

# **Upper Parramatta River Catchment Trust**

## **Water Quality of Upper Parramatta River**

**Analysis of Data Collected between 1990 and 1998**

by

**John H. Laxton**

**January 1999**

**J.H. & E.S. Laxton - Environmental Consultants P/L  
170 Warrimoo Avenue, St Ives, Sydney, 2075. Australia**

**Telephone (02) 9449 7846**

---

## Summary of Findings

- Stations in the upper Parramatta River, Duck River, Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River above Marsden Weir were sampled monthly from 1990 to 1998. Twenty five water quality parameters were sampled in surface and bottom water (Stations 1-4 only).
- Mean water temperatures at all stations were similar over the nine years sampled. A temperature range of 9-26°C
- The saline sections of the upper Parramatta River and Duck River exhibited a wide range of salinity values in 1998 due to above average rainfall. Surface water values ranged from 0.14 to 34.98 ppt.
- There were large seasonal changes in dissolved oxygen concentration in the creeks and saline sections of the water bodies in 1998. Dissolved oxygen levels fell to 3.4% of saturation in the saline section of the rivers in 1998. Dissolved oxygen levels in the creeks fell to 27.8% of saturation during 1998.
- There were wide fluctuations in nutrient concentrations in all the water bodies sampled. Annual mean values were at least two times higher than were recommended for the protection of aquatic ecosystems.
- Water clarity was generally lower than usual in the tidal sections of the upper Parramatta River and Duck River due to the below average rainfall. The creeks carried high quantities of suspended material during wet weather. Toongabbie Creek was also turbid in dry weather due to high phytoplankton standing crop and inorganic suspended solids.
- Annual mean chlorophyll-a concentrations were relatively low in the saline reaches of upper Parramatta River and Duck River over the period 1996 to 1998. Annual mean chlorophyll-a levels in the freshwater creeks were also quite low in the years 1996 to 1998.
- Faecal coliform bacteria concentrations at all Stations sampled were relatively high during 1998 due to the above average rainfall.
- The ecology of the upper Parramatta River system was found to be very productive and dynamic. Large fish populations were supported as were flocks of aquatic birds. The ecology, however, was considered to be too finely balanced to survive any upset such as prolonged cloudy weather or a chemical spill which killed sensitive species. Dissolved oxygen depletion was thought to be the most likely result of any perturbation.
- Using guidelines issued by the SPCC (now EPA) and ANZECC it was found that the waters of the upper Parramatta River system failed to meet most of the criteria for Primary Contact Recreation, Secondary Contact Recreation and Passive Recreation in 1990 to 1998. Lake Parramatta, however, complied with most criteria for each level of recreation particularly during dry weather.

---

# Table of Contents

Summary	2
Table of Contents	3
List of Tables	5
List of Figures	6
Introduction	7
Sampling Strategy	8
Location of Sampling Stations	9
Parameters Sampled	10
Methods Used	11
Ecological significance of Parameters	16
Proposed Water Quality Criteria	21
Results	30
Rainfall	30
Water temperature	31
Salinity	33
Specific gravity	35
pH	37
Dissolved oxygen	39
Nutrients	43
Ammonia	43
Organic nitrogen	45
Oxidized nitrogen	47
Total nitrogen	49
Orthophosphate	51
Total phosphorus	54
Water clarity	56
Turbidity	56
Percentage transmission of light	59
Concentration of total suspended solids	61
Concentration of volatile suspended solids	61
Secchi disc	64
Chlorophyll-a concentration	66
Faecal coliform bacteria	68

---

# Table of Contents

Discussion	70
Ecology of the river system	70
Comparison of Upper Parramatta River with suggested water quality criteria to protect aquatic ecosystems.	73
Upper Parramatta River - Suitability for Recreation	82
Comment on water quality in 1996	90
List of References	91
Acknowledgements	92

---

## List of Tables

Table A	ANZECC Guidelines for the Protection of Aquatic Ecosystems	21
Table B	ANZECC Water Quality Characteristics Relevant to Recreational Use	22
Table C	Summary of ANZECC Water Quality Guidelines for Recreational Waters	23
Table 1	Temperature values (1998)	32
Table 2	Salinity values (1998)	34
Table 3	Specific gravity (1998)	36
Table 4	pH values (1998)	38
Table 5	Dissolved oxygen (Percentage Saturation)	40
Table 6	Dissolved oxygen (mg/L)	41
Table 7	Ammonia concentrations (1998)	44
Table 8	Organic nitrogen concentrations (1998)	46
Table 9	Oxidized nitrogen concentrations (1998)	48
Table 10	Total nitrogen concentrations (1998)	50
Table 11	Orthophosphate concentrations (1998)	53
Table 12	Total phosphorus (1998)	55
Table 13	Turbidity (1998)	58
Table 14	Percentage transmission of light through water (1998)	60
Table 15	Total suspended solids (1998)	62
Table 16	Volatile suspended solids (1998)	63
Table 17	Secchi depth (1998)	65
Table 18	Chlorophyll-a concentration (1998)	67
Table 19	Faecal coliform bacteria concentrations (1998)	69
Table 20	Water quality criteria and compliance - level 2	84
Table 21	Water quality criteria and compliance - Level 3	86
Table 22	Water quality criteria and compliance - Level 4 :	88

---

## List of Figures (see Appendix A)

Figure 1	Location of sampling stations	1
Figure 2	Rainfall (1990 - 1995)	2
Figure 3	Rainfall (1996 - 1998)	3
Figure 4	Water temperatures (1990-1998)	4
Figure 5	Annual mean water temperature changes (1990-1998)	5
Figure 6	Salinity changes (1990-1998)	6
Figure 7	Annual mean salinity changes (1990-1998)	7
Figure 8	pH values - Parramatta River	8
Figure 9	Annual mean pH changes (1990-1998)	9
Figure 10	Dissolved oxygen changes in Parramatta River	10
Figure 11	Dissolved oxygen changes in Duck River	11
Figure 12	Dissolved oxygen changes in tributary creeks	12
Figure 13	Annual mean changes in dissolved oxygen	13
Figure 14	Changes in ammonia concentration in the estuary	14
Figure 15	Changes in ammonia concentration in tributary creeks	15
Figure 16	Annual mean ammonia values (1990-1998)	16
Figure 17	Changes in organic nitrogen concentration in the estuary	17
Figure 18	Changes in organic nitrogen concentration in creeks	18
Figure 19	Annual mean organic nitrogen values (1990-1998)	19
Figure 20	Changes in oxidized nitrogen concentration in the estuary	20
Figure 21	Changes in oxidized nitrogen concentration in creeks	21
Figure 22	Annual mean oxidized nitrogen values (1990-1998)	22
Figure 23	Changes in total nitrogen concentration in the estuary	23
Figure 24	Changes in total nitrogen concentration in creeks	24
Figure 25	Annual mean total nitrogen values (1990-1998)	25
Figure 26	Changes in orthophosphate concentration in the estuary	26
Figure 27	Changes in orthophosphate concentration in the creeks	27
Figure 28	Annual mean orthophosphate values (1990-1998)	28
Figure 29	Changes in total phosphorus concentration in the estuary	29
Figure 30	Changes in total phosphorus concentration in creeks	30
Figure 31	Annual mean changes in total phosphorus (1990-98)	31
Figure 32	Changes in turbidity in the estuary	32
Figure 33	Changes in turbidity in the creeks	33
Figure 34	Annual mean changes in turbidity	34
Figure 35	Changes in percentage transmission of light in the estuary	35
Figure 36	Changes in percentage transmission of light in creeks	36
Figure 37	Annual mean percentage transmission of light changes	37
Figure 38	TSS changes in the estuary	38
Figure 39	TSS changes in creeks	39
Figure 40	Annual mean changes in TSS (1990-1998)	40
Figure 41	Changes in Secchi depth (m) in the estuary	41
Figure 42	Changes in Chlorophyll-a concentration in the estuary	42
Figure 43	Changes in Chlorophyll-a concentration in creeks	42

---

## Introduction

In late 1989 Mr Steve Stickney, Editor of the Parramatta Advertiser commissioned a study of the water quality of the upper Parramatta River and its three major tributaries. The purpose of the study was to determine the present environmental health of the river and to bring this information to the attention of the residents of the area through a series of articles in the Parramatta Advertiser. The Parramatta Advertiser funded the study from January to November 1990 until the programme was taken over by the Upper Parramatta River Catchment Trust. Between 1991 and 1999 the study was administered and funded by the Trust. The water quality monitoring programme is continuing in 1999.

Shell Refining (Australia) Pty. Ltd. operates a facility at Clyde NSW. The plant is located on land bounded by Duck River and Parramatta River. Shell has a licence to discharge treated wastewater into Duck River. J.H. & E.S. Laxton- Environmental Consultants was engaged by Shell to monitor the effects of this outfall on Duck River and the upper Parramatta River.

This report presents the results of investigations carried out up until December 1998.

This monitoring programme has now accumulated 9 full years of data so it is now possible to determine whether any longer term trends in water quality have occurred over the sampling period. A chapter on the ecological significance of the water quality parameters measured is included. Also a set of water quality criteria for the protection of aquatic ecosystems were developed by this firm for fresh and estuarine water of NSW. These criteria are based on data collected in studies carried out by this firm over the period 1977 to 1998 and attempt to establish the conditions that may have existed in the coastal drainages of NSW (those draining to the Tasman Sea) prior to 1788. It also proposes a method of calculating statistics for each water quality parameter to determine compliance or non-compliance with the suggested criteria. These suggested water quality criteria have been applied to the freshwater tributaries and estuarine waters of the upper Parramatta River and Duck River.

---

## Sampling Strategy

Sampling of the upper Parramatta River and its major tributaries was monthly between January 1990 and December 1998. The purpose of this part of the study was to determine the annual range of variation in water quality parameters brought about by seasonal changes and extremes of weather. Now that 9 full years of information have been accumulated the data may be examined for any longer term trends in water quality.

A Station located in Duck River at the outfall from the Shell Refinery was also sampled monthly. In addition, each month grab samples of biotreater effluent from the Refinery were collected to form a composite water sample over 5 consecutive days.

The distribution of sampling stations in the upper Parramatta River system allowed inputs from each major tributary to be determined and compared with that of the treated wastewater from the Shell Refinery. To assist this assessment two further stations were added to the Sampling schedule in January 1995. The first was located on Duck River (Station 11) where it crossed Parramatta Road and the second was located on Duck Creek where it crossed Memorial Drive (Station 12).

---

# Location of Sampling Stations

After the Upper Parramatta Catchment Trust took over the sampling programme changes were made to locations of some sampling stations. The stations were shifted to sites of Trust stream gauging stations.

Twelve stations were sampled in 1998. The locations of all the stations are shown in Figure 1. Where changes in station location were made these will be explained below.

## Estuarine Stations

- Station 1** Parramatta River, just downstream of Silverwater Bridge
- Station 2** Duck River, under second overhead pipeline near the Lubizol plant.
- Station 3** Duck River, just downstream of the Western Freeway bridge.
- Station 4** Parramatta River, opposite the stern of HMAS Parramatta. When dredging of the upper Parramatta River commenced in 1992, this station was shifted progressively downstream until it was located at the railway bridge. In 1994, with the opening of the river, this station was moved upstream once more to its original position.

## Freshwater Stations

- Station 5.** Toongabbie Creek at Redbank Road bridge (1991). It was Finlayson's Creek (tributary to Toongabbie Creek) at Briens Road in 1990.
- Station 6** Darling Mills Creek behind Parramatta Jail at Board Street. This station was at Northmead High School (Campbell Street) in 1990.
- Station 7** Lake Parramatta at overflow into Hunts Creek.
- Station 8** Parramatta River at Marsden Street weir.

## Shell Stations

- Station 9** Shell Refinery wastewater outfall on Duck Creek.
- Station 10** Effluent from the biotreater at the Shell Refinery.
- Station 11.** Upper Duck River (Parramatta Road Crossing) Water at this station is saline in dry weather and fresh in wet weather.
- Station 12.** Upper Duck Creek (freshwater). At crossing on Memorial Drive.

## Go to Appendix A

- Page 1.** **Figure 1. Location of Sampling Stations in Upper Parramatta River and Duck Creek.**

---

# Parameters Sampled

The following parameters were sampled :

Date and time.

Weather (a description of wind speed & direction, cloud cover and previous recent rainfall).

Secchi disc depth (a means of determining water clarity). Used at stations in the estuary sampled by boat (Stations 1-4).

Profiles from surface to bottom at 0.5 m intervals using a calibrated Submerged Datalogger.

Temperature (degrees Celsius).

Conductivity (millsiemens per cm)

Salinity (parts per thousand)

pH

Dissolved oxygen (Percentage Saturation)

Dissolved oxygen (mg/litre).

Specific gravity

Turbidity (Nephelometric Turbidity Units)

Oxidation/Reduction Potential (ORP) commenced November 1997(mV)

In samples of surface and bottom water

Percentage transmission of light through water.

Nutrients

Ammonia (determined directly)

Total Kjeldahl nitrogen (determined directly)

Organic nitrogen (determined by subtraction of ammonia from TKN).

Nitrite (determined directly)

Nitrate (determined directly)

Oxidized nitrogen (sum of nitrite and nitrate)

Total nitrogen (sum of ammonia, TKN and oxidized

nitrogen)

Orthophosphate (determined directly)

Total phosphorus (determined directly)

Ratio of oxidized nitrogen to orthophosphate (calculated in micromoles and in micrograms per litre).

Ratio of Total nitrogen to total phosphorus

(calculated in micromoles and in micrograms per litre).

Phytoplankton standing crop (chlorophyll-a, micrograms per litre)

Concentration of suspended solids (SS), mg per litre.

Concentration of volatile suspended solids (VSS), mg per litre.

In samples of surface water only

Concentration of faecal coliform bacteria (number per 100 ml).

---

# Methods Used

## Profile measurement

Temperature, conductivity, salinity, pH, dissolved oxygen, specific gravity and turbidity profiles were measured using a calibrated Yeo-Kal Submerged Datalogger (Model 606) used in direct sampling mode. In November 1997 this instrument was replaced by a Yeo-Kal Model 612. The instruments were calibrated for each parameter.

Temperature	Using a standard thermometer and the calibration equations.
Salinity	Using standard seawater.
pH	Using buffer solutions of known pH and the calibration equations.
Dissolved oxygen	Using a zero point (shorting out the probe-606 or Na <sub>2</sub> SO <sub>3</sub> -612) and a 100% saturation point (obtained by aeration of water) and the calibration equations.
Turbidity	Using formazin standard (200 NTU and a zero point).
ORP	Using standard solutions of ORP 86mV and 263 mV.

## Surface and bottom water samples

### **Collection of samples**

In the Parramatta River surface water samples were collected by a submersible plastic 12 volt pump mounted just below water level on the transom of the boat. Water was delivered to the work bench by a polythene tube. Care was taken to run the pump long enough to ensure that the tube had been cleared of water from a previous station. The following surface water samples were collected :

- A 500 mL sample of water for determination of percentage transmission of light through water (laboratory) and the remainder as reserve water in case of an accident in the laboratory.
- A 1 litre sample was collected for determination of concentration of total suspended solids (TSS) and volatile suspended solids (VSS).
- A further 1 litre sample was placed directly in a pressure filtration vessel fitted with a 25 mm filter holder. The material collected on the 25 mm glass fibre filter was used to determine the concentration of chlorophyll-a. The volume of water retained by the second chamber of the apparatus was measured and recorded.
- A 500 mL sample of water was placed directly in a second pressure filtration vessel fitted with a 47 mm filter holder. A glass fibre prefilter and a membrane filter were used. About 200 mL of water was flushed through these filters to waste before a further 200 mL was retained in the second chamber of the apparatus for analysis of nitrite, nitrate and orthophosphate.
- A 110 mL sample was collected in a sterile Kayline bottle for later determination of faecal coliform bacteria concentration.
- 60 mL of water was collected from the delivery pipe in a well washed calibrated syringe. 20 mL of water was dispensed into a 50 mL test tube with screw capped top (ammonia determination) and the remaining 40 mL was placed in a second test tube (total Kjeldahl nitrogen and total phosphorus determinations).

Water samples from the creeks were collected from the bank or from bridges in a clean, rinsed 10 litre plastic bucket. Water from the bucket was dispensed into the above listed containers before the submerged datalogger was placed in the bucket (which was resting on a 25 mm thick glass plate-606 instrument only) to record temperature, salinity, pH, dissolved oxygen, specific gravity and turbidity. The SDL 606 was held above the bottom of the bucket (to prevent interference to the conductivity cell) and the turbidity sensor was kept away from the edge of the container (to avoid interference). These procedures were not required when using the Yeo-Kal 612 submerged datalogger.

Bottom water samples were collected at each station in the Parramatta River (Stations 1-4) using a 4 L water sampler. Unfiltered water was used for the determination of ammonia, TKN and total phosphorus. Water filtered through the glass fibre pre-filter and membrane filter was retained for nitrite, nitrate and orthophosphate analysis. Care was taken to flush these filters adequately to ensure that any nitrogen or phosphorus containing compounds were removed and that remnants of a previous sample was eliminated. One litre of water was filtered through a 25 mm glass fibre filter for later Chlorophyll-a determination and another litre of water was filtered through a weighed 47 mm glass fibre filter for total and volatile suspended solids measurement.

#### **Pre-treatment of samples in the field.**

Twenty mL aliquates of whole water for determination of ammonia and 40 mL for total Kjeldahl nitrogen and total phosphorus determinations were dispensed into screw capped pyrex tubes from a 60 mL syringe. Extreme care was taken to rinse the outside and inside of this syringe in running seawater each time it was used to ensure that it was not contaminated by ammonium chloride used in another part of the shipboard procedure.

The tubes for ammonia, and TKN and total phosphorus determination contained 2 drops of concentrated ammonia free sulphuric acid.

Water for nitrite, nitrate and orthophosphate determination was filtered through a 42 mm glass fibre pre-filter (Millipore Corp. Cat. No. AP20 042 00) backed by a 47 mm membrane filter (Millipore Corp. Cat. No. HCWG 047 Pore size 0.7 microns). As these filters appeared to yield nitrite it was essential that they were thoroughly flushed using either distilled water or filtered natural water.

A twenty mL aliquat of filtered water for nitrite determination was added to a screw capped pyrex tube containing 0.5 mL of 35% ammonium chloride solution. A further 100 mL of filtered water for nitrate determination was added to a 100 mL plastic volumetric flask containing 2.5 mL of 35% ammonium chloride solution. Twenty mL of filtered water was placed into a screw capped pyrex tube for orthophosphate determination.

#### **Analytical methods**

##### **Percentage transmission of light through water.**

Two 50 mm path length cuvettes were filled with filtered sample water (filtered through 25 mm HAWP 02500 membranes). Cuvettes were placed in the cell chamber of a Varian DMS 80 Spectrophotometer and the controls set to read 100 percent transmission (at 750 nm and 2 nm slit width). The contents of the sample cell were then replaced with whole water and the percentage transmission read.

### **Ammonia concentration.**

In the field a 20 mL sample of unfiltered surface or bottom water was added to a tube containing 2 drops of ammonia-free concentrated sulphuric acid to preserve the sample. Tubes were then stored in the dark at 4°C while awaiting further treatment. As soon as possible after collection the samples were analysed for ammonia using the technique described in Report No 55 Laboratory Techniques in Marine Chemistry II. Determination of ammonia in seawater and the preservation of samples for nitrate analysis. G. Dal Pont, M. Hogan and B. Newell. CSIRO Division of Fisheries and Oceanography.

Briefly, 2 mL of tri-sodium citrate buffer was added to each sample before it was neutralized with sodium hydroxide using bromocresol purple indicator. Then, 0.7 mL of phenol-nitroprusside reagent and 0.7 mL of oxidizing reagent was added and mixed thoroughly. The blue colour was allowed to develop for at least 2 hours before the absorbance was read at 630 nm.

Standards containing 1000, 500 and 100 micrograms per litre of nitrogen were prepared from standard ammonium chloride in 3.5% sodium chloride solution and treated in the same manner as the samples. Ammonia-free distilled water samples and 3.5% sodium chloride solution samples were prepared similarly as blanks.

### **Total kjeldahl nitrogen.**

Kjeldahl nitrogen is the sum of free ammonia and organic nitrogen compounds converted to ammonium sulphate by the digestion procedure.

In the field 40 mL of unfiltered water was added to a tube containing 2 drops of concentrated ammonia-free sulphuric acid to preserve the sample. Prior to further treatment, the tubes were kept in the dark at 4°C. The analysis was completed as soon as possible after the samples were collected.

In the laboratory each sample was transferred to a 75 mL pyrex digestion tube. 2 mL of Kjeldahl digestion reagent ( $K_2SO_4$ ,  $H_2SO_4$  and  $HgO$ ) and 2 or 3 glass anti-bumping chips were added. The digestion tubes were then placed in a thermostatically controlled aluminium heating block. Initially the samples were evaporated to dryness at 200°C and then the temperature was raised to 350°C for one hour or longer until clear (freshwater samples only). The tubes were then allowed to cool before 40 mL of ammonia-free distilled water was added. The encrusted salts were redissolved by vigorous shaking or warming if necessary before the solution was transferred to the original screw capped pyrex tubes. Each sample was then divided in half, one portion was used for TKN analysis and the other was stored for later total phosphorus determination.

The remainder of the procedure was the same as that described above for ammonia determinations.

Separate standards of ammonium chloride containing 1000, 500 and 100 micrograms of nitrogen per litre were made up from standard ammonium chloride in 3.5% sodium chloride solution and digested and treated in the same way as the samples. Blanks of ammonia-free distilled water and 3.5% sodium chloride were prepared and treated in an identical manner.

### **Nitrite concentration.**

In the field 20 mL of filtered surface or bottom water was added to a screw capped pyrex tube containing 0.5 mL of 35% ammonium chloride solution. Later in the laboratory colouring agents were added according to the method outlined on page 26 of report 51 - Laboratory Techniques in Marine Chemistry. G. A. Major, G. Dal Pont, J. Klye and B. Newell, 1974. CSIRO Division of Fisheries and Oceanography.

Standards containing 2, 1 and 0.2 micromoles-N per litre were made up from standard potassium nitrite solution. A blank of distilled water was also prepared.

### **Nitrate concentration.**

In the field 100 mL of filtered water was added to a polythene volumetric flask containing 2.5 mL of 35% ammonium chloride solution. The contents of this flask was then passed through a cadmium reduction column set up in the boat. The reduction column was prepared, conditioned and the flow rate adjusted to prevent over-reduction.

The last 20 mL of water to pass through the column was retained and transferred to a screw capped pyrex tube. The remainder of the analysis was carried out in the laboratory according to the method outlined on page 26 of Report 51.

Duplicate standards containing 10, 5 and 1 micromoles-N per litre were prepared from a standard solution of potassium nitrate and passed through the cadmium reduction prior to the passage of the samples.

### **Orthophosphate concentration.**

In the field 20 mL of filtered water was added to a screw capped pyrex tube. The remainder of the analysis was carried out in the laboratory, with appropriate modifications due to the sample volume, according to the method outlined on page 10 of Report 51.

Standards were prepared from a standard solution of potassium dihydrogen phosphate containing 100, 50 and 10 micrograms-P per litre.

### **Total phosphorus concentration.**

20 mL of each of the digested samples (TKN digestion) were neutralised with sodium hydroxide using bromocresol purple indicator. Two mL of mixed reagent was then added to each tube in the manner described in Report 51 and the colour allowed to develop. Before the absorbances were read any turbid samples were centrifuged or passed through a 25 mm glass fibre filter.

Standards containing 100, 50 and 10 micrograms-P/litre were prepared from a standard solution of potassium dihydrogen phosphate in 3.5% sodium chloride solution and were treated (digested etc.) in the same way as the samples.

### **Chlorophyll-a concentration.**

A known volume of surface water was filtered in the field through a 25 mm glass fibre filter (Millipore Corp. Cat. No. AP20 2500) in a pressure device. The filter was blown dry and transferred to a polythene centrifuge tube containing 5 mL of acetone. The tube was then capped and shaken vigorously to break up the filter. The tube was kept in the dark in a 12/240 volt refrigerator on the boat for around 24 hours. In the laboratory the tubes were centrifuged at 2000 rpm for 15 minutes. The concentration of chlorophyll-a was determined by measuring the absorbance of the clear sample in a 1 cm cuvette at 750, 665, 645 and 630 nm against an acetone blank. The spectrophotometer was zeroed at 750 nm with both cells filled with acetone and corrections determined for the other wave-lengths. The concentration of chlorophyll-a for each sample was calculated using the formula given on page 49 of Report 51.

### **Faecal coliform bacteria.**

A 110 mL sample of surface water was pumped into a sterile kayline bottle. As soon as possible 100 mL of sample water was filtered through a 47 mm (HCWG 047 - Millipore Corp.) membrane filter held in a heat sterilized steril apparatus (Millipore Corp.). The filter was transferred, using heat sterilized forceps (burning alcohol), into a 47 mm disposable petri dish containing a sterile glass fibre pad and the contents of an ampule of sterile culture medium (MFC) supplied by Millipore Corporation. The petri dish was inverted and incubated for 24 hours at 44.5 +/- 0.2°C. Blue colonies of bacteria were counted and the number expressed per 100 mL.

### **Concentration of suspended solids and volatile suspended solids.**

1 litre samples of surface water were filtered through dry pre-weighed glass fibre filters (Millipore Cat. No. AP40 047 05). These filters were then dried at 45°C for at least 24 hours before they were reweighed. The concentration of suspended solids was the difference in the weights expressed as mg/litre. The dried filters plus solids were then heated to 550°C in an electric muffle furnace for 60 minutes, allowed to cool and reweighed. The difference between the dry weight of the filter plus solids and the weight after combustion was the volatile suspended solids expressed as mg/litre.

A blank filter was weighed and heated to 550°C for one hour and reweighed. The weight loss was applied as a correction to the volatile suspended solids values.

---

# Ecological Significance of Parameters

Each water quality or ecological parameter measured or recorded had an ecological significance. These were as follows :

## **Date of sampling**

As many water quality and ecological parameters change progressively with the seasons it is important to record the date the sample was collected. Parameters such as rainfall, air and water temperature, dissolved oxygen concentration and specific gravity vary with the seasons.

## **Time of sampling**

It is important to record the time of sampling because some water quality and ecological parameters exhibit diurnal rhythms to greater or lesser degrees. Air and water temperature, dissolved oxygen concentration, pH and specific gravity all exhibit diurnal cycles. The time that spot samples were collected allows the observer to fit the results obtained into the diurnal curve for that parameter.

## **Weather prior to sampling**

The weather prior to the sampling date will determine the conditions that occur in the streams, rivers and lagoons under investigation on the day of sampling. Previous rainfall, air temperature over the last few days before sampling, cloud cover and wind speeds and direction all influence water quality at the time of sampling.

## **Weather at the time of sampling**

Weather at the time of sampling also influences water quality. Air temperature, cloud cover and rainfall may influence water flows, water temperatures, conductivity and salinity values, dissolved oxygen concentrations, pH values, turbidity, total and volatile suspended solids concentrations, percentage transmission of light values, nutrient concentrations and numbers of faecal coliform bacteria.

## **Water temperature**

Water temperatures in the sea, creeks, rivers and lakes undergo annual cycles related to seasonal changes in air temperature. The smaller the volume of the water body the larger will be the amplitude of the seasonal water temperature curve. Diurnal temperature changes will be superimposed on the seasonal temperature curve.

Water temperature governs the speed that chemical reactions occur and, thus, controls all aspects of aquatic biology.

### **Conductivity of water**

Conductivity of water is a measure of its ability to conduct electricity. The conductivity of water increases with the concentration of dissolved solids and is also influenced by water temperature. Freshwater has a very low conductivity and seawater has a relatively high conductivity. In these studies conductivity was measured in millisiemens per cm.

The conductivity of freshwater samples can indicate the types of processes going on in the catchment of a stream before it enters the estuarine section of the river or lagoon. For example, streams with high mean conductivity values may drain catchments that are affected by salt spray from the nearby ocean or receive effluent from domestic or industrial sources. The geology of the catchment also effects the conductivity of water draining from it.

### **Salinity of water**

The salinity of water increases as the amount of dissolved solids increases. The salinity of freshwater is very low (less than 1 part per thousand) and the salinity of ocean water is around 35 parts per thousand. Pronounced salinity gradients exist in most estuaries where freshwater draining from the land interacts with seawater from the ocean under the influence of tides.

The salinity of water at the time of sampling determines what kind of animals and plants may live, survive or prosper in it. Salinity values in creeks, estuaries and coastal waters vary with the amount of recent rainfall. Salinities rise during times of drought and fall at times of high rainfall.

In this study salinity was calculated automatically by the Submerged Datalogger from water temperature and conductivity values. Salinity is expressed as parts per thousand dissolved solids.

### **pH of water**

pH is defined as  $-\log_{10}[\text{H}^+]$  or, in words, as minus the logarithm of the Hydrogen ion concentration. It is expressed in a scale of 0 to 14. 0 to 7 denotes acid water (the lower the number the stronger the acidity), 7 is the neutral point where the number of hydrogen ions equals the number of hydroxyl ions, and values of 7 to 14 denote increasing alkalinity.

Aquatic life generally exists in the pH range of 6 to 9 although there are exceptions to this. While the pH of natural waters determines the kind and abundance of life that may be supported, the processes of aquatic life also may alter the pH of the water.

There may be pronounced diurnal pH changes in fresh and brackish waters caused by the uptake of carbon dioxide (a weak acid when in solution) during photosynthesis during the day and its release during respiration at night. The pH rises during the day (water becomes more alkaline) and falls at night (water becomes more acid).

In seawater natural buffering reduces the amplitude of diurnal pH changes.

In these studies pH of water is an important parameter because it gives some clues as to the origin of the water, the geology of the catchment, the type of biological activity occurring in it and the chances that it is contaminated by industrial or domestic waste.

### **Dissolved oxygen**

Dissolved oxygen concentration is probably the most important single parameter to be measured in any water quality study. Most macroscopic aquatic life-forms and many microscopic organisms require dissolved oxygen to live. Some aquatic animals use atmospheric oxygen. In almost all cases organisms obtain the energy to live, move and breed by the controlled combustion of carbohydrates (or similar compounds) in the presence of oxygen.

Oxygen concentration in water may be expressed in three ways. The first is as a mass of oxygen per litre of water (mg/L), the second is a volume of oxygen per litre of water (mL/L) and the third is percentage saturation. Water in contact with air becomes saturated with all the gases that make up that air. The mass of each gas in the saturated solution is in direct proportion to their partial pressure in the surrounding air.

The amount of oxygen at normal atmospheric pressure (or any other gas) required to saturate water varies with the temperature of that water and the concentration of dissolved solids (salinity). For example

<b>Temperature</b>	<b>Salinity</b>	<b>Mass O<sub>2</sub> to saturate water (mg)</b>
10°C	0	11.288
10°C	35	8.959
25°C	0	8.263
25°C	35	6.728

Natural waters are often less than fully saturated by dissolved oxygen and sometimes they may be supersaturated by dissolved oxygen.

Dissolved oxygen concentrations in natural waters undergo both seasonal and diurnal changes. Seasonal changes are caused by annual temperature changes and are related to the solubility of oxygen at each temperature. Diurnal dissolved oxygen changes are mainly caused by biological processes. Planktonic or bottom living (benthic) plants produce oxygen during the day by photosynthesis and respiration by both aquatic plants and animals consumes dissolved oxygen by day and night. The amplitude of the diurnal cycles in natural waters may vary enormously according to the amount of life (biomass) present. Occasionally dissolved oxygen concentrations may fall to zero or rise to more than 200% of saturation.

### **Specific gravity**

Specific gravity is the ratio of the masses of equal volumes of sample water and distilled water at 4°C. The specific gravity of water varies with both temperature and salinity. Specific gravity is a useful measure of the degree that a water body is stratified as it encompasses both temperature and salinity changes within the one index.

The specific gravity of a water body may change with the seasons and diurnally. Within an estuary, tidal interactions cause changes in specific gravity throughout the water column.

### **Turbidity**

Turbidity is one of the ways of measuring the clarity of water or how much suspended material is carried in it. Turbidity is expressed in Nephelometric Turbidity Units (NTU) and

is determined using an instrument that measures light scattering caused by particles suspended in the water.

### **Percentage transmission of light through water**

This is another way of measuring water clarity. A spectrophotometer is used to compare the amount of light passing through a 50 mm section of sample water with the amount passing through the same length of ultra-filtered water (filtered by a membrane filter). The wave length of light used is 750 nm.

### **Suspended solids**

Suspended solids give rise to water turbidity. Total suspended solids (TSS) may be measured by passing a known volume of sample water through a dried and weighed glass fibre filter. The filter is then dried to constant weight and reweighed. The difference in weight is the dry weight of total suspended solids (non filtrable residue, NFR) present in the original water sample.

Suspended solids are composed of particles of organic material, both living and dead, and inorganic substances such as soil and clay particles. By burning the weighed filter plus suspended solids in a muffle furnace at 550°C, the organic fraction (volatile suspended solids, VSS) volatilizes leaving the inorganic fraction (inorganic suspended solids, ISS). The filter is then reweighed and the mass of organic material (VSS) and (inorganic material ISS) is calculated and expressed as masses (mg) per litre of sample.

### **Nutrients**

Nutrients are substances carried by water that are essential for the growth of plants and animals. The main nutrients measured in water quality studies are nitrogen and phosphorus but there are many other substances essential for growth.

#### **Nitrogen**

Nitrogen occurs in natural waters as dissolved gas and as part of simple ions and complex organic molecules. Some primitive aquatic organisms can obtain their nitrogen requirements from the dissolved gas. These are the nitrogen fixing cyanobacteria or blue green algae. Green plants are the only organisms that can use the simple ions to make complex organic molecules. Animals obtain their nitrogen by consuming these complex molecules (that is, by eating plants or by eating other animals that have eaten plants).

In water quality studies the following forms of nitrogen are measured :

Ammonia

Organic nitrogen

Oxidized nitrogen

*Ammonia* is formed from the excretory products of animals and from the bacterial breakdown of organic material. Further oxidation in the environment forms *nitrite ions* ( $\text{NO}_2^-$ ) and eventually *nitrate ions* ( $\text{NO}_3^-$ ). The sum of nitrite and nitrate concentrations is known as *oxidized nitrogen*. Oxidized nitrogen and ammonia are taken up by plants to form complex organic compounds. *Organic nitrogen* includes all nitrogen bound up in living or dead plants and animals, organic detritus and contained in large soluble organic compounds. The sum of ammonia, organic nitrogen and oxidized nitrogen is called *total nitrogen* and includes all the non-gaseous nitrogen in the aquatic environment.

### Phosphorus

Phosphorus occurs in natural waters in an ionic form (*orthophosphate*) or bound up in complex organic molecules. The sum of orthophosphate and organically bound phosphorus is called *total phosphorus*.

Depending upon the circumstances either phosphorus or nitrogen availability may limit plant growth in aquatic ecosystems.

### Phytoplankton and Zooplankton

Phytoplankton are minute plants that live suspended in the water column. Their abundance or biomass may be estimated by extracting and measuring chlorophyll-a from a known volume of water. Chlorophyll-a concentrations vary greatly in natural waters. Values as high as 500 micrograms/L may occur in some nutrient-rich environments with high light intensities.

Zooplankton are small animals that live suspended in the water column. Some zooplankton eat phytoplankton while others are carnivorous and eat other zooplankters.

### Benthos

Benthos are bottom living plants and animals. Phytobenthos (plants) may be composed of attached algae or higher plants such as cryptogams, ferns and angiosperms (flowering plants). These plants may be totally submerged or emergent depending upon the species involved, the water flows in the creeks and the tidal range in the estuary.

### Pelagic organisms

Pelagic organisms are usually macroscopic animals that live in the water column of streams, rivers, lakes, lagoons and the oceans. They may belong to a variety of animal phyla. viz. Coelenterata (Jelly fish), Arthropoda (crustaceans and insect larvae), Chordata (fish, some birds and aquatic mammals).

### Faecal coliform bacteria

Faecal coliform bacteria are natural inhabitants of the guts of mammals and birds. They are present in huge numbers and are voided with the faeces. They are used as an indicator organism to determine the degree to which natural waters are contaminated by material of faecal origin. The presence of large numbers of faecal coliform bacteria in a water body could, but not necessarily, indicate the presence of pathogens of human or animal origin.

## Proposed Water Quality Criteria

In November 1992 the Australian and New Zealand Environment and Conservation Council published a document entitled :

*Australian Water Quality Guidelines for Fresh and Marine Waters*

The following water quality categories apply to estuaries and creeks of the upper Parramatta River system.

- Protection of Aquatic Ecosystems.
- Recreational Water Quality and Aesthetics

Recreational water quality guidelines are divided into three categories. They are :

- Primary Contact Recreation e.g. swimming.
- Secondary Contact Recreation e.g. fishing and boating.
- Passive Recreation e.g. scenic appreciation.

Table A shows ANZECC guidelines for protection of aquatic ecosystems. Tables B and C show ANZECC guidelines for recreational water quality and aesthetics.

**Table A. ANZECC Guidelines for the Protection of Aquatic Ecosystems.**

Indicator	Units	Fresh Waters	Marine Waters
<i>Biological</i>		No specific recommendation	No specific recommendation
<i>Physico-chemical</i>			
Colour & Clarity		< 10% change in euphotic depth.	< 10% change in euphotic depth.
Dissolved Oxygen	mg/L	> 6 (80-90% saturation) based on 1-2 diurnal cycles.	> 6 (80-90% saturation) based on 1-2 diurnal cycles.
Nutrients/Nuisance algae		Total-P : 0.005-0.050 mg/L Total-N : 0.100-0.500 mg/L Chlorophyll-a : 2-10 ug/L	PO <sub>4</sub> -P : 0.005-0.015 mg/L NO <sub>3</sub> -N : 0.010-0.100 mg/L NH <sub>4</sub> -N : <0.005 mg/L Chlorophyll-a : 1-10 ug/L
pH		6.5 - 9.0	< 0.2 pH unit change
Salinity	mg/L	< 1000 (about 1500 uS/cm)	
Suspended solids/ turbidity		< 10% change in seasonal mean concentration	< 10% change in seasonal mean concentration
Temperature		< 2°C increase	< 2°C increase
Toxicants		Not measured in most	Not measured in most

studies.

studies.

**Table B. ANZECC Water Quality Characteristics Relevant to Recreational Use.**

<b>Characteristics</b>	<b>Primary contact (swimming)</b>	<b>Secondary Contact (boating)</b>	<b>Visual use (no contact)</b>
Microbiological guidelines	x	x	
Nuisance organisms (e.g. algae)		x	x
Physical and chemical guidelines			
Aesthetics	x	x	x
Clarity	x	x	x
Colour	x	x	x
pH	x		
Temperature	x		
Toxic chemicals		x	x
Oil, debris	x	x	x

**Table C. Summary of ANZECC Water Quality Guidelines for Recreational Waters.**

<b>Parameter</b>	<b>Guideline</b>
<b>Microbiological</b>	
Primary Contact	The median bacterial content in fresh and marine waters over the bathing season should not exceed 150 faecal coliform organisms per 100 mL (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 out of 5 samples containing less than 600 organisms per 100 mL).
Secondary Contact containing	The median bacterial content in fresh and marine waters should not exceed 1000 faecal coliform organisms/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 out of 5 samples less than 4000 organisms per 100 mL).
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algae mats, sewage fungus, leeches etc. should not be present in excessive amounts. Nutrients values to control nuisance algae are shown in Table 1.  Direct contact activities should be discouraged if algal levels of 15000-20000 cells/mL are present, depending upon the algal species.  Large numbers of midges and aquatic worms should also be avoided
<b>Physical and chemical</b>	
Visual clarity & colour	To protect the aesthetic quality of a water body : 1. the natural visual clarity should not be reduced by more than 20%; 2. the natural hue of the water should not be changed by more than 10 points on the Munsell Scale; 3. the natural reflectance of the water should not be changed by more than 50%.  To protect the visual clarity of waters used for swimming, the horizontal sightings of Secchi disc should exceed 1.6 m.
pH	The pH of the water should be within the 5.0-9.0 range, assuming that the buffering capacity of the water is low near the extremes of the pH limits.
Temperature	For prolonged exposure, temperature should be in the range of 15-35°C.
Toxic chemicals	Water containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed levels given for untreated drinking waters.
Surface films	Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour.

**Suggested Water Quality Guidelines for Protection of Aquatic Ecosystems**

Some of the water quality guidelines for the protection of aquatic ecosystems presented in the ANZECC document are difficult to measure, difficult to interpret and difficult to determine compliance. For these reasons the following water quality guidelines have been developed for NSW catchments draining to the Tasman Sea based upon actual data for these water bodies measured by this firm. The suggested criteria are based upon the belief that soils of the Great Dividing Range and coastal plains were nutrient poor before European Settlement. Thus freshwater streams and rivers, estuaries and coastal lakes and lagoons had ecologies based upon low nutrient concentrations and a high degree of internal recycling of scarce materials. The suggested values for each parameter are based upon an estimation of the pre-European condition of the water body.

### Water temperature

Water temperatures in tributary creeks, rivers, estuaries and coastal lakes and lagoons of NSW coastal zone vary seasonally and diurnally. Many of the aquatic organisms which inhabit these aquatic systems have proscribed temperature tolerances for activities such as breeding and feeding as well as temperature limits that, if exceeded, will cause death. While the general temperature regimen for the drainage system for each catchment is set by their geographic location, modifications to the creeks, rivers, estuaries and lagoons and the surrounding land by man may change the natural temperature regimen to a degree that the thermal tolerance of some species is exceeded. This may result in mass deaths of some species or the curtailing of breeding or feeding activity in others.

Activities of man that cause temperature changes in waterways of eastern NSW that may exceed the natural limits set by geography are as follows :

- Removal of lagoon and creek side vegetation. This removes the natural shading of shallow waters and allows water temperatures to exceed greatly the seasonal limits.
- Alteration to the natural water level of the water body by interfering with the entrance, construction of weirs or removal of natural controls on water levels. These works may change the amount of water covering sensitive sessile species. If the alteration in water level coincides with extreme weather conditions, water temperatures may also exceed seasonal limits. e.g.
  - In unnaturally shallow areas frosts may reduce water temperatures to close to freezing point.
  - At times of extreme solar radiation (cloudless sky and still conditions) the temperature of shallow water may rise by as much as 10°C above the seasonal maximum.
- Routing of stormwater drains directly into tributary creeks or lagoons may also cause temperature shocks during extreme weather conditions. e.g.
  - During major hail storms icy runoff can cause sudden temperature drops of as much as 15-20°C depending upon the time of the year that the storm strikes.

The natural temperature regimen of water bodies in eastern NSW is around 2 - 35°C depending upon the altitude and latitude. For water bodies located from Sydney north to Port Macquarie the annual temperature range is around 10 - 30°C. No mortality of aquatic organisms living in this area of NSW caused by temperatures within this range have been observed. Thus, for creeks, rivers, estuaries and coastal lakes and lagoons on the east coast of NSW between Sydney and Port Macquarie at altitudes of between sea level and 200 m, the recommended temperature range to protect the freshwater and estuarine ecosystems is 10 - 30°C.

## Salinity

Many organisms have narrow salinity tolerances while others can tolerate large changes in salinity. However, even organisms with wide salinity tolerances may be unable to survive sudden massive changes in salinity. Mobile organisms often respond to sudden salinity changes by moving to an area more conducive to their survival. Sedentary organisms, however, may respond to short term salinity reductions by closing their shells or equivalent for the duration of the event. If the event lasts too long mortality may occur.

Many eastern NSW creeks, rivers, estuaries and coastal lakes and lagoons and their catchments has been modified extensively by man. Many of these modifications have affected the salinity regimen of the lagoon and lower sections of the tributary creeks. e.g.

- Construction of a permanent entrances to rivers and coastal lakes and lagoons or the construction of an entrance channel with gates at Manly Lagoon has raised the mean salinity of these lagoons to close to that of seawater. This has allowed many fully marine species to survive in these lagoons. Sudden falls in salinity caused by rainfall and runoff will affect these fully marine species. Some mobile animals will move to more stable areas, such as the bottom water of the deeper parts of the estuaries and lagoons. Other marine organisms will shut their shells until the salinity rises again or die if the event lasts too long. Lagoons with unaltered entrances such as those at Gosford and Dee Why Lagoon and Curl Curl Lagoon have more natural salinity regimens but the increased frequency of opening of these small lagoons to prevent flooding has accerated the natural salinity regimens to abnormal levels. Instead of remaining closed for several years at a time, these small lagoons may now open up to around 12 times a year.
- Dredging of Narrabeen Lagoon, Manly Lagoon, Avoca Lagoon and some others has deepened much of the lagoon bed to below AHD. When a rainfall event occurs the water column becomes highly stratified with respect to salinity. If the rainfall event occurs at a time when the entrance is closed (Narrabeen Lagoon) or the gates to the entrance channel are closed (due to sand buildup at the northern end of Manly Beach) the supply of oxygenated seawater is cut off. Under these conditions turbid freshwater overlies the saline bottom water. This reduces the intensity of light reaching the bottom water. Gradually the dissolved oxygen concentration of the bottom water declines making it unable to support aquatic life. This type of stratification which follows a rainfall event also occurs in undredged shallow lagoons with natural entrances but wind mixing often breaks down the density discontinuity before severe deoxygenation occurs.
- Prior to the modifications to Warringah Lagoons and some Gosford Lagoons, the lower ends of the tributary creeks had a gradation of salinity. In all cases now, the freshwater is separated from the saltwater by a weir of some sort. Above the weirs the ecology is entirely freshwater while below the weir it is estuarine. If, at times of low rainfall, the lagoon level rises to a point where saltwater can flow upstream and over-top the weir, the salinity in the freshwater section will rise to a point above the tolerance of the freshwater organisms. At these times mortality of plants and animals may occur.

A salinity guideline for the freshwater reaches of tributary creeks and rivers (usually above constructed weirs or road culverts) of eastern NSW may be set as follows :

Salinity in the freshwater reaches of tributary creeks should not exceed 5 parts per thousand over any 12 month period.

No salinity guideline is required for river estuaries or the body of lagoons and coastal lakes provided those with ecologies conditioned to permanent entrances are kept open for the maximum time possible.

## pH

The pH of water controls the type of chemical reactions that can take place in it and, thus, effects the type of organisms that can live in it. Freshwater is poorly buffered against pH changes so undergoes quite wide changes in pH depending upon the time of day (diurnal pH changes caused by photosynthesis and respiration) and upon the geology of the rocks and soils in the catchment. The pH of water in creeks leading to many lagoons and coastal lakes is also affected by the presence of submerged concrete structures and by concrete pipes conveying water to the creeks.

Saltwater of estuaries or the body of coastal lakes and lagoons is well buffered against pH changes. Because of this diurnal pH changes are smaller in amplitude.

For freshwater in creeks and rivers of eastern NSW which emanated from slightly acid to alkaline catchments, the following pH range is suggested as a guideline (first ensure that the pH electrode is correctly calibrated and has been properly maintained) :

Lower limit 6.0                      Upper limit 9.0

If pH values out side this range are encountered using a properly maintained and calibrated instrument, the reason should be investigated.

For acidic catchments, such as Hawkesbury sandstone formations, the following pH range is suggested :

Lower limit 4.5                      Upper limit 9.0

For coastal lagoons such as Wamberal Lagoon, Avoca Lagoon, Cockrone Lagoon, Dee Why Lagoon and Curl Curl Lagoon with low salinity waters and dense beds of submerged macrophytes the suggested pH range is (first ensure that the pH electrode is correctly calibrated and has been properly maintained) :

Lower limit 6.0                      Upper limit 10.5

For estuarine waters of rivers and the bodies of large and open coastal lagoons and lakes (e.g. Lake Macquarie) the following pH range is suggested as a guideline :

Lower limit 6.5                      Upper limit 8.5

If values outside these limits are encountered in natural waters of eastern NSW using a properly maintained and calibrated instrument, the reason should be investigated.

## Dissolved Oxygen

Dissolved oxygen is perhaps the most important single parameter measured during water quality sampling. Portable dissolved oxygen instruments require daily calibration checks. Dissolved oxygen concentrations in creeks, rivers, estuaries and coastal lakes and lagoons undergo pronounced diurnal fluctuations. These diurnal fluctuations are related to photosynthesis and respiration of aquatic plants and respiration in aquatic animals. The greater the density of aquatic life in the water body the greater will be the amplitude of the diurnal dissolved oxygen changes.

In freshwater sections of creeks which are choked by aquatic vegetation the dissolved oxygen concentration may fall permanently to very low levels.

In highly and permanently stratified creeks and rivers at the upper end of estuaries (e.g. Kooloonbung Creek, Port Macquarie or the Camden Haven River at Kendall) dissolved oxygen levels in bottom water may remain at or close to zero for years at a time.

In studies of Warringah Lagoons, Gosford Lagoons and the upper Parramatta River all the samples in the tributary creeks were measured in the pre-dawn hours, the time of the expected diurnal dissolved oxygen minima. Dissolved oxygen criteria for both surface water and bottom water are required where the depth of water exceeds 1 metre. In the bodies of Lake Macquarie, Narrabeen Lagoon and Dee Why Lagoon samples were taken during daylight hours when dissolved oxygen levels were rising from their pre-dawn minima.

The following dissolved oxygen criteria, expressed as percentage saturation, are recommended for freshwater in the creeks leading to NSW estuaries.

Upper limit 120 %                      Lower limit 50 %

The following dissolved oxygen criteria, expressed as percentage saturation, are recommended for surface and mid-waters of coastal lakes and lagoons with usually closed entrances, low salinities at maturity and dense beds of submerged macrophytes (e.g. Wamberal Lagoon, Avoca Lagoon, Cockrone Lagoon, Dee Why Lagoon and Curl Curl Lagoon).

Upper limit 150%                      Lower limit 50%

For bottom water in these lagoons at the base of the submerged vegetation quite low dissolved oxygen levels exist. Here the suggested dissolved oxygen criteria are as follows :

Upper limit 150%                      Lower limit 10%

The following dissolved oxygen criteria, expressed as percentage saturation, are recommended for estuarine surface waters of rivers and large NSW coastal lagoons and lakes (e.g. Narrabeen Lagoon and Lake Macquarie) :

Upper limit 120 %                      Lower limit 70 %

The following dissolved oxygen criteria, expressed as percentgae saturation, are recommended for estuarine bottom waters of rivers and large NSW coastal lagoons and lakes :

Upper limit 120 %                      Lower limit 40 %

### Nutrient Concentrations

Nutrient concentrations in freshwater creeks and rivers promote the growth of aquatic macrophytes (both emergent and submerged species), filamentous algae and phytoplankton. In the estuarine sections of creeks and rivers and the saline bodies of coastal lakes and lagoons nutrients promote the growth of emergent macrophytes along the banks of rivers and around the perimeter of lagoons, seagrasses and algae on the bed of estuaries and lagoons and phytoplankton in the water column. High nutrient concentrations lead to excess growth of aquatic plants provided there is sufficient light present.

Prior to European settlement water bodies in eastern NSW received few nutrients from the catchment so the estuaries and lagoons had to operate on a close recycling regime. Today Warringah Lagoons and many other systems with developed catchments receive large amounts of plant nutrients especially from the highly urbanised parts of the catchments (as opposed to those sections of the catchment with bushland or devoted to non-intensive agriculture or animal husbandry). These nutrients lead to excessive growth of aquatic plants in the tributary creeks and phytoplankton blooms in the body of lagoons.

Criteria for the concentration of ammonia, oxidized nitrogen, total nitrogen, orthophosphate and total phosphorus have been developed to reflect the conditions thought to exist prior to European Settlement. These levels will control plant growth in NSW creeks, rivers, estuaries and coastal lakes and lagoons.

Studies of Warringah Lagoons, Gosford Lagoons and other NSW coastal rivers, lakes and lagoons carried out by this firm show that nutrient concentrations fluctuate greatly over a 12 month period so it is suggested that 50 percentile and 90 percentile values for each nutrient be adopted as guidelines. The same values for both freshwater and estuarine waters are suggested as most of the nutrients appear to be derived from the catchment. There is some evidence that nutrients entering NSW estuaries and lagoons in the form of inorganic ions or bound up in organic compounds become incorporated in the bodies of organisms. These organisms eventually die and sink to the bottom of the lagoon where they and their nutrient content may be trapped in the sediment of the lagoon bed. There are mechanisms to recycle these trapped nutrients back into the water column but generally an equilibrium concentration is reached between inputs from the catchment, recycling from the sediment and export/import to/from coastal waters via the entrance channels.

The following 50 percentile and 90 percentile values for each nutrient, calculated from at least 12 samples per station per year, are recommended for fresh and estuarine waters of NSW coastal drainage systems :

Nutrient	50 percentile	90 percentile
Ammonia	0.100 mg-N/L	0.150 mg-N/L
Oxidized nitrogen	0.100 mg-N/L	0.200 mg-N/L
Total nitrogen	0.500 mg-N/L	0.800 mg-N/L
Orthophosphate	0.005 mg-P/L	0.020 mg-P/L
Total phosphorus	0.050 mg-P/L	0.100 mg-P/L

#### Water clarity

Water clarity of NSW coastal drainage systems were measured in the following ways.

Turbidity	NTU
Percentage transmission of light through water (50 mm)	Percentage
Total suspended solids concentration (TSS)	mg/L
Volatile suspended solids (VSS)	mg/L
Secchi depth	metres

Guidelines applicable to eastern NSW creeks, rivers, estuaries and coastal lakes and lagoons may be expressed as 10, 50 and 90 percentile values for each parameter measured at each station at least 12 times over a year.

The following water clarity guidelines are suggested :

	10 %ile	50 %ile	90 %ile	Units
Turbidity	2.0	5.0	8.0	NTU
% trans.	93.5	97.5	99.0	%
TSS	1.5	3.5	8.0	mg/L
VSS	1.0	2.0	4.0	mg/L

Secchi depth    2.0                      3.0                      4.0                      metres

### Chlorophyll-a

Chlorophyll-a is one of the green pigments of plants used in photosynthesis. Chlorophyll-a determinations were carried out on samples of surface water from the tributary creeks and samples of surface and bottom water from the body of eastern NSW estuaries and coastal lakes and lagoons (surface water only for Narrabeen Lagoon and Lake Macquarie). Chlorophyll-a determinations carried out in this way give an estimate of phytoplankton standing crop.

Chlorophyll-a concentration guidelines for creeks, rivers, estuaries and coastal lakes and lagoons of eastern NSW may be expressed as 50 and 90 percentile values. They should be calculated from at least 12 samples from each station each year.

The following chlorophyll-a concentration guidelines are suggested :

	50 %ile	90 %ile	Units
Chlorophyll-a	5	12	ug/L

### **Water Quality Guidelines for Oyster Culture**

The NSW Department of Agriculture, Fisheries Division has set the following water quality criteria for oyster culture.

Class	Description	Faecal Coliform Bacteria Levels	
		50 %ile/100 ml	90%ile/100ml
<b>Approved</b>	Oysters can be sold without employing purification.	< 14	< 43
<b>Restricted</b>	Oysters can only be sold after purification.	14-140	43-430
<b>Prohibited</b>	Sale of oysters not permitted	> 140	> 430

---

# Results

## Rainfall

Rainfall in the catchment of the upper Parramatta River or its absence was one of the main factors which influenced water quality in the creeks and tidal section of the river. Monthly rainfall data for 1990 to 1995 recorded at St Ives are presented in Figure 2. In Figure 3 rainfall at St Ives for 1996 to 1998 has been plotted.

Significant rainfall fell in all months of 1990 except for June, October and November.

In 1991 significant rainfall fell only in the months of January, May, June and December.

In 1992 significant rainfall fell in January, February, March, April, November and December.

In 1993 significant rainfall fell in the months of February and March.

Significant rainfall in 1994 fell in the months of February, March, April and December.

In 1995 significant rainfall fell in the months of January, February, March, May and September. There was almost no rainfall in July and August.

Significant rainfall in 1996 fell in the months January, May, June, August and November. In 1997 the following months had rainfall greater than 100 mm : January, February, May, June, July and September.

In 1998, rainfall greater than 100 mm fell in the months of January, April, May and August.

### Go to Appendix A

**Page 2.      Figure 2. Monthly Rainfall at St. Ives for the years 1990 to 1995.**

**Page 3.      Figure 3. Monthly Rainfall at St. Ives for the years 1996 to 1998.**

The heavily urbanised catchment of the upper Parramatta River and adjacent Duck River caused a very rapid run-off to the rivers. Thus, even quite small showers produced significant flows in the creeks leading to the tidal section of the Parramatta River and Duck Creek.

Total annual rainfalls and number of days rain per year for the period 1990 to 1998 are shown below :

<u>Year</u>	<u>Total rain (mm)</u>	<u>No. of days</u>
1990	2228.6	148
1991	1153.3	103
1992	1500.4	132
1993	847.6	107
1994	989.7	110
1995	1363.6	127
1996	1127.0	110
1997	1014.3	117
1998	1665.3	136

Annual rainfall over the nine years studied varied between 847.6 and 2 228.6 mm.

## **Water Temperature**

Temperatures of surface and bottom water (Stations 1-4 only) at all Stations sampled in 1998 are presented in Table 1. Annual means, variances, standard deviations, maximum and minimum values have been calculated. Figure 4 shows a linear plot of water temperatures at stations in the upper Parramatta River system for the period 1990 to 1998.

Figure 5 shows changes in annual mean water temperatures for surface and bottom water of the tidal section of the upper Parramatta River and Duck River (means of Stations 1-4) and the major tributary creeks (Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River above Marsden Weir) from 1990 to 1998.

In the estuarine section of the upper Parramatta River and Duck River annual mean water temperatures were higher than those recorded for the tributary creeks on each year sampled. The annual mean temperatures of bottom water at the estuarine stations were slightly higher than those for surface water.

### **Go to Appendix A**

**Page 4. Figure 4. Water Quality of Upper Parramatta River - Annual Temperature Changes 1990 - 1998 Degrees Celcius.**

**Page 5. Figure 5. Water Quality of Upper Parramatta River - Annual Mean Temperature Changes 1990 - 1998 Degrees Celcius.**

## Table 1. Water Quality of Parramatta River

Parameter - Water Temperature Units - Degrees Celsius.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	24.35	24.60	23.69	24.88	22.50	22.19	24.71	23.07	25.24		24.40	20.81
6-2-98	28.11	25.81	25.14	28.61	25.90	26.02	27.77	26.89	28.03		24.39	24.06
13-3-98	24.58	24.77	25.39	26.19	22.15	22.37	24.15	23.41	26.00		24.89	19.86
17-4-98	18.98	18.14	19.35	19.95	17.85	17.07	18.33	18.70	26.69		18.53	16.66
8-5-98	17.11	16.89	16.73	17.06	16.67	16.79	16.87	16.76	20.97		16.22	15.18
12-6-98	16.17	16.17	15.55	16.12	14.09	14.32	14.68	14.45	24.20		14.69	13.37
3-7-98	12.68	10.31	11.30	11.20	10.23	10.14	11.41	10.55	19.54		10.53	8.14
7-8-98	13.10	13.30	12.88	12.85	12.77	12.81	12.76	12.81	17.90		12.81	13.00
11-9-98	17.00	16.80	16.91	17.26	15.37	14.89	16.18	16.17	20.79		16.28	14.12
9-10-98	18.22	18.02	17.55	18.43	17.19	16.38	18.08	17.93	23.87		16.64	13.09
13-11-98	19.84	20.56	20.52	20.88	20.68	19.27	21.20	20.48	29.34		20.24	19.81
11-12-98	24.98	24.37	24.67	25.11	24.21	23.08	25.22	24.81	30.34		22.91	21.17
Mean	19.59	19.15	19.14	19.88	18.30	17.94	19.28	18.84	24.41		18.54	16.61
Std	4.71	4.74	4.61	5.21	4.63	4.52	5.06	4.82	3.79		4.63	4.38
Var	22.16	22.42	21.26	27.10	21.41	20.44	25.63	23.21	14.36		21.40	19.22
Max	28.11	25.81	25.39	28.61	25.90	26.02	27.77	26.89	30.34		24.89	24.06
Min	12.68	10.31	11.30	11.20	10.23	10.14	11.41	10.55	17.90		10.53	8.14

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	25.32	25.30	25.86	25.61
6-2-98	27.96	28.05	28.58	28.99
13-3-98	25.07	24.99	25.87	26.33
17-4-98	21.57	21.30	21.23	20.96
8-5-98	19.81	19.91	19.29	19.68
12-6-98	16.48	16.48	17.05	17.09
3-7-98	13.90	14.27	14.61	14.33
7-8-98	14.06	14.37	12.90	12.85
11-9-98	18.11	18.03	17.77	17.95
9-10-98	19.22	19.14	19.45	20.10
13-11-98	21.64	21.71	21.81	21.77
11-12-98	25.54	25.34	25.19	25.08
Mean	20.72	20.74	20.80	20.90
Std	4.44	4.34	4.66	4.73
Var	19.67	18.82	21.70	22.39
Max	27.96	28.05	28.58	28.99
Min	13.90	14.27	12.90	12.85

## Salinity

Salinity of surface and bottom water (Stations 1-4 only) at all Stations sampled in 1998 are presented in Table 2. Annual means, variances, standard deviations, maximum and minimum values have been calculated. Figure 6 shows a linear plot of mean salinities (Stations 1-4) of surface and bottom water of the upper Parramatta estuary each month for the period 1990 to 1998.

Figure 7 (upper) shows changes in annual mean salinity of surface and bottom water of the estuarine section of the upper Parramatta River from 1990 to 1998.

Figure 7 (lower) shows changes to the annual mean salinities of the major freshwater creeks of the upper Parramatta River system from 1990 to 1998.

It was apparent that the mean salinity of surface water was much lower than that of bottom water in the estuarine section of the upper Parramatta River and Duck River. During periods of heavy rainfall surface water at Stations 1-4 was almost fresh. During major rainfall events even the bottom water at Stations 2, 3 and 4 was fresh at least during the ebb tide (Figure 6). In 1998 the mean salinity of surface water of the estuarine section of the upper Parramatta River was less than 18 ppt..

The salinity of freshwater creeks varied slightly from year to year. Upper Duck Creek had the highest mean salinity and Lake Parramatta had the lowest (Figure 7- lower).

### Go to Appendix A

**Page 6.      Figure 6. Water Quality of Upper Parramatta River - Salinity Changes 1990 - 1998 Parts per Thousand.**

**Page 7.      Figure 7. Water Quality of Upper Parramatta River - Annual Mean Salinity Changes 1990 - 1998 Parts per Thousand.**

## Table 2. Water Quality of Parramatta River

Parameter - Salinity Units - Parts per Thousand.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	28.13	27.24	17.39	17.51	0.11	0.13	0.13	0.11	25.23		18.39	0.86
6-2-98	23.40	6.11	4.89	19.08	0.29	0.13	0.12	0.13	10.76		1.37	0.72
13-3-98	30.73	30.33	27.51	26.71	0.20	0.12	0.14	0.21	20.38		25.35	1.02
17-4-98	9.96	5.33	5.72	12.10	0.30	0.23	0.12	0.26	1.60		3.15	0.77
8-5-98	11.56	8.05	4.23	7.99	0.45	0.23	0.18	0.29	8.56		2.94	0.93
12-6-98	24.51	24.51	17.69	14.40	0.44	0.25	0.15	0.29	3.82		9.52	1.27
3-7-98	22.09	16.19	12.11	11.30	0.38	0.28	0.17	0.38	12.87		8.38	1.20
7-8-98	0.44	0.34	0.14	0.14	0.16	0.14	0.16	0.14	0.25		0.13	0.14
11-9-98	19.76	17.36	16.44	13.29	0.43	0.20	0.16	0.20	12.18		12.04	1.43
9-10-98	34.98	34.60	30.52	28.66	0.56	0.38	0.26	0.55	14.03		21.85	2.27
13-11-98	9.65	5.67	1.66	10.99	0.17	0.21	0.24	0.24	3.14		0.58	0.19
11-12-98	28.87	24.64	23.28	28.08	0.41	0.23	0.23	0.33	6.35		11.91	1.32
Mean	20.34	16.70	13.47	15.85	0.33	0.21	0.17	0.26	9.93		9.63	1.01
Std	9.92	10.98	9.85	8.27	0.14	0.07	0.04	0.12	7.28		8.23	0.54
Var	98.42	120.63	97.01	68.37	0.01	0.00	0.00	0.01	52.98		67.74	0.30
Max	34.98	34.60	30.52	28.66	0.56	0.38	0.26	0.55	25.23		25.35	2.27
Min	0.44	0.34	0.14	0.14	0.11	0.12	0.12	0.11	0.25		0.13	0.14

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	31.79	30.50	26.43	23.65
6-2-98	31.01	30.58	26.26	24.43
13-3-98	31.67	30.80	29.09	27.90
17-4-98	24.51	22.29	19.67	17.37
8-5-98	25.82	27.36	18.09	24.14
12-6-98	25.56	25.56	23.37	22.53
3-7-98	25.85	27.90	25.56	25.59
7-8-98	19.18	25.27	0.13	0.14
11-9-98	25.85	24.23	20.34	21.05
9-10-98	34.03	34.24	33.92	33.40
13-11-98	30.57	30.38	29.85	30.38
11-12-98	28.91	28.80	28.37	28.58
Mean	27.90	28.16	23.42	23.26
Std	3.98	3.24	8.29	8.09
Var	15.87	10.53	68.69	65.48
Max	34.03	34.24	33.92	33.40
Min	19.18	22.29	0.13	0.14

## Specific Gravity

Specific gravity data for surface and bottom water (Stations 1-4 only) for Stations sampled in 1998 are presented in Table 3. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

In 1998 the mean specific gravity of surface water at stations in the estuarine section of the upper Parramatta River and Duck River (Stations 1-4) ranged between 1.0086 and 1.0137. For bottom water the mean specific gravity range at stations 1-4 was between 1.0137 to 1.0245.

### Table 3. Water Quality of Parramatta River

Parameter - Specific Gravity Units - s.g.

#### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	1.0186	1.0179	1.0107	1.0105	0.9979	0.9980	0.9975	0.9978	1.0160		1.0113	0.9989
6-2-98	1.0141	1.0017	1.0009	1.0108	0.9973	0.9972	0.9968	0.9970	1.0047		0.9985	0.9980
	1.0205	1.0201	1.0179	1.0171	0.9981	0.9980	0.9976	0.9978	1.0124		1.0164	0.9992
17-4-98	1.0061	1.0029	1.0028	1.0076	0.9990	0.9990	0.9988	0.9988	0.9981		1.0010	0.9995
8-5-98	1.0077	1.0050	1.0021	1.0050	0.9993	0.9991	0.9990	0.9991	1.0047		1.0012	0.9999
12-6-98	1.0177	1.0177	1.0126	1.0100	0.9996	0.9995	0.9993	0.9995	1.0030		1.0065	1.0030
3-7-98	1.0165	1.0122	1.0089	1.0083	1.0000	0.9999	0.9997	0.9999	1.0083		1.0061	1.0006
7-8-98	0.9997	0.9996	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9989		0.9995	0.9995
11-9-98	1.0139	1.0122	1.0114	1.0090	0.9995	0.9994	0.9991	0.9992	1.0074		1.0082	1.0004
9-10-98	1.0253	1.0250	1.0220	1.0204	0.9993	0.9993	0.9989	0.9991	1.0081		1.0156	1.0011
13-11-98	1.0057	1.0026	0.9995	1.0065	0.9984	0.9987	0.9983	0.9985	0.9987		0.9988	0.9986
11-12-98	1.0190	1.0160	1.0149	1.0184	0.9978	0.9979	0.9974	0.9976	1.0008		1.0067	0.9991
Mean	1.0137	1.0111	1.0086	1.0103	0.9988	0.9988	0.9985	0.9987	1.0051		1.0058	0.9998
Std	0.0071	0.0081	0.0072	0.0056	0.0008	0.0007	0.0009	0.0008	0.0053		0.0060	0.0012
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000
Max	1.0253	1.0250	1.0220	1.0204	1.0000	0.9999	0.9997	0.9999	1.0160		1.0164	1.0030
Min	0.9997	0.9996	0.9995	0.9995	0.9973	0.9972	0.9968	0.9970	0.9981		0.9985	0.9980

#### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	1.0211	1.0201	1.0178	1.0149
6-2-98	1.0199	1.0195	1.0162	1.0147
13-3-98	1.0211	1.0204	1.0189	1.0179
17-4-98	1.0173	1.0150	1.0130	1.0113
8-5-98	1.0180	1.0191	1.0186	1.0167
12-6-98	1.0185	1.0185	1.0167	1.0160
3-7-98	1.0192	1.0207	1.0188	1.0189
7-8-98	1.0140	1.0186	0.9995	0.9995
11-9-98	1.0184	1.0184	1.0142	1.0147
9-10-98	1.0243	1.0245	1.0242	1.0237
13-11-98	1.0211	1.0210	1.0205	1.0210
11-12-98	1.0189	1.0189	1.0186	1.0188
Mean	1.0193	1.0196	1.0164	1.0157
Std	0.0024	0.0021	0.0057	0.0057
Var	0.0000	0.0000	0.0000	0.0000
Max	1.0243	1.0245	1.0242	1.0237
Min	1.0140	1.0150	0.9995	0.9995

## pH

pH values for surface and bottom water (Stations 1-4 only) for stations sampled in 1998 are presented in Table 4. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

Figure 8 shows a linear plot of pH of pH changes in the estuarine section of the upper Parramatta River over the period 1990 to 1998.

Figure 9 shows changes in annual mean pH values of freshwater creeks leading to the upper Parramatta River between 1990 and 1998.

Mean pH values for surface and bottom water of the estuarine sections of Duck River and the upper Parramatta River appear to have declined slightly over the period 1990 to 1993 before becoming relatively stable from 1993 to 1998..

Annual mean pH values for surface and bottom water of the estuary for the period 1990 to 1998 are shown below :

Year	Surface	Bottom
1990	7.97	8.05
1991	7.92	8.04
1992	7.81	7.74
1993	7.47	7.62
1994	7.72	7.76
1995	7.53	7.63
1996	7.49	7.52
1997	7.49	7.53
1998	7.59	7.66

### **Go to Appendix A**

**Page 8. Figure 8. Water Quality of Parramatta River - pH Changes 1990 - 1998.**

**Page 9. Figure 9. Water Quality of Parramatta River - Annual Mean pH Changes 1990 - 1998.**

## Table 4. Water Quality of Parramatta River

Parameter - pH Units.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	7.85	7.82	7.70	7.42	7.30	7.44	7.76	7.55	7.70		7.70	8.34
6-2-98	8.10	7.25	7.22	7.72	7.54	7.44	7.68	7.89	7.52		7.31	8.44
13-3-98	7.37	7.37	7.19	7.18	7.16	7.17	7.23	7.43	7.30		7.06	7.87
17-4-98	7.35	7.63	7.45	7.48	7.80	7.98	7.52	8.01	8.13		7.43	8.45
8-5-98	7.48	7.38	7.22	7.24	7.85	7.92	7.52	7.90	6.93		7.35	8.45
12-6-98	8.19	8.19	7.70	7.84	8.18	8.21	7.81	8.27	7.81		7.76	8.59
3-7-98	7.72	7.59	7.36	7.78	7.78	7.75	7.64	7.80	7.49		7.35	8.05
7-8-98	7.94	8.32	8.27	8.55	8.04	8.06	7.88	8.08	9.77		8.02	8.04
11-9-98	7.56	7.49	7.35	7.50	7.61	7.40	8.17	7.69	7.25		7.16	7.93
9-10-98	7.84	7.82	7.64	7.65	7.61	7.53	7.81	7.95	7.64		7.54	8.28
13-11-98	7.24	7.20	7.21	7.27	7.35	7.36	7.54	7.39	7.43		7.24	7.70
11-12-98	7.85	7.45	7.07	7.14	7.17	7.28	7.76	7.64	6.60		7.20	7.97
Mean	7.71	7.63	7.45	7.56	7.62	7.63	7.69	7.80	7.63		7.43	8.18
Std	0.29	0.34	0.32	0.37	0.32	0.33	0.22	0.26	0.75		0.27	0.27
Var	0.08	0.11	0.10	0.14	0.10	0.11	0.05	0.06	0.56		0.07	0.07
Max	8.19	8.32	8.27	8.55	8.18	8.21	8.17	8.27	9.77		8.02	8.59
Min	7.24	7.20	7.07	7.14	7.16	7.17	7.23	7.39	6.60		7.06	7.70

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	8.15	8.00	7.61	7.46
6-2-98	7.88	7.82	7.71	7.94
13-3-98	7.39	7.37	7.27	7.19
17-4-98	7.44	7.33	7.21	7.24
8-5-98	7.58	7.42	7.11	7.02
12-6-98	8.14	8.14	7.89	7.88
3-7-98	7.83	7.82	7.44	7.68
7-8-98	8.15	8.31	8.36	8.78
11-9-98	7.75	7.66	7.47	7.44
9-10-98	7.96	7.84	7.68	7.68
13-11-98	7.62	7.50	7.05	7.19
11-12-98	7.96	7.81	7.33	7.23
Mean	7.82	7.75	7.51	7.56
Std	0.26	0.30	0.35	0.46
Var	0.06	0.08	0.13	0.21
Max	8.15	8.31	8.36	8.78
Min	7.39	7.33	7.05	7.02

## Dissolved Oxygen

Dissolved oxygen concentrations in surface and bottom water (Stations 1-4 only) of all Stations sampled in 1998 are presented in Tables 5 (dissolved oxygen concentration as percentage saturation) and 6 (dissolved oxygen concentration as mg/L). Annual means, variances, standard deviations, maximum and minimum values have been calculated.

Figure 10 shows a linear plot of mean surface and bottom water dissolved oxygen concentrations (Stations 1-4) of the estuarine section of the upper Parramatta River for the period 1990 to 1998. Figure 11 shows a linear plot of surface and bottom water dissolved oxygen concentrations for Station 3 (Duck Creek) over the same period. Station 3 is located at the confluence of Duck River and Duck Creek. Figure 12 shows a linear plot of dissolved oxygen concentrations in freshwater of Toongabbie Creek, Darling Mills Creek, Lake Parramatta and the upper Parramatta River.

### Go to Appendix A

- Page 10. Figure 10. Water Quality of Upper Parramatta River - Dissolved Oxygen Changes 1990 - 1998 Percentage Saturation.**
- Page 11. Figure 11. Water Quality of Upper Parramatta River -Dissolved Oxygen Changes in Duck Creek 1990 - 1998 Percentage Saturation.**
- Page 12. Figure 12. Water Quality of Upper Parramatta River - Dissolved Oxygen Changes in Tributaries 1990 - 1998 Percentage Saturation.**
- Page 13. Figure 13. Water Quality of Upper Parramatta River - Annual Mean Dissolved Oxygen Changes 1990 - 1998 Percentage Saturation.**

## Table 5. Water Quality of Parramatta River

Parameter - Dissolved Oxygen Units - Percentage Saturation.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	69.5	69.9	72.8	44.5	27.8	45.9	92.0	51.1	62.6		89.4	69.6
6-2-98	83.8	3.4	3.4	48.1	32.6	50.1	80.9	93.2	58.0		51.1	75.0
13-3-98	67.2	68.3	67.3	68.6	68.9	83.2	82.1	89.4	77.6		71.1	73.5
17-4-98	63.1	61.1	29.5	65.1	70.6	87.3	59.9	71.5	91.3		56.9	89.1
8-5-98	63.7	60.2	52.4	74.9	78.6	93.4	63.0	84.8	67.3		70.2	92.1
12-6-98	73.5	73.5	53.0	67.0	67.9	85.8	43.0	67.4	79.2		65.5	83.9
3-7-98	82.5	73.0	57.6	88.2	72.4	86.8	50.1	80.0	85.7		68.8	86.9
7-8-98	95.5	91.1	91.5	102.7	94.2	96.6	85.0	94.5	72.9		93.6	92.1
11-9-98	68.6	68.1	63.0	73.1	79.7	87.8	106.6	98.3	70.3		74.9	83.2
9-10-98	57.0	52.7	34.6	48.6	34.9	50.4	93.8	79.4	74.9		60.1	69.6
13-11-98	62.9	49.1	53.9	67.9	70.1	74.8	84.8	65.4	75.8		68.4	81.8
11-12-98	106.0	71.6	16.3	42.8	38.5	61.6	96.9	91.4	84.9		53.9	65.8
Mean	74.4	61.8	49.6	66.0	61.4	75.3	78.2	80.5	75.0		68.7	80.2
Std	14.1	20.5	23.7	17.3	21.0	17.5	18.9	13.7	9.3		12.4	8.8
Var	198.8	418.5	563.4	300.4	439.3	307.8	358.1	186.4	86.0		153.9	78.0
Max	106.0	91.1	91.5	102.7	94.2	96.6	106.6	98.3	91.3		93.6	92.1
Min	57.0	3.4	3.4	42.8	27.8	45.9	43.0	51.1	58.0		51.1	65.8

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	99.5	82.3	51.6	39.5
6-2-98	45.2	40.9	31.6	56.2
13-3-98	66.0	67.2	68.2	65.9
17-4-98	35.5	32.0	15.9	40.8
8-5-98	38.4	29.4	30.1	9.2
12-6-98	75.5	75.5	62.0	64.8
3-7-98	89.7	79.3	57.7	69.5
7-8-98	83.7	82.2	91.1	102.7
11-9-98	72.9	67.8	64.3	57.9
9-10-98	64.5	56.5	37.1	45.1
13-11-98	57.9	47.0	8.8	1.7
11-12-98	95.5	75.9	46.0	43.5
Mean	68.7	61.3	47.0	49.7
Std	20.6	18.7	22.6	25.8
Var	425.9	351.1	508.5	665.7
Max	99.5	82.3	91.1	102.7
Min	35.5	29.4	8.8	1.7

**Table 6. Water Quality of Parramatta River**

**Parameter - Dissolved Oxygen Units - mg/L.**

**Surface Water**

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	4.9	5.0	5.6	3.3	2.4	4.0	7.6	4.4	4.5		6.7	6.2
6-2-98	5.7	0.3	0.3	3.3	2.6	4.1	6.4	7.4	4.3		4.2	6.3
13-8-98	4.7	4.8	4.7	4.8	6.0	7.2	6.9	7.6	5.6		5.1	6.7
17-4-98	5.5	5.6	2.6	5.5	6.7	8.4	5.6	6.7	7.2		5.2	8.6
8-5-98	5.7	5.6	5.0	6.9	7.6	9.1	6.1	8.2	5.7		6.8	9.1
12-6-98	6.2	6.2	4.8	6.0	7.0	8.8	4.4	6.9	6.5		6.3	8.7
3-7-98	7.6	7.4	5.9	9.0	8.1	9.8	5.5	8.9	7.3		7.3	10.2
7-8-98	10.0	9.5	9.7	10.9	10.0	10.2	9.0	10.0	6.9		9.9	9.7
11-9-98	5.9	6.0	5.5	6.5	8.0	8.9	10.5	9.7	5.9		6.8	8.5
9-10-98	4.4	4.1	2.8	3.8	3.4	4.9	8.9	7.5	5.8		5.1	7.2
13-11-98	5.4	4.3	4.8	5.7	6.3	6.9	7.5	5.9	5.7		6.2	7.5
11-12-98	7.4	5.2	1.2	3.0	3.2	5.3	8.0	7.6	6.2		4.3	5.8
Mean	6.1	5.3	4.4	5.7	5.9	7.3	7.2	7.6	6.0		6.2	7.9
Std	1.5	2.1	2.4	2.3	2.4	2.1	1.7	1.5	0.9		1.5	1.4
Var	2.2	4.3	5.6	5.3	5.6	4.6	2.8	2.2	0.8		2.2	2.0
Max	10.0	9.5	9.7	10.9	10.0	10.2	10.5	10.0	7.3		9.9	10.2
Min	4.4	0.3	0.3	3.0	2.4	4.0	4.4	4.4	4.3		4.2	5.8

**Bottom Water**

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	6.8	5.7	3.6	2.8
6-2-98	3.0	2.7	2.1	3.8
13-8-98	4.5	4.7	4.7	4.5
17-4-98	2.7	2.5	1.3	3.3
8-5-98	3.0	2.3	2.5	0.7
12-6-98	6.3	6.3	5.2	5.5
3-7-98	7.9	6.8	5.0	6.1
7-8-98	7.7	7.2	9.6	10.9
11-9-98	5.9	5.5	5.4	4.8
9-10-98	4.9	4.3	2.8	3.4
13-11-98	4.3	3.5	0.6	1.7
11-12-98	6.6	5.3	3.2	3.0
Mean	5.3	4.7	3.8	4.2
Std	1.8	1.6	2.3	2.5
Var	3.1	2.6	5.2	6.2
Max	7.9	7.2	9.6	10.9
Min	2.7	2.3	0.6	0.7

Changes in annual mean concentrations of dissolved oxygen (percentage saturation) for surface and bottom water (Stations 1-4 only) of the estuary and freshwater creeks are presented in Figure 13 for 1990 to 1998.

Mean dissolved oxygen concentrations in surface and bottom water of the estuary of the upper Parramatta River (Stations 1-4) were generally less than 100% of saturation for the period 1990 to 1998. The main reason for this was that the measurements were all made soon after dawn (Figure 10). These dissolved oxygen values represented diurnal minima. For most of the period 1996 to 1998 these mean minimum values for the upper estuary were much lower than they had been in previous years sampled.

Dissolved oxygen concentrations at Station 3 (located at the confluence of Duck River and Duck Creek) were very variable over the nine years sampled. Between 1995 and 1998 there were periods when dissolved oxygen concentrations were very low at Station 3 (Figure 11). These were between October 1995 and February 1996, between October to December 1996 and 1997 and in February and December 1998.

Dissolved oxygen concentrations in freshwater creeks leading to the upper Parramatta River (Figure 12) were very variable over the period 1990 to 1998. Values ranged from around 140% of saturation to less than 15% of saturation.

Figure 13 shows changes in annual mean concentration of dissolved oxygen in the upper estuary of the Parramatta River and in creeks leading to the river. Annual mean dissolved oxygen concentrations for each station varied slightly from year to year. The greatest annual mean variation occurred in Toongabbie Creek and the freshwater section of the upper Parramatta River (Marsden Weir).

## Nutrients

The plant nutrients measured in this study were the various forms of nitrogen and phosphorus.

The following forms of nitrogen were measured :

- Ammonia
- Total Kjeldahl nitrogen (TKN)
- Organic nitrogen (TKN-ammonia)
- Nitrite
- Nitrate
- Oxidized nitrogen (Nitrite+nitrate)
- Total nitrogen (ammonia+organic nitrogen+oxidized nitrogen)

Nitrogen concentration was expressed as mg-N per litre.

The following forms of phosphorus were measured in the study.

- Orthophosphate
- Total phosphorus (orthophosphate+organic phosphorus)

Phosphorus concentrations were expressed as mg-P per litre.

### Ammonia

Ammonia concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 7. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

Figure 14 shows changes in the mean concentration of ammonia in surface and bottom of the estuarine section of the upper Parramatta River (Stations 1-4) for the period 1990 to 1998. Figure 15 shows changes in ammonia concentration in freshwater creeks entering the upper Parramatta River system from 1990 to 1998.

Changes in annual mean ammonia concentrations at Stations in the upper Parramatta River system are shown in Figure 16 for the years 1990 to 1998.

#### Go to Appendix A

- Page 14. Figure 14. Water Quality of Upper Parramatta River - Ammonia Concentration Changes 1990 - 1998 mg-N/L.**
- Page 15. Figure 15. Water Quality of Upper Parramatta River - Ammonia Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-N/L.**
- Page 16. Figure 16. Water Quality of Upper Parramatta River - Annual Mean Ammonia Concentration Changes 1990 - 1998 mg-N/L.**

## Table 7. Water Quality of Parramatta River

Parameter - Ammonia Concentration Units - milligrams-N/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.139	0.056	0.292	0.424	0.160	0.191	0.074	0.128	0.073	0.091	0.156	0.094
6-2-98	0.163	0.129	0.088	0.189	0.186	0.090	0.063	0.080	0.090	5.101	0.109	0.146
13-3-98	0.305	0.351	0.304	0.447	0.154	0.116	0.113	0.179	1.867	1.067	0.271	0.147
17-4-98	0.189	0.185	0.273	0.354	0.104	0.076	0.112	0.189	1.516	4.379	0.299	0.115
8-5-98	0.431	0.444	0.314	0.327	0.157	0.097	0.070	0.126	0.240	6.000	0.135	0.115
12-6-98	0.217	0.204	0.203	0.265	0.109	0.072	0.160	0.094	0.085	2.891	0.180	0.096
3-7-98	0.070	0.064	0.177	0.123	0.088	0.055	0.120	0.104	0.386	0.270	0.229	0.079
7-8-98	0.279	0.300	0.268	0.186	0.208	0.158	0.865	1.280	2.430	1.851	0.279	0.213
11-9-98	0.241	0.121	0.151	0.270	0.116	0.087	0.049	0.065	2.251	1.364	0.077	0.152
9-10-98	0.133	0.044	0.132	0.155	0.135	0.186	0.079	0.133	1.631	1.534	0.136	0.147
13-11-98	0.216	0.302	0.318	0.203	0.078	0.090	0.071	0.150	0.682	0.282	0.345	0.089
11-12-98	0.124	0.298	0.365	0.321	0.275	0.159	0.120	0.113	4.681	16.593	0.108	0.177
Mean	0.209	0.208	0.240	0.272	0.148	0.115	0.158	0.220	1.328	3.452	0.194	0.131
Std	0.093	0.124	0.083	0.100	0.053	0.044	0.215	0.322	1.319	4.386	0.084	0.038
Var	0.008	0.015	0.006	0.010	0.002	0.001	0.046	0.103	1.739	19.237	0.007	0.001
Max	0.431	0.444	0.365	0.447	0.275	0.191	0.865	1.280	4.681	16.593	0.345	0.213
Min	0.070	0.044	0.088	0.123	0.078	0.055	0.049	0.065	0.073	0.091	0.077	0.079

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.07	0.16	0.31	0.18
6-2-98	0.06	0.18	0.20	0.20
13-3-98	0.21	0.16	0.31	0.46
17-4-98	0.35	0.57	0.45	0.65
8-5-98	0.27	0.31	0.51	0.47
12-6-98	0.17	0.15	0.09	0.31
3-7-98	0.06	0.08	0.14	0.12
7-8-98	0.35	0.18	0.24	0.19
11-9-98	0.21	0.18	0.14	0.29
9-10-98	0.08	0.09	0.07	0.16
13-11-98	0.53	0.19	0.38	0.18
11-12-98	0.06	0.06	0.25	0.27
Mean	0.20	0.19	0.26	0.29
Std	0.14	0.13	0.13	0.15
Var	0.02	0.01	0.01	0.02
Max	0.53	0.57	0.51	0.65
Min	0.06	0.06	0.07	0.12

Monthly mean ammonia concentrations in surface and bottom water of the estuarine section of the upper Parramatta River were usually around or less than 0.5 mg-N/L over the period 1990 to 1998 (Figure 14). On two occasions there were peaks of ammonia that reached between 1.0 and 2.4 mg-N/L. The cause of these peaks in concentration were not determined.

In the freshwater creeks leading to the upper Parramatta River ammonia concentrations were usually around 0.5 mg-N/L (Figure 15) over the nine years sampled. There were also peaks of ammonia concentration recorded for each freshwater station sampled between 1990 and 1998. These peaks in ammonia concentration once exceeded 3 mg-N/L.

Figure 16 shows changes in the annual mean concentration of ammonia for each section of the upper Parramatta River system. There was considerable variation in the annual mean values calculated for each station each year of the study. Annual mean values ranged from 0.10 to 0.45 mg-N/L.

## **Organic Nitrogen**

Organic nitrogen concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 8. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

Mean organic nitrogen concentrations (Stations 1-4) of surface and bottom water of the estuarine section of the upper Parramatta River for each month over the period January 1990 to December 1998 are plotted in Figure 17. Figure 18 shows organic nitrogen concentrations at freshwater stations in creeks leading to the upper Parramatta River over the period 1990 to 1998.

Annual mean organic nitrogen values calculated for surface and bottom water of the estuarine section of the upper Parramatta River and the freshwater tributaries over the period 1990 to 1998 are plotted in Figure 19.

In the estuarine section of the upper Parramatta River system organic nitrogen concentrations were extremely variable (Figure 17) and fluctuated between almost zero and 2.0 mg-N/L. Most of the organic nitrogen values in the estuary were less than 1 mg-N/L.

Organic nitrogen concentrations in the freshwater creeks leading to the Parramatta River were also variable and ranged between almost zero and 3.0 mg-N/L. Most of the organic nitrogen values were less than 1.5 mg-N/L (Figure 18).

Annual mean organic nitrogen values varied from creek to creek and in the estuary of the upper Parramatta River (Figure 19). There was also considerable variation from year to year at each station sampled between 1990 and 1998.

### **Go to Appendix A**

- Page 17. Figure 17. Water Quality of Upper Parramatta River - Organic Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**
- Page 18. Figure 18. Water Quality of Upper Parramatta River - Organic Nitrogen Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-N/L.**
- Page 19. Figure 19. Water Quality of Upper Parramatta River - Annual Mean Organic Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**

## Table 8. Water Quality of Parramatta River

Parameter - Organic Nitrogen Concentration Units - milligrams-N/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.519	0.563	0.981	0.435	0.846	0.788	0.435	0.446	2.681	7.753	0.338	0.795
6-2-98	0.328	0.428	0.787	0.765	0.690	0.524	0.557	0.527	4.469	4.248	0.584	0.936
13-3-98	0.348	0.299	0.341	0.352	0.165	0.498	0.209	0.212	6.227	3.424	0.113	1.028
17-4-98	0.480	0.466	0.452	0.443	0.684	0.719	0.865	0.530	8.378	6.573	0.524	0.935
8-5-98	0.997	0.821	0.790	0.167	0.252	0.622	0.694	1.084	2.361	5.820	0.236	0.741
12-6-98	0.105	0.168	0.197	0.406	0.310	0.276	0.365	0.256	3.898	0.266	0.108	0.341
3-7-98	0.924	0.713	1.029	0.420	0.751	0.871	0.519	0.647	8.331	11.381	0.982	0.847
7-8-98	0.942	0.923	1.151	1.052	1.070	0.336	0.216	1.108	3.158	2.769	0.809	0.851
11-9-98	0.366	0.496	0.865	0.362	0.255	0.389	0.601	0.322	3.365	4.143	0.715	1.045
9-10-98	0.079	0.567	0.224	0.065	0.390	0.057	0.257	0.246	0.629	0.274	0.075	0.142
13-11-98	0.439	0.514	0.720	0.461	0.812	0.360	0.369	0.493	4.743	5.597	0.700	0.539
11-12-98	0.149	0.551	0.571	0.393	0.248	0.528	0.485	0.433	1.685	2.239	0.211	0.566
Mean	0.473	0.542	0.676	0.443	0.539	0.497	0.464	0.526	4.160	4.541	0.450	0.730
Std	0.309	0.199	0.305	0.244	0.289	0.222	0.190	0.285	2.339	3.033	0.296	0.269
Var	0.095	0.039	0.092	0.059	0.083	0.049	0.036	0.081	5.469	9.200	0.087	0.072
Max	0.997	0.923	1.151	1.052	1.070	0.871	0.865	1.108	8.378	11.381	0.982	1.045
Min	0.079	0.168	0.197	0.065	0.165	0.057	0.209	0.212	0.629	0.266	0.075	0.142

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.07	0.36	0.36	0.99
6-2-98	0.37	0.40	0.71	0.88
13-3-98	0.40	0.42	0.42	0.41
17-4-98	0.37	0.38	0.82	0.41
8-5-98	1.23	1.01	0.25	0.04
12-6-98	0.20	0.09	0.18	0.23
3-7-98	0.80	0.45	0.36	0.56
7-8-98	0.47	0.46	0.74	1.36
11-9-98	0.39	0.22	0.37	0.36
9-10-98	0.12	0.26	0.27	0.05
13-11-98	0.28	0.27	0.51	0.60
11-12-98	0.52	0.68	0.62	0.33
Mean	0.43	0.42	0.47	0.52
Std	0.30	0.23	0.20	0.37
Var	0.09	0.05	0.04	0.14
Max	1.23	1.01	0.82	1.36
Min	0.07	0.09	0.18	0.04

## **Oxidized Nitrogen**

Oxidized nitrogen concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 9. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

Mean oxidized nitrogen concentrations (Stations 1-4) of surface and bottom water of the estuarine section of the upper Parramatta River for each month over the period January 1990 to December 1998 are plotted in Figure 20. Figure 21 shows oxidized nitrogen concentrations at freshwater stations in creeks leading to the upper Parramatta River over the period 1990 to 1998.

Annual mean oxidized nitrogen values calculated for surface and bottom water of the estuarine section of the upper Parramatta River and the freshwater tributaries over the period 1990 to 1998 are plotted in Figure 22.

In the estuarine section of the upper Parramatta River system oxidized nitrogen concentrations were variable (Figure 20) and fluctuated between almost zero and 0.75 mg-N/L. Most of the oxidized nitrogen values in the estuary were less than 0.4 mg-N/L.

Oxidized nitrogen concentrations in the freshwater creeks leading to the Parramatta River were also extremely variable and ranged between almost zero and 2.3 mg-N/L. Most of the oxidized nitrogen values were less than 1.0 mg-N/L (Figure 21).

### **Go to Appendix A**

**Page 20. Figure 20. Water Quality of Upper Parramatta River - Oxidized Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**

**Page 21. Figure 21. Water Quality of Upper Parramatta River - Oxidized Nitrogen Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-N/L.**

**Page 22. Figure 22. Water Quality of Upper Parramatta River - Annual Mean Oxidized Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**

Annual mean oxidized nitrogen values varied from creek to creek and in the estuary of the upper Parramatta River (Figure 22). There was also considerable variation from year to year at each station sampled between 1990 and 1998.

## Table 9. Water Quality of Parramatta River

Parameter - Oxidised Nitrogen Concentration Units - milligrams-N/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.117	0.083	0.243	0.185	0.139	0.196	0.019	0.237	8.283	18.184	0.185	0.148
6-2-98	0.150	0.206	0.077	0.039	0.319	0.098	0.020	0.117	7.535	9.020	0.409	1.383
13-3-98	0.067	0.074	0.094	0.097	0.040	0.076	0.019	0.107	1.638	2.528	0.115	0.125
17-4-98	0.461	0.527	0.224	0.339	0.255	0.295	0.300	0.508	5.230	5.210	0.509	0.777
8-5-98	0.543	0.687	0.340	0.511	0.981	0.592	0.410	0.852	6.803	10.471	0.607	0.915
12-6-98	0.328	0.354	0.375	0.431	1.302	0.766	1.057	1.044	15.747	19.490	0.822	0.641
3-7-98	0.487	0.538	0.403	0.436	0.758	0.642	1.028	1.143	3.861	7.025	0.883	0.625
7-8-98	1.020	0.355	0.674	0.915	1.028	0.810	0.485	1.078	4.650	5.777	0.472	0.955
11-9-98	0.312	0.457	0.366	0.391	0.742	0.413	0.337	0.365	6.262	11.186	0.459	0.406
9-10-98	0.098	0.105	0.148	0.090	0.159	0.196	0.074	0.045	5.475	7.578	0.347	0.217
13-11-98	0.329	0.329	0.202	0.175	0.331	0.202	0.031	0.206	12.395	29.328	0.210	0.374
11-12-98	0.338	0.642	0.184	0.123	0.361	0.236	0.028	0.059	22.306	32.744	0.175	0.555
Mean	0.354	0.363	0.277	0.311	0.535	0.377	0.318	0.480	8.349	13.212	0.433	0.593
Std	0.251	0.205	0.159	0.238	0.394	0.250	0.363	0.412	5.554	9.301	0.238	0.358
Var	0.063	0.041	0.025	0.056	0.155	0.062	0.132	0.170	30.847	86.501	0.056	0.128
Max	1.020	0.687	0.674	0.915	1.302	0.810	1.057	1.143	22.306	32.744	0.883	1.383
Min	0.067	0.074	0.077	0.039	0.040	0.076	0.019	0.045	1.638	2.528	0.115	0.125

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.04	0.07	0.20	0.14
6-2-98	0.04	0.10	0.05	0.03
13-3-98	0.05	0.07	0.07	0.10
17-4-98	0.20	0.25	0.24	0.27
8-5-98	0.22	0.22	0.34	0.23
12-6-98	0.26	0.33	0.45	0.43
3-7-98	0.23	0.22	0.30	0.29
7-8-98	0.42	0.26	0.76	1.13
11-9-98	0.18	0.27	0.39	0.29
9-10-98	0.07	0.09	0.14	0.08
13-11-98	0.09	0.14	0.13	0.14
11-12-98	0.05	0.12	0.16	0.09
Mean	0.15	0.18	0.27	0.27
Std	0.11	0.08	0.19	0.28
Var	0.01	0.00	0.03	0.07
Max	0.42	0.33	0.76	1.13
Min	0.04	0.07	0.05	0.03

## **Total Nitrogen**

Total nitrogen concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 10. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

### **Go to Appendix A**

**Page 23. Figure 23. Water Quality of Upper Parramatta River - Total Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**

**Page 24. Figure 24. Water Quality of Upper Parramatta River - Total Nitrogen Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-N/L.**

**Page 25. Figure 25. Water Quality of Upper Parramatta River - Annual Mean Total Nitrogen Concentration Changes 1990 - 1998 mg-N/L.**

Mean total nitrogen concentrations (Stations 1-4) of surface and bottom water of the estuarine section of the upper Parramatta River for each month over the period January 1990 to December 1998 are plotted in Figure 23. Figure 24 shows total nitrogen concentrations at freshwater stations in creeks leading to the upper Parramatta River over the period 1990 to 1998.

Annual mean total nitrogen values calculated for surface and bottom water of the estuarine section of the upper Parramatta River and the freshwater tributaries over the period 1990 to 1998 are plotted in Figure 25.

In the estuarine section of the upper Parramatta River system total nitrogen concentrations were variable (Figure 23) and fluctuated between almost zero and 4.2 mg-N/L. Most of the total nitrogen values in the estuary were less than 2.0 mg-N/L.

Total nitrogen concentrations in the freshwater creeks leading to the Parramatta River were also extremely variable and ranged between almost zero and 4.2 mg-N/L. Most of the total nitrogen values were less than 3.0 mg-N/L (Figure 24).

Annual mean total nitrogen values varied from creek to creek and in the estuary of the upper Parramatta River (Figure 25). There was also considerable variation from year to year at each station sampled between 1990 and 1998.

## Table 10. Water Quality of Parramatta River

Parameter - Total Nitrogen Concentration Units - milligrams-N/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.776	0.703	1.515	1.044	1.145	1.175	0.528	0.812	11.038	26.029	0.679	1.037
6-2-98	0.640	0.764	0.953	0.994	1.194	0.713	0.641	0.725	12.094	18.369	1.103	2.465
13-3-98	0.720	0.725	0.740	0.896	0.359	0.690	0.341	0.499	9.732	7.019	0.499	1.300
17-4-98	1.131	1.177	0.949	1.135	1.044	1.091	1.277	1.228	15.124	16.162	1.332	1.828
8-5-98	1.971	1.952	1.444	1.005	1.390	1.311	1.174	2.062	9.404	22.291	0.978	1.771
12-6-98	0.591	0.817	0.918	0.928	1.911	1.322	1.797	1.699	18.897	25.039	1.219	1.089
3-7-98	1.482	1.315	1.609	0.979	1.598	1.569	1.668	1.894	12.578	18.676	2.094	1.552
7-8-98	2.241	1.577	2.093	2.153	2.306	1.304	1.565	3.466	10.238	10.397	1.561	2.018
11-9-98	0.918	1.075	1.382	1.023	1.114	0.889	0.987	0.752	11.878	16.693	1.251	1.604
9-10-98	0.311	0.717	0.504	0.311	0.684	0.439	0.412	0.424	7.735	9.386	0.558	0.505
13-11-98	0.983	1.145	1.240	0.839	1.222	0.652	0.472	0.850	17.819	35.207	1.255	1.003
11-12-98	0.611	1.490	1.120	0.837	0.884	0.923	0.633	0.606	28.672	51.577	0.493	1.298
Mean	1.031	1.122	1.206	1.012	1.237	1.006	0.958	1.251	13.768	21.404	1.085	1.456
Std	0.561	0.387	0.415	0.397	0.501	0.328	0.503	0.853	5.524	11.815	0.459	0.506
Var	0.315	0.149	0.172	0.158	0.251	0.107	0.253	0.727	30.512	139.594	0.211	0.256
Max	2.241	1.952	2.093	2.153	2.306	1.569	1.797	3.466	28.672	51.577	2.094	2.465
Min	0.311	0.703	0.504	0.311	0.359	0.439	0.341	0.424	7.735	7.019	0.493	0.505

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.19	0.59	0.86	1.31
6-2-98	0.47	0.69	0.96	1.11
13-3-98	0.67	0.65	0.82	0.97
17-4-98	0.91	1.20	1.52	1.33
8-5-98	1.72	1.53	1.10	0.75
12-6-98	0.62	0.75	0.91	1.00
3-7-98	1.08	0.76	0.80	0.97
7-8-98	1.24	0.90	1.74	2.68
11-9-98	0.78	0.67	0.90	0.94
9-10-98	0.28	0.46	0.48	0.30
13-11-98	0.90	0.59	1.01	0.91
11-12-98	0.63	0.87	1.03	0.70
Mean	0.79	0.81	1.01	1.08
Std	0.41	0.29	0.32	0.55
Var	0.16	0.08	0.10	0.30
Max	1.72	1.53	1.74	2.68
Min	0.19	0.46	0.48	0.30

## Orthophosphate

Orthophosphate concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 11. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

Mean orthophosphate concentrations (Stations 1-4) of surface and bottom water of the estuarine section of the upper Parramatta River for each month over the period January 1990 to December 1998 are plotted in Figure 26. Figure 27 shows orthophosphate concentrations at freshwater stations in creeks leading to the upper Parramatta River over the period 1990 to 1998.

Annual mean orthophosphate values calculated for surface and bottom water of the estuarine section of the upper Parramatta River and the freshwater tributaries over the period 1990 to 1998 are plotted in Figure 28.

Mean orthophosphate concentrations in surface water of the estuarine section of the upper Parramatta River (Stations 1-4) were variable over the period January 1990 to December 1998. Most of the orthophosphate values were below 0.05 mg-P/L. On 25 occasions, however, orthophosphate concentrations exceeded 0.05 mg-P/L. Orthophosphate concentrations reached more than 0.18 mg-P/L. In 1998 mean orthophosphate concentrations in surface water of the estuary reached the highest values recorded since the study began in 1990. The source of this orthophosphate was Duck River rather than Parramatta River.

Mean bottom water orthophosphate concentrations for the estuarine section of the upper Parramatta River (Stations 1-4) ranged between 0.005 and 0.110 for the period 1990 and 1998

Orthophosphate concentrations in freshwater creeks leading to the upper Parramatta River were very variable. In Lake Parramatta (Figure 27) orthophosphate concentrations were low for the entire period sampled. Annual mean values fluctuated between 0.06 and 0.022 mg-P/L over the nine years sampled (Figure 28). The freshwater section of the upper Parramatta River (Station 8 - sampled at Marsden Weir) showed some minor fluctuations in orthophosphate concentration over the period 1991 to 1998. Spikes of orthophosphate concentration of up to 0.12 mg-P/L were recorded. Orthophosphate concentrations in Toongabbie Creek were less than 0.05 mg-P/L over most of the period sampled but some concentration spikes of up to 0.3 mg-P/L were measured. For most of the nine years sampled, orthophosphate concentrations in Darling Mills Creek were less than 0.1 mg-P/L but on 7 occasions spikes of concentration occurred. The highest of these concentration spikes reached 0.66 mg-P/L (Figure 27).

Changes in annual mean concentration of orthophosphate were similar for surface and bottom water of the estuary and for Toongabbie Creek, Lake Parramatta and the fresh water section of the upper Parramatta River. Annual mean orthophosphate concentrations were relatively high in 1990, 1996, 1997 and 1998 and lower in the intervening years. Changes in annual mean orthophosphate concentrations in Darling Mills Creek were quite different from the other creeks sampled. Annual mean orthophosphate concentrations rose steeply between 1990 and 1993 before declining over the next two years (1995). In 1996 annual mean orthophosphate concentrations in Darling Mills Creek rose again before falling again in 1997 (Figure 28).

**Go to Appendix A**

**Page 26. Figure 26. Water Quality of Upper Parramatta River - Orthophosphate Concentration Changes 1990 - 1998 mg-P/L.**

**Page 27. Figure 27. Water Quality of Upper Parramatta River - Orthophosphate Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-P/L.**

**Page 28. Figure 28. Water Quality of Upper Parramatta River - Annual Mean Orthophosphate Concentration Changes 1990 - 1998 mg-P/L.**

## Table 11. Water Quality of Parramatta River

Parameter - Orthophosphate Concentration Units - milligrams-P/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.0499	0.0499	0.1305	0.1159	0.0161	0.0297	0.0034	0.0257	0.4272	3.2135	0.0697	0.0282
6-2-98	0.0232	0.0207	0.0186	0.0585	0.0195	0.0093	0.0018	0.0071	0.0672	0.1643	0.0124	0.0291
13-3-98	0.0635	0.0647	0.0985	0.1187	0.0158	0.0207	0.0021	0.0114	0.0821	0.1491	0.0629	0.0793
17-4-98	0.0275	0.0412	0.0396	0.0328	0.0415	0.0207	0.0232	0.0254	0.2675	0.2536	0.0186	0.0254
8-5-98	0.1141	0.4018	0.0883	0.0685	0.0861	0.0173	0.0111	0.0523	3.7352	3.5402	0.0536	0.0334
12-6-98	0.0384	0.0387	0.0403	0.0446	0.0440	0.0127	0.0248	0.0474	0.6014	0.3497	0.0279	0.0195
3-7-98	0.1091	0.5183	0.0341	0.0837	0.0477	0.0096	0.0170	0.0396	5.3518	3.7718	0.0179	0.0105
7-8-98	0.1305	0.1727	0.1463	0.2114	0.1435	0.0638	0.0096	0.1485	2.1715	2.1492	0.0775	0.1683
11-9-98	0.0337	0.0353	0.0229	0.0390	0.0210	0.0111	0.0037	0.0148	0.2846	0.5329	0.0108	0.0102
9-10-98	0.0585	0.0607	0.0499	0.0561	0.0542	0.0139	0.0031	0.0068	1.0869	0.9811	0.0310	0.0179
13-11-98	0.0548	0.0734	0.0263	0.0409	0.0415	0.0207	0.0043	0.0297	2.3901	1.8867	0.0229	0.0319
11-12-98	0.0759	0.1668	0.0880	0.0771	0.0248	0.0167	0.0031	0.0043	4.9817	6.3101	0.0133	0.0201
Mean	0.0649	0.1370	0.0653	0.0789	0.0463	0.0205	0.0089	0.0344	1.7873	1.9418	0.0349	0.0395
Std	0.0341	0.1536	0.0417	0.0482	0.0351	0.0142	0.0080	0.0376	1.8573	1.8555	0.0232	0.0424
Var	0.0011	0.0235	0.0017	0.0023	0.0012	0.0002	0.0000	0.0014	3.4497	3.4429	0.0005	0.0018
Max	0.1305	0.5183	0.1463	0.2114	0.1435	0.0638	0.0248	0.1485	5.3518	6.3101	0.0775	0.1683
Min	0.0232	0.0207	0.0186	0.0328	0.0158	0.0093	0.0018	0.0043	0.0672	0.1491	0.0108	0.0102

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.0189	0.0396	0.1181	0.1246
6-2-98	0.0003	0.0440	0.0564	0.0750
13-3-98	0.0579	0.0750	0.0917	0.1358
17-4-98	0.0387	0.0589	0.0514	0.0449
8-5-98	0.0657	0.0926	0.0812	0.1004
12-6-98	0.0310	0.0378	0.0406	0.0483
3-7-98	0.0737	0.0635	0.1414	0.1680
7-8-98	0.0737	0.0635	0.1414	0.1680
11-9-98	0.0316	0.0384	0.0285	0.0480
9-10-98	0.0489	0.0570	0.0610	0.0678
13-11-98	0.0313	0.0489	0.0533	0.0756
11-12-98	0.0251	0.0403	0.0815	0.0895
Mean	0.0414	0.0550	0.0789	0.0955
Std	0.0219	0.0162	0.0362	0.0424
Var	0.0004	0.0002	0.0013	0.0018
Max	0.0737	0.0926	0.1414	0.1680
Min	0.0003	0.0378	0.0285	0.0449

## **Total Phosphorus**

Total phosphorus concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 12. Annual mean, standard deviations, variances, maximum and minimum values have been calculated.

Mean total phosphorus concentrations (Stations 1-4) of surface and bottom water of the estuarine section of the upper Parramatta River for each month over the period January 1990 to December 1998 are plotted in Figure 29. Figure 30 shows total phosphorus concentrations at freshwater stations in creeks leading to the upper Parramatta River over the period 1990 to 1998.

Annual mean total phosphorus values calculated for surface and bottom water of the estuarine section of the upper Parramatta River and the freshwater tributaries over the period 1990 to 1998 are plotted in Figure 31.

### **Go to Appendix A**

- Page 29.      Figure 29. Water Quality of Upper Parramatta River - Total Phosphorous Concentration Changes 1990 - 1998 mg-P/L.**
- Page 30.      Figure 30. Water Quality of Upper Parramatta River - Total Phosphorous Concentration Changes in Freshwater Tributaries 1990 - 1998 mg-P/L.**
- Page 31.      Figure 31. Water Quality of Upper Parramatta River - Annual Mean Total Phosphorous Concentration Changes 1990 - 1998 mg-P/L.**

Mean total phosphorus concentrations in surface and bottom water of the estuary of the upper Parramatta River (Stations 1-4) were variable over the nine years sampled. Mean total phosphorus concentrations ranged from 0.04 to 0.68 mg-P/L (Figure 29).

Total phosphorus concentrations in freshwater creeks leading to the upper Parramatta River were generally less than 0.5 mg-P/L (Figure 30). There were spikes of total phosphorus concentration in Toongabbie Creek, Darling Mills Creek and, to a lesser extent in Lake Parramatta and the Parramatta River at Marsden Weir.

Annual mean total phosphorus concentrations in the upper estuary of the Parramatta River and the freshwater creeks leading to the river varied substantially over the nine years sampled without exhibiting any obvious trends (Figure 31).

## Table 12. Water Quality of Parramatta River

Parameter - Total Phosphorous Concentration Units - milligrams-P/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	0.0824	0.0858	0.1141	0.1417	0.2399	0.2192	0.2548	0.3156	3.3675	2.3622	0.1104	0.1736
6-2-98	0.1113	0.1283	0.1733	0.1643	0.1262	0.1150	0.1141	0.0926	2.7897	0.9514	0.1699	0.1600
13-3-98	0.0908	0.1060	0.1525	0.1764	0.0700	0.0499	0.0093	0.0688	0.2604	0.6135	0.0889	0.1801
17-4-98	0.0635	0.0930	0.0954	0.0902	0.1401	0.0657	0.0474	0.0877	0.4796	0.3171	0.0604	0.0706
8-5-98	0.2021	0.3773	0.1637	0.1804	0.2703	0.0809	0.0703	0.1782	5.2229	8.4974	0.2167	0.1088
12-6-98	0.1088	0.0750	0.0762	0.0784	0.0954	0.0489	0.0452	0.0914	1.0931	0.5264	0.0539	0.0440
3-7-98	0.2040	0.6749	0.0663	0.0796	0.0948	0.0403	0.0499	0.1113	5.8181	4.5341	0.0753	0.1101
7-8-98	0.4036	1.4548	0.4746	0.3249	0.3689	0.1786	0.1073	0.4337	5.2632	4.3896	0.2027	0.3856
11-9-98	0.0576	0.0657	0.0551	0.0961	0.0790	0.0337	0.0418	0.0523	0.4179	1.0134	0.0396	0.0809
9-10-98	0.0973	0.1178	0.1159	0.1128	0.0917	0.0570	0.0164	0.0663	1.2818	0.9920	0.0747	0.1519
13-11-98	0.1913	0.2492	0.1575	0.1705	0.2223	0.0988	0.0511	0.1906	4.3031	3.3502	0.1640	0.1386
11-12-98	0.1296	0.3094	0.2015	0.1460	0.1076	0.0424	0.0244	0.0393	5.9126	6.0329	0.0796	0.0709
Mean	0.1452	0.3114	0.1539	0.1468	0.1589	0.0859	0.0693	0.1440	3.0175	2.7983	0.1114	0.1396
Std	0.0921	0.3847	0.1063	0.0650	0.0904	0.0562	0.0637	0.1145	2.1501	2.4989	0.0583	0.0855
Var	0.0084	0.1480	0.0112	0.0042	0.0081	0.0031	0.0040	0.0131	4.6230	6.2444	0.0034	0.0073
Max	0.4036	1.4548	0.4746	0.3249	0.3689	0.2192	0.2548	0.4337	5.9126	8.4974	0.2167	0.3856
Min	0.0576	0.0657	0.0551	0.0784	0.0700	0.0337	0.0093	0.0393	0.2604	0.3171	0.0396	0.0440

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	0.0883	0.1299	0.1048	0.1054
6-2-98	0.1163	0.1290	0.2251	0.2536
13-3-98	0.1085	0.1119	0.1618	0.2055
17-4-98	0.0899	0.1125	0.0964	0.1187
8-5-98	0.1628	0.1835	0.1990	0.2725
12-6-98	0.0716	0.0864	0.0663	0.0843
3-7-98	0.0812	0.1355	0.0601	0.1082
7-8-98	0.2393	0.3199	0.4638	0.5121
11-9-98	0.0703	0.0678	0.0551	0.1355
9-10-98	0.1011	0.1144	0.1159	0.1435
13-11-98	0.1395	0.1879	0.2173	0.2440
11-12-98	0.1370	0.1891	0.1848	0.2279
Mean	0.1172	0.1473	0.1625	0.2009
Std	0.0459	0.0637	0.1082	0.1129
Var	0.0021	0.0040	0.0117	0.0127
Max	0.2393	0.3199	0.4638	0.5121
Min	0.0703	0.0678	0.0551	0.0843

## Water Clarity

Water clarity in the tidal section of the upper Parramatta River and Duck River and the creeks leading to the river was measured in several ways. They were :

Turbidity (Nephelometric Turbidity Units)

Percentage transmission of light through water

Concentration of total suspended solids (mg/L)

Concentration of volatile suspended solids (mg/L)

Secchi depth (metres) Estuarine Stations only.

### Turbidity

Turbidity data for surface and bottom water for stations in the estuarine sections of Duck River and the upper Parramatta River and the creeks leading to the upper Parramatta River in 1998 are presented in Table 13.

Mean turbidity data for surface and bottom water of the estuarine section of the upper Parramatta River (Stations 1-4) are shown in Figure 32 for the period February 1992 to December 1998. Figure 33 shows a linear plot of turbidity changes at stations in freshwater creeks leading to the upper Parramatta River (Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River at Marsden Weir).

Annual mean changes in turbidity of the estuarine section of the upper Parramatta River (Stations 1-4) and freshwater tributary creeks are shown in Figure 34 for the period 1992 to 1998.

Mean turbidity values for the estuarine section of the upper Parramatta River (Stations 1-4) were around 15-20 NTU during dry weather (Figure 32). In and following wet weather the mean turbidity of the upper estuary rose to over 50 NTU. Major rainfall events caused large increases in turbidity (in excess of 150 NTU).

The turbidity of Lake Parramatta was relatively low throughout the period February 1992 to December 1998 in both dry and wet weather (Figure 33). The turbidity of Toongabbie Creek was high during dry weather and extremely high during wet weather. Darling Mills Creek and Parramatta River at Marsden Weir were also turbid during dry weather and very turbid during wet weather. Wet weather turbidity values for these three creeks reached over 300 NTU.

Annual mean turbidity of surface and bottom water of the upper estuary of Parramatta River varied only slightly over the six years studied (1992 to 1998). The annual mean turbidity of Lake Parramatta varied little over the 6 years sampled (Figure 34). Annual mean turbidity values for Toongabbie Creek, Darling Mills Creek and Parramatta River (FW) varied greatly from year to year. The main factor influencing these changes was above and below average annual rainfall in the catchment of the upper Parramatta River.

**Go to Appendix A**

**Page 32. Figure 32. Water Quality of Upper Parramatta River - Turbidity Changes 1990 - 1998 Nephelometric Turbidity Units.**

**Page 33. Figure 33. Water Quality of Upper Parramatta River - Turbidity Changes in Freshwater Tributaries 1990 - 1998 Nephelometric Turbidity Units.**

**Page 34. Figure 34. Water Quality of Upper Parramatta River - Annual Mean Turbidity Changes 1990 - 1998 Nephelometric Turbidity Units.**

## Table 13. Water Quality of Parramatta River

Parameter - Turbidity Units - Nephelometric Turbidity Units.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	8.8	13.1	18.0	13.6	121.7	24.3	3.9	58.9	11.2		7.8	9.7
6-2-98	5.9	24.9	26.5	3.5	16.8	5.9	1.4	12.4	18.4		38.9	13.5
13-3-98	9.3	9.2	2.9	4.5	13.5	7.2	1.3	17.1	6.2		1.7	6.4
17-4-98	6.4	7.5	20.8	17.9	51.5	20.8	1.7	38.8	11.3		5.5	2.0
8-5-98	5.4	8.9	8.9	13.5	52.4	4.6	0.9	38.7	6.9		11.5	1.4
12-6-98	5.0	5.0	7.2	8.9	38.6	8.1	3.9	37.8	36.9		7.5	7.5
3-7-98	5.0	3.6	4.2	15.8	64.4	8.3	0.3	37.8	9.2		6.7	6.9
7-8-98	139.5	55.8	106.5	174.7	119.7	73.2	6.1	149.1	64.4		63.5	33.3
11-9-98	8.7	2.8	2.6	25.3	53.3	10.0	7.4	38.8	13.0		5.0	24.6
9-10-98	5.7	6.4	10.6	10.0	20.4	4.5	5.3	16.6	13.6		0.4	16.2
13-11-98	25.4	28.2	42.1	32.9	96.6	30.2	5.6	60.5	17.8		21.3	26.4
11-12-98	3.7	3.7	3.1	3.7	20.4	35.2	8.7	4.6	6.0		2.8	4.0
Mean	19.1	14.1	21.1	27.0	55.8	19.4	3.9	42.6	17.9		14.4	12.7
Std	36.7	14.8	28.1	45.3	36.9	19.1	2.7	36.2	16.1		18.0	10.0
Var	1348.6	219.8	792.4	2053.4	1359.4	366.5	7.1	1308.4	260.8		323.1	99.5
Max	139.5	55.8	106.5	174.7	121.7	73.2	8.7	149.1	64.4		63.5	33.3
Min	3.7	2.8	2.6	3.5	13.5	4.5	0.3	4.6	6.0		0.4	1.4

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	29.7	52.1	17.0	11.2
6-2-98	16.5	10.8	8.9	50.3
13-3-98	29.5	11.0	5.6	5.7
17-4-98	8.7	16.5	3.8	13.3
8-5-98	2.3	5.2	2.3	8.9
12-6-98	11.7	11.7	2.5	7.5
3-7-98	5.0	3.6	2.8	6.1
7-8-98	82.0	19.3	108.4	193.4
11-9-98	16.6	9.7	3.3	30.5
9-10-98	15.8	10.2	5.7	11.3
13-11-98	11.2	10.6	11.8	22.5
11-12-98	36.5	14.7	3.3	7.6
Mean	22.1	14.6	14.6	30.7
Std	20.6	12.0	28.6	50.6
Var	425.0	144.7	817.8	2563.3
Max	82.0	52.1	108.4	193.4
Min	2.3	3.6	2.3	5.7

## **Percentage transmission of light through water**

Percentage transmission of light through water data for surface and bottom water (Stations 1-4 only) for Stations sampled during 1998 are presented in Table 14. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

Mean percentage transmission of light through water values for surface and bottom water of the estuarine section of the upper Parramatta River for the period 1990 to 1998 are shown in Figure 35. Figure 36 shows changes in percentage transmission values for the freshwater creeks entering the upper Parramatta River from 1990 to 1998 (Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River (FW)).

Annual mean changes in percentage transmission of light through water for surface and bottom water of the estuary and freshwater creeks leading to the Parramatta River are presented in Figure 37

### **Go to Appendix A**

**Page 35. Figure 35. Water Quality of Upper Parramatta River - Percentage Transmission of Light Through Water Changes 1990 - 1998 %T.**

**Page 36. Figure 36. Water Quality of Upper Parramatta River - Percentage Transmission of Light Through Water Changes in Freshwater Tributaries 1990 - 1998 %T.**

**Page 37. Figure 37. Water Quality of Upper Parramatta River - Annual Mean Percentage Transmission of Light Through Water Changes 1990 - 1998 %T.**

Mean percentage transmission of light through water values for surface and bottom water of the estuarine section of the upper Parramatta River (Figure 35) for the period 1990 to 1998 showed some interesting features. From January 1990 to September 1993 the percentage transmission of light through water values were similar for both surface and bottom water. Between October 1992 to December 1996 bottom water had significantly lower percentage transmission values than surface waters. In 1997 and 1998 these differences disappeared. These differences were also apparent when turbidity data were examined (Figure 32). Except for rainfall events, water in the estuarine section of Parramatta River had percentage transmission values of between 80 and 90%. Bottom water values ranged from 40 to 90%.

Water in Lake Parramatta had consistently high percentage transmission of light values regardless of weather conditions. Freshwater creeks leading to the upper Parramatta River had extremely variable percentage transmission values (Figure 36).

Annual mean percentage transmission values for the estuary and freshwater creeks varied from year to year but there were no obvious trends (Figure 37).

**Table 14. Water Quality of Parramatta River**

**Parameter - Percentage Transmission of Light Through Water Units - Percentage.**

**Surface Water**

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	86.5	85.1	82.4	89.2	54.9	75.9	92.0	66.1	82.5	96.3	83.9	92.1
6-2-98	82.6	79.5	68.3	88.3	71.6	88.7	94.8	96.2	65.1	94.4	55.8	83.8
13-3-98	85.8	89.6	94.0	89.7	80.9	91.6	96.5	82.8	91.6	90.3	97.2	90.1
17-4-98	86.8	85.2	81.6	74.1	50.0	75.8	91.6	60.8	80.0	94.0	86.3	95.0
8-5-98	86.2	83.2	86.3	75.9	54.0	85.5	93.9	54.0	80.2	93.8	71.7	93.7
12-6-98	86.5	88.1	94.2	84.3	60.3	79.1	92.5	60.5	36.8	87.5	88.1	89.3
3-7-98	91.4	91.0	95.0	79.6	37.8	78.4	91.4	59.2	74.7	95.7	82.9	80.5
7-8-98	11.2	40.6	21.2	9.5	19.6	35.9	86.3	16.7	24.0	85.8	35.5	64.0
11-9-98	89.4	96.0	97.2	66.6	48.1	81.2	89.1	56.1	80.0	88.3	80.8	68.8
9-10-98	92.9	91.9	93.3	89.6	77.4	90.7	87.9	79.6	82.4	92.9	95.2	87.3
13-11-98	71.2	68.7	59.5	63.9	28.9	66.7	93.8	41.8	73.5	95.9	76.5	75.8
11-12-98	88.8	84.5	91.7	92.5	76.1	86.0	97.2	87.2	89.0	93.4	92.8	92.1
Mean	79.9	82.0	80.4	75.3	55.0	78.0	92.3	63.4	71.7	92.4	78.9	84.4
Std	21.4	14.1	21.0	21.8	18.8	14.4	3.2	20.6	19.8	3.4	17.0	9.7
Var	456.9	199.5	441.1	475.5	352.1	208.5	10.0	425.9	390.5	11.4	287.7	94.3
Max	92.9	96.0	97.2	92.5	80.9	91.6	97.2	96.2	91.6	96.3	97.2	95.0
Min	11.2	40.6	21.2	9.5	19.6	35.9	86.3	16.7	24.0	85.8	35.5	64.0

**Bottom Water**

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	81.6	82.5	79.2	86.5
6-2-98	73.6	84.8	77.2	70.0
13-3-98	88.0	87.1	88.9	88.4
17-4-98	88.8	83.4	92.0	72.8
8-5-98	82.9	88.2	88.6	75.8
12-6-98	67.4	80.2	94.5	87.6
3-7-98	82.2	85.5	93.7	77.0
7-8-98	42.9	71.4	21.3	9.4
11-9-98	76.5	84.0	94.7	46.1
9-10-98	87.4	87.8	93.9	90.4
13-11-98	80.3	72.2	86.1	71.5
11-12-98	80.7	74.1	91.8	85.1
Mean	77.7	81.8	83.5	71.7
Std	12.0	5.8	19.6	22.1
Var	144.8	33.1	382.4	488.8
Max	88.8	88.2	94.7	90.4
Min	42.9	71.4	21.3	9.4

## **Concentration of total suspended solids**

Total suspended solids data for surface and bottom water (Stations 1-4 only) for Stations sampled during 1998 are presented in Table 15. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

Mean total suspended solids (TSS) concentrations of surface and bottom water for the estuarine section of the upper Parramatta River for the period 1990 to 1998 are plotted in Figure 38. Figure 39 shows total suspended solids concentrations for freshwater creeks entering the upper Parramatta system between 1990 and 1998 (Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River above Marsden Weir).

Annual mean total suspended solids concentration changes in surface and bottom water of the estuary and the freshwater creeks leading to the river for the period 1990 to 1998 are shown in Figure 40.

As with turbidity and percentage transmission of light through water values, mean total suspended solids values for surface and bottom water in the estuary were similar for the period January 1990 to October 1992. Between November 1992 and December 1996 surface water TSS values differed from bottom water values (Figure 38). In 1997 and 1998 these differences disappeared. Surface water TSS values ranged around 10-15 mg/L while bottom water values were between 15 and 80 mg/L.

Total suspended solids concentrations in Lake Parramatta were low for the entire sampling period irrespective of rainfall. In Toongabbie Creek, Darling Mills Creek and Parramatta River at Marsden Weir total suspended solids concentrations were variable in both wet and dry weather and were usually higher than those measured in Lake Parramatta over the period 1990 to 1998 (Figure 39).

Annual mean changes in total suspended solids concentration for surface and bottom water of the estuary and freshwater from creeks draining to the Parramatta River were quite variable in all cases except Lake Parramatta (Figure 40). There was very little change in annual mean total suspended solids concentration in Lake Parramatta over the nine years sampled.

## **Concentration of volatile suspended solids**

Volatile suspended solids data for surface and bottom water (Stations 1-4 only) for Stations sampled during 1998 are presented in Table 16. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

### **Go to Appendix A**

- Page 38.**      **Figure 38. Water Quality of Upper Parramatta River - Total Suspended Solids Concentration Changes 1990 - 1998 mg/L.**
- Page 39.**      **Figure 39. Water Quality of Upper Parramatta River - Total Suspended Solids Concentration Changes in Freshwater Tributaries 1990 - 1998 mg/L.**
- Page 40.**      **Figure 40. Water Quality of Upper Parramatta River - Annual Mean Total Suspended Solids Changes 1990 - 1998 mg/L.**

## Table 15. Water Quality of Parramatta River

Parameter - Total Suspended Solids (TSS) Units - milligrams/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	6.6	8.6	12.1	6.3	18.1	14.1	3.9	13.9	11.6	1.7	6.6	5.9
6-2-98	8.1	10.6	26.7	7.5	13.4	5.3	2.4	11.5	50.3	2.1	29.4	16.4
13-3-98	8.1	6.5	3.8	5.6	8.4	6.4	2.4	16.1	6.7	5.1	2.4	13.5
17-4-98	6.9	8.5	12.3	17.6	19.5	13.6	4.0	19.1	14.9	3.9	7.4	5.2
8-5-98	6.3	7.8	6.2	10.6	27.6	13.6	3.6	25.8	14.0	3.3	17.5	4.0
12-6-98	9.0	6.9	3.6	8.2	22.3	14.0	1.9	20.2	45.7	7.8	5.6	5.4
3-7-98	5.6	6.3	2.6	12.6	47.2	8.5	2.6	26.9	20.1	5.5	10.4	20.1
7-8-98	82.7	30.2	112.4	145.5	42.0	30.6	2.3	50.3	81.7	7.6	25.8	12.3
11-9-98	4.3	2.9	1.8	19.7	31.7	5.3	4.1	17.5	29.8	7.5	3.5	37.8
9-10-98	3.6	5.0	2.8	5.6	14.9	4.6	4.2	11.6	23.3	2.8	1.7	20.5
13-11-98	10.8	13.5	17.4	18.6	47.9	12.3	3.2	28.2	19.8	1.8	9.8	8.6
11-12-98	5.6	7.4	3.6	5.1	12.8	6.4	1.0	5.6	8.9	2.5	2.9	4.0
Mean	13.1	9.5	17.1	21.9	25.5	11.2	3.0	20.6	27.2	4.3	10.3	12.8
Std	21.1	6.7	29.6	37.6	13.2	6.9	1.0	11.1	21.0	2.2	8.8	9.5
Var	443.6	45.4	877.6	1414.8	175.1	47.7	1.0	122.7	441.4	5.0	78.2	90.3
Max	82.7	30.2	112.4	145.5	47.9	30.6	4.2	50.3	81.7	7.8	29.4	37.8
Min	3.6	2.9	1.8	5.1	8.4	4.6	1.0	5.6	6.7	1.7	1.7	4.0

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	13.7	34.1	15.0	12.5
6-2-98	13.9	6.1	11.8	38.5
13-3-98	21.0	9.3	5.9	8.6
17-4-98	9.4	14.4	6.7	37.5
8-5-98	14.7	10.5	8.6	15.9
12-6-98	18.5	19.1	4.8	10.0
3-7-98	12.0	13.3	7.3	20.4
7-8-98	41.9	27.0	77.6	168.5
11-9-98	16.3	7.8	5.0	37.8
9-10-98	26.1	5.0	5.0	8.2
13-11-98	17.8	22.4	7.8	18.3
11-12-98	14.9	18.2	5.1	14.9
Mean	18.4	15.6	13.4	32.6
Std	8.2	8.5	19.6	42.4
Var	67.8	72.8	383.6	1798.9
Max	41.9	34.1	77.6	168.5
Min	9.4	5.0	4.8	8.2

## Table 16. Water Quality of Parramatta River

Parameter - Volatile Suspended Solids (VSS) Units - milligrams/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	1.4	1.7	3.6	1.2	3.2	5.2	3.3	3.2	5.9	1.6	3.7	1.7
6-2-98	2.2	3.7	9.3	2.4	2.7	2.0	1.5	3.2	24.0	1.2	8.8	3.1
13-3-98	1.8	1.7	1.4	2.1	2.0	2.7	1.5	6.3	2.6	3.6	0.4	4.4
17-4-98	1.4	1.7	2.1	4.5	3.0	2.4	1.3	2.9	9.7	3.0	2.2	1.1
8-5-98	1.1	2.0	1.2	3.5	3.7	2.8	1.7	4.1	7.9	2.8	3.7	1.2
12-6-98	2.1	1.8	1.0	1.6	3.7	3.6	0.9	3.1	32.5	5.1	1.4	1.3
3-7-98	1.2	1.9	0.8	2.1	6.9	1.0	0.7	3.0	6.3	4.6	3.1	3.8
7-8-98	11.1	6.0	19.4	17.5	5.5	4.8	1.3	7.3	37.7	5.6	6.0	4.0
11-9-98	0.8	0.7	0.5	3.3	4.4	1.7	2.9	3.3	12.3	6.6	1.4	7.5
9-10-98	0.9	1.2	1.1	1.3	3.2	1.8	2.8	3.7	11.9	2.2	1.0	6.5
13-11-98	2.5	3.2	3.5	3.5	8.0	3.1	2.6	5.2	15.3	1.7	3.0	1.9
11-12-98	2.2	4.0	2.6	2.1	3.1	2.0	1.0	2.5	5.9	2.2	1.2	1.6
Mean	2.4	2.5	3.9	3.8	4.1	2.8	1.8	4.0	14.3	3.4	3.0	3.2
Std	2.7	1.4	5.2	4.3	1.7	1.2	0.8	1.4	10.8	1.7	2.3	2.0
Var	7.2	2.0	27.1	18.1	3.0	1.4	0.7	2.1	115.6	2.8	5.3	4.2
Max	11.1	6.0	19.4	17.5	8.0	5.2	3.3	7.3	37.7	6.6	8.8	7.5
Min	0.8	0.7	0.5	1.2	2.0	1.0	0.7	2.5	2.6	1.2	0.4	1.1

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	2.9	4.4	4.0	1.9
6-2-98	2.8	1.7	4.3	9.8
13-3-98	3.4	1.8	1.3	2.2
17-4-98	2.4	2.9	1.2	11.0
8-5-98	2.6	1.9	1.9	3.7
12-6-98	2.4	3.8	1.0	2.3
3-7-98	3.7	4.1	1.6	3.7
7-8-98	6.5	5.4	14.2	23.5
11-9-98	2.4	1.5	0.8	6.2
9-10-98	5.2	1.6	1.2	1.5
13-11-98	3.2	4.2	2.9	3.6
11-12-98	5.0	4.0	2.6	2.1
Mean	3.5	3.1	3.1	6.0
Std	1.3	1.3	3.5	6.1
Var	1.6	1.7	12.5	36.9
Max	6.5	5.4	14.2	23.5
Min	2.4	1.5	0.8	1.5

## **Secchi disc**

Secchi disc data for the estuarine sections of Duck River and the upper Parramatta River for 1998 are presented in Table 17. Annual mean values in 1998 ranged from 0.8 to 1.2 metres.

Figure 41 shows changes in Secchi depth values for Stations 1-4 in the estuarine section of the upper Parramatta River over the period 1990 to 1998.

### **Go to Appendix A**

**Page 41. Figure 41. Water Quality of Upper Parramatta River - Secchi Depth Changes 1990 - 1998 metres.**

## Table 17. Water Quality of Parramatta River

Parameter - Secchi Depth Units - metres.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	1.1	1.0	1.0	1.4
6-2-98	0.9	0.5	0.4	1.0
13-3-98	1.0	0.9	1.4	1.4
17-4-98	1.0	0.8	0.4	0.3
8-5-98	0.9	0.6	0.8	0.4
12-6-98	1.0	1.0	2.0	0.9
3-7-98	1.3	1.3	2.3	0.9
7-8-98	0.1	0.1	0.1	0.1
11-9-98	1.1	1.9	1.9	0.4
9-10-98	1.5	1.6	1.9	1.5
13-11-98	0.4	0.4	0.5	0.3
11-12-98	1.2	1.0	1.5	1.5
Mean	1.0	0.9	1.2	0.8
Std	0.4	0.5	0.7	0.5
Var	0.1	0.2	0.5	0.3
Max	1.5	1.9	2.3	1.5
Min	0.1	0.1	0.1	0.1

## Chlorophyll-a Concentration

Chlorophyll-a is one of the major light sensitive pigments of plants. Determination of chlorophyll-a concentration in the water column provided an estimate of phytoplankton standing crop at the time of measurement.

Chlorophyll-a concentrations for surface and bottom water (Stations 1-4 only) for 1998 are presented in Table 18. Annual means, standard deviations, variances, maximum and minimum values have been calculated.

Mean chlorophyll-a concentrations for surface and bottom water of the estuarine section of the upper Parramatta River (Stations 1-4) for the period 1990 to 1998 are plotted in Figure 42. Figure 43 shows linear plots of chlorophyll-a concentration in water from freshwater creeks leading to the upper Parramatta River system over the period 1990 to 1998.

Annual mean chlorophyll-a concentrations for surface and bottom water in the estuary and for freshwater creeks leading to the upper Parramatta River (Toongabbie Creek, Darling Mills Creek, Lake Parramatta and Parramatta River at Marsden Weir) for the period 1990 to 1998 are shown in Figure 44.

Mean chlorophyll-a concentrations in surface and bottom water of the upper Parramatta River estuary varied from almost zero to almost 150 micrograms per litre over the eight years sampled (Figure 42). For most of 1996, 1997 and 1998 mean chlorophyll-a concentrations in the estuary were relatively low.

In freshwater creeks leading to the upper Parramatta River system chlorophyll-a concentrations were variable over the period 1990 to 1998. Most of the chlorophyll-a values measured were less than 50 micrograms per litre although some values exceeded 110 micrograms per litre (Figure 43).

Annual mean chlorophyll-a concentrations in surface and bottom water of the estuary and in freshwater creeks leading to the river varied greatly from year to year. In surface water of the estuary, upper Parramatta River at Marsden Weir, Toongabbie Creek there was a downward trend in annual mean chlorophyll-a concentration. Bottom water in the estuary, Darling Mills Creek and Lake Parramatta showed no obvious trends in annual mean chlorophyll-a concentration over the period 1990 to 1998 (Figure 44).

### **Go to Appendix A**

**Page 42. Figure 42. Water Quality of Upper Parramatta River - Chlorophyll-a Concentration Changes 1990 - 1998 micrograms/L.**

**Page 43. Figure 43. Water Quality of Upper Parramatta River - Chlorophyll-a Concentration Changes in Freshwater Tributaries 1990 - 1998 micrograms/L.**

**Page 44. Figure 44. Water Quality of Upper Parramatta River - Annual Mean Chlorophyll-a Concentration Changes 1990 - 1998 micrograms/L.**

## Table 18. Water Quality of Parramatta River

Parameter - Chlorophyll-a Units - micrograms/L.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	6.819	13.444	47.267	5.717	2.788	4.709	12.907	7.023	13.728	1.640	63.456	6.381
6-2-98	26.602	35.158	21.513	42.273	10.623	16.260	8.568	32.137	21.867	2.134	4.832	11.247
13-3-98	6.240	7.110	7.379	23.154	16.870	16.542	9.711	25.662	6.004	3.295	1.128	22.190
17-4-98	2.499	1.948	2.712	7.686	4.789	2.095	8.035	12.434	6.560	2.038	2.575	1.496
8-5-98	2.568	2.748	3.000	3.296	3.312	6.698	8.834	11.610	1.470	1.443	3.836	1.783
12-6-98	35.485	24.324	8.838	15.953	5.312	7.166	3.216	3.265	10.507	1.182	1.556	2.767
3-7-98	14.333	17.038	3.775	20.600	7.330	2.254	2.364	10.293	25.495	1.241	3.391	61.840
7-8-98	7.200	7.383	22.000	11.971	6.643	5.429	9.251	11.173	5.644	0.853	5.253	2.617
11-9-98	3.240	3.237	2.055	12.144	7.047	14.964	37.773	40.305	16.613	2.604	3.613	58.496
9-10-98	4.492	4.806	2.562	5.972	11.379	8.114	29.604	24.647	8.144	2.897	1.054	37.797
13-11-98	2.499	2.606	3.718	5.497	7.614	3.063	8.410	6.160	6.107	1.310	3.219	2.460
11-12-98	13.180	43.447	10.621	14.195	9.040	3.697	3.170	16.888	12.521	0.852	3.196	4.869
Mean	10.430	13.604	11.287	14.038	7.729	7.583	11.820	16.800	11.222	1.791	8.092	17.829
Std	10.115	13.299	12.757	10.400	3.733	5.150	10.351	10.954	6.864	0.771	16.741	21.544
Var	102.307	176.862	162.741	108.160	13.933	26.518	107.148	119.985	47.116	0.595	280.253	464.131
Max	35.485	43.447	47.267	42.273	16.870	16.542	37.773	40.305	25.495	3.295	63.456	61.840
Min	2.499	1.948	2.055	3.296	2.788	2.095	2.364	3.265	1.470	0.852	1.054	1.496

### Bottom Water

Date	Stn.1	Stn.2	Stn.3	Stn.4
9-1-98	14.6	17.0	38.4	7.4
6-2-98	28.3	25.5	50.2	67.6
13-3-98	5.4	4.0	10.1	17.7
17-4-98	11.0	9.2	5.4	10.2
8-5-98	5.0	5.2	5.1	9.5
12-6-98	19.3	26.2	8.2	13.9
3-7-98	40.2	50.6	13.0	41.7
7-8-98	10.6	27.9	13.0	8.4
11-9-98	4.9	2.9	2.8	9.2
9-10-98	5.0	4.3	2.5	4.4
13-11-98	11.5	9.6	4.4	6.0
11-12-98	34.8	33.1	5.9	14.0
Mean	15.9	18.0	13.3	17.5
Std	11.7	14.3	14.5	17.8
Var	137.9	203.1	210.0	316.4
Max	40.2	50.6	50.2	67.6
Min	4.9	2.9	2.5	4.4

## **Faecal Coliform Bacteria**

Faecal coliform bacteria are natural inhabitants of the guts of mammals and birds. The presence of these organisms in water was used as an indicator that the water was contaminated by faecal material. The origin of these bacteria may be human or other animals.

Faecal coliform bacteria data for surface water of Duck River, upper Parramatta River, and the creeks leading to the rivers for 1998 are presented in Table 19.

## Table 19. Water Quality of Parramatta River

Parameter - Faecal Coliform Bacteria Units - Numbers per 100 mL.

### Surface Water

Date	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11	Stn.12
9-1-98	500	50	1000	800	900	900	500	500	450	200	100	2000
6-2-98	2000	2000	20000	200	400	600	400	300	20000	50	10000	10000
13-8-98	14	26	8	72	450	70	200	16	3	10	30	500
17-4-98	600	1000	400	800	300	500	400	300	200	33	400	2000
8-5-98	1000	2000	900	2000	1000	430	200	10000	2000	100	400	300
12-6-98	118	170	170	145	140	200	350	245	20	10	166	600
3-7-98	210	300	210	150	400	350	280	250	300	50	200	450
7-8-98	20000	2000	10000	20000	10000	1000	1000	5000	20000	50	20000	10000
11-9-98	54	110	45	120	150	320	700	200	50	10	55	1000
9-10-98	120	200	280	36	105	300	400	110	200	800	120	2000
13-11-98	1000	1000	1000	600	900	600	900	500	200	50	1300	1000
11-12-98	175	200	200	70	500	350	600	400	2000	0	200	10000
Mean	2149	755	2851	2083	1270	468	494	1485	3785	114	2748	3321
Std	5411	784	5814	5429	2648	261	248	2880	7283	213	5856	3901
Var	29273738	614993	33801615	29474595	7014010	67931	61708	8295768	53039833	45548	34296276	15213941
Max	20000	2000	20000	20000	10000	1000	1000	10000	20000	800	20000	10000
Min	14	26	8	36	105	70	200	16	3	0	30	300
50 %ile	355.000	250.000	340.000	175.000	425.000	390.000	400.000	300.000	250.000	50.000	200.000	1500.000
80 %ile	1000	1800	1000	800	900	600	680	500	2000	90	1120	8400

---

# Discussion

## Ecology of the Upper River System

The catchment of the upper Parramatta River was heavily urbanised and industrialized. A large proportion of the land surface was paved with impervious material or covered by buildings. Stormwater run-off in the catchment was carried very quickly to the tributaries of the two major creeks (Toongabbie Creek and Darling Mills Creek) which eventually join to form the upper Parramatta River. There were also a number of large drains which flowed directly to the freshwater and estuarine sections of the upper Parramatta River. The catchment of Duck River was also heavily urbanised and industrialized and run-off rates were very rapid during rainfall periods.

During rainfall events water from roofs, paved surfaces and gardens was carried rapidly via stormwater drains to the creeks. The swift flowing water transported accumulated garbage, soil, bacteria, organic material and dissolved substances to the upper Parramatta River. During a major rainfall event of more than, say, 200 mm most of the debris, garbage, soil, bacteria and dissolved substances were carried down the Parramatta River to the sea along with similar material from other parts of the catchment.

During the many minor rainfall events accumulated garbage, soil, bacteria and dissolved substances were carried by the storm water drains and creeks to the upper Parramatta River and Duck River. Since there was not enough freshwater to flush this material into the lower reaches of the Parramatta River or the sea, most of it stayed in the upper reaches of the river and was carried backwards and forwards by the tides.

Under these circumstances a great deal of the floating material, composed of plant material, plastic, polystyrene packaging and plastic or metal canisters became trapped in the mangroves along the river's edge. This floating and trapped garbage was picked up daily by Waterways Garbage Collection Vessels and crews. Bacteria eventually were consumed by filter feeding organisms or died off as a result of exposure to the inhospitable environment. The dissolved substances, often rich in plant nutrients, were assimilated by phytoplankton living in the brackish surface water or more saline bottom waters. The abundant nutrient supply expanded the phytoplankton population greatly causing the water to become quite green at times.

There was also another major source of particulate material, faecal bacteria and nutrients to the upper Parramatta River during rainfall events. Sewage from the western suburbs was carried by a viaduct to North Head STW. This viaduct, built more than 50 years ago, is today almost adequate for dry weather flows but is unable to carry the entire 1990s wet weather flows. During heavy rainfall periods considerable volumes of raw sewage overflow to the upper Parramatta River catchment. When overflows occur faecal coliform bacteria concentrations in river water become very high (between 10,000 and 50,000 organisms per 100 mL). Phosphorus concentrations and, to a lesser extent, nitrogen levels in stormwater and in the river were increased significantly by surcharging sewage.

After a rainfall event water flows in the creeks decreased rapidly until they were only a few litres per second. Both Toongabbie Creek and its tributaries and Darling Mills Creek became a series of billabongs.

A large proportion of the nutrients which reached the upper Parramatta River during a light to moderate rainfall event remained in the tidal section of the river. Here they stimulated the growth of phytoplankton and riverside vegetation. Annual mean chlorophyll-a concentrations in the tidal sections of the upper Parramatta River and Duck River were usually relatively high. In 1996, 1997 and 1998, however, chlorophyll-a concentrations in the estuarine section of the upper Parramatta River were relatively low for most of the year.

High productivity in the upper estuarine section of the Parramatta River during the period 1990 to 1995 supported large populations of mullet and other species of fish and provided food for quite large numbers of aquatic birds.

While a large proportion of the nutrients which contributed to primary production in the estuarine section of Parramatta River were carried into the system by freshwater runoff, there was another source of nutrients to the river which operated in both dry and wet weather. This was effluent from the Shell Refinery biotreater which was discharged, via a licenced outfall, to Duck River. This effluent contained high concentrations of total nitrogen (mean in 1998 of 21.404 mg-N/L) and moderate amounts of phosphorus (mean in 1998 of 2.798 mg-P/L).

Diurnal dissolved oxygen curves for surface and bottom water of Duck River and the upper Parramatta River made in 1990 and 1991 (reported in the Water Quality Reviews of 1990 and 1991) revealed the dynamic nature of the ecology of the system. There were very large diurnal changes in dissolved oxygen concentration. Also, during a succession of sunny days the mean daily concentration of dissolved oxygen rose progressively until the surface water and bottom water was supersaturated for most of the time. Conversely, a series of cloudy days could progressively reduce the daily mean dissolved oxygen concentration to a low level that could cause stress to aquatic animals. In 1990 the lowest dissolved oxygen concentration recorded for the tidal sections of Duck River and the upper Parramatta River was around 40% of saturation. In 1991 the lowest dissolved oxygen concentration recorded for the estuarine stations was 9.7% (surface water) and 9.3% (bottom water). The 1991 minimum dissolved oxygen levels were likely to have caused stress to aquatic animals although no dead aquatic organisms were seen at the time the measurements were made.

The ecology of the upper Parramatta River and Duck River over the period 1990 to 1998 was found to be very dynamic and extremely productive during the years 1990 to 1995. From 1996-98 productivity, as measured by phytoplankton standing crop, appeared to decrease. High rates of production were fine if it was allowed to continue without perturbation. This system was, however, delicately balanced. Anything that reduced dissolved oxygen production in the water column for more than a few days could cause the diurnal minimum concentration to fall to a level that could kill the most susceptible species. Decay of these susceptible animals would require oxygen and would further deplete dissolved oxygen concentrations in the water column. This could lead to further deaths and the eventual collapse of the whole system. The visible result of such a collapse would be large fish kills. However, since a large proportion of the biomass in the upper Parramatta River and Duck River was composed of fish (mainly mullet), migration of these organisms downstream to more oxygenated water, could and does relieve the pressure on the ecology. If the factors causing the deoxygenation of the water simultaneously affect a long stretch of the upper Parramatta River, the migrating fish may become exhausted before they reach safer waters. Fish deaths and collapse of the ecological system under these circumstances was highly likely.

On Sunday December 22nd 1996 a worker at Shell Refinery reported to the EPA and Shell Environment Managers that part of the estuarine section of Duck River had turned black and there was a strong smell of sulphide. Inspectors from the EPA investigated the phenomenon and found large numbers of small to medium sized eels (*Anguilla reinhardtii*) dead or dying either on the banks or trying to make their way upstream and over the weir into freshwater (Mr Kyran O'Donnell -EPA, Personal communication). A small number of dead mullet were also found.

Water in Duck River was found to have a very low dissolved oxygen concentration. Enquiries by the EPA indicated that the event probably started on Saturday 21st December. The weather on Saturday was extremely hot and this hot weather coincided with a very low tide. Sampling of Duck River by this firm showed that early morning dissolved oxygen levels had been low for some months prior to this event (surface water - 26.5, 40.7 and 27.1% of saturation, bottom water - 23.7, 32.2 and 22.3% of saturation for October, November and December 1996). This suggested that the estuarine section of Duck River had been under stress for some time and that the conjunction of a very low tide and extremely hot weather had reduced oxygen levels to below that able to be

tolerated by estuarine fauna. The reducing environment produced mobilized sulphides from the sediments which reacted with iron to produce black iron sulphide.

A safer ecology would be a less productive one that could withstand perturbation without collapsing. The key to production in this system was the ready supply of plant nutrients to the river from the catchment. Production in the river could be controlled by reducing the amount of plant nutrients reaching the water body.

Before nutrient controls to the river could be implemented a study of the catchment of the upper Parramatta River would be required to identify the sources of nutrients. Once these were known, strategies to control them could be worked out. To achieve sufficient nutrient reductions to control productivity in the river would also require the application of nutrient reduction strategies to adjacent sub-catchments of the Parramatta River.

In 1992 dredging of the upper Parramatta River was commenced. Most of the river bed from Silverwater Road bridge to the Charles Street weir was progressively removed. These works which continued on into 1993 affected water quality in the river to some extent. Even though the dredging work was carried out within curtailed areas, there was some increase in turbidity in the river especially at Station 4 (upper Parramatta River).

By December 1993 these dredging works were completed and the River Cat ferry service was operating. The River Cat ferries produce very little wake at all operating speeds and therefore should cause little bank erosion. From about half tide to half tide, however, the small wash and a pressure wave that precedes the craft breaks on the exposed mud of the river banks. These small breaking waves entrained the fine surface sediment and carried it back into the water. This caused significant increases in the turbidity of the water column. The effect was similar to that generated naturally by wind waves. Over a period of time, the operation of the River Cat ferries may bring about a redistribution of sediments in the upper Parramatta River. Gradually fine sediment will be transferred to the deeper dredged sections of the river. This may eventually undermine the mangroves along the banks of the narrow upper river.

By 1996 inspection of the upper part of Parramatta River during low tide revealed that large volumes of mud had been removed from around the roots of the mangroves. This exposed a network of roots and left the outer edge of the fringing mangroves very unstable. The consequences of this erosion will be followed in 1997.

Mangrove inspections made during 1997 and 1998 revealed further removal of supporting mud from around the roots of mangroves in the estuarine section of the upper Parramatta River. Many of the mangroves on the outer edge of the community were collapsing into the river. Each day these fallen trees were removed by the crews of Waterways Harbour Cleaning Vessels.

## Comparison of Upper Parramatta River with Suggested Water Quality Criteria for the Protection of Aquatic Ecosystems

The Water Quality Criteria proposed in this report are those thought to have existed in the freshwater and saltwater of the upper Parramatta River prior to European Settlement of the catchment.

### Water Temperature

For the coastal drainages between Sydney and Port Macquarie up to an altitude of 200 m, the suggested temperature range for saline and freshwaters is 10 - 30°C.

The following temperature data for saline and freshwaters of the upper Parramatta River system for the years 1990 to 1998 represent maximum and minimum values.

Year	Saline Waters		Freshwaters	
	Max	Min	Max	Min
1990	27.16	10.28	25.24	<b>7.80</b>
1991	28.17	10.37	26.27	<b>9.01</b>
1992	27.55	12.52	24.37	10.17
1993	28.16	10.71	27.10	10.06
1994	26.33	<b>9.90</b>	26.11	<b>8.17</b>
1995	25.65	10.05	24.73	<b>8.40</b>
1996	25.01	10.76	24.13	<b>9.01</b>
1997	26.61	11.78	25.47	<b>9.44</b>
1998	28.61	10.31	27.77	<b>8.14</b>

Units - Degrees Celsius      Bold figures denote non-compliance

Saline waters within the upper Parramatta River system met the maximum and minimum temperature criteria. Maximum criteria were met in the freshwater creeks in all years sampled but minimum temperatures less than 10°C were recorded for 7 out of the 9 years studied.

## Salinity

There is no salinity requirement for estuarine or freshwaters of the upper Parramatta River system. The freshwaters are separated from the saline waters by a series of weirs. The following maximum and minimum salinities for saline and freshwaters were recorded between 1990 and 1998.

<u>Salinity</u>	Saline Waters				Freshwaters	
	Surface		Bottom		Surface	
	Max	Min	Max	Min	Max	Min
1990	31.07	0.06	32.29	0.01	0.99	0.02
1991	32.11	12.08	33.68	22.68	0.81	0.12
1992	29.51	3.10	32.88	16.56	0.52	0.09
1993	30.28	1.48	31.80	16.56	0.45	0.04
1994	33.12	1.64	33.89	13.05	0.47	0.07
1995	29.50	1.02	31.42	11.91	1.34	0.10
1996	27.78	0.10	31.38	0.10	1.90	0.06
1997	32.26	12.71	33.41	16.90	1.84	0.12
1998	34.98	0.14	34.24	0.13	2.27	0.11

Units - Parts per Thousand. Bold figures denote non-compliance.

In the estuarine section of the upper Parramatta River it was possible for salinity values to approach that of full seawater (35 ppt) or to fall to as low as 0.10 ppt from surface to bottom during major rainfall events.

There were quite large changes in salinity of freshwater in the upper Parramatta River system over the period sampled. The salinity of freshwater increased as flow rates in the creeks decreased. The highest freshwater salinities recorded were for upper Duck Creek (Station 12).

## pH

The suggested pH limits for freshwater creeks to protect aquatic ecosystems were :

Lower limit 6.0

Upper limit 9.0

For creeks with sandstone catchments the suggested pH limits were :

Lower limit 4.5

Upper limit 9.0

For estuarine waters the suggested pH limits were :

Lower limit 6.5

Upper limit 8.5

Maximum and minimum pH values for saline and freshwaters of the upper Parramatta River system were as follows :

<u>pH</u>	Saline Waters				Freshwaters	
	Surface		Bottom		Surface	
	Max	Min	Max	Min	Max	Min
1990	<b>8.85</b>	7.10	<b>8.79</b>	7.08	8.82	6.59
1991	<b>8.89</b>	7.30	<b>8.85</b>	7.32	8.63	6.46
1992	8.32	7.37	8.08	7.14	8.89	6.78
1993	8.28	6.87	8.20	6.97	8.90	6.74
1994	8.30	7.33	8.31	7.32	8.13	7.39
1995	<b>8.52</b>	6.73	8.48	6.86	8.75	6.07
1996	8.00	6.93	8.19	6.73	8.47	6.74
1997	8.09	7.12	8.20	7.09	8.48	6.97
1998	<b>8.55</b>	7.07	<b>8.78</b>	7.02	8.59	7.06

Units - pH.

Bold figures denote non-compliance.

pH limits for freshwater were met for all years sampled. In saline waters the upper limit of pH was exceeded in 1990, 1991, 1995 and 1998. Lower limits of pH for saline waters were not exceeded during the study.

## Dissolved Oxygen

The suggested dissolved oxygen criteria for surface and bottom saline and freshwaters of the upper Parramatta River system were as follows :

Freshwater	Upper limit 120%	Lower limit 50%
Saline (surface)	Upper limit 120%	Lower limit 70%
Saline (bottom)	Upper limit 120%	Lower limit 40%

Dissolved oxygen maxima and minima for saline surface and bottom water and freshwaters between 1990 and 1998 were as follows :

Year	<u>Dissolved Oxygen</u> Saline Waters				Freshwaters	
	Surface		Bottom		Surface	
	Max	Min	Max	Min	Max	Min
1990	115.5	<b>39.1</b>	107.2	<b>8.0</b>	<b>134.7</b>	<b>12.0</b>
1991	<b>121.5</b>	<b>9.7</b>	116.7	<b>9.3</b>	115.0	<b>17.2</b>
1992	116.3	<b>37.6</b>	104.5	<b>3.9</b>	<b>120.5</b>	<b>11.8</b>
1993	<b>138.9</b>	<b>7.3</b>	103.4	<b>12.0</b>	119.9	<b>20.1</b>
1994	105.2	<b>12.6</b>	102.9	<b>4.3</b>	100.9	<b>10.9</b>
1995	113.4	<b>26.1</b>	118.9	<b>6.4</b>	<b>127.8</b>	<b>26.1</b>
1996	97.1	<b>26.5</b>	101.6	<b>15.7</b>	109.8	<b>25.7</b>
1997	94.2	<b>14.0</b>	92.5	<b>19.3</b>	<b>138.5</b>	<b>7.2</b>
1998	106.0	<b>3.4</b>	102.7	<b>1.7</b>	106.6	<b>27.8</b>

Units - Percentage Saturation.

Bold figures denote non-compliance.

In both saline and freshwaters of the upper Parramatta River maximum dissolved oxygen criteria were sometimes exceeded. It must be remembered that the sampling was conducted in the early morning so the values quoted above represent diurnal dissolved oxygen minima. Minimum dissolved oxygen criteria for saline surface and bottom waters and freshwaters were exceeded in each year of the study.

## Nutrients

The following 50 percentile and 90 percentile values for each nutrient, calculated from at least 12 samples per station per year, are recommended for fresh and estuarine waters of NSW coastal drainage systems :

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	0.100 mg-N/L	0.150 mg-N/L
Oxidized nitrogen	0.100 mg-N/L	0.200 mg-N/L
Total nitrogen	0.500 mg-N/L	0.800 mg-N/L
Orthophosphate	0.005 mg-P/L	0.020 mg-P/L
Total phosphorus	0.050 mg-P/L	0.100 mg-P/L

The following 50 percentile and 90 percentile concentrations for each nutrient for 1998 were calculated. Bold figures denote non-compliance.

### Freshwater - Toongabbie Creek (1998)

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	<b>0.145</b> mg-N/L	<b>0.206</b> mg-N/L
Oxidized nitrogen	<b>0.346</b> mg-N/L	<b>1.023</b> mg-N/L
Total nitrogen	<b>1.169</b> mg-N/L	<b>1.879</b> mg-N/L
Orthophosphate	<b>0.042</b> mg-P/L	<b>0.083</b> mg-P/L
Total phosphorus	<b>0.117</b> mg-P/L	<b>0.267</b> mg-P/L

### Freshwater - Darling Mills Creek (1998)

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	0.094 mg-N/L	<b>0.183</b> mg-N/L
Oxidized nitrogen	<b>0.265</b> mg-N/L	<b>0.753</b> mg-N/L
Total nitrogen	<b>1.007</b> mg-N/L	<b>1.321</b> mg-N/L
Orthophosphate	<b>0.017</b> mg-P/L	<b>0.029</b> mg-P/L
Total phosphorus	<b>0.061</b> mg-P/L	<b>0.172</b> mg-P/L

Freshwater - Lake Parramatta (1998)

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	0.096 mg-N/L	<b>0.156</b> mg-N/L
Oxidized nitrogen	<b>0.188</b> mg-N/L	<b>0.974</b> mg-N/L
Total nitrogen	<b>0.814</b> mg-N/L	<b>1.658</b> mg-N/L
Orthophosphate	0.004 mg-P/L	<b>0.023</b> mg-P/L
Total phosphorus	0.049 mg-P/L	<b>0.113</b> mg-P/L

Freshwater - Parramatta River at Marsden Weir (1998)

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	<b>0.127</b> mg-N/L	<b>0.188</b> mg-N/L
Oxidized nitrogen	<b>0.301</b> mg-N/L	<b>1.074</b> mg-N/L
Total nitrogen	<b>0.831</b> mg-N/L	<b>2.045</b> mg-N/L
Orthophosphate	<b>0.026</b> mg-P/L	<b>0.052</b> mg-P/L
Total phosphorus	<b>0.092</b> mg-P/L	<b>0.303</b> mg-P/L

Freshwater - Upper Duck Creek (1998)

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	<b>0.131</b> mg-N/L	<b>0.174</b> mg-N/L
Oxidized nitrogen	<b>0.590</b> mg-N/L	<b>0.951</b> mg-N/L
Total nitrogen	<b>1.426</b> mg-N/L	<b>1.999</b> mg-N/L
Orthophosphate	<b>0.027</b> mg-P/L	<b>0.075</b> mg-P/L
Total phosphorus	<b>0.124</b> mg-P/L	<b>0.180</b> mg-P/L

Saltwater - Parramatta River and Duck River (1998) Surface water

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	<b>0.216</b> mg-N/L	<b>0.353</b> mg-N/L
Oxidized nitrogen	<b>0.329</b> mg-N/L	<b>0.542</b> mg-N/L
Total nitrogen	<b>0.988</b> mg-N/L	<b>1.606</b> mg-N/L
Orthophosphate	<b>0.059</b> mg-P/L	<b>0.145</b> mg-P/L
Total phosphorus	<b>0.123</b> mg-P/L	<b>0.323</b> mg-P/L

Saltwater - Parramatta River and Duck River (1998) Bottom water

<u>Nutrient</u>	<u>50 percentile</u>	<u>90 percentile</u>
Ammonia	<b>0.187</b> mg-N/L	<b>0.464</b> mg-N/L
Oxidized nitrogen	<b>0.188</b> mg-N/L	<b>0.400</b> mg-N/L
Total nitrogen	<b>0.897</b> mg-N/L	<b>1.384</b> mg-N/L
Orthophosphate	<b>0.058</b> mg-P/L	<b>0.128</b> mg-P/L
Total phosphorus	<b>0.129</b> mg-P/L	<b>0.247</b> mg-P/L

No part of the upper Parramatta River system complied with the suggested nutrient criteria in 1998 or any of the previous years sampled.

### Water Clarity

The following water clarity guidelines are suggested for protection of aquatic ecosystems of the upper Parramatta River system:

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	2.0	5.0	8.0	NTU
% trans.	93.5	97.5	99.0	%
TSS	1.5	3.5	7.0	mg/L
VSS	1.0	2.0	4.0	mg/L
Secchi depth	2.0	3.0	4.0	metres

The following data were calculated for of creek and the estuarine section of the upper Parramatta River system.

Freshwater - Toongabbie Creek (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	<b>17.2</b>	<b>52.0</b>	<b>117.4</b>	NTU
% trans.	<b>21.5</b>	<b>54.0</b>	<b>77.1</b>	%
TSS	<b>9.3</b>	<b>19.5</b>	<b>46.2</b>	mg/L
VSS	<b>2.1</b>	<b>3.2</b>	<b>6.6</b>	mg/L

Freshwater - Darling Mills Creek (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	<b>4.7</b>	<b>9.2</b>	<b>34.7</b>	NTU
% trans.	<b>42.1</b>	<b>79.1</b>	<b>90.3</b>	%
TSS	<b>4.7</b>	<b>8.5</b>	<b>14.1</b>	mg/L
VSS	<b>1.1</b>	<b>2.4</b>	<b>4.6</b>	mg/L

Freshwater - Lake Parramatta (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	0.9	3.9	7.3	NTU
% trans.	<b>86.6</b>	<b>92.0</b>	<b>96.2</b>	%
TSS	1.2	2.6	4.1	mg/L
VSS	0.7	1.5	2.9	mg/L

Freshwater - Upper Parramatta River at Marsden Weir (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	<b>12.8</b>	<b>38.3</b>	<b>60.3</b>	NTU
% trans.	<b>21.7</b>	<b>60.5</b>	<b>86.3</b>	%
TSS	<b>6.8</b>	<b>17.5</b>	<b>27.9</b>	mg/L
VSS	<b>2.6</b>	<b>3.2</b>	<b>6.1</b>	mg/L

Freshwater - Upper Duck Creek (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	<b>2.2</b>	<b>8.6</b>	<b>26.2</b>	NTU
% trans.	<b>65.0</b>	<b>87.3</b>	<b>93.4</b>	%
TSS	<b>4.0</b>	<b>8.6</b>	<b>20.4</b>	mg/L
VSS	<b>1.1</b>	1.9	<b>6.1</b>	mg/L

### Saltwater - Upper Parramatta River and Duck River (1998)

	<u>10 %ile</u>	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Turbidity	<b>3.6</b>	<b>8.9</b>	<b>37.5</b>	NTU
% trans.	<b>62.6</b>	<b>86.3</b>	<b>93.3</b>	%
TSS	<b>3.6</b>	<b>7.5</b>	<b>19.6</b>	mg/L
VSS	1.0	2.1	4.5	mg/L
Secchi depth	<b>0.3</b>	<b>1.0</b>	<b>1.7</b>	meters

No part of the upper Parramatta River system met the suggested water clarity criteria for the protection of aquatic ecosystems in 1998 or in the previous years sampled.

### Chlorophyll-a

The following chlorophyll-a concentrations are suggested as guidelines for the protection of aquatic ecosystems.

	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Chlorophyll-a	5	12	ug/L

In 1998 freshwater and saltwater sections of the upper Parramatta River had the following 50 percentile and 90 percentile chlorophyll-a concentrations.

	<u>50 %ile</u>	<u>90 %ile</u>	<u>Units</u>
Toongabbie Creek	<b>7.05</b>	<b>11.23</b>	ug/L
Darling Mills Creek	<b>5.43</b>	<b>16.00</b>	
Lake Parramatta	<b>8.56</b>	<b>26.26</b>	
Parramatta River	<b>11.61</b>	<b>30.84</b>	
Upper Duck Creek	4.87	<b>54.36</b>	
Estuary (S)	<b>7.29</b>	<b>26.37</b>	
Estuary (B)	<b>10.16</b>	<b>38.93</b>	

No part of the upper Parramatta River system complied with the suggested chlorophyll-a criteria for the protection of aquatic ecosystems.

# Upper Parramatta River - Suitability for Recreation

In November 1990 the State Pollution Control Commission (NSW) issued a discussion Paper called :

## **Water Quality Criteria for New South Wales.**

Four levels of recreational activity were recognised each with different water quality requirements. This discussion paper was never finalised and was superceded in November 1992 by :

## **Australian Water Quality Guidelines for Fresh and Marine Waters.**

Published by Australian and New Zealand Environment and Conservation Council.

### **Level 1 : Passive Recreation in a Pristine Environment.**

There is increasing demand for passive recreation in pristine environments. This is characterised by people travelling to observe pristine areas. Water quality criteria for such areas would be set at the background levels.

### **Level 2 : Primary Contact Recreation**

This is characterised by bodily immersion or submersion where there is direct contact with the water. It includes swimming, diving, water skiing and surfing. Water quality criteria for the protection of these uses fall into three categories.

- (1) health criteria
- (2) safety criteria
- (3) aesthetics

The water quality criteria recommended for primary contact recreation are given in Table 20.

### **Level 3 : Secondary Contact Recreation**

This includes activities such as wading, boating, fishing, etc, in which some contact with the water may occur but in which the probability of bodily immersion or the intake of significant amounts of water is minimal. The following categories of criteria are relevant.

- (1) health criteria
- (2) safety, including protection of vessels
- (3) aesthetics
- (4) recreational fisheries criteria

Water quality criteria recommended for the protection of secondary contact recreation are given in Table 21.

**Level 4 : Passive Recreation - Non-Pristine Environment**

Aesthetic enjoyment is the primary consideration for this type of recreation.

Water quality criteria recommended to protect passive recreation in a non-pristine environment are given in Table 22.

Recreational levels 2, 3 and 4 apply to Duck River and the upper Parramatta River and freshwater streams.

**Table 20. Water Quality Criteria Level 2 (Primary Contact). Compliance of Upper Parramatta River System in 1998.**

<b>INDICATOR</b>	<b>CRITERION</b>	<b>COMPLIANCE</b>
<b>1. Biological</b>		
(a) Faecal Coliform bacteria	The median values shall not exceed 150 organisms per 100 mL for a minimum of 5 samples taken at regular intervals not exceeding 1 month with 4 out of 5 samples containing less than 600 organisms per 100 mL.	Compliance in estuary.
	Pathogenic free-living protozoans should be absent from warm (>24°C) freshwater bodies.	Not known.
(b) Blue Green Algae	No quantitative figures have yet been produced. Waters with obvious algal blooms considered unsuitable for primary contact recreation.	Compliance in 1998.
<b>2. pH</b>	The pH should be in the range of 6.5 to 8.5, pH values in the range 5.0 to 9.0 may be acceptable in waters of low buffering capacity.	Compliance in 1998.
<b>3. Light Penetration</b>	A Secchi disc should be visible at a minimum depth of 1.2 m. In learn to swim areas a Secchi disc should be visible on the bottom.	Non-compliance in 1998.
<b>4. Aesthetic Quality</b>	There should be no visible floating debris, oil, scum, foam or other objectionable matter.	Non compliance except for Lake Parramatta.
<b>5. Dangerous Objects</b>	The waters should not contain floating or submerged objects which might injure or obstruct users.	Non-compliance except for Lake Parramatta.

**Table 20. Water Quality Criteria Level 2 (Primary Contact). Compliance of Upper Parramatta River System in 1998.**

**Other Indicators.**

<b>INDICATOR</b>	<b>CRITERION</b>	<b>COMPLIANCE</b>
<b>1. Temperature</b>	For prolonged exposure, temperatures should be in the range 15-35°C.	Compliance October to May.
<b>2. Toxicants</b>	An average person consumes approximately 2L of fluid per day. Toxicant concentrations in Schedule 1 (Potable water) are based on this level of intake. The NHMRC (1989) states that, in a normal swimming season, a maximum ingestion of 100 mL of water would occur. Thus to protect a swimmer from harmful effects of toxicants, the concentrations should be less than 2L/100 mL = 20 times the toxicant concentrations listed in Schedule 1.	Compliance except during chemical spills.
	Waters containing chemical which are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation	Not known.
<b>3. Nutrients and Biostimulants</b>	Levels of nutrients or other biological growth stimulants should be below : Nitrogen (Total) 0.5 mg/L, Phosphorus (Total) 0.05 mg/L.	Non-compliance in 1998.
<b>4. Aesthetic Quality</b>		
(a) Odours, Taints and Colours	The water should be free of objectionable odours and taints, and colour should not exceed 100 Pt-Co units.	Non-compliance except for Lake Parramatta in 1998.
(b) Settleable Matter	The water should be free of all materials which settle to form objectionable deposits in areas where they would not occur naturally.	Non-compliance except for Lake Parramatta in 1998.

**Table 21. Water Quality Criteria Level 3 (Secondday Contact).  
Compliance of Upper Parramatta River System (1998).**

INDICATOR	CRITERION	COMPLIANCE
<b>1. Biological</b>		
(a) Faecal coliform bacteria  Creek in 1998.	The median value shall not exceed 1000 faecal coliform organisms per 100 mL for a minimum of 5 samples taken at regular intervals not exceeding 1 month, with 4 out of 5 samples containing less than 4000 organisms per 100 mL.	Compliance except for upper Duck
<b>2. pH</b>	The pH of the water should be within the range 5.0 to 9.0.	Compliance in in 1998.

**Table 21. Water Quality Criteria Level 3 (Secondary Contact).  
Compliance of Upper Parramatta River System (1998).**

**Other Indicators.**

<b>INDICATOR</b>	<b>CRITERION</b>	<b>COMPLIANCE</b>
<b>1. Biological</b>		
(a) Blue-Green Algae	No quantitative figures have been set, however, waters should be free of visibly excessive growths of algae.	Compliance in 1998.
<b>2. Temperature</b>	The temperature range should be in the 15-35°C range.	Compliance October to May.
<b>3. Nutrients and Biostimulants</b>	Levels of nutrients or other biological growth stimulants should be below : nitrogen (Total) 0.5 mg/L and phosphorus (Total) 0.05 mg/L.	Non-compliance in 1998.
<b>4. Aesthetic Quality</b>	Aesthetic criteria are the same as for Level 2 : Recreation (Table 20)	Non-compliance except for Lake Parramatta in 1998.
<b>5. Dangerous Objects</b>	The waters should not contain floating or submerged objects which might injure or obstruct users, damage boats or interfere with fishing.	Non-compliance except for Lake Parramatta in 1998.

**Table 22. Water Quality Criteria Level 4 (Aquatic Scenery Only).  
Compliance of Upper Parramatta River System.**

<b>INDICATOR</b>	<b>CRITERION</b>	<b>COMPLIANCE</b>
<b>1. Abiotic Considerations</b>		
(a) Odours, Taints and Colours	The water should be free of objectionable odours and taints, and colour should not exceed 100 Pt-Co units.	Non-compliance except for Lake Parramatta in 1998.
(b) Floatable Matter	There should be no visible floating debris, oil, scum, foam or other objectionable matter.	Non-compliance except for Lake Parramatta in 1998.
(c) Settleable Matter	The water should be free of all materials which settle to form objectionable deposits in areas where they would not occur naturally.	Non-compliance except for Lake Parramatta in 1998.
<b>2. Biotic Considerations</b>		
(a) Plant Growths	Levels of nutrients or other biological growth stimulants should be below : nitrogen (Total) 0.5 mg/L phosphorus (Total) 0.05 mg/L.	Non-compliance.
(a) Wildlife	Water quality criteria necessary to protect native plant and animal life with respect to watering and habitat are outlined in Maintenance of Water-Associated Wildlife (Schedule 19 of SPCC document).	Compliance as indicated by abundant wildlife and fish in the Parramatta River system in 1998.

Using EPA and ANZECC criteria it was apparent that the upper Parramatta River system failed to comply with most criteria for recreational uses in 1998 : viz.

**Level 2** : Primary Contact Recreation

**Level 3** : Secondary Contact Recreation

**Level 4** : Passive Recreation - Non-Pristine Environment

The only part of the system to comply with Level 3 and 4 recreational criteria was Lake Parramatta. Lake Parramatta could also comply with Level 2 criteria during dry weather as most of the faecal coliform bacteria measured during dry periods could have been derived from the faeces of the abundant water fowl that inhabit the area.

## **Comment on Water Quality in 1998**

### **Estuarine section**

Rainfall in 1998 was above average. Significant rainfall (more than 100 mm per month) fell in the months of January, April, May, and August. Very little rain fell in the catchment in the other months of 1998. There were three major rainfall events that flushed the Parramatta River in 1998. Dissolved oxygen levels in surface water of the estuarine section of the upper Parramatta River and Duck River were often quite low (less than 50% of saturation). Bottom water dissolved oxygen concentrations in the estuarine sections of the river were also very low at the times of sampling (early morning) in 1998. Values as low as 1.7% of saturation were recorded.

Annual mean total nitrogen levels in the estuarine sections of Duck River and the upper Parramatta River were similar for all years sampled. The 50 percentile and 90 percentile levels, however, were almost twice the concentration suggested to protect aquatic ecosystems.

Annual mean total phosphorus levels in the estuarine sections of Duck River and the upper Parramatta River were also similar over the nine years sampled. The 50 and 90 percentile levels were almost three times the concentration suggested to protect aquatic ecosystems.

Water clarity in surface water of the estuarine sections of Duck River and the upper Parramatta River was much worse than it was in 1997 because of the above average rainfall.

Mean chlorophyll-a levels in the estuarine sections of the rivers were variable in 1996, 1997 and 1998 but the 50 percentile concentrations were much lower than they had been in previous years. Fifty percentile values for faecal coliform bacteria concentrations were above 150 at all stations within the upper estuary.

### **Tributary creeks**

Water quality in the tributary creeks in 1998 was below the values of the suggested criteria to protect aquatic ecosystems. Lake Parramatta came close to complying with the suggested water quality guidelines in 1997 but water quality declined in 1998. In the tributary creeks dissolved oxygen concentration, nutrients and water clarity were below the suggested criteria to protect aquatic ecosystems.

---

## List of References

**Dal Pont, G. M. Hogan and B. Newell** (1974). Report 55 - Laboratory techniques in marine chemistry. II Determination of ammonia in sea water and the preservation of samples for nitrate analysis. CSIRO - Division of Fisheries and Oceanography.

**Laxton, J.H. & E.S. 1991.** Water quality in the upper Parramatta River. Analysis of data collected in 1990. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1992.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1991. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1993.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1992. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1994.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1993. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1995.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1994. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1996.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1995. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1997.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1996. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1998.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1997. Upper Parramatta River Catchment Trust.

**Laxton, J.H. & E.S. 1999.** Water quality in the upper Parramatta River. Analysis of data collected between 1990 and 1998. Upper Parramatta River Catchment Trust.

**Major, G.A. G. Dal Pont, J. Klye and B. Newell** (1972). Report 51 - Laboratory Techniques in Marine Chemistry. CSIRO- Division of Fisheries and Oceanography.

---

## Acknowledgements

We wish to acknowledge the assistance given by Mrs Elizabeth Laxton and Ms Emma Laxton in the field and Laboratory.