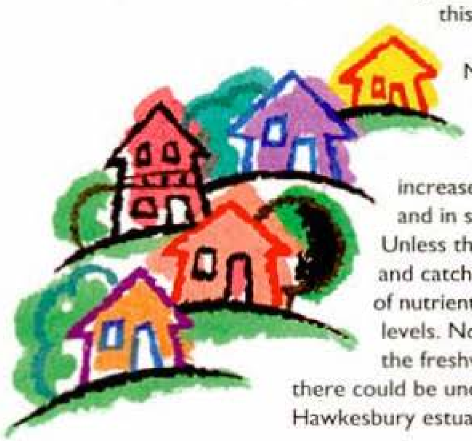
Watching the river flow from satellite city

Emilia Tagaza

Sydney's next satellite city is beginning to take shape on the plains adjacent to the Hawkesbury River about 30 kilometres north-west of the city. Authorities expect the existing pockets of population in places such as Kellyville and Rouse Hill to spread out and reach 250 000 people in the next 10-15 years, a size similar to Canberra.

Additional development to house up to 450 000 people is likely to occur in the South Creek Valley and Macarthur South sectors which also lie in the catchment of the Hawkesbury River. Unless these developments are appropriately planned, the demands on the river for water supply, irrigation, recreation and disposal of treated sewage effluent is likely to affect the health of this already stressed river system.



The most dramatic impact in the North-west Sector will be caused by the change in land use from primarily low-density agriculture to urban and industrial. This will lead to a large increase in the volumes of urban stormwater and in sewage effluent requiring treatment. Unless there is a substantial change in effluent and catchment management practices, the flux of nutrients into the river could rise above critical levels. Not only would this affect the health of the freshwater part of the river system, but there could be undesirable downstream effects in the Hawkesbury estuary and the adjacent ocean.

Playing Neptune on dry land

Six 2000-litre tanks or 'mesocosms' high on a hill in Perth's northern suburbs are the focus of CSIRO research into the impact of pollutants on the biology of Australia's coastal environment.

Inside the mesocosms is a selection of marine life - starfish, shrimps, crabs and others – which has been plucked from the ocean floor. They are the guinea pigs in a project which by the end of this year will have cost CSIRO $2 million in mesocosms alone.

Project leader, Dr Trevor Ward, says the tanks give the scientists control. 'For example, it is impossible for us to be underwater during storms, yet storms are crucial to the study of the biological impacts of pollutants,' Ward says. 'In the mesocosms we can create the storms and conduct safe, effective research at the same time.'

Pollutants in our coastal waters mostly lie in the sediments on the ocean floor. Salt water precipitates out these 'nasties' from the 'fresh' water discharges of rivers and industries. Storms move these pollutants back onto the water column. The mesocosms also allow controlled study of the many types of pollutants and the impact of variables such as water temperatures on marine life. Last month (March) CSIRO commissioned 24 more mesocosms, each of 35 000-litre capacity, at the Division of Fisheries' Marmion laboratory.

The first step to reduce the load of nutrients from sewage effluent produced by the North-west Sector Development has been taken by the installation of a modern sewage treatment plant able to service up to 40 000 people. This plant will produce treated effluent to be recirculated back to the urban area, along with a secondary system of pipes for use in watering gardens and playing fields.

Research into how the Hawkesbury-Nepean River system is likely to respond to future development is being conducted by scientists from the CSIRO Coastal Zone Program and state agencies including the New South Wales Environmental Protection Agency and Sydney Water.

The Coastal Zone Program is studying how pollutants originating from urban and agricultural catchments are delivered to estuaries. Scientists are examining the physical and chemical processes involved in controlling the flow, transport and destination of pollutants (nutrients, organics and heavy metals) along coastal rivers.

Dr David Jones of CSIRO's Division of Coal and Energy Technology, who leads a team investigating in-stream processes, says understanding the processes that control the movement of contaminants in waterways is crucial to predicting the likely impacts of different land-development plans.

'We have collaborated with scientists from AWT Ensight (formerly the Scientific Services Section of Sydney Water) to see what happens to nutrients as they move downstream from sewage treatment plants and urban areas in Cattai Creek, which is a tributary of the Hawkesbury River,' Jones says.

The team has found that the removal of nitrogen from the water is highly sensitive to season, with much less removal in winter than in summer. This finding has important implications in the design of wetlands intended for the 'final polishing' of tertiary treated sewage effluent. Wetlands are marsh-like systems where nutrients from sewage and agricultural run-off are absorbed before the water flows into the river. They can also be used to trap metal-laden particulates in urban stormwater run-off. The work has now been extended to the Hawkesbury River, where Jones and his team are collaborating with the NSW Environment Protection Authority.

'In the long term, the program is expected to deliver computer models and tools to help planners and managers draw better designs of new urban areas, with reduced adverse impact on the coastal zone,' says Jones. He adds that the general knowledge gained from the studies in the Hawkesbury-Nepean catchment should be applicable to other coastal metropolitan areas.

Jones and his research team are looking particularly at the transport of nutrients, which appear to be the major pollutants in the Hawkesbury-Nepean, but in many other coastal rivers, metals and pesticides can be an additional concern. His team works closely with another CSIRO group examining the role played by sediments in the fate of pollutants in the coastal zone.

Most pollutants bind tightly to sediment particles. The initially-contaminated sediments are deposited in the slow-moving reaches of the river during periods of low water flow. When the currents are strong, such as during floods, these sediments are resuspended and carried downstream, ultimately to be discharged and deposited in coastal estuaries. Here they are joined by the many pollutants, particularly metals, that enter as a result of urban stormwater and industrial discharges.

Sediments are therefore frequently the ultimate repository for many pollutants and nutrients entering the waterways. However, according to Dr Graeme Batley of CSIRO's Centre for Advanced Analytical Chemistry, sediments can also be a source of pollution. Contaminants such as mercury, copper, cadmium, lead and zinc together with nutrients and organic compounds such as phenols and pesticides, can be taken up from the concentrated sediment store by burrowing plants or animals. They can also be released by tidal changes, which introduce oxygen, changing the chemical properties of the sediments, and the way in which the contaminants are bound. His team has been studying the processes controlling pollutant mobilisation from sediments, and has developed techniques for sampling pollutants in the porewaters of buried sediments.

To help determine when sediments are going to act as a source or sink for pollutants, scientists have constructed and tested a prototype sediment corer-reactor to collect undisturbed sediment cores from the stream and river beds. This will allow them to observe the processes in the laboratory.

The storage capacity of sediments is influenced by the rate at which dissolved nutrients (solutes) move through sediments. According to Dr Ian Webster of CSIRO's Centre for Environmental Mechanics, several factors stimulate the movement of solutes in coastal sediments. These include molecular diffusion through the porewaters, waves, currents and changes to salinity. Burrowing and biological processes of organisms living in or feeding on the sediments also influence the movement of solutes through sediments.

'One can treat sediments as a giant chemical reactor, fuelled by oxygen from the water column and the organic matter that lands on the sediment surface,' Webster says. 'The chemical and biological reactions that occur in the sediments break down the organic matter into various substances, while the types of reaction that occur are influenced by the rate at which fuel is supplied to the reactor.'

For example, the amount of oxygen supply determines the potential for oxidation and reduction, and hence the mobility of substances such as iron, manganese and phosphate.

Webster's team is developing models that describe the mechanisms of solute transport in specific regions of the coastal zone. These mathematical models are being linked with models of the chemical behaviour for sediments developed by the teams led by Batley and Jones.

Sampling river water and river sediments.

The predictions will be verified by experiments in large tanks or mesocosms operated by Dr Trevor Ward and his team at CSIRO's Division of Fisheries (see story opposite). These are controlled replicas of the estuary, containing recirculated water, contaminated sediments and stocked with representative biological communities.

Multidisciplinary studies of this scope are rarely undertaken. The Coastal Zone Program's approach of linking the chemistry, physics and biology to fully understand the system will ultimately help authorities understand the behaviour of pollutants: how much of the contaminated sediment is transported by rivers under different flow conditions, how much of the contaminants is permanently retained by the sediments and how much is re-released into the water column. From that point they can define the levels of control of inputs and the acceptability of remediation techniques, and design effective catchment management systems.

Peeping at contaminated sediments

Many pollutants entering a water system accumulate in bottom sediments. Research suggests the uptake of heavy metals in aquatic sediments by living organisms is controlled by the concentrations that dissolve in the sediment pore waters. But sampling these waters is extremely difficult.

CSIRO's Centre for Advanced Analytical Chemistry has been developing a field technique using in situ dialysis samplers (peepers). These are made from perspex blocks about 10 cm by 2 cm, into which are machined a series of horizontal chambers, 1 cm apart. The chambers are filled with water, covered with a permeable membrane, pushed into the sediments and left for several days.

During this period, metals and other ions in the pore waters diffuse into the chambers, until their concentration is the same as in the surrounding pore water. The peepers are then retrieved and the chamber water sub-sampled and analysed, giving a depth profile of the distribution of contaminant elements in the sediment pore waters. Peepers are being used to study physical and chemical factors controlling the mobilisation and bioavailability of metals from contaminated sediments.

Experiments are being conducted in mesocosms (see story opposite) and at sites such as the Georges and Hawkesbury rivers and Lake Macquarie in NSW, the Derwent in Tasmania, and water bodies in river systems affected by mining in Papua New Guinea. These studies will aid the development of sediment quality criteria.