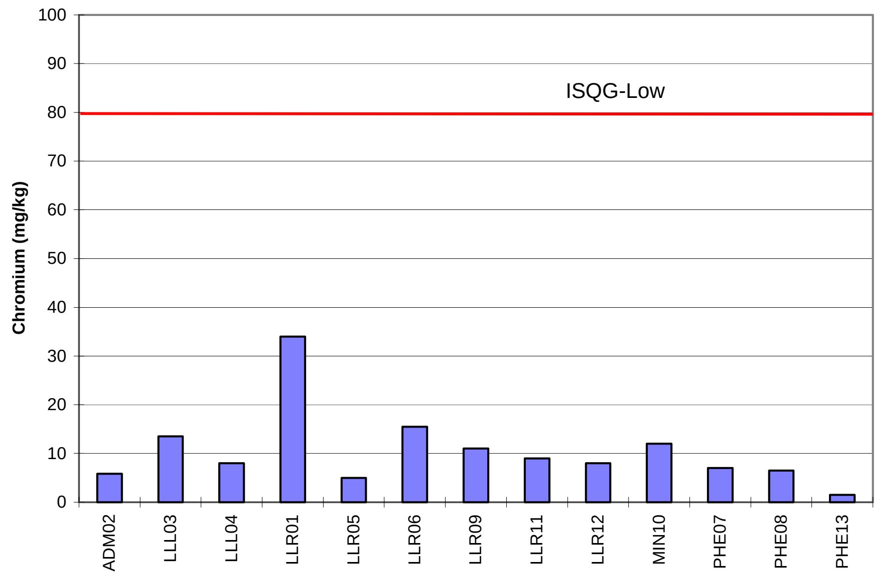


Figure 35: Chromium concentrations in fine sediments collected from the Lang Lang River catchment

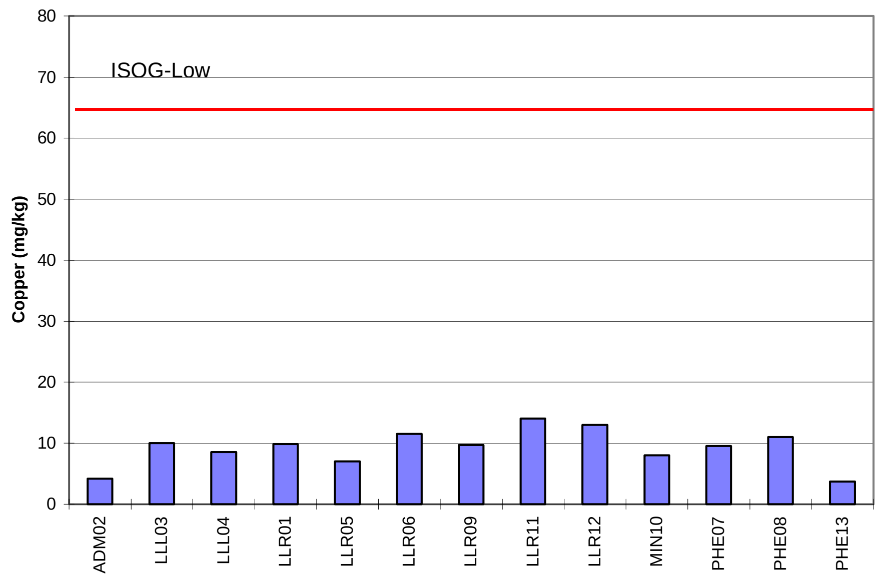


Copper

Concentrations of copper in fine sediments collected from the Lang Lang River catchment are presented in Figure 36. Copper concentrations were low throughout the catchment, with no sites exceeding the ISQG-Low of 65 mg/kg. The highest concentration was 14 mg/kg in the Lang Lang River at Stanfields Road (LLR11) and lowest was 3.2 mg/kg in Pheasant Creek at Houlahans Road (PHE13).

Historically, copper concentrations in sediments of the Lang Lang River have also been low (Table 12).

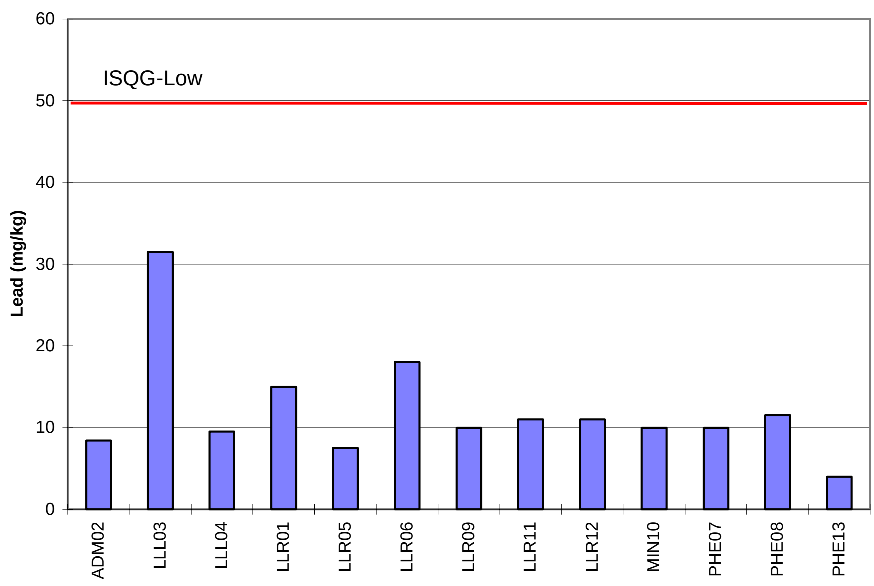
Figure 36: Copper concentrations in fine sediments collected from the Lang Lang River catchment



Lead

Concentrations of lead in fine sediments collected from the Lang Lang River catchment are presented in Figure 37. Lead levels were low throughout the catchment, with no sites exceeding the ISQG-Low of 50 mg/kg. Lead levels in the Lang Lang River are also low in the historical data (Table 12).

Figure 37: Lead concentrations in fine sediments collected from the Lang Lang River catchment



Mercury

Concentrations of mercury in fine sediments collected from the Lang Lang River catchment are presented in Figure 38. The concentration of mercury was below the ISQG-Low of 0.15 mg/kg at every site. The highest concentration was 0.1 mg/kg in the Lang Lang River at Heath Hill (LLR06) and Pheasant Creek at Clifton Road (PHE07).

Results during this study were similar to historical figures (Table 12). The Lang Lang River at South Gippsland Highway (LLR01) exceeded the ISQG-Low on one occasion, which was 0.2 mg/kg during spring sampling in 1994.

Nickel

Concentrations of nickel in fine sediments collected from the Lang Lang River catchment are presented in Figure 39. Nickel concentrations were low in the Lang Lang River catchment, with all sites below the ISQG-Low of 21 mg/kg. The highest concentration was 13 mg/kg in the Lang Lang River at South Gippsland Highway (LLR01). Nickel concentrations along the Lang Lang River tended to increase downstream.

Samples collected from the Lang Lang River between spring 1996 and spring 1997 were also well below the ISQG-Low (Table 12). These results also support the finding that nickel concentrations are slightly higher in the lower section of the river.

Figure 38: Mercury concentrations in fine sediments collected from the Lang Lang River catchment

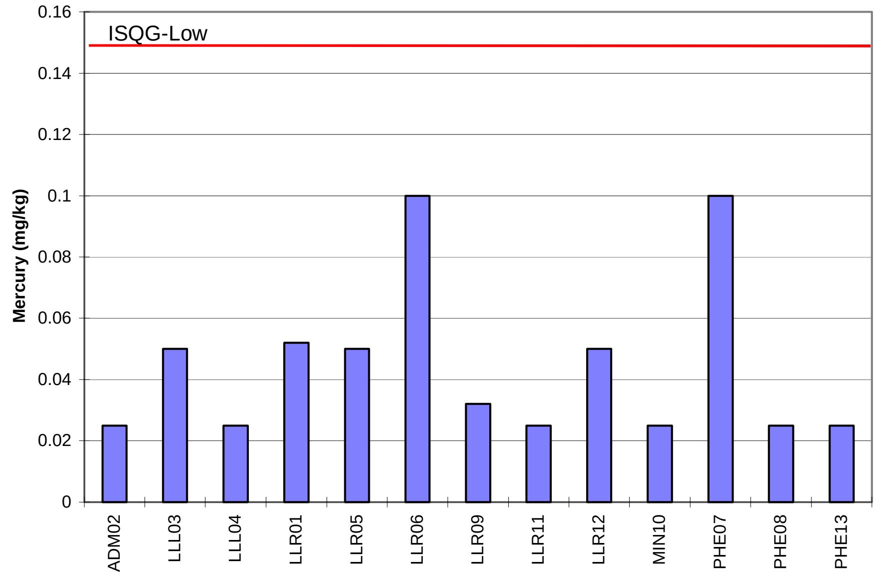
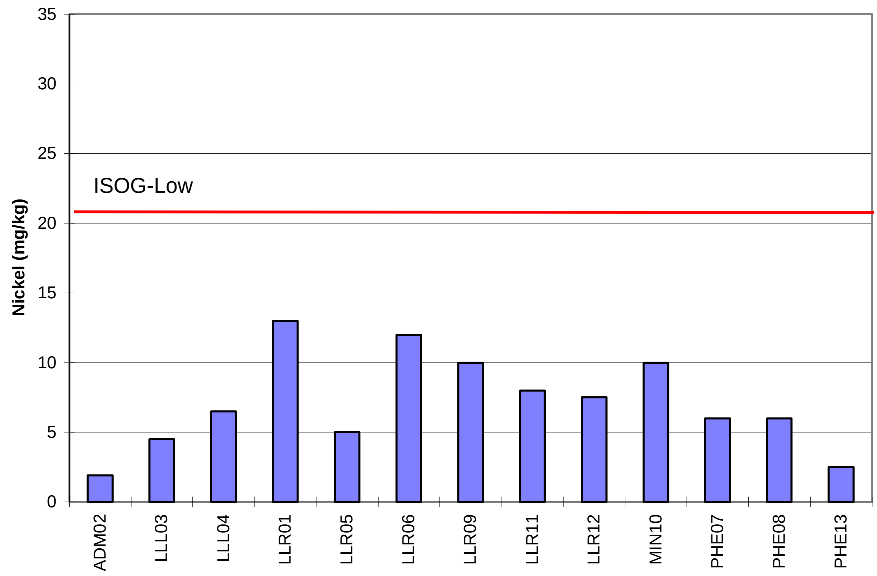
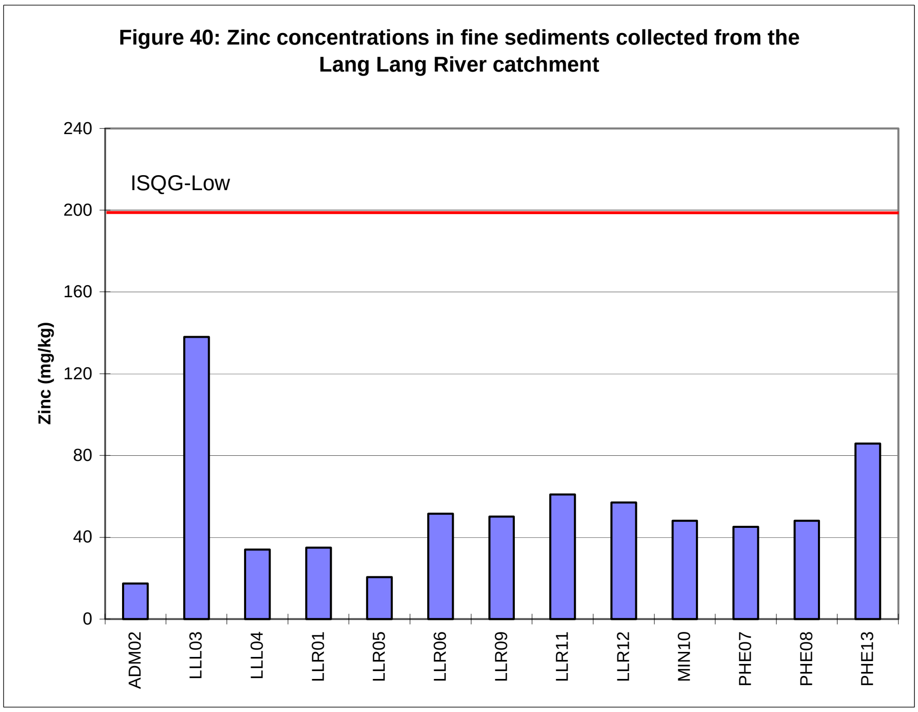


Figure 39: Nickel concentrations in fine sediments collected from the Lang Lang River catchment



Zinc

Concentrations of zinc in fine sediments collected from the Lang Lang River catchment are presented in Figure 40. All sites had zinc concentrations below the ISQG-Low of 200 mg/kg. Historical data for zinc in sediments of the Lang Lang River are also well below the ISQG-Low (Table 12).



Summary metals in water data collected during the study, as part of the routine water quality monitoring network, are given in Table 13. Where specified, these results are all below the Lang Lang River SEPP objectives for these toxicants; that is, cadmium, 0.0004 mg/L; chromium, 0.05 mg/L; nickel, 0.1 mg/L; lead, 0.03 mg/L; zinc, 0.03 mg/L (EPA 1979).

Table 13: Summary metals in water data (in mg/L) collected between January 1998 and June 1998 from the Lang Lang River at Drouin-Poowong Road (LLR09) and the South Gippsland Highway (LLR01)*

Site		As	Cd	Cr	Cu	Pb	Ni	Zn
LLR09	*n*	6	6	6	6	6	6	6
	Lowest	0.0010	0.0002	0.0010	0.0010	0.0010	0.0010	0.0030
	25th Percentile	0.0010	0.0002	0.0010	0.0013	0.0010	0.0010	0.0040
	Median	0.0010	0.0002	0.0010	0.0025	0.0010	0.0010	0.0040
	75th Percentile	0.0010	0.0002	0.0010	0.0038	0.0010	0.0010	0.0048
	Highest	0.0020	0.0002	0.0010	0.0040	0.0030	0.0010	0.0150
LLR01	*n*	5	5	5	5	5	5	5
	Lowest	0.0010	0.0002	0.0010	0.0030	0.0010	0.0010	0.0040
	25th Percentile	0.0020	0.0002	0.0010	0.0030	0.0020	0.0010	0.0070
	Median	0.0030	0.0002	0.0010	0.0030	0.0020	0.0010	0.0070
	75th Percentile	0.0040	0.0002	0.0030	0.0070	0.0030	0.0020	0.0080
	Highest	0.0040	0.0002	0.0050	0.0090	0.0040	0.0020	0.0220

*Data were collected as part of the Melbourne Water water quality monitoring network. As, arsenic; Cd, cadmium; Cr, chromium; Cu, copper; Pb, lead; Ni, nickel; Zn, zinc; *n*, number of samples.

Organics
Whole sediment samples were analysed for insecticide (and their derivatives) contamination at four sites. These four sites were the Lang Lang River at Patullos Road (LLR05) and Drouin-Poowong Road (LLR09), the Little Lang Lang River at Western Port Road (LLL03) and Adams Creek (ADM02). Samples were analysed for lindane, aldrin, chlorpyrifos, endosulfan I, endosulfan II, endosulfan sulfate, dieldrin, endrin, pp-DDE, op-DDE, pp-DDT and op-DDT.

Dieldrin and pp-DDE were the only organics to yield concentrations above the detection limit of 0.005 mg/kg. Dieldrin is an organochlorine pesticide commonly used to control termites (ANZECC 1992). DDE is a breakdown product of the organochlorine insecticide DDT. DDE, like dieldrin, is persistent and has the ability to accumulate in the fat tissue of organisms (especially those at the higher end of the food chain, such as birds and fish). Because of the persistence and accumulative properties of these chemicals, DDT and dieldrin were banned in Victoria in 1987 (ANZECC 1992).

Results for dieldrin and pp-DDE concentrations in whole sediments collected from the Lang Lang River catchment are presented in Figures 41 and 42, respectively. Only dieldrin and pp-DDE concentrations exceeded detection limits at both Lang Lang River sites (LLR05 and LLR09). Dieldrin concentrations in the Lang Lang River at Patullos Road (LLR05) and Drouin-Poowong Road (LLR09) were 0.01 and 0.03 mg/kg, respectively. These results correspond to a percentage of total organic carbon (as estimated by volatile solids) of 14% in the Lang Lang River at Patullos Road (LLR05) and 6% at Drouin-Poowong Road (LLR09) (Fig. 43). Normalised to 1% percentage total organic carbon according to the ISGQ guidelines, these concentrations were 0.0007 and 0.005 mg/kg, respectively. Dieldrin levels at Patullos Road and Drouin-Poowong Road exceeded the ISQG-Low of 0.02 µg/kg, but not the ISQG-High of 0.008 mg/kg. According to the guidelines, these levels represent a moderate risk to ecosystem health.

The pp-DDE concentrations at both of these sites were 0.007 mg/kg. Normalised to 1% percentage volatile solids according to the ISQG guidelines, these concentrations were 0.0005 mg/kg at Patullos Road and 0.0012 mg/kg at Drouin-Poowong Road, which are both below the ISQG-Low concentration of 0.0022 mg/kg.

Figure 41: Dieldrin concentrations in whole sediments collected from the Lang Lang River catchment

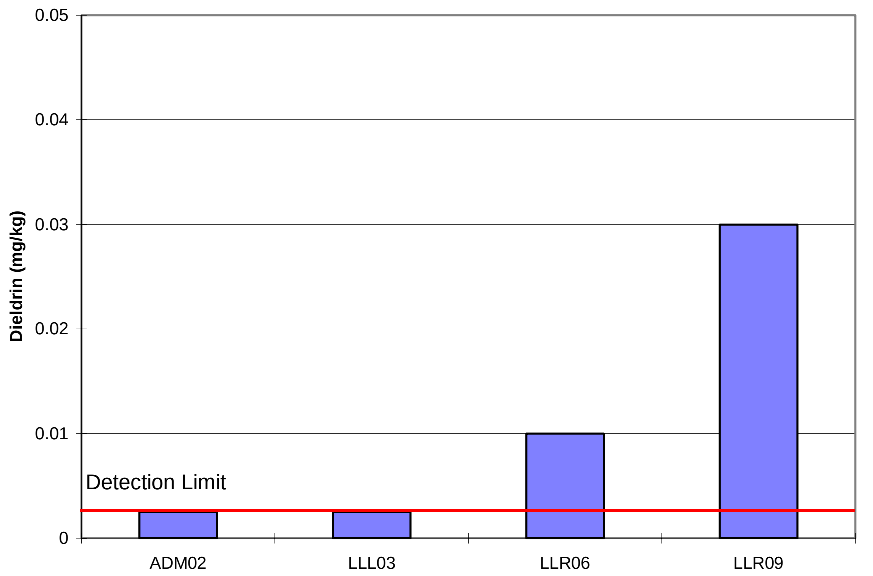


Figure 42: pp-DDE concentrations in whole sediments collected from the Lang Lang River catchment

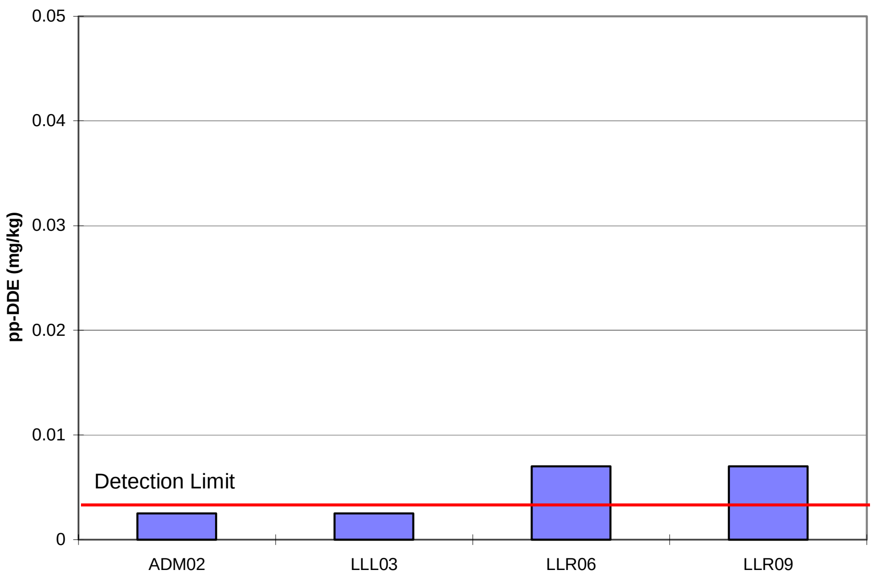
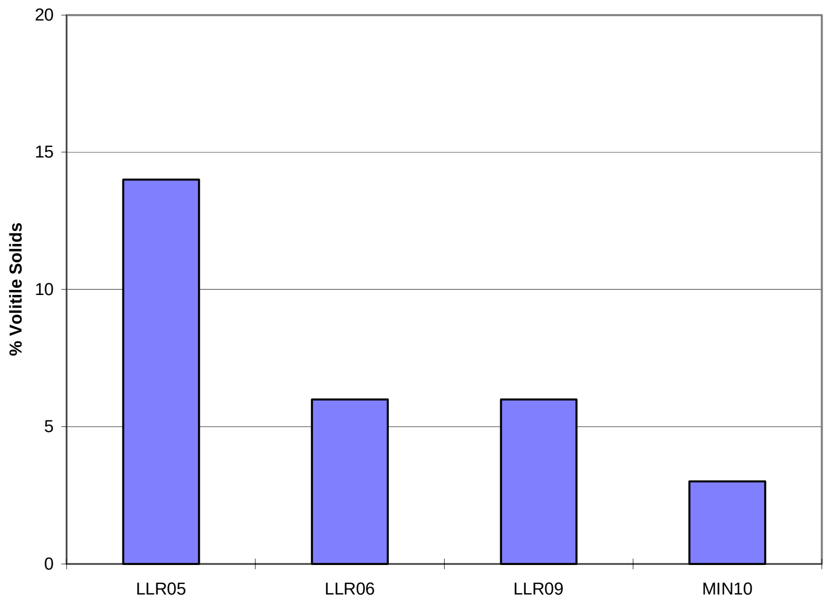


Figure 43: Volatile solids in whole sediments collected from the Lang Lang River catchment



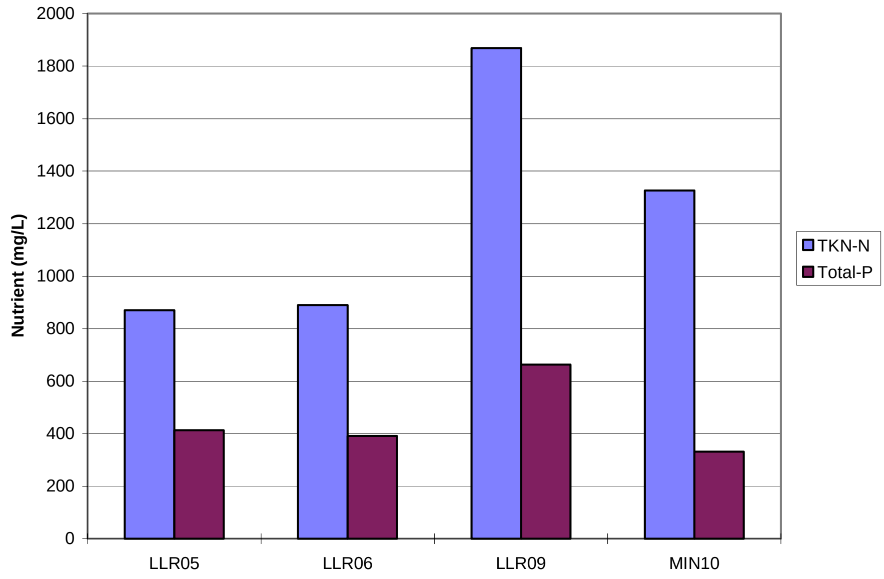
Nutrients

Sediments were analysed for nutrients and iron at four sites: Minnieburn Creek (MIN10), the Lang Lang River at Patullos Road (LLR05), Western Port Road (LLR06) and Drouin-Poowong Road (LLR09).

Results are presented in Figure 44, and are represented as whole nutrient concentrations (i.e. <63 µm concentration multiplied by <63 mm % sediment fraction divided by 100). This conversion to whole sediment concentrations is based on a reasonable assumption that nutrients are only associated with the fine sediments. Of the four sites sampled, nutrient levels in whole sediments were greatest in the Lang Lang River at the Drouin-Poowong Road (LLR09). The whole concentration of total Kjeldahl nitrogen (TKN) and total phosphorus were 1,869 and 663 mg/kg, respectively. The lowest whole concentration of TKN in sediments was 870 mg/kg in the Lang Lang River at Patullos Road (LLR05). The lowest whole concentration of total phosphorus in sediments was 332 mg/kg in Minnieburn Creek (MIN10). Nutrient levels in both lower Lang Lang River sites (LLR05 & LLR06) were similar for both TKN and total phosphorus.

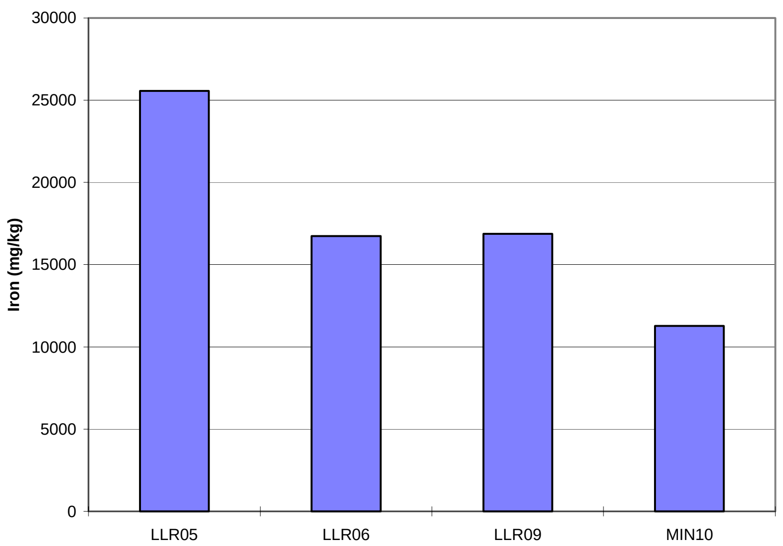
The concentration of nutrients in whole sediments from the Lang Lang River catchment were higher than in the Woori Yallock Creek catchment (Pettigrove & Coleman, unpubl. data, 1998), in which the mean concentrations for TKN were 1,239 and 781 mg/kg, respectively, and for total phosphorus - 450 and 244 mg/kg, respectively. Woori Yallock Creek results were based on single samples at 17 sites.

Figure 44: Nutrient concentrations in whole sediments collected from the Lang Lang River catchment (TKN-N is total Kjeldahl nitrogen; Total-P is total phosphorus)



Iron results are presented in Figure 45. As iron has the ability to bind with phosphates, iron concentrations in sediments give an indication of the potential to 'lock up' bioavailable phosphorus in oxic conditions (the reverse is true for anoxic conditions). Iron results have been converted to whole sediments and ranged between 11,271 mg/kg in Minnieburn Creek (MIN10) and 25,568 mg/kg in the Lang Lang River at Patullos Road (LLR05), indicating a greater potential to 'lock up' phosphates at the latter site. On average, these concentrations were slightly greater than the Woori Yallock Creek catchment, where mean concentrations of iron in whole sediments was 17,614 mg/kg in the Lang Lang River catchment and 14,736 mg/kg in the Woori Yallock Creek catchment.

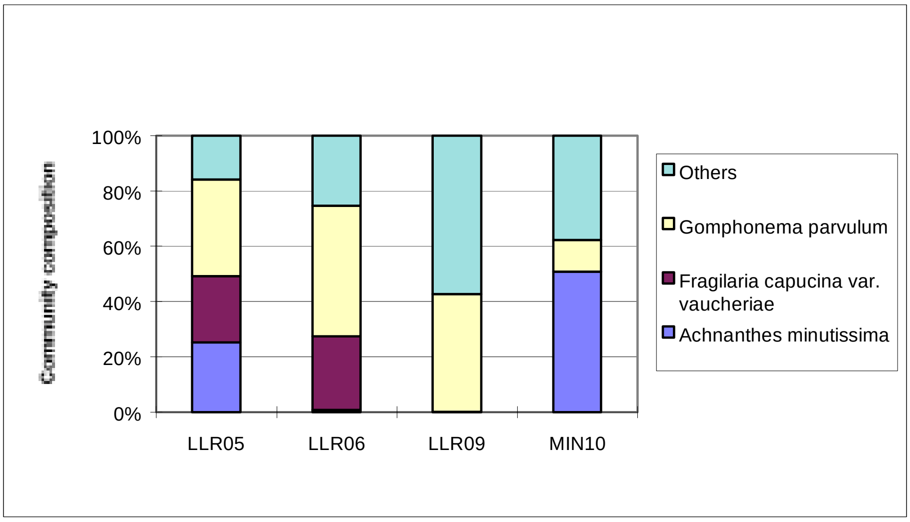
Figure 45: Iron concentrations in whole sediments collected from the Lang Lang River catchment



4.3 Diatoms

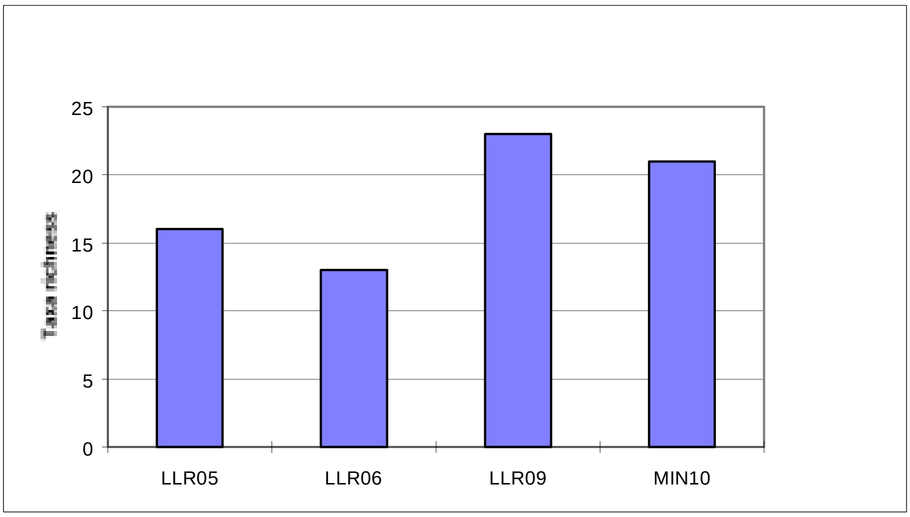
A list of taxa and their mean percentage composition at each site is given in Appendix 8.2. A total of 54 taxa was identified. *Achnanthes minutissima*, *Fragilaria capucina* var. *vaucheriae* and *Gomphonema parvulum* had a mean composition of greater than 20% at one or more sites. Dominant taxa and their mean percentage composition at each site are presented in Figure 46.

Figure 46: Mean percentage composition of dominant benthic diatoms at each site



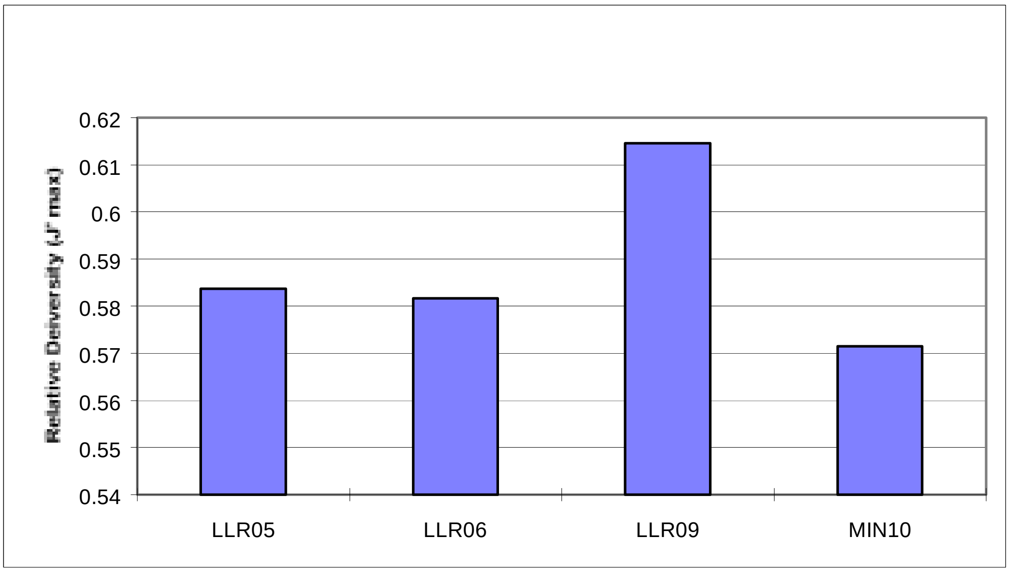
Known ecological requirements and pollution tolerances of the dominant benthic diatoms are indicated in Appendix 8.3. Mean species richness (Figure 47) ranged from 13 taxa in the Lang Lang River at Western Port Road (LLR06) to 23 at Drouin-Poowong Road (LLR09). Minnieburn Creek (MIN10) had a similar richness to the Lang Lang River at Drouin-Poowong Road, and the Lang Lang River at Patullos Road (LLR05) had a similar richness to Western Port Road (LLR06).

Figure 47: Mean benthic diatom taxa richness at each site



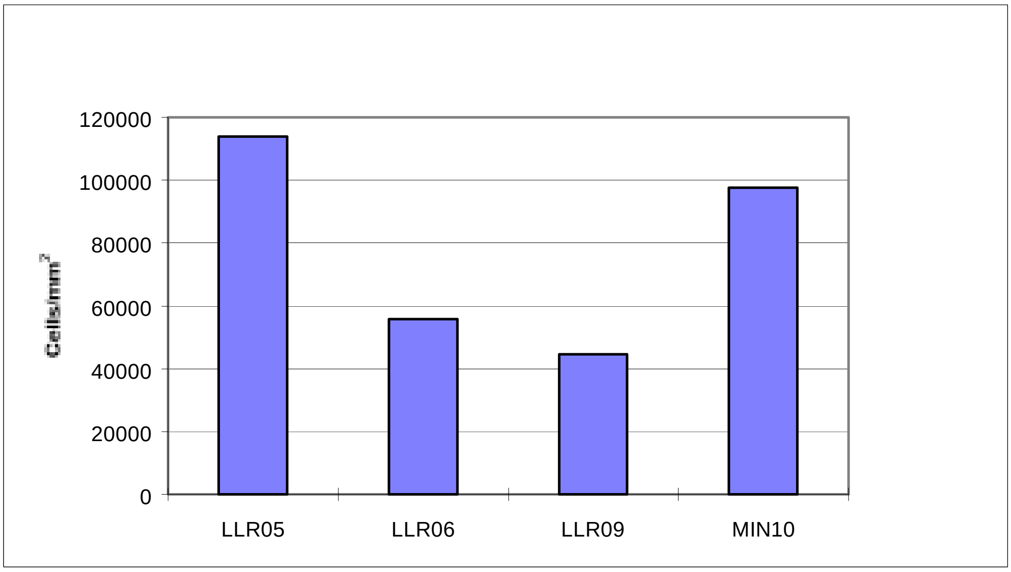
The relative diversity of benthic diatom communities (*J*') at each site (Figure 48) was determined using the Shannon-Weiner Index of diversity (*H*') and dividing this by the maximum possible diversity (*H*' max). Diatom diversity is clearly greatest in the Lang Lang River at Drouin-Poowong Road (LLR09). Although taxa richness was relatively high in Minnieburn Creek, its diversity is low compared to the other sites.

Figure 48: Mean benthic diatom diversity at each site



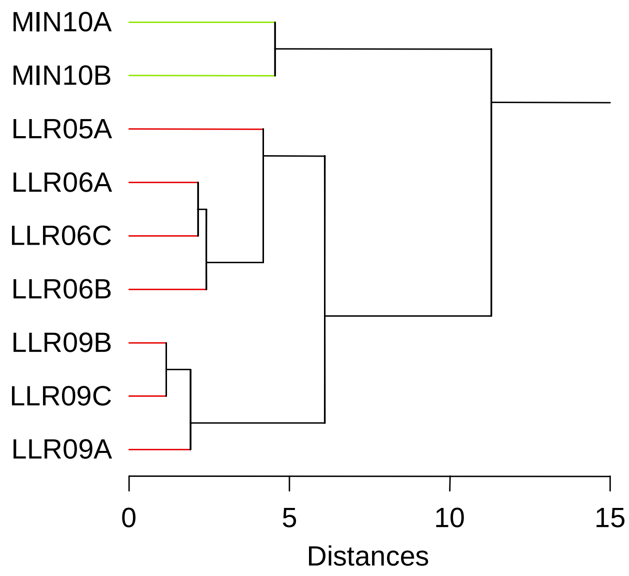
The density of diatoms was greatest in Minnieburn Creek and the Lang Lang River at Patullos Road (Figure 49).

Figure 49: Mean benthic diatom density at each site



Cluster analysis indicated that diatom communities growing on the artificial substrata were more similar within sites than substrata between sites (Figure 50).

Figure 50: Cluster analysis produced using SYSTAT V.7 with settings of complete linkage and euclidean (numbers refer to site number and letters refer to replicates)



Results for the DAIpo (Watanabe *et al.*. 1988) and Sabrobity Index (Reid 1996) at each site are presented in Table 14. The DAIpo index generates a value from 0 to100, where 100 indicates no organic pollution and 0 indicates gross organic pollution. Taxa not listed by Watanabe *et al*. (1988) were assumed to be 'eurysaprobic' or tolerant of a wide range of organic pollution. The Saprobity Index also gives an indication of organic pollution (1–5), but a higher value suggests more organic pollution. The calculation of this index is described below:

Trophic or Saprobity state = $\Sigma(X_{(i)}A_{(j)})/ \Sigma A_{(j)}$

where,
X is the numerical saprobity or trophic state class assigned by Van Dam *et al*. (1994) to a particular taxon $_{(i)}$
A is the abundance of taxon $_{(I)}$ in sample $_{(j)}$

The DAIpo and Saprobic scores complement each other, and indicate the possibility of moderate organic pollution at all sites. They also show that organic pollution is likely to be greatest in the Lang Lang River at Drouin-Poowong Road (LLR09).

Table 14: Level of organic pollution at each site as indicated by the mean site DAIpo (Watanabe *et al*. 1988) and Saprobity Index (weighted average calculation based on the saprobic classifications of Van Dam *et al*. 1994)

Site	*N*	DAIpo	Range	Saprobic	Range	% Count
LLR05	1	45.79	na	3.02	Na	99
LLR06	3	44.49	6.73	3.40	0.08	100
LLR09	3	37.54	2.98	3.94	0.07	97
MIN10	2	48.63	0.85	2.75	0.39	98

% Count, the percentage of the total community used for the calculation; na, not applicable

Results for the Trophic Index (Reid 1996) and Trophic Diatom Index (TDI) (Kelly & Whitton 1995) at each site are given in Table 15. The Trophic Index is an indication of the concentration of inorganic nitrogen and phosphorus (1–7), where the increasing value indicates the increasing concentration of these nutrients. The Trophic Index is calculated using the equation above.

The TDI produces a value from 1 (very low nutrient concentrations) to 5 (very high nutrient concentrations). Kelly and Whitton (1995) found that this index was more highly correlated with phosphorus concentrations than previous diatom indices, but it was difficult to discern the effects of eutrophication in instances where there was high organic pollution. To account for this problem, they suggest providing an indication of the proportion of the sample which is composed of taxa that is tolerant of organic pollution, where:

Proportion of count belonging to organic pollution-tolerant taxa	Interpretation
<20%	Free of significant organic pollution
21–40%	Some evidence of organic pollution
41–60%	Organic pollution likely to contribute significantly to eutrophication of site
>61%	Site is heavily contaminated with organic pollution

Both the Trophic Index and the TDI indicate elevated nutrients throughout the catchment. In the Lang Lang River at Drouin-Poowong Road (LLR09) and Heath Hill (LLR06), proportions of organic pollution-tolerant taxa (i.e. % OTS in Table 15) were high. This indicates that organic pollution is likely to be contributing significantly to the TDI score. Trophic results show little difference in nutrient concentrations between sites, with Minnieburn Creek having the highest score.

Table 15: Level of nutrients at each site as indicated by the mean site Trophic Index (weighted average calculation based on the saprobic classifications of Van Dam *et al*. 1994) and Trophic Diatom Index (TDI) (Kelly & Whitton 1995)

Site	*n*	Trophic	Range	% Count	TDI	Range	% Count	% OTS
LLR05	1	5.44	na	99	3.69	Na	100	35
LLR06	3	4.98	0.10	100	4.29	0.20	100	47
LLR09	3	5.22	0.08	97	4.77	0.08	100	76
MIN10	2	6.18	0.53	98	2.96	0.44	100	27

% Count, the percentage of the total community used for the calculation; % OTS, the percentage of count composed of taxa tolerant of organic pollution; na, not applicable

Dominant diatom taxa at each site and the various calculated indices reflect a catchment with elevated nutrients and some organic pollution (Appendix 8.3). This complements water quality data, where these sites have median BOD_5 concentrations ranging from 4 to 6 mg/L, median total phosphorus concentrations ranging from 0.14 to 0.15 mg/L, and median total nitrogen concentrations ranging from 0.28 to 0.74 mg/L (Figures 10, 12 & 13).

The greater dominance of *Achnanthes minutissima* in Minnieburn Creek (MIN10) would suggest that, although nutrients may be elevated and organic pollution may occur, enrichment of this waterway is not as great as the other study sites where diatoms were sampled. It also suggests that there is a higher saturation of dissolved oxygen in Minnieburn Creek compared to other sites. The highest DAIpo score and lowest Saprobic score were calculated for this site, which also suggests that organic pollution is lower in Minnieburn Creek. The TDI value, but not the Trophic value, also indicates that nutrients are lower in Minnieburn Creek. Diatom results support water quality data in terms of there being lower total nitrogen and higher dissolved oxygen in Minnieburn Creek; total phosphorus and BOD_5 concentrations were about the same (Figures 10–13).

The dominance of *Gomphonema parvulum* at the three Lang Lang River sites suggests that these sites have elevated nutrients and organic pollution. The additional dominance of *Fragilaria capucina* var. *vaucheriae* in the lower two sites also indicates elevated nutrients, but perhaps slightly lower organic pollution. Inclusion of a third dominant species in the Lang Lang River at Patullos Road (LLR05); that is, *Achnanthes minutissima,* indicates improvements in nutrient levels and dissolved oxygen.

Although similar values occur between sites, both the DAIpo and the Saprobic Indices show a slight downstream decrease in organic pollution between these three sites. The TDI shows a similar pattern, but the Trophic Index fluctuates. Differences in diatom diversity and richness between the upper and two lower Lang Lang River sites also suggest water quality changes. In contrast with ecological information on dominant taxa and the TDI, density values suggest a downstream increase in nutrients, although other factors such as increase in temperature and, perhaps, light availability and grazing may significantly influence diatom biomass.

Diatoms support the water quality data in terms of the Lang Lang River having elevated nutrients, some organic pollution and a pH of neutral to slightly alkaline.

They also complement each other with the inferred downstream increase in dissolved oxygen. Where they differ is evidence in the diatom data of a slight downstream decrease in nutrients and organic pollution from the Drouin-Poowong Road to Patullos Road. On the other hand, the water quality data are about the same for these sites, with perhaps a slight downstream increase in nutrients. A significant difference between these sites is a downstream increase in conductivity. This has been determined in Melbourne streams as having a strong influence on diatom communities and may reflect water quality changes that are primarily related only to conductivity, rather than to other parameters (Sonneman *et al.*, unpubl. data, 1998).

4.4 Macroalgae

A total of 16 macroalgal taxa was observed in the Lang Lang catchment streams, namely:

Batrachospermum antipodites	*Pseudanabaena* sp. ?
Chara sp.	*Rhizoclonium* sp.
Compsopogon coeruleus	*Spirogyra* sp. ECG
Melosira varians	*Spirogyra* sp. MFG
Microspora flocculosa	*Spirogyra* sp. SFG
Oedogonium sp. BFG	*Stigeoclonium* sp.
Oedogonium sp. MFG	*Vaucheria* sp.
Phormidium sp.	*Zygnema* sp.

Table 16 lists the habitat and light available for macroalgal growth at each site. Several sites were not suitable for macroalgal growth, being either dry or heavily shaded by floating macrophytes (e.g. duckweeds and *Azolla*). From those sites where macroalgae were collected, shading varied from “low” to “moderate to high”. Shading was greatest in the Little Lang Lang River at Western Port Road (LLL03). Shading was low in Minnieburn Creek (MIN10) and, generally, in the Lang Lang River. Substrata were mostly unstable in the Lang Lang River at the South Gippsland Highway (LLR01), Minnieburn Creek and Pheasant Creek at Timms Road (PHE08). Suitable, stable substrata for macroalgal growth were more prevalent in the Lang Lang River at Patullos Road (LLR05), Western Port Road (LLR06) and Drouin-Poowong Road (LLR09).

Table 16: Habitat and light available for algal growth at each site

Site	Bedrock/ boulders	Cobbles/ Pebbles	Gravel/ sand	In-stream debris	Vegetation	Other	Other description	Shade of water surface
LLR01	0	0	0	0	0	5	Silt	Low
ADM02	Stagnant pool, covered in *Azolla* and duckweeds							
LLL03	2	2	0	2	2	3	Clay	Mod to high
LLL04	Site dry							
LLR05	4	2	1	1	2	1	Silt, weir	Low
LLR06	3	2	1	1	2	2	Silt	Low to mod
PHE07	Site dry							
PHE08	2	0	0	1	2	4	Clay	Mod
LLR09	2	2	1	2	2	2	Silt/clay	Low
MIN10	0	0	0	1	3	5	Clay/silt	Low
LLR11	Stagnant pool, covered in *Azolla* and duckweeds							
LLR12	Stagnant pool, covered in *Azolla* and duckweeds							

Values refer to proportion of the total site substrata (i.e. 0, 0% of total site substrata; 1, <10% of total site substrata; 2, 10–35% of total site substrata; 3, 35–65% of total site substrata; 4, 65–90% of total site substrata; and 5, >90% of total site substrata. Mod, moderate.

Up to eight macroalgal samples were collected from each site (Table 17), with taxa richness varying from one (Land Lang River at South Gippsland Highway (LLR01) and Pheasant Creek at Timms Road (PHE08)) to 10 (Lang Lang River at Patullos Road (LLR05)). *Vaucheria* sp. and *Spirogyra* spp. were the most frequently occurring and abundant taxa.

The Lang Lang River at South Gippsland Highway (LLR01) was dominated by *Phormidium* sp. and benthic diatoms, whereas at Patullos Road (LLR05) the macroalgal community was dominated by *Compsopogon coeruleus*, *Phormidium* sp. and *Spirogyra* spp. Further upstream, at Western Port Road (LLR06), *Chara* sp. and *Spirogyra* spp. were dominant. At the uppermost macroalgal site in the Lang Lang River; that is, at Drouin-Poowong Road (LLR09), *Chara* sp. was the most prevalent macroalga. Also of note was the conspicuous growth of *Batrachospermum antipodites* at this site.

The Little Lang Lang River (LLL03) and Pheasant Creek (PHE08) were dominated by *Vaucheria* sp. In Minnieburn Creek (MIN10) both *Vaucheria* sp. and *Pseudoanabaena* sp.? were most abundant.

Table 17: Macroalgal species abundance and habitat at each site

Site	Sample 1	A	Habitat	Substrata attached	Cover	Sample 2	A	Habitat	Substrata attached	Cover
LLR01	*Phormidium* sp.	1	Run	Silt	1	ns				
LLL03	*Chara* sp. *Spirogyra* sp. MFG	3 1	Pool	Clay	1	*Vaucheria* sp. *Spirogyra* sp. ECG	3 1	Riffle	Boulders/ Cobbles	1
LLR05	*Compsopogon coeruleus*	3	Riffle	Boulders/ cobbles	2	*Spirogyra* sp. ECG	3	Riffle	All	1
LLR06	*Chara* sp.	3	Pool	Silt	2	*Spirogyra* sp. MFG *Spirogyra* sp. ECG *Rhizoclonium* sp.	3 3 1	Pool	Vegetation	2
PHE08	*Vaucheria* sp.	3	Pool	Clay	1	ns				
LLR09	*Chara* sp.	3	Pool	Silt/clay	2	*Batrachospermum antipodites*	3	Pool/ riffle	Boulders/ cobbles/ debris	1
MIN10	*Pseudanabaena* sp.?	3	Pool	Vegetation/ silt/clay	1	*Vaucheria* sp. *Stigeoclonium* sp. *Spirogyra* sp. ECG *Spirogyra* sp. MFG *Melosira varians*	3 2 1 1 1	Riffle	Vegetation	1

Site	Sample 3	A	Habitat	Substrata attached	Cover	Sample 4	A	Habitat	Substrata attached	Cover
LLR01	Ns					ns				
LLL03	*Vaucheria* sp. *Oedogonium* sp. BFG *Spirogyra* sp. ECG	3 1 1	Riffle	All	2	*Stigeoclonium* sp.	3	Riffle	Boulders/ Cobbles	1
LLR05	*Phormidium* sp.	3	Pool/ Riffle	Boulders/ cobbles	2	*Vaucheria* sp.	3	Riffle	Boulders/ Cobbles	1
LLR06	Ns					ns				
PHE08	*Vaucheria* sp. *Spirogyra* sp. MFG	3 1	Pool	Clay/ boulders/ cobbles	2	*Spirogyra* sp. MFG	3	Pool	Vegetation	1
LLR09	*Vaucheria* sp. *Oedogonium* sp. BFG *Spirogyra* sp. MFG *Melosira varians*	3 2 1 1	Riffle	Debris	1	ns				
MIN10	Ns					ns				

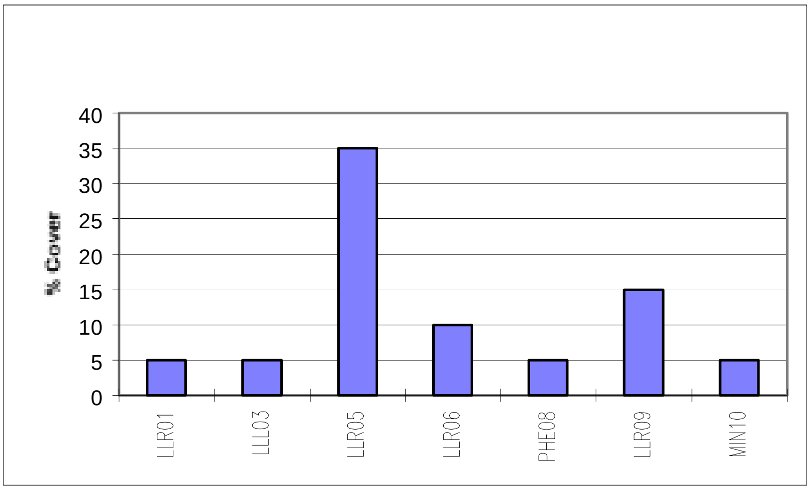
Site	Sample 5	A	Habitat	Substrata attached	Cover	Sample 6	A	Habitat	Substrata attached	Cover
LLR01	Ns					ns				
LLL03	Ns					ns				
LLR05	*Phormidium* sp.	3	Riffle/ pool	Boulders/ cobbles/ weir	1	*Chara* sp.	3	Riffle/ pool	Silt	1
LLR06	Ns					ns				
PHE08	Ns					ns				
LLR09	Ns					ns				
MIN10	Ns					ns				

Site	Sample 7	A	Habitat	Substrata attached	Cover	Sample 8	A	Habitat	Substrata attached	Cover
LLR01	Ns					ns				
LLL03	Ns					ns				
LLR05	*Microspora flocculosa,* *Spirogyra* sp. SFG *Rhizoclonium* sp. *Zygnema* sp.	3 3 2 1	Pool	Vegetation	1	*Rhizoclonium* sp. *Spirogyra* sp. SFG *Stigeoclonium* sp.	3 2 2	Riffle	Debris	1
LLR06	Ns					ns				
PHE08	Ns					ns				
LLR09	Ns					ns				
MIN10	Ns					ns				

A, abundance value from 0–3, where 0, absent; 1, isolated plants; 2, not common; and 3, common and easily observed (as in Entwisle 1989). 'Cover' refers to the cover of the sample on the substrata, where 0, 0%; 1, <10%; 2, 10–35%; 3 ,35–65%; 4, 65–90%; and 5, >90%. Na, not applicable; ns, not specified.

Algal cover was only significant in the Lang Lang River, particularly at Patullos Road (LLR05). The Lang Lang River at the South Gippsland Highway (LLR01) was the only site in this waterway to have a low macroalgal cover (Figure 51).

Figure 51: Visual estimate of total macroalgal cover at each site



As with diatoms, care must be taken when relating macroalgal communities to nutrient levels as they are also strongly influenced by light, temperature, water velocity and grazing (Kelly & Whitton 1995, Stevenson *et al*. 1996). Water velocity and grazing primarily influence macroalgal biomass, but some taxa are more resistant than others to these factors (Stevenson *et al*. 1996).

The dominance of *Vaucheria* sp. and *Spirogyra* spp. in the Lang Lang River and tributaries would indicate some nutrient elevation throughout the catchment (Appendix 8.4). Abundance of *Vaucheria* sp., in particular, appears to be typical for an agricultural catchment (Appendix 8.4).

Due to a complete lack of stable habitat in the Lang Lang River at South Gippsland Highway (LLR01), the low cover of macroalgae and "low" shading is unlikely to indicate a significant reduction in nutrients between the site upstream and at Patullos Road (LLR05). Figures 12 and 13 support this conclusion for they show that total phosphorus and total nitrogen medians are similar at these sites. Similarly, low macroalgal covers in the Little Lang Lang River at Western Port Road (LLL03), Pheasant Creek at Timms Road (LLR08) and Minnieburn Creek (MIN10) would be influenced, to a large extent, by a lack of suitable habitat rather than low nutrient levels. Macroalgal species composition data (Table 17) and water quality data support this view. In the Little Lang Lang River at Western Port Road (LLL03), moderate to high shading and a high turbidity (Figure 30) would also influence macroalgal cover.

From the algal cover and macroalgal community (in particular the dominance of *Compsopogon coeruleus* and the presence of other taxa associated with some nutrient enrichment), it appears that the Lang Lang River at Patullos Road has elevated nutrient levels. This complements the water quality data collected during the study, where median total nitrogen at this site was 0.74 mg/L (Figure 13) and median total phosphorus was 0.15 mg/L (Figure 12)(which was the same as the median orthophosphate result). These results do suggest, however, that nutrient levels are not extremely high and that the lack of shading and the abundance of stable habitat are probably contributing to high macroalgal cover. The lower algal cover and absence of more pollution-tolerant taxa in the Lang Lang River at Western Port Road (LLR06) compared to Patullos Road (LLR05) does suggest less polluted water at the former site. The difference in water quality may not be significant, as the water quality results reflect, particularly because of more shading and less habitat at Western Port Road (LLR06). Abundance of *Spirogyra* spp. does indicate at least some nutrient enrichment.

An estimated macroalgal cover of 15% and the presence of taxa such as *Vaucheria*, *Oedogonium*, *Spirogyra* and *Melosira varians* is in accordance with the water quality and diatom data, which indicate some nutrient elevation in the Lang Lang River at Drouin-Poowong Road (LLR09). Figures 12 and 13 show this site to have a median total phosphorus concentration of 0.14 mg/L and a median total nitrogen concentration of 0.63 mg/L, respectively. A conspicuous presence of *Batrachospermum antipodites* does imply reasonable water quality at this site.

The presence of dense mats of duckweed (i.e. *Lemna* spp., *Wolffia* spp. and *Spirodela* spp.) and *Azolla* in the upper Lang Lang River and Adams Creek is a strong indication of high nutrient levels (Sainty & Jacobs 1981). This supports the water quality data collected during the study in which, at these sites, median total nitrogen ranged from 2.01 to 2.77 mg/L (Figure 13) and median total phosphorus ranged from 0.29 to 0.98 mg/L (Figure 12).

Algal growth in the Lang Lang River at Patullos Road (LLR05) and *Azolla/*duckweed growths in the upper Lang Lang River and Adams Creek could be classified as nuisance weed growth. Besides algal toxins, excessive algal growth is problematic aesthetically and from the perspective of stream health. In terms of stream health, it limits the potential for the establishment and maintenance of a rich and diverse biological community. For example, it reduces light for other algae and plants, reduces substrata for algae, plants and invertebrates, and limits the variety of food for herbivores (and, indirectly, carnivores). Excessive algal growth can also cause significant diurnal fluctuations in dissolved oxygen and pH, which could have a detrimental effect on other biota. Dieback of massive algal growths, which is associated with changes in conditions that initially favoured growth (e.g. reduced light, temperature or nutrients), can also be problematic for many aquatic organisms in terms of the reduction in dissolved oxygen that is associated with bacterial breakdown of the algal matter.

4.5 Macroinvertebrates

Flows were extremely low during March 1998 and some sites had completely dried up. The three sites on Pheasant Creek (PHE07, PHE08 and PHE13) and the upper site on the Little Lang Lang River at Martins/Pooles Roads (LLL04) were sampled on one occasion only, as they were dry. The Little Lang Lang River at Western Port/Pioneer Road (LLG03), Pheasant Creek at Houlahans Road (PHE13) and the Lang Lang River at Korumburra-Drouin Road (LLG12) were a series of disconnected pools in March 1998. Only a trickle flow persisted in Adams Creek (ADM02) during both occasions it was sampled.

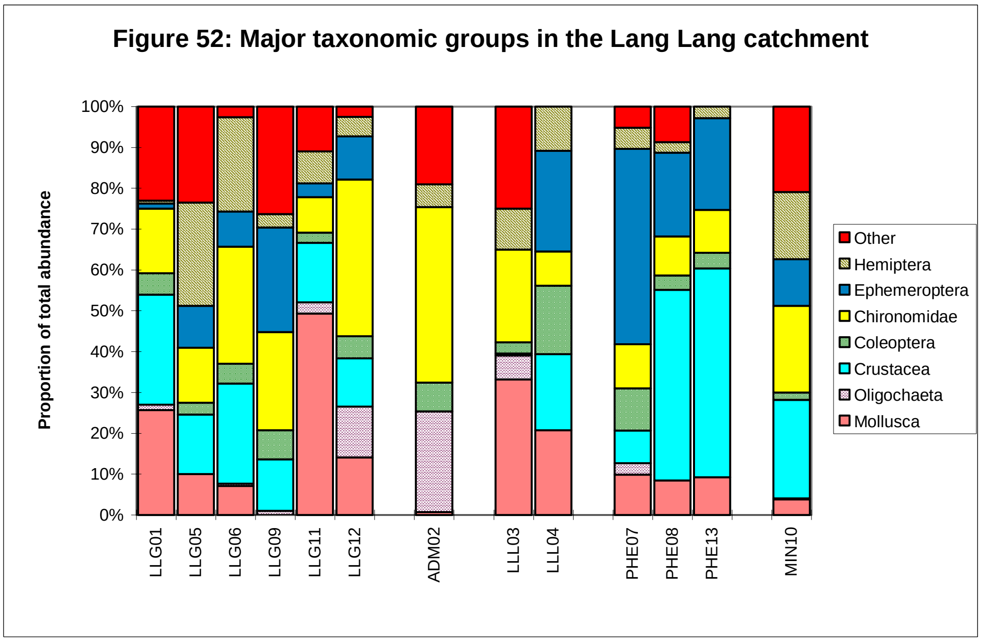
Raw macroinvertebrate data collected during this study are presented in Appendices 8.5–8.7. Major taxonomic groups present at each site are illustrated in Figure 52. Lang Lang River sites were composed of a variety of taxa including:

- hydrobiid snails and freshwater clams (Mollusca);
- scuds and, from sites upstream of Heath Hill (LLG06), freshwater shrimps (Crustacea);
- elmids, dytisicids and other beetles (Coleoptera);
- non-biting midges (Chironomidae);
- corixids and other true bugs (Hemiptera).

Fauna inhabiting Adams Creek were predominantly composed of worms (Oligochaeta), leeches (Hirudinea) and a non-biting midge species (*Chironomus* sp.). Sites on the Little Lang Lang River were dominated by Hydrobiid and Planorbiidae/Physidae snails and the non-biting midge *Chironomus* sp., where the upper site, LLG04, was also well represented by the mayfly *Atalophlebia* MMBW sp. 5/11 (Ephemeroptera), scuds (Crustacea) and Dytiscid beetles (Coleoptera). Pheasant Creek had a similar fauna to the Little Lang Lang River, being dominated by snails, *Atalophlebia* MMBW sp. 5/11, scuds and *Chironomus* sp. In addition, sites PHE07 and PHE08 were well represented by damselflies (Zygoptera). Minnieburn Creek (MIN10) had a variety of taxa, particularly scuds and freshwater shrimps (Crustacea), *Chironomus* and many other species of non-biting midges, several mayfly taxa, corixids (Hemiptera), damselflies (Zygoptera), dragonflies (Anisoptera) and caddisflies (Trichoptera).

The total number of macroinvertebrate taxa collected from each site is presented in Figure 53. Only taxa found during the second sampling event, which were not collected in the first event, are added to the total number of taxa for each site. There were generally more taxa collected during the first than during the second sampling event. Minnieburn Creek had the highest number of taxa, with 47 taxa being collected during December 1997 and 24 taxa (of which 15 were not collected in the previous run) during the March 1998 sampling event. On both occasions, of all the sites, Adams Creek had the lowest number of taxa. Number of taxa along the Lang Lang River was lowest at the South Gippsland Highway. Sites along the middle section of Lang Lang River, from Patullos Road to Stanford Road, had similar numbers of taxa. Comparatively fewer taxa, however, were collected from Korumburra-Drouin Road, which had dried out into a series of discontinuous pools in March 1998. Numerous taxa were also collected from the Little Lang Lang River at Martins/Pooles Road (LLL04) and Pheasant Creek at Clifton Road (PHE07) during December 1997, but these waterways had dried out by March 1998.

SIGNAL scores (Stream Invertebrate Grade Number – Average Level) of macroinvertebrates in the Lang Lang River catchment from pool and riffle habitats are presented in Figure 54. Results indicate that there is little variation in the pollution tolerance of taxa that occurred throughout the catchment. The highest scores, exceeding the draft SEPP objective of 6.0 (EPA 2000), were recorded from riffles in the Lang Lang River at Patullos Road and Heath Hill, and from pools in the Lang Lang River at Poowong-Drouin Road and in Minnieburn Creek. The lowest score on the Lang Lang River occurred at South Gippsland Highway. Tributaries tended to have lower SIGNAL scores than the main stream.



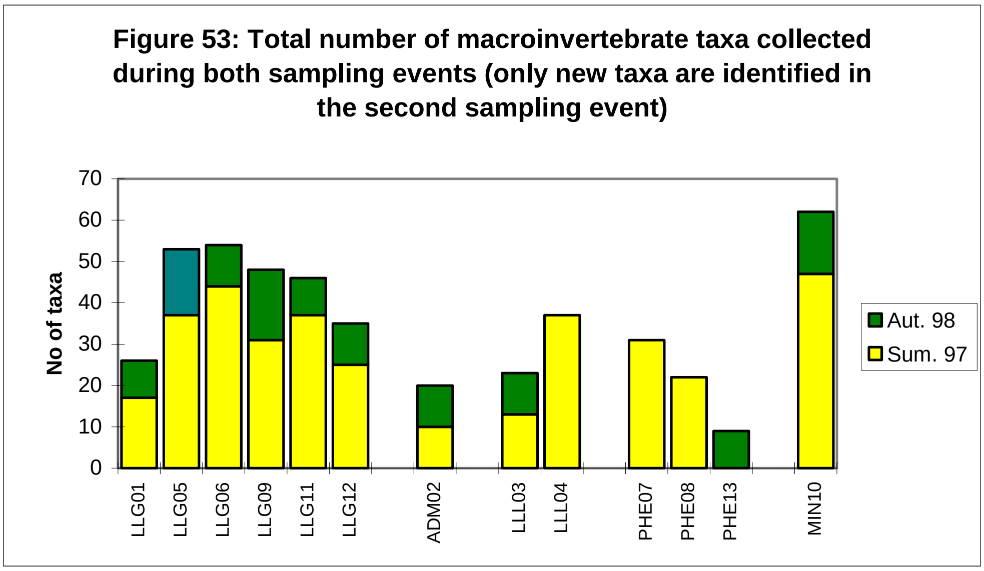
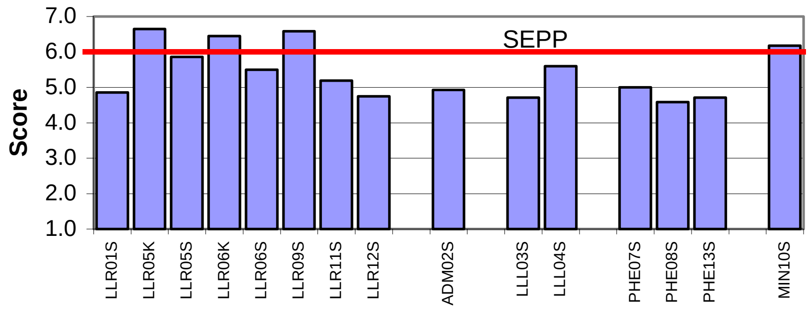


Figure 54: SIGNAL scores of the macroinvertebrates from pool (suffixed S) and riffle (suffixed K) habitats in the Lang Lang catchment



Macroinvertebrate fauna collected from the Western Port catchment have been reviewed by Hewlett (1998). She separated the fauna into four categories. The lower Lang Lang River, in the vicinity of the South Gippsland Highway, was grouped with the most impoverished sites in the catchment; this group included the lower reaches of most major waterways in the catchment. The present study also found the lower Lang Lang River to have the poorest invertebrate fauna in the catchment. The poor representation of invertebrates in the lower Lang Lang River would appear to result from a combination of poor in-stream and riparian habitats, and that this site is subjected to tidal influences that would increase salinities to levels that could only be tolerated by few normally, freshwater macroinvertebrates.

Hewlett (1998) also reviewed data collected by Melbourne Water and EPA Victoria from four other sites in the Lang Lang River catchment. Two sites on the Lang Lang River at Heads and Poowong-Drouin Roads were grouped with "…mainly larger streams but some smaller lowland sites…generally located in the northern area of the catchment" (p. 30). This group of sites generally had good riparian zones, in-stream habitat and good water quality compared with most other waterways in the Western Port catchment.

The other two sites on Pheasant Creek at Timms Road and Lang Lang River at Main Road South were grouped with "…smaller and/or more upland sites…most of which are located in the south-eastern foothill area of the catchment" (ibid. p. 28). Typically, these sites had degraded waterways, which were slow flowing, had low dissolved oxygen concentrations and considerable nutrient enrichment.

Additional sites surveyed for macroinvertebrates in the present study, and the severe drought conditions that occurred during this study, provide greater insight into the patterns that occur in the macroinvertebrate fauna in the Lang Lang River catchment. Lang Lang River upstream of the Minnieburn Creek confluence ceased flowing and dried out into a series of pools in its headwaters around Korumburra-Poowong Road. Furthermore, fauna in the Little Lang Lang River and Pheasant and Adams Creeks were severely affected by drought conditions in the summer of 1998/99. In contrast, Minnieburn Creek continued to flow throughout this summer and maintained a relatively healthy ecosystem. Minnieburn Creek is apparently one of the few areas in the catchment that is fed by springs (smaller springs may also occur in other parts of the headwaters of the Lang Lang River). These flows ensured that the middle section of Lang Lang River received some flows and were able to provide refuge for aquatic biota. It is crucial that natural spring-fed flows in Minnieburn Creek are maintained to protect the aquatic ecosystem in future droughts.

4.6 Fish

Fish were surveyed by Raadik and Zampatti (1998) from five sites on the Lang Lang River and from one site on Minnieburn Creek. This section summarises some findings of their report.

Eleven species of fish were collected from these sites. Their common and scientific names, conservation status and whether they are migratory species are presented in Table 18. Seven native fish were collected, of which the river blackfish is considered threatened, whereas the other fish are common. One species of spiny cray and three species of mussel were also recorded.

Table 18: Common and scientific names of fish species recorded in this study, including their conservation status (DCNR 1995) and whether the native species migrate (adapted from Raadik & Zampatti 1998)

Common name	Scientific name	Conservation status	Migratory
FISH			
Common native species			
Shortfin eel	*Anguilla australis*	Common	Yes
River blackfish	*Gadopsis marmoratus*	Indeterminate	No
Broad-finned galaxias	*Galaxias brevipinnis*	Common	Yes
Common galaxias	*Galaxias maculatus*	Common	Yes
Tupong	*Pseudaphritis urvillii*	Common	Yes
Australian smelt	*Retropinna semoni*	Common	No
Southern pygmy perch	*Nannoperca australis*	Common	No
Exotic species			
Goldfish	*Carassius auratus*	–	–
Brown trout	*Salmo trutta*	–	–
Mosquitofish	*Gambusia holbrooki*	–	–
Redfin	*Perca fluviatilis*	–	–
CRAYFISH			
Gippsland Spiny Cray		Common	–
Burrowing Crays	*Engaeus* sp.	–	–
MUSSELS			
South-eastern mussel	*Hydriella drapeta*	Common	–
Eastern mussel	*Hydriella australis*	Common	–
River mussel	*Velesunio ambiguus*	Common	–

Twelve species of native fish and five species of exotic fish have been recorded previously in the Lang Lang River catchment. In addition to the species listed in Table 18, the rare spotted galaxias (*Galaxias truttaceus*) and pouched lamprey (*Geotria australis),* and the vulnerable, FFG-listed Australian grayling (*Prototroches* *maraena*) and dwarf galaxias (*Galaxiella pusilla*), and the exotic rainbow trout (*Oncorhynchus mykiss*) have also been recorded from the Lang Lang River catchment.

The most significant result was that the Gippsland Spiny Cray was recorded from the Lang Lang River for the first time. This result extends the known range of this species southward from the Bunyip River and westward from the La Trobe River system to the east of Western Port.

Type and numbers of fish, crays and mussels collected from the six sites surveyed are presented in Table 19. Aquatic fauna of the Lang Lang River were rated by Raadik and Zampatti (1998) as being in relatively moderate to poor condition, with two sites rated as poor, two as moderate and one rated as good. Four of the six sites had native-fish richness less than 50% of that expected. The lowest species richness was recorded in the Lang Lang River at Drouin-Korumburra Road, where the river had dried into a series of small pools.

Table 19: The type and abundance of fish collected from five sites in the Lang Lang River (Patullos Road, Heath Hill, Athlone at Drouin-Poowong Road, Timms Road and Drouin-Korumburra Road) and in Minnieburn Creek. An overall rank and rating made by Raadik and Zampatti (1998) is also presented.

Common name	Patullos Road	Heath Hill	Drouin-Poowong Road	Timms Road	Drouin-Korumburra Road	Minnieburn Creek
FISH						
Common native species						
Shortfin eel	97	79	88	20	7	46
River blackfish				2		10
Broad-finned galaxias	2	3	2			
Common galaxias	1					
Tupong	8					
Australian smelt	56		1			
Southern pygmy perch			43	1		14
Exotic species						
Goldfish	53		39	33		
Brown trout	6					3
Mosquitofish		13				
Redfin		1				4
CRAYFISH						
Gippsland Spiny Cray			9			8
Burrowing Crays			+			+
MUSSELS						
South-eastern mussel			+			+
Eastern mussel						+
River mussel				+		
Overall rank and description	8 Moderate	6 Poor	8 Moderate	6 Poor	–	10 Good

Three of the six sites recorded exotic species abundances in excess of 20% of total fish abundance, although only one site had an abundance exceeding 20%. Overall, the most degraded sites were the Lang Lang River at Heath Hill, with low expected native species richness, and at Timms Road, which had low native and high exotic species abundances. The most natural site was Minnieburn Creek, which had a medium number of expected native fish and low exotic species abundance.

At all sites a number of migratory native species was absent - these being Australian grayling, spotted galaxias, short-headed lamprey and pouched lamprey. Common galaxias and tupong were present at Patullos Road but at the time, several barriers between the weir at this site and Heath Hill prevented these species from being able to move further up the Lang Lang River. Since 1998, Melbourne Water has undertaken several works to remove several fish barriers within Lang Lang River. These works include Heath Hill, downstream of Patullos Road and downstream of the Dandenong-Leongatha Railway line. Other fish barriers remain, including a large concrete drop structure at Heads Road.

Short-finned eel and broad-finned galaxias were widely distributed in the catchment. These two species are also migratory and they are able to pass structures that are impassable for many other native migratory species. River blackfish and Southern pygmy perch were present in upper catchment waterways but were not collected downstream of Athlone.

Raadik and Zampatti (1998) identified several factors that have contributed to the current poor state of fisheries in the Lang Lang River catchment. Loss of wetlands in the lower reaches downstream of Heath Hill is likely to have caused a decline in non-migratory species, such as river blackfish and Southern pygmy perch. Middle and upper catchment waterways have degraded riparian and in-stream habitats. This poor habitat, together with drought conditions experienced during this study, appears to have severely affected fish populations.

4.7 Platypus

A total of three platypus (two adult males and a juvenile male) were caught at two of the Lang Lang River sites. To our knowledge, these are the first official records of platypus occurring in the Lang Lang River catchment. One adult male and a juvenile male were collected from the Lang Lang River at Western Port Road and another male was collected from the Smethurst property, which is located about 2 km west of the Drouin-Poowong Road.

No platypus were collected from the site located on Minnieburn Creek, or Lang Lang River at Drouin-Poowong Road or from another site slightly further downstream on the Monks property. These negative results do not mean that platypus are absent from these areas but that numbers may be low.

Several non-target species were also collected. The native water rat (*Hydromys* sp.) was found in the river at the Monks property. Short-fin eels were collected from the Smethurst property and from Drouin-Poowong Road. Finally, brown trout were collected from the Western Port Road site.

5. DISCUSSION

Due to a series of modifications since European settlement, the Lang Lang River catchment has changed dramatically from its natural state. These changes are reflected in a generally degraded aquatic ecosystem. Because there are severe limitations on the ability to restore the catchment to its former state of mostly dense forest and swamps, efforts to manage the aquatic ecosystem need to define realistic goals (not necessarily modelled on the pre-European condition). Accepting some restraints, ecosystem rehabilitation goals should seek improved native diversity and sustainability – both in the Lang Lang River system and Western Port.

It is acknowledged that conditions described in this study are biased by the drought. Rather than being an impediment, this study, in conjunction with long-term water quality monitoring data, has provided useful a insight into catchment conditions experienced during times of greater stress.

There are several key stream-health issues within the Lang Lang River catchment, in particular, erosion, stream flows, riparian vegetation and lack of in-stream habitat. Other issues include fish barriers, nutrients and possibly biocides. These issues will now be discussed in further detail.

Erosion

It is suspected that the Lang Lang River catchment is a major contributor of suspended solids loads to Western Port. Reasons for this comparatively high sediment yield may include historical channel modification (and subsequent incision), unsealed roads, clearing of vegetation (catchment and riparian), frequent stock access to streams and heavy grazing. Since the channel-straightening works in the lower Lang Lang River in the early 1900s, numerous stabilisation works have been conducted in an attempt to control major headward erosion. Significant erosion is continuing in some reaches. Sediment loads originating from Lang Lang River are not only a concern for the health of the river, but also the health of Western Port. Although uncertain, it is a common belief that increased sediment loads resulted in the widespread loss of seagrass, which is a fundamental component of the bay ecosystem (EPA 2000).

In order to target erosion management, in 2000 Melbourne Water commissioned a three-year study of sediment sources to Western Port. The study is being conducted by CSIRO with support from EPA Victoria. It aims to identify dominant sources of sediment to Western Port, including determining sediment loads for major waterways and the relative contribution of sediment from land and in-stream erosion. Depending upon outcomes of this study, future management activities may include increased stream-frontage works, bed and bank stabilisation, catchment revegetation, sealing of roads and fostering best-management practices on farms.

Stream Flows

Stream flows are an issue in the Lang Lang River catchment during both high and low flows. A lack of flow during this study seemed to cause significant stress to the aquatic ecosystem. Stream health tended to be better in those areas experiencing steady flows (e.g. middle to lower Lang Lang River and Minnieburn Creek), whereas at sites lacking flows there were clear indications of stress (e.g. low dissolved oxygen and a poor variety and number of invertebrate and fish communities). The spring-fed Minnieburn Creek is the best example of the need to maintain steady flows in the Lang Lang River system. It was the only tributary flowing consistently during the study and it was found to possess markedly better stream health than other Lang Lang River tributaries. Because of the importance of flows, it would be beneficial to produce a stream-flow management plan for the river that would ensure sustainability of the resource for human use and the environment. Southern Rural Water is the regional authority for stream diversions and would lead the development of such a plan.

The relatively shorter and more intense flows in the Lang Lang River system during storm events (primarily resulting from forest clearing and channel straightening) are also causing concern. Not only do they increase the risk of flooding, as demonstrated by historical management (e.g. levee construction), but they also increase stress on aquatic organisms during events, increase erosion rates and result in lower base flows. Options to manage this problem should be explored, and possibly include re-engaging sections of the floodplain, catchment revegetation and the construction of riffles (recognising the additional benefits of some in-stream stabilisation works). Riffles could help to reduce stream power and provide refuge for aquatic organisms during storm events. Several riffles have been constructed recently by Melbourne Water as part of stream stabilisation works, and further works of a similar nature are anticipated.

Riparian Vegetation

Riparian vegetation is lacking in large sections of the catchment. These reaches could be targeted for inclusion in the Stream Frontage Management Program. Riparian vegetation is important not only for stream stability but also, for example, habitat (including in-stream habitat from large woody debris), which is a food resource for many organisms (especially leaf litter), and stream shade (to prevent excessive water temperatures and restrict nuisance algal growth). Continuous riparian vegetation can also play an important role in providing migratory corridors for various terrestrial organisms (Tonkinson *et al*. 2000).

To preserve the integrity of the riparian zone, the Stream Frontage Management Program should also involve restricting stock access, weed control (e.g. blackberries) and willow removal. In the Melbourne Water public survey (section 2.7), farmers expressed a personal responsibility for weed control. This could be encouraged through the Stream Frontage Management Program.

Willows are a problem for numerous physical, chemical and biological reasons. Some problems include reducing hydraulic capacity, trapping organic matter and increasing biochemical oxygen demand, hence potentially forming barriers to fish migration and providing sub-optimal habitat and a discontinuous leaf supply (Suter 1990; Bobbi 1999).

Willow removal should be conducted strategically, for example, from reaches where trees dominate the stream channel and preferably in the upper catchment where there is less chance of renewal from upstream. Where willows are removed, revegetation needs to follow quickly so as to avoid exposure of bare banks. Care also needs to be taken where willows may be holding erosion heads, such as in the O'Mahony and Minnieburn Creeks system. Willow removal needs to be conducted according to the Standard Work Procedure in order to minimise environmental impact (Melbourne Water Corporation 1998).

Because it forms an important flow corridor in the upper catchment, Minnieburn Creek should be a priority for rehabilitation works.

Lack of in-stream habitat
In-stream habitat is poor throughout much of the Lang Lang River system and lessens the potential for a rich and diverse aquatic ecosystem. Habitat could be provided through the Stream Frontage Management Program (where riparian vegetation progressively provides large woody debris) and creation of riffles as part of bed and bank stabilisation works. As has been suggested by Brizga *et al*. (1997), additional habitat may be provided by re-engaging sections of the old watercourse. A feasibility study should be initiated.

In the Melbourne Water public survey (section 2.7), locals indicated that the river system is valued for fishing. This being the case, waterway improvements such as increased in-stream habitat, maintenance of steady stream flows and healthy riparian zones should be highlighted as being critical for preserving and enhancing fish populations.

Nutrients
Nutrient concentrations are elevated throughout the catchment. Possible dominant nutrient sources include fertilisers, dairy waste, sewage treatment plant discharges and suspended solids. Efforts to reduce nutrient levels could involve erosion control, riparian buffer strips, in-stream revegetation and fostering best-management practices on farms. Although some nuisance algal and macrophyte growths are evident within the Lang Lang River system, a reduction in nutrients should be viewed as important for the health of Western Port, where there are possible implications for seagrass beds. Nutrients encourage epiphytic growth on seagrass stems and blades that may smother the seagrass. The cause of seagrass decline in Western Port is unknown and, once determined, will influence the direction of management programs in the bay and catchment (e.g. allowing the targeting of the more important nutrients, sediment, surfactants or biocides).

Biocides
Although metal concentrations in sediments were relatively low, the detection of organochlorines in sediments is of some concern for both the health of the Lang Lang River and Western Port. It is likely that these organochlorines are from past practices in the catchment, as they are highly persistent (ANZECC 1992). Therefore, organochlorine concentrations are expected to decline in future years and consequently are not considered to represent a high priority for further investigation.

Fish Barriers
Several fish barriers to fish migration have been identified in the lower Lang Lang River. In order to encourage a diversity of native fish, barriers should be removed.

Melbourne Water has already conducted some fish passage works at the South Gippsland Highway, Patullos Road and Heath Hill. Other fish barriers exist, in particular, an approximately 2-metre drop structure at Heads Road.

Adams Creek

Stream condition within Adams Creek was degraded, particularly in terms of its low dissolved oxygen, elevated nutrients and poor invertebrates. Degrading processes were not identified in this study; however, any impact from the sewage treatment plant is likely to be reduced as there are plans proposed for 100% effluent re-use. The impact of sand extraction activities is also unknown.

6. CONCLUSIONS

Stream health within the Lang Lang River catchment is generally fair to poor. Although quite degraded, several values still exist in the system such as platypus and native fish. Aquatic ecosystem rehabilitation goals in this catchment should seek improved native diversity and sustainability – both in the Lang Lang River system and Western Port.

There are several key stream health issues within the Lang Lang River catchment, in particular, erosion (and subsequent sedimentation in streams and Western Port), stream flows, riparian vegetation and lack of in-stream habitat. Other issues include removing fish barriers and reducing nutrient loads.

Melbourne Water has commissioned a three-year study of sediment sources to Western Port. This study is being conducted by CSIRO with support from EPA Victoria. It is anticipated that the study will determine critical areas for erosion-control works in the Western Port catchment, including the Lang Lang River catchment. The study will also contribute to work aimed at determining the causes of seagrass loss in Western Port.

"Stream flows" is an issue in the Lang Lang catchment during both high and low flows. Because of the importance of flows, it would be beneficial to produce a Stream Flow Management Plan for the catchment that ensures the sustainability of this resource for human use and the environment.

Riparian vegetation is lacking in large sections of the catchment. Reaches affected could be targeted for inclusion in the Stream Frontage Management Program. Stream-frontage management would also involve restricting stock access to streams and controlling weeds (including willows). In-stream habitat is also lacking throughout much of the Lang Lang River system. Habitat could be provided by management activities, such as stream-frontage management (large woody debris) and bed and bank stabilisation works (creation of riffles). The feasibility of re-engaging sections of the old watercourse should be investigated.

As it forms an important flow corridor into the upper catchment, Minnieburn Creek should be a priority for rehabilitation works.

7. REFERENCES

ANZECC (1992) *National Water Quality Management Strategy. Australian Water Quality Guidelines For Fresh And Marine Waters.* Canberra, Australian and New Zealand Environment and Conservation Council.

ANZECC (1997) *ANZECC Interim Sediment Quality Guidelines*. Prepared for the Environmental Research Institute of the Supervising Scientist. March 1997.

Biggs B (1988) Artificial substrate exposure times for periphyton biomass estimates in rivers. *New Zealand Journal of Marine and Freshwater Research* **22**: 507–575.

Bobbi C (1999) River management arising from willow removal (where there's a willow there's a way). *Second Australian Stream Management Conference*, 8–11 February 1999, Adelaide, South Australia.

Brizga S, Craigie N, Condina P (1997) *Melbourne Water - Stream Condition Assessments, Overview Report.* Report to Melbourne Water Corporation. Melbourne, Melbourne Water Corporation.

Chessman BC, Growns JE, Kotlash AR (1997) Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. *Marine and Freshwater Research* **48**: 159–172.

Coleman R and Pettigrove V (1998) *Waterway Assessment in the Yarra Catchment: The Health of the Watts River.* Melbourne, Melbourne Water Corporation.

Coleman R and Pettigrove V (1999) Assessing the health of Melbourne's waterways. *Second Australian Stream Management Conference*, 8–11 February 1999, Adelaide, South Australia.

Cummins K (1993) Riparian stream linkages: In-stream issues. In: (Eds. S Bunn, B Pusey, P Price) *Ecology And Management Of Riparian Zones In Australia*, pp. 05/93: 15–20. Canberra, Land and Water Resources Research and Development Corporation.

Dandenong Valley Authority (1986) *Westernport Bay Study*. Melbourne, Dandenong Valley Authority.

DCNR (1995) Threatened fauna in Victoria - 1995. Department of Conservation, Forests and Lands, Melbourne, Victoria.

Denys L (1991) A check-list of the diatoms in the holocene deposits of the western Belgian coastal plain with a survey of their apparent ecological requirements. *Ministere Des Affaires Economiques - Service Geologique De Belgique* **1** (Professional paper 1991/2-No. 246).

Entwisle T (1989a) Macroalgae in the Yarra River basin: Flora and distribution. *Proceedings of the Royal Society of Victoria* **101**: 1–76.

Entwisle T (1989b) *An introduction to macroalgal monitoring in Australian streams.* Unpublished data. Melbourne, National Herbarium of Victoria.

Entwisle T (1990) Macroalgae in the upper Yarra and Watts River catchments: Distribution and phenology. *Australian Journal of Marine and Freshwater Research* **41**: 505–522.

Entwisle T (1994) *Aquatic Cryptogams of Australia: A Guide to the Larger* of *Fungi, Lichens, Macroalgae, Liverworts and Mosses of Australian Inland Waters*. Australian Society for Limnology.

Entwisle TJ, Sonneman JA *et al*. (1997) *Freshwater Algae in Australia*. City. Sainty & Associates.

EPA (1998) *Rapid Bioassessment of Victorian Streams. The Approach and Methods of the Environment Protection Authority*. Publication 604. Melbourne, Environment Protection Authority of Victoria.

EPA (2000) *Protecting the Waters of Western Port and Catchment. A Summary of the Western Port and its Catchment.* Schedule (F8) to State Environment Protection Policy (Waters of Victoria). Draft report. Publication 706. Melbourne, Environment Protection Authority of Victoria.

Fjerdingstad E (1965) Taxonomy and saprobic valency of benthic phytomicro-organisms. *Int. Revue ges. Hydrobiol. Hydrogr.* **50**: 475–604.

Foged N (1978) *Diatoms in Eastern Australia*. Germany, J. Kramer.

Forstner U and Muller G (1976) *Metal Pollution in the Aquatic Environment.* Berlin, Springer-Verlag.

GHD (1998) *Fluvial Geomorphology of the Lang Lang River, Melbourne Water - Internal Report*. Gutteridge, Haskin and Davey Pty Ltd, in association with Centre for Environmental Applied Hydrology, University of Melbourne.

Hardwick R (1998) *Waterway Assessment in the Mornington Peninsula: The Health of the Western Port Streams.* Melbourne, Melbourne Water Corporation.

Hardwick R and Lewin K (1999) *Macroinvertebrates and Sediment Toxicants Monitoring Program. Biennial Report – Autumn – Spring 1997.* Report prepared for Melbourne Water Corporation.

Hewlett R (1998) *Environmental Health of Streams in the Western Port Catchment.* Publication No. 600. Melbourne, Environment Protection Authority of Victoria.

Johansson C (1982) Attached algal vegetation in running waters of Jamtland, Sweden. *Acta Phytogeogr. Suec.* **71**: 84.

Kelly MG and Whitton BA (1995) The Trophic Diatom Index: A new index for monitoring eutrophication in rivers. *Journal of Applied Phycology* **7**: 433–444.

Koehn J and O'Connor W (1990) Threats to Victorian native freshwater fish. *Victorian Naturalist* **107** (10): 5–12.

Lakey RC (1982) Base flow evaluation and interpretation for the Bunyip-Tarago River catchment. *Hydrology and Water Resources Symposium*, Melbourne, The Institution of Engineers, Australia.

Laws EA (1993) *Aquatic Pollution: An Introductory Text.* New York, John Wiley & Sons.

Lewin K (1997) *Streamwatch Toxicant Monitoring Program: Annual Report.* Melbourne, Melbourne Water Corporation.

Lowe R (1974) *Environmental Requirements and Pollution Tolerance of Freshwater Diatoms.* Ohio, US Environmental Protection Agency.

Mancy K H and Weber WJJ (1971) *Analysis of Industrial Wastewaters.* Sydney, Wiley-Interscience.

Melbourne Parks and Waterways (1995) *Stream Condition Inventory, Yarra And Maribyrnong Catchments Data Report.* Streamwatch report series No. 2. Melbourne, Melbourne Parks and Waterways.

Melbourne Water Corporation (1998) *Standard Work Procedure #9: Willow Control and Management.* Melbourne, Melbourne Water Corporation.

Ministry for Conservation (1977) *Westernport Regional Environmental Study: A Review of the Extent and Environmental Effects of Erosion in the Westernport Catchment.* Melbourne, Ministry for Conservation Victoria.

Ministry for Conservation (1980) *Westernport Regional Environmental Study: Land Use and Erosion Control Guidelines for the Western Port Catchment*. Melbourne, Ministry for Conservation Victoria.

Monitoring River Health Initiative (1994) *River Bioassessment Manual*, Version 1.0. *National River Processes and Management Program Monitoring River Health Initiative.* Canberra, Commonwealth Environment Protection Agency.

Pettigrove V and Coleman R (1998a) *Waterway Assessment in the Yarra Catchment: The Health of Andersons and Jumping Creeks.* Melbourne, Melbourne Water Corporation.

Pettigrove V and Coleman R (1998b) *Waterway Assessment in the Dandenong Valley: The Health of Corhanwarrabul, Monbulk and Ferny Creeks.* Melbourne, Melbourne Water Corporation.

Prescott GW (1978) *Freshwater Algae.* Iowa, Wm.C.Brown Company Publishers.

Raadik T and Zampatti B (1998) *An Assessment of Aquatic Biota of Selected Sites in the Lang Lang River System, and South-Eastern Mornington Peninsula, Rolling Tributaries Program.* Melbourne, Marine & Freshwater Resources Institute.

Reid M, Tibby J, Penny D and Gell P (1995) The use of diatoms to assess past and present water quality. *Australian Journal of Ecology* **20**: 57–64.

Reid M (1996) *Dandenong Creek BACI Study: Preliminary Report on the Analysis of Diatom Communities Colonizing Artificial Substrates, Dandenong Creek VI.* Melbourne, WATER ECOscience Pty Ltd.

ResearchWise (1998a) *Waterways Expectations and Satisfaction Monitor. A Report for Melbourne Water. July 1998.* Melbourne, Melbourne Water Corporation.

ResearchWise (1998b) *A Qualitative Report on Attitudes to and Expectation of Waterways: A Report for Melbourne Water. June 1998.* Melbourne, Melbourne Water Corporation.

River Basin Management Society (1997) *Monitoring River Health*. Winter Conference, Latrobe University, Melbourne.

Round F (1993) A review and methods for the use of epilithic diatoms for detecting and monitoring changes in river water quality. *Methods for the Examination of Waters and Associated Materials.* London, HMSO.

Sainty GR and Jacobs SW (1981) *Waterplants of New South Wales.* Alexandria, Water Resources Commission NSW.

Sainty GR and Jacobs SW (1994) *Waterplants in Australia.* Darlinghurst, NSW, Sainty & Associates.

Seymour BS (1987) *Assessment of the Conservation Values of the Rivers and Streams in the Western Port Region.* Prepared for the Department of Water Resources by the Dandenong Valley Authority.

Shapiro A (1975) *Westernport Bay Environmental Study.* Melbourne, Ministry for Conservation Victoria.

Smith T, Vertessy D and Hardwick R (1997) *Streamwatch Biological Monitoring Program: Annual Report.* Melbourne, Melbourne Water Corporation.

Sonneman J (1996) *Ecological Information for Common Macroalgae Found in Australian Streams.* Sydney, New South Wales Department of Land & Water Conservation.

Sonneman J, Breen P, Walsh C and Sharpe A (unpublished) *Effects of Urbanisation on Streams of the Melbourne Region, Victoria, Australia. III. Benthic Diatom Communities.*

State Of the Environment (1988) *State of the Environment Report 1988: Victoria's Inland Waters.* Melbourne, Government of Victoria.

State Rivers & Water Supply Commission (1984) *Victorian Surface Water Information, State Rivers and Water Supply Commission*, Vol. 1. River Basins (pp. 21–28).

Stevenson R, Bothwell M and Lowe R (1996) *Algal Ecology: Freshwater Benthic Ecosystems*. San Diego, CA, Academic Press.

Suter P (1990) *The Effect of Willows on River Ecology.* Adelaide, Office of the Environment Protection Authority, Adelaide, South Australia.

Tonkinson D, Brown G, Clemann N and Loyn R (2000) *The Merits of Potential Options for Establishing a Native Vegetation Corridor as Habitat for Terrestrial Flora and Fauna in the Bunyip River Catchment During Reconstruction Works Along Main Drain.* A report for Melbourne Water. Department of Natural Resources and Environment.

Van Dam H, Mertens A and Sinkeldam J (1994) A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Netherlands Journal of Aquatic Ecology* **28**: 117–133.

Watanabe T, Asai K and Houki A (1988) Numerical index of water quality using diatom assemblages. *4th IUBS International Symposium on Biomonitoring of the State of the Environment.* Tokyo: Tokyo University Press.

WPCCG (1979) The Westernport Catchment Resources Inventory. Western Port Catchment Co-ordinating Group.

WPCCG (1980) The Western Port Catchment Resources Inventory. Western Port Catchment Co-ordinating Group.

WPCCG (1984) *A Case Study of the Upper Lang Lang River Catchment and a Proposal for a Full Scale Study of the Western Port Catchment.* Melbourne, Western Port Catchment Co-ordinating Group.

Williams G, Serena M and Thomas J (1998) *Distribution of Platypus in the Melbourne Metropolitan Region: Survey Results, 1997/98.* Australian Platypus Conservancy report for Melbourne Water. Melbourne, Australian Platypus Conservancy.

8. APPENDICES

8.1 Summary Descriptions of the Survey Sites

<u>SITE DESCRIPTION</u> **LLR01**

Waterway: Lang Lang River
Location: South Gippsland Highway
MEL/ES MAP: 796C12

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 7 Bank Width: 8 Bank Height: 6

Mean Pool Depth (m): 0.15 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
10–35	0	0	65–90	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	5	0	0	0	20	75

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
<5	<5

Habitat Assessment Rating: Poor
Comments: Heavy deposition of silt.

SITE DESCRIPTION ADM02

Waterway: Adams Creek
Location: South Gippsland Highway
MEL/ES MAP: 824C1

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 5 Bank Width: 11 Bank Height: 2

Mean Pool Depth (m): 1 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
65–90	0	0	0	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	0	0	100

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
30	10

Habitat Assessment Rating: Poor
Comments: Anaerobic sediment odour, *Lemna* and *Azolla* abundant on water surface.

SITE DESCRIPTION LLL03

Waterway: Little Lang Lang River
Location: Western Port Road
MEL/ES MAP: **796E13**

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 4 Bank Width: 10 Height: 2

Mean Pool Depth (m): 0.5 **Mean Riffle Depth (m):** <0.05

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
65–90	<10	0	<10	<10	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	5	5	10	10	60	10

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
5	5

Habitat Assessment Rating: Fair
Comments: None

SITE DESCRIPTION LLL04

Waterway: Little Lang Lang River
Location: Pooles Road
MEL/ES MAP: 825D1

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 7 Bank Width: 30 Bank Height: 5

Mean Pool Depth (m): <0.05 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
>90	0	<10	0	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	0	10	90

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
0	10

Habitat Assessment Rating: Poor
Comments: Site had very little water for the duration of the study. Anaerobic sediment odour, with slight sediment oils.

SITE DESCRIPTION LLR05

Waterway: Lang Lang River
Location: Patullos Road
MEL/ES MAP: 797C9

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroinvertebrates (riffle)	At site
Macroalgae	At site
Benthic Diatoms	At site
Fish	At site to 100 m downstream

Mean Stream/Bank Dimensions (m)
Stream Width: 5 Bank Width: 20 Bank Height: 10

Mean Pool Depth (m): 2 **Mean Riffle Depth (m):** 0.4

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
35–65	10–35	0	10–35	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	30	30	20	10	5	5

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
15	0

Habitat Assessment Rating: Good
Comments: Barrier to fish passage present, approximately 1 m high.

SITE DESCRIPTION LLR06

Waterway: Lang Lang River
Location: Western Port Road, at Heath Hill
MEL/ES MAP: 797G10

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroinvertebrates (riffle)	At site
Macroalgae	At site
Benthic Diatoms	At site
Fish	10 m downstream to 50 m upstream of site

Mean Stream/Bank Dimensions (m)
Stream Width: 10 bank width: 40 Height: 20

Mean Pool Depth (m): 1 **Mean Riffle Depth (m):** 0.4

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
65–90	10–35	0	<10	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	10	20	20	20	20	10

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
10	0

Habitat Assessment Rating: Good
Comments: Heavy historical erosion.

SITE DESCRIPTION **PHE07**

Waterway: Pheasant Creek
Location: Clifton Road
MEL/ES MAP: 798H11

Sampling Activity and Location

Activity	**Location**
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 2 Bank Width: 10 Bank Height: 5

Mean Pool Depth (m): <0.1 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
10–35	0	0	65–90	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	0	0	100

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
0	20

Habitat Assessment Rating: Very poor
Comments: Anaerobic sediment odour, little water for the study duration.

SITE DESCRIPTION **PHE08**

Waterway: Pheasant Creek
Location: Timms Road
MEL/ES MAP: **826D5**

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 4 Bank Width: 15 Bank Height: 3

Mean Pool Depth (m): 0.1 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
35–65	0	0	35–65	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	10	10	80

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
10	25

Habitat Assessment Rating: Fair
Comments: Very little water for the duration of the study.

SITE DESCRIPTION **LLR09**

Waterway: Lang Lang River
Location: Drouin-Poowong Road
MEL/ES MAP: 798D9

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroinvertebrates (riffle)	At site
Macroalgae	At site
Benthic Diatoms	At site
Fish	Two sections: (a) 15 m downstream to 25 m upstream; (b) 55 m to 115 m upstream of bridge

Mean Stream/Bank Dimensions (m)
Stream Width: 4 Bank Width: 3 Bank Height: 5
Mean Pool Depth (m): **Mean Riffle Depth (m):**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
65–90	5	0	10–35	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	5	20	0	0	0	75

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
5	0

Habitat Assessment Rating: Good
Comments: None

SITE DESCRIPTION MIN10

Waterway: Minnieburn Creek
Location: Main South Road
MEL/ES MAP: **798H9**

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site
Benthic Diatoms	At site
Fish	At site to 100 m downstream

Mean Stream/Bank Dimensions (m)
Stream Width: 4 Bank Width: 10 Bank Height: 2

Mean Pool Depth (m): 1 **Mean Riffle Depth (m):** –

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
10–35	0	0	65–90	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	0	10	90

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
20	80

Habitat Assessment Rating: Poor
Comments: None

SITE DESCRIPTION LLR11

Waterway: Lang Lang River
Location: Standfields Road
MEL/ES MAP: 826G3

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site
Fish	At Timms Road, 17–82 m downstream of bridge

Mean Stream/Bank Dimensions (m)
Stream Width: 7 Bank Width: 4 Bank Height: 3

Mean Pool Depth (m): 1.5 **Mean Riffle Depth (m): –**

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
100	0	0	0	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
10	20	10	10	10	10	30

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
20	30

Habitat Assessment Rating: Fair
Comments: Reach reduced to pools for the duration of the study.

SITE DESCRIPTION: **LLR12**

Waterway: Lang Lang River
Location: Korrumburra-Drouin Road
MEL/ES MAP: 826H6

Sampling Activity and Location

Activity	Location
Physico-chemical	At site
Macroinvertebrates (pool)	At site
Macroalgae	At site
Fish	At site

Mean Stream/Bank Dimensions (m)
Stream Width: 5 Bank Width: 20 Bank Height: 3

Mean Pool Depth (m): 1 **Mean Riffle Depth (m):** –

Habitat (% in reach)

Pools	Riffles	Backwaters	Runs	Littoral	Waterfalls	Other
35–65	0	0	35–65	0	0	0

Inorganic Substratum Description (% cover)

Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt/Clay
0	0	0	0	10	10	80

Organic Substratum (% cover of inorganic substrata)

Detritus (coarse organics)	Mud/Muck (fine organics)
20	0

Habitat Assessment Rating: Fair
Comments: Very little water for the duration of the study. Evidence of heavy local erosion.

8.2 Benthic Diatoms Identified in the Lang Lang River Catchment and Their Mean Percentage Composition at Each Site

Taxa	LLR05	LLR06	LLR09	MIN10
Achnanthes clevei	0.0	0.0	0.3	0.0
Achnanthes delicatula	0.0	0.0	0.3	0.0
Achnanthes lanceolata var. *frequentissima*	0.0	0.1	0.0	0.0
Achnanthes lanceolata var. *lanceolatum*	0.0	0.0	0.6	0.0
Achnanthes minutissima	25.3	0.7	0.3	50.5
Amphora lybica	0.0	0.0	0.1	0.8
Cocconeis placentula var. *lineata*	0.4	0.3	0.9	8.1
Cyclotella stelligera	0.0	0.0	0.0	0.2
Entomoneis cranulata	0.0	0.0	0.3	0.0
Eunotia intermedia	0.0	0.1	0.0	0.0
Eunotia pectinalis	0.0	0.0	0.0	0.2
Fragilaria capucina var. *capucina*	0.0	0.1	0.0	0.0
Fragilaria capucina var. *vaucheriae*	23.9	26.7	0.0	0.0
Fragilaria pulchella	0.0	0.3	0.0	0.0
Frustulia vulgaris	0.0	0.3	0.1	0.8
Gomphonema accuminatum	0.4	0.9	0.4	1.4
Gomphonema aff. *gracile*	1.4	3.2	0.5	0.0
Gomphonema angustatum	0.7	0.3	0.0	0.0
Gomphonema angustum	0.7	0.0	0.3	0.2
Gomphonema augor	1.4	0.0	0.0	0.0
Gomphonema cf. *pumillum*	0.0	0.0	0.0	0.2
Gomphonema clavatum	0.4	0.4	0.3	0.0
Gomphonema contraturris	0.0	0.0	0.8	0.0
Gomphonema parvulum	35.1	47.1	42.5	11.4
Gomphonema pseudoaugor	8.8	11.4	0.5	0.0
Gomphonema sp. a	0.4	0.0	0.0	0.0
Gomphonema truncatum var. *capitatum*	0.4	0.0	0.0	0.6
Melosira varians	0.4	4.3	0.6	2.5
Navicula atomus	0.4	0.0	9.2	1.0
Navicula capitata	0.0	0.0	0.5	0.0
Navicula gregaria	0.0	0.0	1.0	1.4
Navicula pupula	0.0	0.0	0.1	0.0
Navicula rhyncocephala	0.0	0.0	0.1	0.4
Navicula schroeterii	0.0	0.0	0.3	0.4
Navicula seminulum	0.0	0.0	16.2	0.0
Navicula sp.	0.0	0.0	1.0	0.0
Navicula veneta	0.0	0.0	0.1	0.8
Navicula virudula	0.0	0.1	4.3	1.9
Nitzschia aguita	0.0	0.0	0.1	0.6
Nitzschia bergii	0.0	0.0	0.0	0.0
Nitzschia clausii	0.0	0.0	0.4	0.8
Nitzschia desertorum	0.0	0.0	0.6	0.0
Nitzschia frustulum	0.0	0.1	0.0	0.0
Nitzschia graciliformis	0.0	0.0	0.3	0.0
Nitzschia inconspicua	0.0	0.0	0.5	0.0
Nitzschia palea?	0.0	0.1	13.6	12.8
Nitzschia sigma	0.0	0.0	0.1	0.0
Nitzschia sp.	0.0	0.0	0.0	0.2
Nitzschia tryblionella?	0.0	0.0	0.1	0.0
Pinnularia sp.	0.0	0.0	0.1	0.0
Rhoicosphenia abbreviata	0.4	0.1	0.3	0.0
Surirella angusta	0.0	0.0	0.3	0.6
Surirella brebisonii var. *kuetzingii*	0.0	0.7	1.5	1.7
Synedra ulna	0.0	2.2	0.6	0.8

8.3 Known Ecological Requirements and Pollution Tolerances of the Dominant Benthic Diatoms in the Lang Lang River Catchment

Achnanthes minutissima

Mainly occurs at a pH values around 7 and conductivities <800 µS/cm^{-1} (Lowe 1974; Denys 1991; Van Dam *et al*. 1994). Typical of low to moderate organic pollution (i.e. BOD_5 between 2 and 4 mg/L) (Lowe 1974; Watanabe *et al*. 1988; Denys 1991; Round 1993; Van Dam *et al*. 1994). Indicator of high dissolved oxygen (Lowe 1974; Denys 1991; Round 1993; Van Dam *et al*. 1994).

Characteristic of moderate (Van Dam *et al*. 1994; Kelly & Whitton 1995) to high nutrient levels (Stevenson *et al*. 1996).

Fragillaria capucina* var. *vaucheriae

Mainly occurs in eutrophic and organically polluted (i.e. BOD_5 between 4 and 13 mg/L), fresh to brackish water, with a pH >7 (Van Dam *et al*. 1994). Tolerates elevated concentrations of organic nitrogen and requires a moderate saturation of dissolved oxygen (i.e. >50%) (Van Dam *et al*. 1994).

Gomphonema parvulum

Typical of eutrophic and organically rich (e.g. BOD5 between 13 and 22 mg/L), fresh to brackish water, with a neutral to slightly alkaline pH (Lowe 1974; Denys 1991; Van Dam *et al.* 1994). Needs periodic elevations in organic nitrogen, has a low dissolved oxygen requirement (e.g. >30% saturation) (Lowe 1974; Denys 1991;Van Dam *et al.* 1994). Most abundant in waters with high concentrations of orthophosphate (i.e. >0.3 mg/L) and is tolerant of organic pollution (Kelly & Whitton 1995).

8.4 Known Ecological Requirements and Pollution Tolerances of the Macroalgae in the Lang Lang River Catchment

Batrachospermum antipodites
The presence of *Batrachospermum* spp. is a good indication of a non-polluted environment (Sonneman 1996). Populations mainly occur in shaded habitats where the surrounding vegetation is natural forest or where there is minimal land disturbance or low nutrient levels (Entwisle 1989a; 1990). However, *Batrachospermum gelatinosum s*eems to tolerate some eutrophication (Fjerdingstad 1965; Entwisle 1989a).

***Chara* spp.**
Mostly found in hard water or alkaline lakes and slowly flowing streams in which calcium is abundant (Prescott 1978; Sainty & Jacobs 1994). Sometimes found in brackish water (Prescott 1978; Entwisle 1994).

Compsopogon coeruleus
Grows in eutrophic waters throughout coastal and near-coastal Australia (Entwisle 1994). Is a potential nuisance weed (possibly introduced) and occasionally abundant during warmer months (Entwisle *et al*.1997). It has been reported in irrigation ditches (Prescott 1978).

Melosira varians
A pH range of 6.4–9.0 with an optimum around 8.5 (Lowe 1974). Tolerates conductivities upto 800 μS/cm (Lowe 1974), but growth may also be stimulated by these conductivities (Foged 1978). Species of *Melosira* are common in urban or slightly eutrophic streams (Entwisle 1994). It is usually considered indicative of eutrophic conditions (Lowe 1974).

When occurring in masses, it is usually an indication of organic pollution (Fjerdingstad 1965). It shows a great range of tolerance to organic pollution, but is generally found in moderately polluted water where the form of nitrogen is mainly as ammonia compounds (Lowe 1974). Maximum growth occurs in summer (Lowe 1974).

Microspora flocculosa
Widespread and usually found during spring and autumn in cool, unpolluted streams (Entwisle 1989a; Entwisle *et al*. 1997).

***Oedogonium* spp.**
Generally, does not occur in polluted waters (Entwisle 1989a), as it is found more in water with moderate nutrient levels (Sonneman 1996). Growths are apparent all year round, but some species are more seasonal (Entwisle 1989b). *Oedogonium* sp. MFG is generally found in autumn, winter and spring in the upper part of the Yarra catchment where there was some disturbance (Entwisle 1989a). *Oedogonium* sp. BFG was found in the upper and middle areas of the Yarra catchment (Entwisle 1989a).

Pseudanabaena sp.
Some species of *Pseudanabaena* (especially *P. catenata*) are characteristic of heavily polluted waters when found in large numbers (Fjerdingstad 1965).

Rhizoclonium sp.
Generally found in alkaline and/or saline streams and is common in estuaries (Entwisle *et al.* 1997). It may cause nuisance growths and dominate in enriched streams (Stevenson *et al*. 1996). Characteristically, it is found growing on large stable substrata in fast currents (Stevenson *et al*. 1996).

***Spirogyra* spp.**

Is found mostly in streams with some eutrophication (Entwisle 1989a; Sonneman 1996). The presence of large growths is usually the result from some form of nutrient enrichment (Sonneman 1996).

It is common in autumn and rare in summer, as it is mostly restricted to the upper parts of the Yarra catchment in streams with little pollution (Entwisle 1989b).

Stigeoclonium spp.

S. tenue can tolerate a wide range of eutrophication (Entwisle 1989a). It is common in organically polluted streams, but is not restricted to the environment (Entwisle 1989b).

Generally found in temperatures ranging 8–25^oC (Entwisle 1989a). Temperatures >20^oC are known to be detrimental to the growth of this species, with death occurring at temperatures >25^oC (Entwisle 1989a).

Commonly occurs in cooler months, when there is always some physical disturbance at its site (Entwisle 1989a). It is found in various areas ranging from urban creeks to pristine mountain streams, and is tolerant of metals (Entwisle 1989a).

***Vaucheria* spp.**

Prefers cool, shaded and slightly alkaline water (Johansson 1982; Entwisle 1989b). Commonly found in waters with a conductivity range of 140 to 320 $\mu S/cm^{-1}$ (Johansson 1982). May thrive in moderately polluted waters, but is generally present in non-polluted waters (Fjerdingstad 1965; Entwisle 1989b). If the water is highly aerated it may withstand higher pollution levels (Johansson 1982).

When found growing as large mats in flowing water, it is indicative of a moderate level of eutrophication (Entwisle 1989b). It is thought not to tolerate extreme eutrophication, but does require a substantial input of nutrients for growth (Entwisle 1989b). Its distribution is closely linked with agricultural land use, particularly in Diamond Creek (Entwisle 1989b). Generally, it has a maximum growth in winter and spring, but this depends on the species (Entwisle 1989b).

***Zygnema* spp.**

Zygnema spp. is found in still or slow-flowing, freshwater habitats (Entwisle *et al.*. 1997), in autumn, winter and spring in cool water (Entwisle 1989b). It is widely distributed throughout the Yarra River Basin, but is generally not abundant (Entwisle 1989a). Although in the Yarra River Basin, *Zygnema* spp. are mostly found in oligotrophic sites, it can, apparently, withstand some eutrophication (Entwisle 1989a).

Appendix 8.5 The Macroinvertebrates from Pools in the Lang Lang River Downstream of Patullos Road, Yannathan and Two Sites on the Little Lang Lang River

Taxa	LLG01	LLG01	LLL03	LLL03	LLL04	LLG05	LLG05
	12/02/97	20/03/98	9/12/97	20/03/98	8/12/97	8/12/97	20/03/98
All Turbellaria			3				6
Planorbidae/Physidae spp.			8	9	27	5	1
Hydrobiidae spp.	20	18	30	1	14	13	12
*Pisidium casertanu*m			20	5		1	
Sphaerium tasmanicum	1				1		10
Corbiculina australis							
Glossiphonidae unidentified		2		1			
Oligochaeta (all unidentified spp.)	1	1	5	8			
All unidentified mites		1			9	2	
Afrochiltonia spp.	2	20	1		29	15	3
Austrogammarus multispinatus					7		
Cymodetta sp.	11	6					
Paratya australiensis						20	23
Cherax spp.					2		
Amarinus lacustris	1	1					
Chostonectes sharpi ?A					7		
Chostonectes sp. (L)					15		
Antiporus spp. (L)					2		1
Sternopriscus females						1	
Necterosoma penicullatus					2		2
Necterosoma (L)					1	4	
Liodessus praelargus	1						
Rhantus saturalis (A)					2		
Rhantus sp. (L)					1		
Gyrinidae SRV sp. 1 (L)					1		
Anacaena unident (females)						1	
Enochrus				1			
Helochares australis		3		1			
Limnoxenus MDFRC sp. 2 (A)					1		
Paracymus pygmaeus		1			1		
Hydraena unidentified				1			
Scirtidae unidentified				3	1		1
Austrolimnius NMV L58E						1	
Notriolus quadriplagiatus	1					1	
Notriolus victoriensis	2						
Anopheles annulipes					1		
Culex sp.					2		
Immature *Ceratopogonidae*		1					
Apsectrotanypus spp.				1			
Procladius spp. (NMV sp. 66)			1		7	3	1
Ablabesmyia spp.					1	2	
Paramerina levidensis						19	
Pentaneura spp.							1
Thienemanniella trivitatta	2						
Corynoneura spp.			1				
Cladotanytarsus spp.						12	

Taxa	LLG01	LLG01	LLL03	LLL03	LLL04	LLG05	LLG05
	12/02/97	20/03/98	9/12/97	20/03/98	8/12/97	8/12/97	20/03/98
Tanytarsus spp.					2	0	
Paratanytarsus spp.		6			2	4	
Rheotanytarsus sp.	2					1	
Chironomus spp.		13	23	24	3	2	
Dicrotendipes spp.					1		
Kiefferulus spp.					1		
Polypedilum spp.		1				9	
Chironomini unidentified						2	
Cloeon spp.							15
Centroptilum sp.							3
Immature *Leptophlebiidae*	1					3	
Atalophlebia MMBW sp. 3/13						5	
Atalophlebia MMBW sp. 5/11					50	4	
Koornonga sp. A1						5	
Nousia spp.	1					4	
Caenidae unidentified						4	
Microvelia paramoena	1			3			2
Microvelia (females)				4			1
Immature *Veliidae*			5		4	2	
Sigara truncatipala				4	2		
Sigara unid (inc.females)			1		3	1	5
Micronecta unid (inc.females)						16	10
Immature *Corixidae*					6	55	
Immature *Corixidae*							5
Enithares bergrothi				4			3
Anisops (female)							3
Immature *Anisops*					4	2	
Anisops							1
Immature *Notonectid*			1		3		
Ischnura heterosticta			1		1	2	
Immature *Ischnura*		2					
Immature *Coenagrionidae*							7
Argiolestes icteromelas						1	
Synlestes tillyardi						4	
Immature *Aeshnidae*							1
Hellyethira simplex complex					1	6	1
Notalina spira						7	
Costora spp.	4						
Triplectides australis	1				1		
Immature *Triplectides*						4	
Immature *Trichoptera*							1
Grand total	**52**	**76**	**100**	**70**	**218**	**243**	**119**
No. taxa	**16**	**14**	**13**	**15**	**37**	**37**	**25**

Appendix 8.6 The Macroinvertebrates Collected from Pool Sites on Minnieburn (MIN), Pheasant (PHE) and Adams (ADM) Creeks

Taxa	**MIN10**	**MIN10**	**PHE07**	**PHE08**	**PHE13**	**ADM02**	**ADM02**
	4/12/97	19/03/98	8/12/97	8/12/97	19/03/98	3/12/97	20/03/98
All *Turbellaria*			1				
Planorbidae/Physidae spp.	2	5	12	8	10	1	
Hydrobiidae spp.	2		2	17			
Corbiculina australis		4					
Pisidium casertanum			7	11			
Glossiphonidae unidentified	1			2			25
Oligochaeta (all unidentified spp.)		1	6			19	16
All unidentified mites	2		1				
Afrochiltonia spp.	28	32	17	200	24		
Austrogammarus sp.					1		
Immature *Amphipoda*	5						
Paratya australiensis	12	4					
Euastacus cf. *yarrensis*		1					
Chostonectes johnstoni					2		
Chostonectes gigas (A & L)					1		1
Chostonectes sharpi ?A			12	1			
Chostonectes sp. (L)			7				
Sternopriscus (females)							1
Necterosoma penicullatus		2		4			1
Necterosoma regulare (A)					6		
Necterosoma (L)				3			
Rhantus saturalis (A)					1		
Rhantus sp. (L)							1
Helochares australis							1
Hydrophilidae sp. (L)						1	
Ochthebius australis			1				
Scirtidae unidentified	1		1	7			4
Austrolimnius sp. (A)	2						
Notriolus quadriplagiatus NMV L43E	1						
Immature *Notriolus/Simsonia*			1				
Tipulidae SRV sp. 46		1					
Dixidae MV sp. 1	1						
Culicidae unidentified				1			
Culicini			1				
Sciomyzidae unidentified			1				
Unknown *Muscidae*						1	
Dipteran pupae						1	
Coelopynia pruinosa NMV sp 67		5					
Apsectrotanypus spp.	1	5					
Procladius spp. (NMV sp. 66)			3	18			
Ablabesmyia spp.	1	3					
Paramerina levidensis SRV sp. 67		1					
Pentaneurini genus D	1						
Thienemanniella trivatatta	1						
Cricotopus/Paratrichocladius sp.	13						
Riethia spp.			1				
Tanytarsus spp.	1						
Paratanytarsus spp.	5					2	

Taxa	MIN10	MIN10	PHE07	PHE08	PHE13	ADM02	ADM02
	4/12/97	19/03/98	8/12/97	8/12/97	19/03/98	3/12/97	20/03/98
Rheotanytarsus sp.	7						
Chironomus spp.	3		15	23	1	45	9
Kiefferulus spp.							1
Polypedilum spp.	21		2			1	
Immature *Chironomini*							1
Damaged *Chironomidae*						1	1
Immature *Chironomidae*	3		1				
Chironomidae pupae	1		1				
Cloeon spp.		1					
Immature *Atalophlebia*			5				
Atalophelbia MMBW 9/NMV 4	3						
Atalophlebia MMBW sp. 5/11	14		77	81			
Koornonga sp. A1	2		20				
Ulmerophlebia sp. A2 (MV sp. 1)	12						
Ulmerophlebia sp. A1 (MV sp. 2)		2					
Damaged *Leptophlebiidae*	1						
Leptophlebiidae				7			
Caenidae unidentified	4						
Microvelia paramoena			1			3	
Microvelia (females)		2					4
Immature *Veliidae*	1		3	1			
Sigara sublaevifrons			2				
Sigara unid (inc.females)	3		2	2			1
Immature *Micronecta*	12						
Micronecta unid (inc.females)	15	20					
Immature *Corixidae*				5			
Immature *Sigara-Agraptocorixa*			2				
Enithares bergrothi (now *E.woodwardi*)	1	2		3			
Anisops doris					1		
Immature *Notonectid*			1				
Ischnura heterosticta		9		18			
Xanthagrion erythroneurum			1				
Immature *Coenagrionidae*				10			
Austrolestes annulosus				5			
Austrolestes leda				1			
Argiolestes icteromelas	1						
Synlestes weyersi	10		6				
Immature *Synlestes*	9						
Austroaeschna unicornis	1						
Immature *Austrogomphus*	1						
Procordulia/Hemicordulia complex	1						
Dinotoperla fontana	1						
Taschorema evansi	2						
Taschorema complex	1						
Costora spp.	7						
Aphilorheithrus SRV sp. 2		2					
Marilia fusca	3	1					
Notalina spira		2					
Triplectides australis	2						
Triplectides ciuskus	1	10					
Triplectides similis		1					
Immature *Triplectides*		1					
Grand total	**223**	**117**	**213**	**428**	**47**	**75**	**67**
No. taxa	**47**	**24**	**31**	**22**	**9**	**10**	**14**

Appendix 8.7 The Macroinvertebrates Collected from Pools on the Lang Lang River Upstream of Heath Hill

TAXA	LLG06	LLG06	LLG09	LLG09	LLG11	LLG11	LLG12	LLG12
	8/12/97	20/03/98	31/10/97	19/03/98	4/12/97	19/03/98	8/12/97	19/03/98
All *Turbellaria*				1	1	5		1
Planorbidae/Physidae spp.	1	1			4	4	38	17
Hydrobiidae spp.	7	2			212	20	3	
Gyraulus tasmanicus	3							
Corbiculina australis		17						
Pisidium casertanum					17	4	9	1
Immature *Bivalvia*					17			
Glossiphonidae unidentified		1				1		1
Oligochaeta (all unidentified spp.)	1	1		3	11	5	40	20
All unidentified mites	17	1		1	2		9	4
Afrochiltonia spp.	15	9	17	6	47	2	31	13
Immature *Amphipoda*					11			
Paratya australiensis	21	23	9	5	9	10		
Immature *Atyidae*	20				1			
Euastacus sp.				1				
Chostonected gigas (A & L)								4
Chostonectes sharpi ?A							1	
Chostonectes sp. (L)							1	10
Antiporus (females)		2						1
Necterosoma penicullatus	4	9			9	1	2	4
Necterosoma (L)	3				1			
Platynectes decempunctatus								1
Rhantus saturalis (A)							2	
Hydrophilidae sp (L)	1							
Ochthebius australis	1							
Unidentified *Scirtidae*				1	2			
Austrolimnius sp. (A)			8	3				
Austrolimnius NMV L58E						1		
Notriolus quadriplagiatus			7	1				
Notriolus victoriae				2				
Coxelmis novemnotata	1							
Tipulidae SRV sp. 46			2					
Anopheles annulipes	1							
Simulium ornatipes				25				
Immature *Simuliidae*				11				
Coelopynia pruinosa		1						
Procladius spp. (NMV sp. 66)	17	18			15	3	10	41
Ablabesmyia spp.	8	1						
Paramerina levidensis	8	1		1				
Immature *Tanypodinae*	1							
Corynoneura spp.							1	
Thienemanniella trivatatta			5					
Cricotopus spp.				2				
'grape th' SRV sp. 38				1				
Nannocladius SRV sp.10			2					
Cricotopus/Paratrichocladius	3							
Paralimnophyes sp.			1					
Riethia spp.		3						

TAXA	LLG06	LLG06	LLG09	LLG09	LLG11	LLG11	LLG12	LLG12
	8/12/97	20/03/98	31/10/97	19/03/98	4/12/97	19/03/98	8/12/97	19/03/98
Cladotanytarsus spp.	6	1						
Tanytarsus spp.	8	1	1					
Paratanytarsus spp.				3			5	
Rheotanytarsus sp.	1		22	2				
Chironomus spp.	5	1			10	17	122	4
Kiefferulus spp.						3		
Polypedilum spp.	29		33	1			2	
Paracladopelma spp.					1			
Immature *Chironomini*	1	2						
Immature *Chironomidae*	8							
Baetis MV sp. 5			4	6				
Baetis MV sp. 6				7				
Immature *Atalophlebia*	1							
Atalophlebia MMBW sp. 3/13	9	2	2	1				
Atalophlebia MMBW sp. 9			9					
Atalophlebia MMBW sp. 5/11	2				16		42	
Austrophlebioides pusillus				9				
Nousia sp. A1 (MV sp. 2)			6	23				
Koornonga sp. A1	20		1	1	3		8	
Jappa sp. A1				1				
Ulmerophlebia sp. A2	1		4					
Damaged *Leptophlebiidae*							1	
Immature *Leptophlebiidae*	2		1	1				
Caenidae unidentified			2	1				
Microvelia paramoena	2	1						
Microvelia fluvialis		1						1
Microvelia (females)	3			1	1			1
Immature *Veliidae*	2				1			
Sigara sublaevifrons							1	
Sigara truncatipala		1						2
Sigara unid (inc. females)	1	1			1	4	8	2
Agraptocorixa eurynome								1
Agraptocorixa (females)					1			
Immature *Micronecta*	36				3			
Micronecta unid	13	28	9					1
Immature *Corixidae*						2		
Immmature *Sigara-Agraptocorixa*					1		2	
Enithares bergrothi		2				5		
Anisops deanei		3				7		
Anisops (female)		6			2	5		4
Immature *Anisops*						11		
Archicauliodes sp.				4				
Austroagrion cyane					1		2	
Ischnura heterosticta			2		1			
Xanthagrion erythroneurum							5	
Immature *Coenagrionidae*					4			
Austrolestes annulosus						15	2	
Argiolestes icteromelas			1		2			
Synlestes weyersi	2		4					
Aeshna brevistyla					1			
Austroaeschna unicornis		2						

TAXA	LLG06	LLG06	LLG09	LLG09	LLG11	LLG11	LLG12	LLG12
	8/12/97	20/03/98	31/10/97	19/03/98	4/12/97	19/03/98	8/12/97	19/03/98
Procordulia/Hemicordulia							1	
Dinotoperla brevipennis			2					
Austrocercella/Austrocercoides					1			
Taschorema evansi				3				
Hellyethira simplex complex	1							
Asmicridea MMBW sp 1				6				
Immature *Hydropsychidae*					1			
Lingora spp.				1				
Immature *Philorheithridae*					1			
Marilia fusca			5					
Atriplectides dubius					1			
Anisocentropus sp.	1		2					
Notalina spira	1							
Triplectides australis			8					
Triplectides ciuskus	1		1		1	4		
Triplectides similis	1							
Oecetis spp.			1					
Immature *Triplectides*					21			
Immature *Leptoceridae*						1		
Grand total	**290**	**142**	**171**	**135**	**434**	**130**	**348**	**134**
No. taxa	**44**	**29**	**29**	**32**	**37**	**22**	**25**	**21**