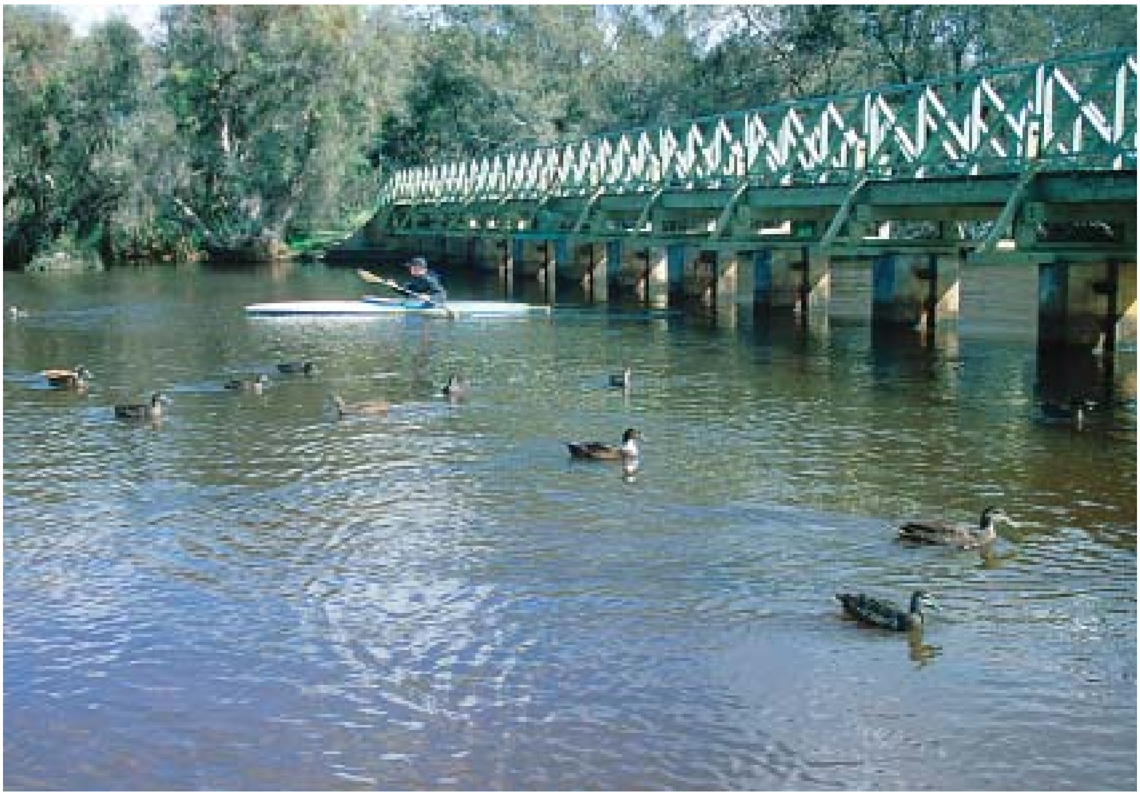
GOVERNMENT OF WESTERN AUSTRALIA

River SCIENCE 9

The science behind the Swan-Canning Cleanup Program

Issue 9, October 2002



Kent Street Weir on the Canning River

Seasonal Nutrient Dynamics in the Canning River and Estuary, 1995–98

The Canning River joins with the lower reaches of the Swan River at Melville Water to form the Swan-Canning estuary. The Canning is relatively shallow, ranging from 1 to 6 metres deep. It drains a heavily populated subcatchment that incorporates diverse residential, commercial, industrial and agricultural land uses. Upstream pumping by local water users, releases from upstream dams and the downstream Kent Street Weir regulate river flow. There is considerable seasonal variability in flow, with high flows during the winter months and almost negligible flow in summer.

The Kent Street Weir was built and rebuilt several times during the early 20th century to maintain freshwater conditions for irrigation and domestic water supply. Weir boards are put in place in September or October corresponding to reduced river flow. They are then removed with the onset of the first winter rains, usually in April or May. When the weir boards are in place, the freshwater section upstream of the weir is impounded in a pool with minimal flow and low levels of oxygen.

CONTENTS

Swan-Canning Cleanup Program

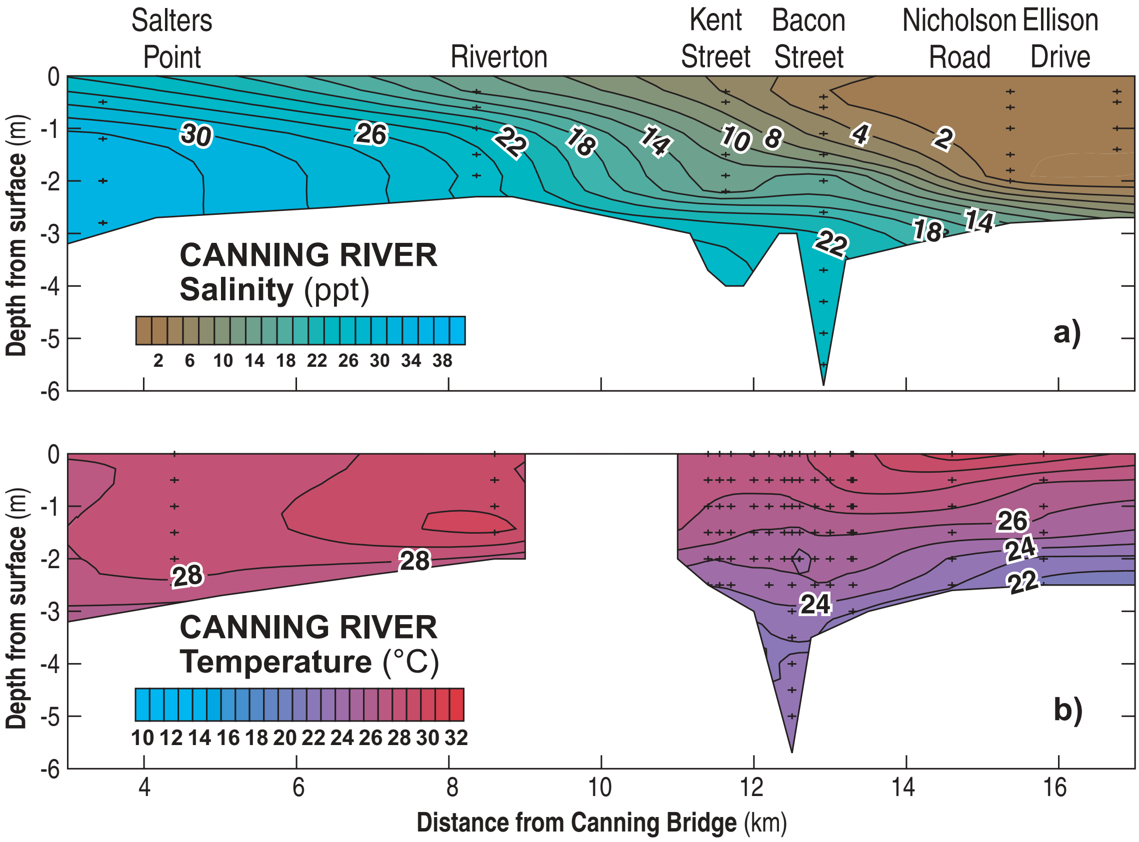


Figure 1: *examples of a) salinity stratification associated with upstream movement of the salt wedge, and b) thermal stratification above the weir (Kent Street)*

Every week, longitudinal vertical profiles of salinity, dissolved oxygen and temperature are published on the Swan River Trust website: <www.wrc.wa.gov.au/srt/riverscience/profiles.html>. These images show the relative influence of tidal exchange and freshwater inflows and the effect on the oxygen status of estuary waters (see figures 1 above).

High nutrient loading from the catchment and sediment nutrient release, coupled with negligible flow and high temperatures, make the Canning an ideal environment for plant and algal growth during summer. Above the Kent Street Weir, proliferation of macrophytes in early summer has in recent years often been followed by blooms of potentially toxic blue-green algae. These blooms can be responsible for significant water quality and human health threats. The development of remediation techniques aimed at reducing the occurrence of harmful algal blooms in the upper Canning (see *River Science 13-14* and *17-18*) has centred on an evolving understanding of nutrient processes in the river. This document provides a background analysis of the seasonal nutrient patterns in the Canning River prior to current remediation efforts, to explain the major causes of the algal bloom problem.

Note that all technical terms highlighted in blue are defined in the glossary.

Tidal dynamics of the Canning River

Tidal influence in the Canning is mostly limited to the lower reaches by Kent Street Weir. The lower Canning (the area below the weir to the junction with Melville water) experiences tidal flow year round. The upper Canning (above Kent Street Weir) is influenced by tidal movement when the weir boards are removed, but during this time is usually flushed with fresh water from catchment inflows. Salt water can move upstream above the Kent Street Weir when the weir boards are removed (figure 1a), but this does not happen every year and depends on river flow.

Salt wedge and stratification

The Mediterranean climate of Perth is reflected in seasonal patterns in the water quality of the Swan-Canning Estuary. When river flow reduces towards the end of winter, tidal movement causes salt water to move progressively up the estuary. Since the more saline water is denser it tends to travel upstream along the bottom and the lighter fresh water flows downstream on top. This layering is referred to as *stratification*. The saltwater layer pushing its way upstream underneath a surface layer of fresh water is often referred to as a *salt wedge* (figure 1a). Stratification restricts mixing of the denser bottom waters with the lighter surface waters. When bottom waters are rich in organic material, decomposition by bacteria uses up dissolved oxygen, which is not readily replaced from the surface. The oxygen-depleted waters of the salt wedge can promote nutrient release from bottom sediments as they move up the estuary.

In the Canning, upstream movement of the salt wedge is restricted by the Kent Street Weir. The weir boards are usually put in place around September or October to prevent the salt wedge moving into the upper reaches of the river. Stratification still occurs above the weir over summer, however. Because the water above the weir is impounded as a stationary pool surface waters heated by the sun often form a lighter layer which does not mix readily with bottom waters. This process is referred to as *thermal stratification* (figure 1b). The low-oxygen environment of bottom waters facilitates the release of phosphorus from the sediment. Ammonium can also build up in this area because nitrification cannot occur in an oxygen-limited environment (see *River Science 4* for a more detailed explanation of these processes).

Water quality is monitored weekly

Water quality has been monitored regularly in the Canning since the establishment of the Swan-Canning Cleanup Program (SCCP) in 1994 (details are given in *River Science 1: Water quality monitoring is a vital part of the SCCP Action Plan*). Prior to the current program, water quality sampling was carried out on an *ad hoc* basis often in response to algal blooms or suspected pollution events. From 1994, weekly sampling of physical and chemical attributes, nutrient concentrations, and phytoplankton composition and abundance has occurred across the Swan-Canning estuarine system. For details on the Swan refer to *River Science 8: Seasonal nutrient dynamics in the Swan Estuary, 1995-2000*.

From 1995-98, weekly monitoring occurred at two sites in the estuarine lower Canning and four in the usually freshwater upper Canning. Four additional sites above the weir are sampled for phytoplankton only, to allow health warnings to be issued to local authorities when required.

Nitrogen and phosphorus are the nutrients of most concern

Nitrogen and phosphorus are the nutrients most commonly responsible for algal bloom problems worldwide. Human activities, such as the widespread application of nitrogen- and phosphorus-rich fertilisers to farmland, lawns and gardens have led to increased levels of these nutrients in coastal waterways. Phytoplankton blooms in the Canning are fuelled by nitrogen and phosphorus from both agricultural and urban sources.

Nitrogen is an essential element required in large amounts for growth by all organisms. There are several different forms of nitrogen found in water. Dissolved inorganic nitrogen (DIN), comprised of ammonium, nitrate and nitrite, is the form used by phytoplankton and other aquatic plants. Phosphorus is also an essential element but is required in smaller amounts by living organisms. Dissolved inorganic phosphorus (DIP) consists of free *orthophosphate* (PO_4). Reported DIP values include a certain amount of PO_4 loosely bound to very small sediment particles, and for this reason DIP is more accurately reported by the technical term *filterable reactive phosphorus* (FRP). Phosphorus is also found bound to particles in the water column and sediments.

More information on the importance of these two nutrients is presented in *River Science 4: The Nitrogen and Phosphorus Cycles*.

Nutrients in the Canning come from diverse sources

Nutrients are delivered into the water by external means such as catchment runoff and groundwater inflow, or by internal means such as release from the sediments or decomposition of crashing phytoplankton blooms. (*River Science 5* and *6* discuss these nutrient sources in more detail). With the onset of rains runoff from the land filters down into waterways. This runoff can contain significant amounts of nutrients, either dissolved or attached to soil particles. Increases in agriculture, intensive livestock operations and the spread of residential and commercial areas (leading to 'leakage' of sewage, fertilisers and detergents) have greatly increased nutrient loads in the rivers and estuary.

Unlike the Swan River, which receives the majority of runoff from the huge inland catchment of the Avon River, the Canning has a small coastal catchment originating in the Darling Range. As it traverses through southern metropolitan Perth it is joined by the Southern River and a number of minor tributaries and drains. The Canning catchment includes significant rural (broadacre agriculture, horticulture, intensive livestock operations, turf farms), urban, industrial and commercial land uses. These land uses represent a diversity of nutrient sources to the Canning River. All of the major subcatchments of the Canning were recognised as 'major nutrient contributors' to the Swan-Canning estuary in the Swan-Canning Cleanup Program *Action Plan*.

Urban drains are at times a significant source of nutrients and other contaminants such as hydrocarbons, to the Canning. Many drains are not monitored regularly and few flow throughout the year. Compared to other catchment runoff, drains contribute very little flow volume to the Swan-Canning system; however, water quality within the drains is often poor. During summer, when there is little flow from the catchment, relatively small rainfall events can cause drains to discharge into the river and estuary.

Groundwater can also be a nutrient source to the system. Groundwater movement occurs readily through the sandy soils of the Swan Coastal Plain, and groundwater in the area has been shown to be high in dissolved nutrients. Knowledge of the particulars of groundwater nutrient inputs is sketchy, but it is likely to be important at some sites, particularly when other nutrient sources are small.

Pathways… what happens to the nutrients once they enter the estuary?

Nutrients entering the lower reaches of the Canning River can be transformed and transported within the system, or exported to Melville Water (and then potentially flushed out to sea). Organic and particulate nutrients can sink and accumulate in the sediments. Some of the soluble phosphorus entering from the catchment attaches (adsorbs) to suspended particles and settles out onto the sediment. The sediments can become a source of bioavailable nutrients (especially phosphate and ammonium) under certain conditions – notably low-oxygen conditions at the sediment surface. Dissolved inorganic nutrients are taken up by phytoplankton and aquatic plants and converted to organic forms. Death and decay of organisms leads to re-release of bioavailable nutrients.

The fate of nutrients entering an estuary is discussed in more detail in *River Science 4: The nitrogen and phosphorus cycles*.

The role of sediments

Sediments in the upper Canning are generally rich in nitrogen and phosphorus compared to other Australian and overseas estuaries. The sediments are highly variable – both from site to site, and also with depth in the river. High nutrient concentrations are mainly associated with certain sediment types, most notably fine silts and muddy silts with high organic matter content. These sediments are abundant at several of the monitoring sites in the Canning, particularly in shallower depositional zones. The iron content of Canning sediments is also high, and most sediment phosphorus is thought to be bound to iron compounds. However, bioavailable phosphorus can be released into the water column if the sediment surface becomes anoxic.

Nutrients are known to be released from these sediments into bottom waters over summer, though thermal stratification tends to restrict nutrient movement into surface waters. Even during bloom events only a fraction of what is released is taken up by phytoplankton, which are usually unable to access the large store of nutrients below the thermocline. Nevertheless, bottom water nutrients may still become available to phytoplankton through periodic deepening of the wind-mixed surface layer. In addition the capacity of phytoplankton for luxury uptake of nutrients when they are available may be sufficient to maintain growth, even when surface nutrient concentrations are low.

The surface sediments represent the largest pool of nutrients in the upper Canning, and are important as a nutrient source for macrophytes, phytoplankton and bacteria. For this reason, remediation efforts over the past five years have focussed on reducing sediment nutrient release (readers should refer to *River Science 13-14* and *17-18* for more information).

Phytoplankton and macrophytes in the Canning

Plants and algae form the basis of aquatic food chains by capturing light energy and converting simple inorganic nutrients to forms that can be used by other organisms. In the Canning, raised nutrient levels promote the growth of phytoplankton (figure 2) and larger aquatic plants known as macrophytes.

The upper Canning has tended to shift between macrophyte- and phytoplankton-dominated stages over the past decade. Macrophytes are often found in abundance, though the dominant species have changed over the years, often as a result of human activities (see *River Science* 19). Macrophytes may play an important role in limiting the extent and severity of phytoplankton blooms in the upper Canning. Macrophytes can suppress phytoplankton growth in a number of ways, including shading, nutrient uptake and storage in direct competition with phytoplankton, and providing habitat for zooplankton (animal plankton) which feed on phytoplankton. Conversely, large numbers of phytoplankton in the water increase turbidity, which can affect macrophyte growth by reducing light penetration through the water column.

Seasonal nutrient patterns in the Canning

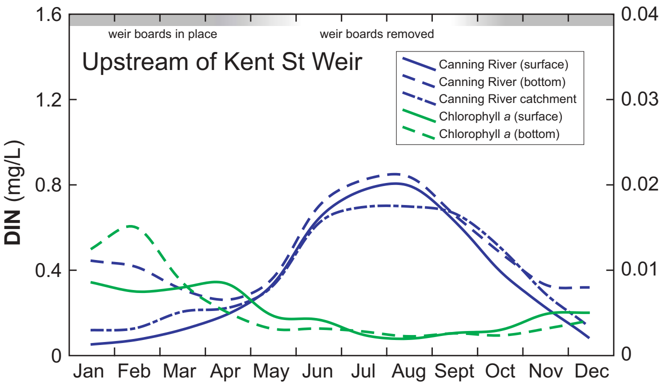
The Canning, like the Swan, is influenced strongly by the seasonal climate of Perth. However, the presence of Kent Street Weir is a dominant feature in the Canning that leads to a much sharper distinction between the upper and lower reaches than is the case in the Swan. When the weir boards are removed the Canning behaves as a typical 'salt wedge' type estuary with the extent and location of the salt wedge determined by river flows. When the boards are in place, the upper and lower Canning are two distinct systems with the weir acting as a barrier between freshwater and saltwater reaches. With this in mind, the seasonal patterns of water quality are discussed separately for the upper and lower reaches of the Canning. The upper Canning is discussed in more detail as it has been the focus of community concern, monitoring and remediation efforts due to the regular summer occurrence of toxic cyanobacteria blooms since the early 1990s.

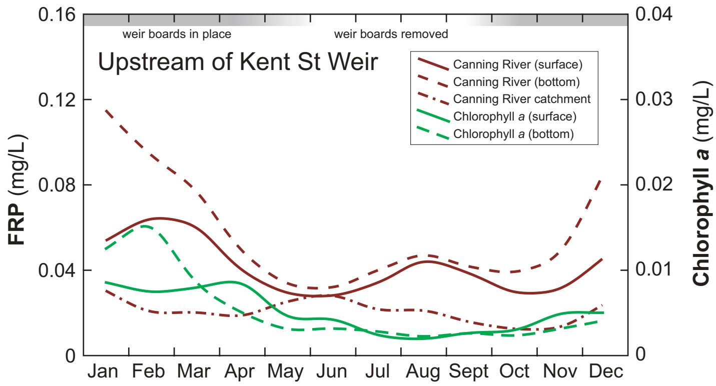
Figure 2: *Anabaena, a toxic blue-green alga responsible for blooms in the upper Canning (photo WRC Phytoplankton Ecology Unit)*

The following discussion refers to the monthly median concentrations of dissolved nutrients (DIN and DIP) and chlorophyll *a* for the years 1995-1998, shown in figures 4-5 and 8-9.

The relative abundance of phytoplankton and macrophytes in any given year will depend on the temperature and water flow. A hot start to the summer may give phytoplankton a growth advantage for the rest of the summer (as in 1997-98). High water levels above the weir may also restrict the growth of submerged macrophytes in early summer.

Figure 3: aerial view of the Canning River above Kent Street Weir, with the Greenfield Street bridge in the centre of the picture (photo D. Tracey)





***Figures 4 (DIN) and 5 (FRP)**: Median concentrations of dissolved inorganic nitrogen (DIN) and phosphorus (DIP), and chlorophyll* a *(1995-1998) in the Upper Canning above Kent St Weir and in the catchment (Canning River only). Note the winter peak of DIN, and elevated DIN levels in bottom waters over summer; also the high summer peak of FRP in bottom waters, and elevated chlorophyll* a *throughout spring and summer.*

Upper Canning

Winter flows mobilise large amounts of dissolved inorganic nitrogen (DIN) from throughout the catchment. This leads to a winter peak of DIN as fresh water flushes the upper Canning. As flow drops away in spring, nutrient uptake by macrophytes and phytoplankton depletes the available DIN in the water, resulting in declining DIN concentrations. Over summer, DIN concentrations in surface waters remain low but there is a notable increase in bottom water values due to a combination of ammonium release from the sediments and groundwater seepage.

The dominant pattern in soluble phosphate (DIP) concentration is the occurrence of high summer values in bottom waters. Much of the phosphorus delivered from the catchment is bound to particulate matter and tends to accumulate in sediments as these particles settle out. Phosphate release from the sediments is promoted by the low-oxygen conditions that occur periodically over summer when the upper Canning doesn't flow. Thermal stratification tends to trap phosphate (as well as ammonium) in bottom waters.

The decrease in DIN over spring and summer, combined with high DIP concentrations, results in

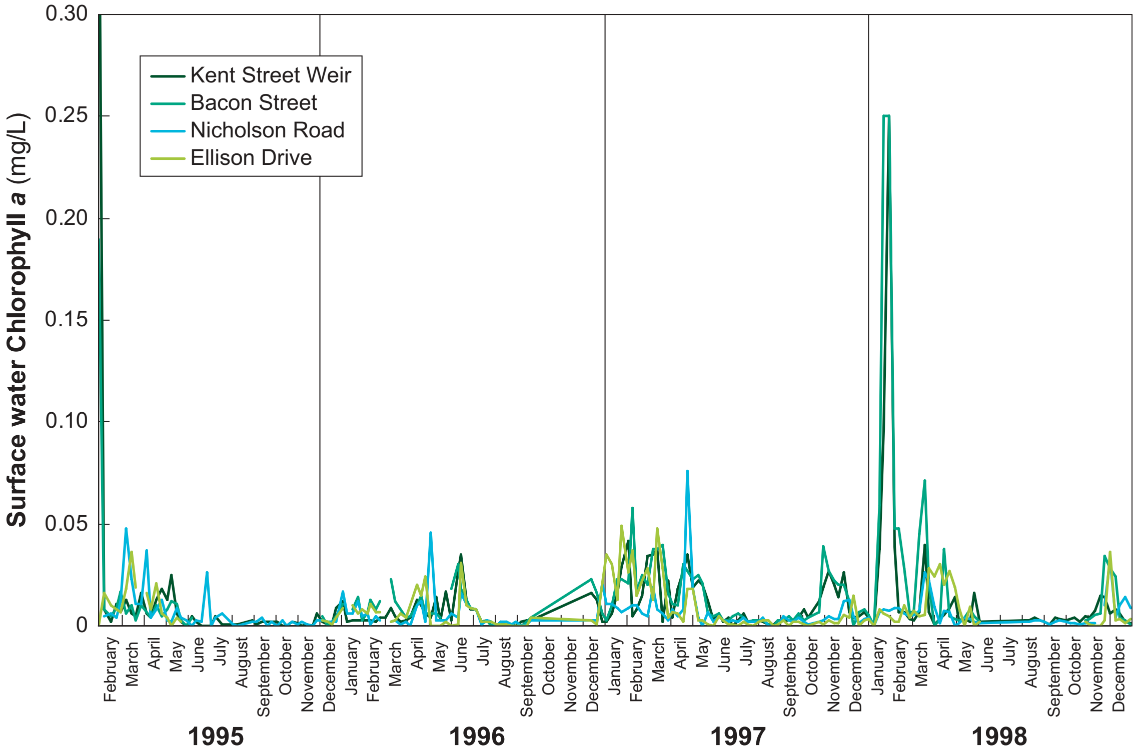


Figure 6: *Weekly phytoplankton abundance (chlorophyll* a*) at sampling sites in the upper Canning, 1995-98. (NB chlorophyll* a *values for Jan '95 at Kent Street Weir (0.4) and Nicholson Road Bridge (0.32) exceeded the maximum scale of this graph)*

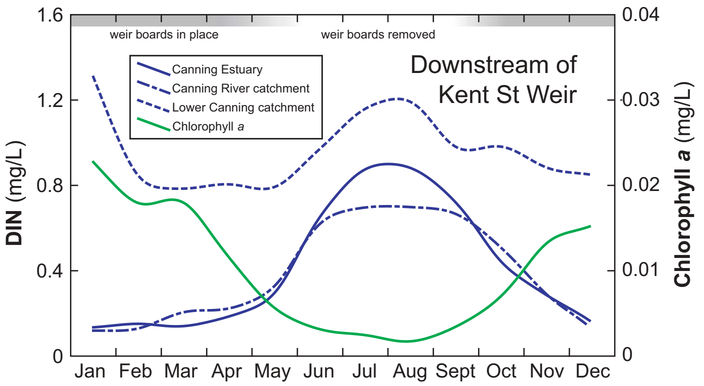
an increasing ratio of dissolved phosphorus to nitrogen over this period. This encourages the growth of certain cyanobacteria (blue-green algae) which are able to supplement their nitrogen supply by 'fixing' atmospheric nitrogen.

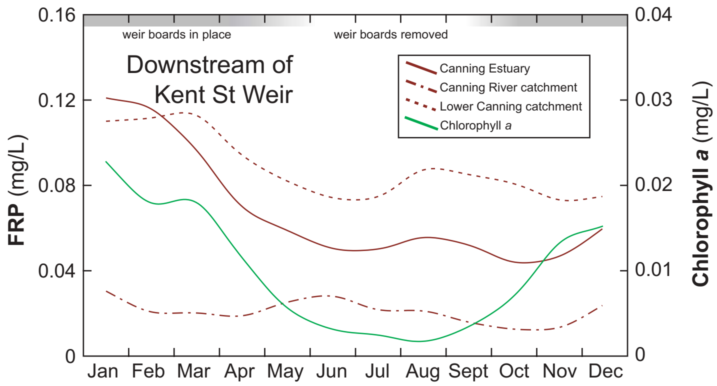
Chlorophyll *a* concentration (which measures the density of phytoplankton cells in the water) shows a distinct seasonal pattern in the upper Canning – with relatively high median values over summer and autumn and low values over winter. Phytoplankton growth in winter is limited by low light levels, low temperatures and short day lengths, and as a result most phytoplankton are flushed from the system before they can reach bloom proportions. When the weir boards are put in place, the lack of flow along with increasing temperatures and increased light penetration makes the upper Canning conducive to phytoplankton growth. Indeed, median chlorophyll *a* values in the upper Canning are at their highest over summer. It is interesting to note that values are higher in bottom waters than surface waters for much of this time. Unlike in the upper Swan where phytoplankton (e.g. dinoflagellates) are thought to migrate to bottom waters to access nutrients it is unlikely that the much smaller cyanobacteria in the upper Canning could do this. The higher bottom water values may result from physical conditions (intense light at the water surface, lack of mixing) that favour heavier phytoplankton which remain buoyant deeper in the water column.

Phytoplankton populations are highly dynamic, and when conditions are favourable they are capable of explosive growth. From about November to May, phytoplankton proliferate and crash repeatedly, resulting in a series of peaks in chlorophyll *a* concentration (figure 6). Occasional very high chlorophyll *a* values (e.g. Jan 1995, Jan-Feb 1998) are associated with major bloom events. Of most concern in the upper Canning is the occurrence of blooms of toxic, nitrogen-fixing cyanobacteria, such as the large *Anabaena* bloom in January 1998 (figure 12).

The growth of macrophytes (such as *Potamogeton* and *Azolla*) appears to be an important factor controlling phytoplankton abundance. Actively growing macrophytes may limit phytoplankton growth, both by shading the surface of the water and competing with phytoplankton for nutrients. Dense macrophyte growth can tie up large amounts of nutrients, from both the water and sediments. The downside is that death of macrophytes (especially *Potamogeton*, which often dies back in late summer) may provide a nutrient source for phytoplankton as they decay. Large phytoplankton blooms have on occasion followed the natural collapse or manual removal of dense macrophyte growth.

Figure 7: aerial view of the lower Canning, looking over the Shelley (bottom) and Riverton (top) bridges towards the Canning River Regional Park wetlands (photo D. Tracey)





***Figures 8 (DIN) and 9 (FRP)**: Median concentrations of dissolved inorganic nitrogen and phosphorus, and chlorophyll* a *(1995-1998) in the Lower Canning. DIN and FRP concentrations are also given for the upper (Canning River) and lower (Mills St Main Drain and Bannister Creek) catchment. Note the winter peak of DIN in both the upper catchment and estuary, and the high summer levels of FRP and chlorophyll* a. *Samples are integrated across the depth of the water column in these shallow sites.*

Lower Canning

From 1995-98, water quality data from the shallow sites in the lower Canning was integrated across the entire depth of the water column; therefore there is no separation here into surface and bottom waters.

The lower Canning also experiences a seasonal trend of DIN concentration, with a winter peak corresponding to catchment inflows (figure 8). Again, most of this nitrogen is flushed from the lower Canning to Melville Water by freshwater flow. Concentrations decline in spring and remain low over summer, suggesting that a combination of phytoplankton growth and denitrification removes DIN from the system over this time.

Dissolved phosphate concentrations peak in summer, which is likely to be driven by sediment release rather than catchment inflow. When the Kent Street Weir is closed, freshwater input to the lower Canning is minimal. From around September to November there is often some flow over the weir boards from the upper Canning. A number of small urban catchments (mainly the Mills Street Main Drain and Bannister Creek) also discharge directly into the lower Canning throughout the year. However, though DIP concentrations in urban drains are high (figure 9), the volumes discharged are insufficient to explain the high DIP concentrations in the lower estuary.

As in the upper Swan and Canning estuaries (but distinct from the lower Swan), phytoplankton density in the lower Canning is highest throughout summer and autumn when physical conditions are optimal for growth. Median chlorophyll *a* values are actually slightly higher than in the upper Canning. Factors likely to favour phytoplankton growth in the lower Canning could include the shallowness of the sites, and lack of competition from macrophytes. High salinity prevents the sort of toxic blue-green blooms evident in the upper Canning. Phytoplankton dynamics in the lower Canning are more similar to those of the upper Swan. The spring-summer-autumn blooms involve several groups of phytoplankton in a succession related to changes in salinity and sediment nutrient release.

Summary of nutrient dynamics in the Canning

1. Nutrient dynamics with the weir open (late autumn to spring)

The weir boards are usually removed from the Kent Street Weir in response to early winter rainfall. If rainfall continues then the upper Canning is likely to be flushed fresh throughout the water column. However, if rainfall is inconsistent after the boards are removed, the salt wedge can move upstream of the weir into the normally freshwater section of the river. The extent of the surface layer of fresh water into the lower Canning also depends on flow. When the weir boards are removed the Canning behaves as a typical 'salt wedge' estuary, with distinct salinity stratification of the water column. Stratification in the Canning is often associated with low-oxygen conditions at the sediment surface, and anoxic water can be transported up or down the estuary with the movement of the salt wedge.

The freshwater layer in the Canning is high in DIN (mostly nitrate) washed down from rural and urban catchment areas. While the weir is open, most of this nitrogen is flushed from the Canning into Melville Water. Adsorption of phosphate to suspended particles and inflow of particulate phosphorus leads to deposition of phosphorus-rich particles in the upper and lower Canning over winter and spring.

Phytoplankton and macrophyte growth is minimal during winter. Physical conditions (high flow, low temperature and short day length) do not encourage plant growth. In addition, the inflowing water is relatively turbid in winter, which restricts light availability to aquatic plants, including phytoplankton. Some macrophytes die back over winter; others are perennial but grow little or are killed off by salinity if the salt wedge moves up into the riverine section of the Canning.

Spring is characterised by a strong decrease in flow, with a concomitant decrease in DIN delivery from runoff. A combination of denitrification and uptake by phytoplankton and macrophytes leads to a decrease in N:P ratio, driven mainly by a strong decline in nitrate concentration in the water column. The decreasing N:P ratio increases the likelihood of toxic cyanobacteria blooms in the upper Canning; however short residence times and low light levels prevent the development of significant blooms while the weir is open.

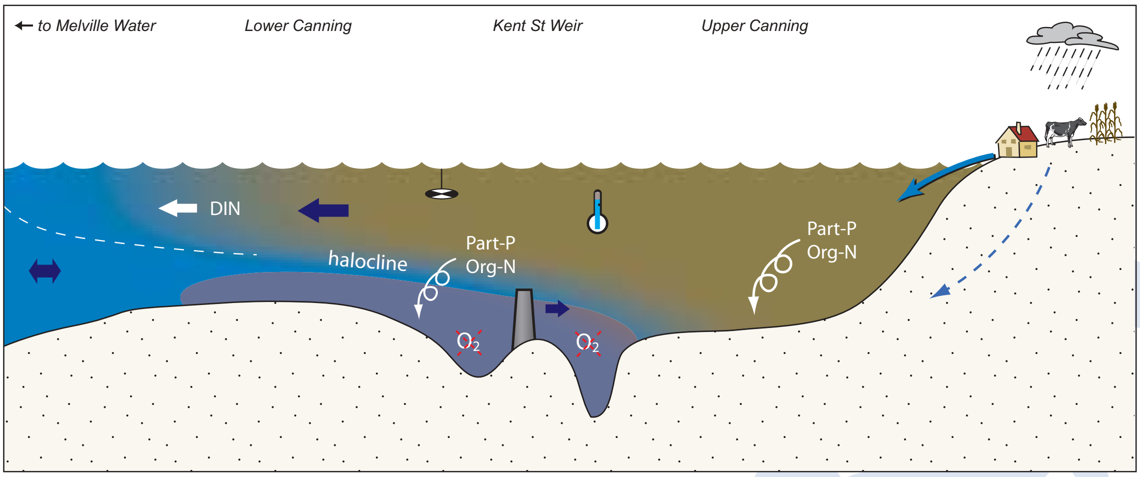


Figure 10: *conceptual model of the Canning River with the Kent Street Weir boards removed, during the winter flow period. Refer to the Symbol Glossary for an explanation of the symbols used*

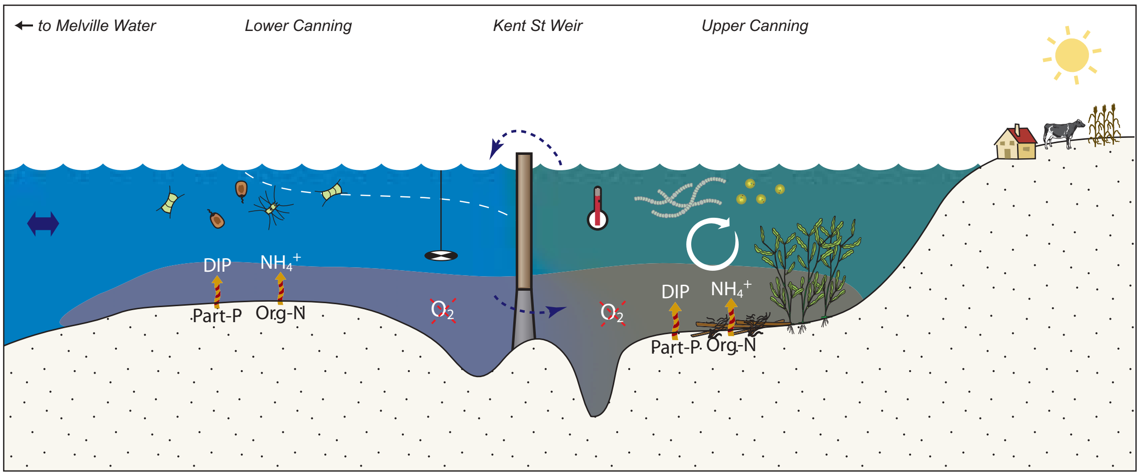


***Figure 11:** conceptual model of the Canning River with the weir boards in place, during the summer low flow period. Refer to the Symbol Glossary for an explanation of the symbols used*

2. Nutrient dynamics with the weir closed (late spring-summer-autumn)

The weir boards are usually put in place around September or October to prevent movement of the salt wedge into the upper Canning. There can still be some movement of both fresh and salt water through or across the weir due to flows, tidal surges and leakage through the weir boards. However, the Canning is basically divided into a brackish to saltwater lower section and a freshwater upper section. In summer the upper Canning becomes a relatively stagnant freshwater pool. While the weir is closed there is rarely substantial mixing of the water column, resulting in strong and persistent differences in surface and bottom water chemistry.

After impoundment, the upper Canning is characterised by thermal stratification, falling oxygen levels in bottom waters, and increasing temperature and water clarity. Anoxic events promote sediment nutrient release, but stratification tends to restrict nutrient movement into surface waters. During late spring and early summer, macrophyte growth is often active but major phytoplankton blooms are uncommon. Nevertheless, phytoplankton activity increases as conditions become more favourable. Nitrogen to phosphorus ratios tend to decrease during this time, increasing the likelihood of nitrogen-fixing cyanobacteria blooms as summer progresses.

***Figure 12:** This dense bloom of blue-green algae (Anabaena) occurred in January-February 1998 (photo K. McMahon)*

Mid to late summer is the greatest risk period for toxic cyanobacteria blooms in the upper Canning. Low N:P ratios promote the growth of nitrogen-fixing cyanobacteria, while the final bloom biomass may be determined by the availability of DIP. During a large bloom, dense growth of phytoplankton reduces water clarity and as a result the bloom growth tends to be restricted to surface waters. (This may also help blue green algae outcompete other species as they have greater buoyancy control). Much of the phosphorus released from the sediments over summer may not become available to phytoplankton due to thermal stratification. During the 1998 bloom for instance (figure 12), although bloom biomass appeared to be limited by surface DIP, the bloom was estimated to have consumed only about 15% of phosphorus efflux from the sediments. At some stage demand for a resource – such as phosphorus or carbon – outstrips availability, leading to the collapse of the bloom.

Curiously, there are rarely repeated big blooms in one summer in the upper Canning – even though physical conditions may be suitable. This 'lag period' following a major bloom is not completely understood, but could be due to phytoplankton cell damage under conditions of intense light and nutrient limitation.

In the lower Canning, summer is a productive time for phytoplankton. When the weir boards are first put in place, upstream movement of anoxic salt

Symbol glossary

urban catchment		exchange with Melville water	water movement across Kent Street Weir	mixed marine phytoplankton
rural catchment	Part-P	particulate phosphorus	nutrient flux	chlorophytes
nutrient movement	Org-N	organic nitrogen	deoxygenation	blue-green algae
water movement	DIN	dissolved inorganic nitrogen	cold water	macrophytes (*Potamogeton*)
deposition	DIP	dissolved inorganic phosphorus	warm water	
groundwater movement	NH_4^+	ammonium	secchi depth	nutrient recycling

water promotes sediment nutrient release. A combination of uptake and denitrification leads to low DIN concentrations over summer, and phytoplankton dynamics are likely to be dominated by rapid cycling of nutrients. The high salinity in the lower Canning prevents the growth of both macrophytes and the cyanobacteria which bloom above the weir. Rather, several groups of mainly marine phytoplankton are common at different times throughout the spring-summer-autumn period.

Addressing nutrient problems in the Canning

Reducing the occurrence of toxic phytoplankton blooms in the Canning River is a major goal of the Swan-Canning Cleanup Program. The results from weekly water quality monitoring in the Canning provided the basis for trials of innovative methods aimed at modifying conditions in the river to reduce the occurrence of blooms. The aim of these techniques (oxygenation and sediment remediation using Phoslock™, a modified clay) is to reduce the supply and availability of nutrients to phytoplankton. Information on the development and implementation of these techniques from early trials in 1997-98 to 1999-2000 can be found in *River Science 13-14* and *17-18*.

The implementation of these techniques has coincided with a marked decrease in nutrient concentrations across the Canning (both in treated and control sites), yet summer blooms of cyanobacteria have still occurred. Results have been promising but it is clear that in practice the relationship between deoxygenation, nutrient release and phytoplankton response is not straightforward – for instance it appears that cyanobacteria are very efficient at exploiting even occasional pulses of phosphate availability. Operation of two oxygenation plants, and further Phoslock trials, have continued over the subsequent two summers. Future use beyond 2002-03 depends on the availability of funding. For more information on these remediation techniques contact the Swan River Trust.

Caring for the Canning: A plan to revitalise the Canning, Southern and Wungong rivers, released in August 2002, is a river management plan for the Canning River system, focusing on riparian zone and catchment issues. This report, which is available from the Swan River Trust, outlines actions to address the decline of the Canning River system that will be implemented over the next five years.

Conclusion

The Canning River is a very different ecosystem to the one encountered by early European observers. The seasonal interaction of fresh and salt water has been modified by upstream impoundments, dredging of the Fremantle sill, the development of an urban drainage network, and construction of the Kent Street Weir. Nutrient inputs from the catchment have resulted in advancing eutrophication in the Canning, which in recent years has been manifested by periodic blooms of nuisance and potentially toxic blue-green algae. Although there is no possibility of returning the river to its pristine, pre-settlement condition, hopefully with time it can be restored to a healthier and more resilient system. The Swan-Canning Cleanup Program is making progress towards long-term goals of improving land use practices, and restoring foreshores, drainage lines and streams within the catchment. In conjunction with the short-term remediation techniques mentioned above the expectation is to achieve a healthy and attractive river that is valued by the community.

Water and Rivers Commission

Glossary

Adsorption – is the process where phosphate binds to the surface of solid particles.

Anoxic – without oxygen.

Bioavailable – refers to nutrients that phytoplankton and other plants can take up directly from the water.

Biomass – the amount of living matter in a unit area or volume of habitat.

Chlorophyll *a* – a green pigment found in all plants and phytoplankton, which is critical in the capture of light energy during photosynthesis. The concentration of chlorophyll *a* in water is commonly used as a measure of phytoplankton abundance.

Cyanobacteria – also known as blue-green algae, are a group of photosynthetic bacteria. Some species produce toxins harmful to people and other flora and fauna.

Denitrification – the conversion of nitrate to gaseous nitrogen (N_2) by bacterial action.

Deoxygenation – the depletion of oxygen.

Dinoflagellates – a group of phytoplankton that have one or more flagella (whip-like structures) with which they can move through the water column; includes several toxic and nuisance species.

Eutrophication – the process of nutrient enrichment, especially due to increased nutrient inputs resulting from human activity.

FRP – filterable reactive phosphorus; this is the correct technical term for the form of dissolved inorganic phosphorus (DIP) measured in standard water quality sampling.

Hydrocarbons – organic compounds containing only carbon and hydrogen, such as grease and oils.

Luxury uptake – (of phosphorus) is uptake and storage by phytoplankton of DIP that is present in excess of growth requirements; this stored phosphate can then be used for continued growth when DIP becomes scarce.

Macrophytes – aquatic plants and algae – including ‘waterweeds’ – that are large enough to be seen with the naked eye (see *River Science 19* for information on macrophytes in the Canning).

Median – an ‘average’ value calculated as the middle value in a set of data when all results are arranged from lowest to highest.

Nitrification – chemical transformation of ammonium to nitrate facilitated by bacteria under an oxygen rich environment.

Nitrogen fixation – the conversion of N_2 gas to inorganic nitrogen.

Nutrient limitation – when the availability of a nutrient limits phytoplankton growth or biomass.

Phytoplankton – free floating or weakly mobile photosynthetic organisms, usually single-celled or chain-forming (e.g. diatoms, dinoflagellates, chlorophytes, cyanobacteria).

Phytoplankton bloom – a proliferation of phytoplankton sufficient to discolour the water column (for management purposes blooms are defined by the density of algal cells in the water – if moderate to large algal cells exceed 20 000 cells/mL it is referred to as a bloom; cyanobacteria densities greater than 20 000 cells/mL will lead to closure of the waterway to the public).

Stratification – layering of a water body due to density differences caused by salinity or temperature.

Thermocline – a sharp vertical gradient in water temperature.

Turbid – having a high concentration of suspended particles; murky in appearance.

Acknowledgments

The *River Science* series is an initiative of the Aquatic Science Branch of the Water and Rivers Commission with funding from the Swan-Canning Cleanup Program. This issue was written by Catherine Thomson and Dieter Tracey. Thanks to Malcolm Robb, Bruce Greenop and Dr Tom Rose for editorial comments.

For more information

More detailed publications on water quality in the Swan-Canning Estuary and catchment are available from the Swan River Trust. The complete list of Swan-Canning Cleanup Program publications is available on the internet at <www.wrc.wa.gov.au/srt/publications/>. *River Science* publications can be obtained from the Swan River Trust or downloaded in PDF format through <www.wrc. wa.gov.au/srt/riverscience/ publications.html>.

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ISSN 1443-4539
Printed on environmentally friendly paper
October 2002