Government of **Western Australia**
Department of **Water**

Vasse Wonnerup Wetlands and Geographe Bay

water quality improvement plan

Looking after all our water needs

March 2010

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Department of Water

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Front cover photo Vasse Wonnerup Wetlands courtesy Bernie Masters

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  Department of Agriculture and Food
  Department for Planning and Infrastructure
  Department of Environment and Conservation
  Water Corporation
  Geographe Catchment Council
  South West Catchments Council
  Department of the Environment, Water, Heritage and the Arts

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Foreword

The *Water quality improvement plan for the Vasse Wonnerup Wetlands and Geographe Bay* is the culmination of four years of data collection, modelling and collation of best available science. The plan has been developed around the many factors affecting water quality in the Vasse Wonnerup and Geographe Bay, including urban, agricultural and horticultural land uses, with decision support systems and predictive modelling forming the basis of the plans targets and recommendations.

The main purpose of this plan is to protect the internationally recognised Vasse Wonnerup Wetlands and Geographe Bay from nutrient pollution both now and into the future. The recommended management measures have been developed to alleviate and prevent symptoms of nutrient pollution such as sudden mass fish deaths, blooms of toxic algae and macroalgae, nuisance odours and mosquitoes, and loss of biodiversity. We face many challenges in addressing these issues, given that Geographe Bay and the Vasse Wonnerup Wetlands sit within a catchment experiencing one of the highest rates of population growth in Australia.

Computer models underpinned by sound science forecast the potential impact of climate and land-use change in the catchment over a 20-year period. These sophisticated models have also enabled the prioritising and selecting of management measures on the basis of their expected nutrient-reduction performance, value for money and suitability for specific geographic areas.

We have endeavoured to find the right balance between land use activities in the catchment and protection of the environmental systems. Improving how we manage water will be needed across all sectors – from urbanisation through to broad acre dairying and beef farming.

The plan builds on the work of the local community over the past two decades to manage its natural resources and this work underpins the implementation strategy.

Kim Taylor,

Director General

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Executive summary

The long-term protection of two highly valued ecosystems – the Vasse Wonnerup Wetlands[1] and Geographe Bay – has motivated the development of this water quality improvement plan. Land-use changes as a result of urbanisation and more intensive agriculture in the south-west region have resulted in large loads of nutrients being discharged into the wetlands and bay. Without management intervention, this pollution is predicted to significantly increase over the next 20 years. Thus the purpose of this plan is to guide management strategies to reduce the total nitrogen and phosphorus loads being delivered to these important ecosystems.

The Vasse Wonnerup Wetlands provide habitat for thousands of waterbirds every year and are included on a list of wetlands of international importance under the Ramsar Convention on Wetlands. The wetlands have experienced severe nutrient problems for many years including sudden mass fish deaths, blooms of macroalgae, toxic phytoplankton, nuisance odour and mosquito problems. Geographe Bay supports extensive and diverse seagrass meadows that provide vital habitat for many fish and other marine fauna. It is also highly valued as a recreational resource and sits within a proposed marine park area. Because seagrasses are known to be sensitive to the impacts of elevated nutrients, a 'watching brief'[2] is being maintained on Geographe Bay's seagrass ecosystem.

This plan brings together the best-available scientific knowledge about the current water quality status of Vasse Wonnerup Wetlands, Geographe Bay and their waterways for the purposes of nutrient management planning. Water quality modelling tools developed by the Department of Water are used to provide a breakdown of each catchment's nutrient sources and to identify how much nutrient reduction is required to prevent or alleviate water quality problems in each system. This modelling has established nutrient-load reduction targets for each catchment (shown on the next page) expressed as the required reduction in tonnes per year, and as the required percentage reduction of the current nutrient loads. These are ambitious targets that will require a concerted and cooperative effort if they are to be achieved.

[1] Scientists often use the term 'system' to describe wetlands – in this case, the Vasse Wonnerup Wetland system. This is to recognise their complexity; for example, the Vasse Wonnerup Wetland system is comprised of the Vasse and Wonnerup estuaries and their exit channels; the Wonnerup Inlet; and the seasonal connection between the two estuaries known as Malbup Creek. However, for the purposes of brevity, this report will refer to the Vasse Wonnerup Wetlands without the word 'system'.

[2] The University of Western Australia has undertaken a two-year study of the distribution patterns of seagrass, epiphytes, fish, invertebrates and water quality in Geographe Bay. This study will enable changes in these variables to be monitored over time (Westera et al. 2007).

Loads and targets	Vasse Wonnerup Wetlands	Geographe Bay
Total phosphorus		
Current load (tonnes/yr)	15.6	53.4
Long-term reduction targets (reduce by x tonnes/yr)	6.4	20.0
Long-term reduction targets (% of current load)	41%	38%
Interim 10-yr reduction targets (reduce by x tonnes/yr)	3.7	10.3
Interim 10-yr reduction targets (% of current load)	23%	19%
Total nitrogen		
Current load (tonnes/yr)	133.7	409.2
Long-term reduction targets (reduce by x tonnes/yr)	73.8	177.4
Long-term reduction targets (% of current load)	55%	43%
Interim 10-yr reduction targets (reduce by x tonnes/yr)	48.7	124.9
Interim 10-yr reduction targets (% of current load)	36%	30%

Water quality modelling techniques have calculated that the vast majority of current phosphorus and nitrogen loads from both catchments are derived from diffuse agricultural sources. Of these sources, broadacre grazing for beef and dairy cattle are dominant. Point sources such as dairy effluent, wastewater treatment plants and septic tanks also make significant contributions in some subcatchments. In terms of future nutrient loads, urban expansion is predicted to be the main contributor to large increases in both phosphorus and nitrogen. These predictions have confirmed that remedial nutrient management is required in the rural catchment to tackle current loads, while action to prevent further increases must focus on urban expansion. Meeting targets will, however, require a comprehensive and prioritised program of action to address all sources. To this end, the plan outlines 18 recommended management measures as follows:

- **Managing diffuse agricultural nutrients:**
  1 improving fertiliser management throughout the catchment
  2 implementing riparian management and stock control on streams and drains
  3 using soil amendments on sandy soils
  4 using perennial pastures in suitable locations and situations.
- **Managing point-source agricultural nutrients:**
  5 improving effluent management at dairy sheds and feedlots.
- **Managing diffuse nutrients from the urban landscape:**
  6 reducing nutrient use and export risk in urban areas
  7 ensuring new urban developments incorporate water sensitive urban design
  8 achieving no net increase or a net reduction in nutrient loads from large new urban developments
  9 undertaking strategic retrofitting of water sensitive urban design in existing urban areas.

- **Managing urban point sources**:
  10 achieving no net increase in nutrient loads from wastewater treatment plants in recovery catchments
  11 developing solutions to large nutrient loads delivered by septic systems in specific reporting catchments.
- **Managing environmental flows:**
  12 implementing surveys and flow management assessments for the Carbunup and Capel rivers
  13 integrating management of environmental flows with water quality management objectives.
- **Filling gaps in research and development:**
  14 understanding nutrient dynamics in the Vasse Wonnerup Wetlands
  15 understanding the ecological impacts of high nutrient loads in Geographe Bay
  16 understanding groundwater sources of nutrients
  17 developing and evaluating best-management practices (BMPs) for nutrients
  18 undertaking extensive and ongoing monitoring and modelling in the catchment.

The plan supports these management measures by providing detailed guidance on their benefits, current uptake and barriers to adoption, as well as advice to aid implementation. The plan’s implementation strategy details the actions required under each management measure, who is responsible for implementing the measure and, where possible, the associated capital costs. Specific recommendations for individual reporting catchments (subcatchments) have also been included to ensure the plan is relevant to small-scale catchment groups and projects.

The Vasse Wonnerup Wetlands and Geographe Bay are two of the most significant and valuable natural resources in the south-west region. Protecting them from the impacts of nutrient pollution is a high priority, yet this will require a substantial effort by governments, industry and the community for many years to come. Of utmost importance is achieving the right balance between protecting the bay and wetlands and facilitating continued agricultural production and further urban growth in the catchment.

1 Introduction

1.1 The need for a water quality improvement plan

The Vasse Wonnerup Wetlands and Geographe Bay have outstanding ecological, social and cultural values. The wetlands provide habitat for thousands of waterbirds every year and, as a result, are included on a list of wetlands of international importance under the Ramsar Convention on Wetlands. Geographe Bay supports extensive seagrass meadows that serve important ecological functions, while an array of marine life makes use of the sheltered embayment. The bay is highly valued and used extensively for recreation by the local community and visitors to the area. The protection and management of these two systems is of utmost priority for the Geographe catchment.

The Vasse Wonnerup Wetlands and the catchment waterways have experienced severe water quality problems for many years. These problems have included regular blooms of toxic algae, sudden mass fish deaths, reduced recreational opportunities and unpleasant odours resulting from the decomposition of algae and exposure of anoxic sediments. Limited flushing opportunities arising from the installation of floodgates at the mouth of the estuaries is likely to have increased the susceptibility of this system to nutrients. Thousands of waterbirds have continued to use the Vasse Wonnerup Wetlands each year despite severe nutrient enrichment, but there is concern that further increases in nutrient loads may alter the waterbirds' food sources. Managing the levels of nutrients that enter the wetlands from catchment sources will not only minimise risks to waterbirds, but also help to mitigate nuisance water quality problems in the area.

The nutrients flowing into Geographe Bay may be putting its seagrass meadows at risk: seagrass systems are known to be sensitive to eutrophication and can be slow to recover once damage has occurred. Large areas of seagrass have been lost from other marine embayments and estuaries in Western Australia as a result of nutrient enrichment (Cambridge & McComb 1984). Scientists' current understanding of the critical nutrient-threshold levels in seagrass meadows is limited, yet on a global scale sedimentation and nutrient enrichment are regarded as the greatest threats to seagrass ecosystems (Spalding et al. 2003). To help improve knowledge in this area, the University of Western Australia is maintaining a watching brief on nutrients flowing into Geographe Bay.

Without management, the nutrient load to Geographe Bay and the Vasse Wonnerup Wetlands is likely to continue to increase as a result of urban expansion and the intensification of agricultural industries. The catchment's population growth rate is one of the highest in Australia (ABS 2006). This growth is fuelling rapid urban expansion of the Busselton, Dunsborough and Capel town sites into surrounding agricultural areas. Recent surveys of urban nutrient use have demonstrated that nutrient loads from urban areas can be much greater than those from agricultural grazing land – due to the large quantities of fertilisers added to home gardens (Kitsios & Kelsey 2008). In recent times, agricultural industries have needed to increase productivity to maintain viability. This has led to higher nutrient exports from the catchment, in line with other rural areas on the Swan coastal plain. As nutrient exports continue to increase from both urban and agricultural sources, improvements in the management of nutrients will become more critical for the protection of Geographe Bay and the Vasse Wonnerup Wetlands.

In recognition of the values and issues described above, the Australian Government identified the Geographe catchment as a national nutrient hotspot in June 2006. The hotspot includes the Vasse Wonnerup Wetlands and southern Geographe Bay catchments. This plan refers to these combined areas as the Geographe catchment. Funding to develop a water quality improvement plan for the area was allocated under the Australian Government's Coastal Catchments Initiative. This resulting plan is a culmination of three years of cooperative government effort.

1.2 Overview and aims

This water quality improvement plan provides a strategic approach to reducing nutrients in the Vasse Wonnerup Wetlands and Geographe Bay. The management practices described in the plan have been selected for the local area using scientific models and decision-support tools based on current knowledge and data. The plan's aim is to provide clear and achievable advice about the best-possible mix of management tools to meet reduction targets for total nitrogen and total phosphorus loads from the catchment over the next 10 years and in the longer term.

1.3 Approach and supporting projects

The plan's development has been supported by four interim projects, each of which contributed important information to the final plan. Each project provided valuable long-term tools for nutrient management in their own right (Figure 1). The four interim projects were as follows:

1 **Agricultural best-management practices by the Department of Agriculture and Food.** This project developed, trialled and monitored a series of agricultural best-management practices across the Swan coastal plain to assess the rates of nutrient reduction achieved by different techniques.

2 **Predictive water quality modelling by the Department of Water.**
This project:

- developed a model of the water quality and hydrology of the Geographe catchment
- implemented a comprehensive water quality monitoring program for the Geographe catchment that was used to improve the model's calibration and can be used in the future to track progress towards meeting this water quality improvement plan's targets
- calculated the nutrient-load reduction targets for each reporting catchment that were used in this plan and by the decision-support system described below.

The predictive water quality model is explained in more detail in Appendix A.

3 **Decision-support system by the Department of Agriculture and Food.**
This project developed computer-based decision-support tools to evaluate the net cost and nutrient reduction of different scenarios of land management interventions on a catchment, subcatchment and farm scale. The decision-support system is explained in more detail in Appendix B.

4 **A framework for implementing water sensitive urban design.**
This project was undertaken by the Western Australian Local Government Association, Department for Planning and Infrastructure, and the Department of Water. It achieved the following:

a. developed a statutory water sensitive urban design framework: *Better urban water management*

b. finalised the *Stormwater management guidelines* for water sensitive urban design

c. calibrated urban design modelling tools for water quality protection

d. incorporated model (standard) planning provisions and policy into town planning schemes to improve the implementation of water sensitive urban design in new developments

e. developed and implemented a water sensitive urban design capacity-building program for local government and industry.

Further information about the *Better urban water management* framework and the supporting components listed above are presented in Appendix C.

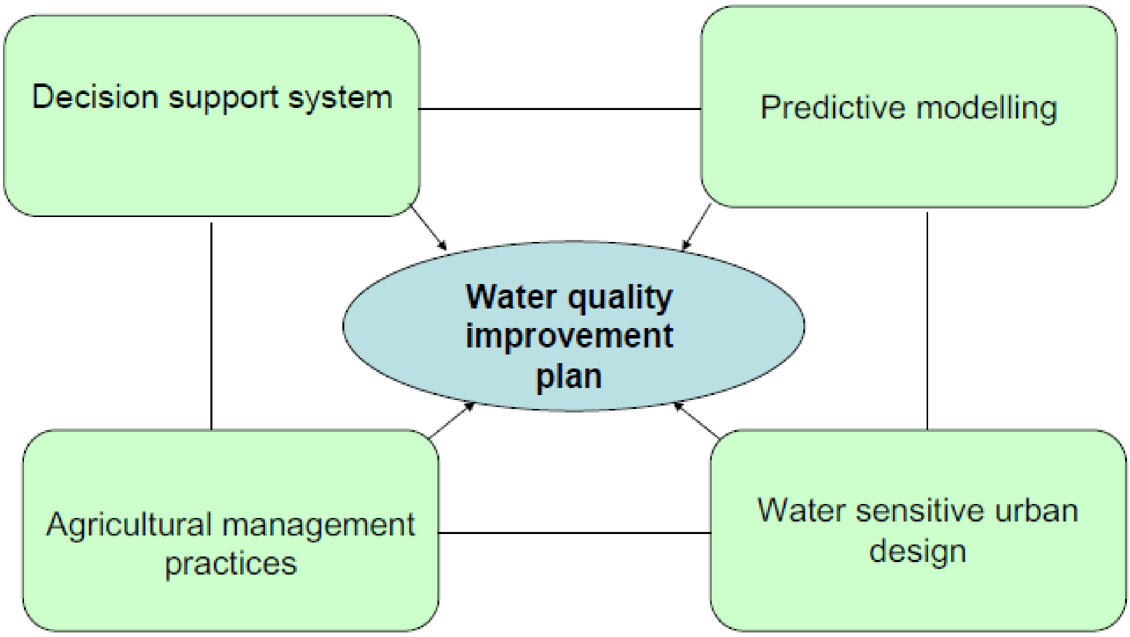


Figure 1: Components of the Vasse Geographe Coastal Catchments Initiative program.

1.4 The framework for marine and estuarine water quality protection

This water quality improvement plan has been developed in accordance with the *Framework for marine and estuarine water quality protection*, which was developed as a nationally consistent approach to protecting the marine environment from the effects of land-based pollution.

The framework includes identification of:

- the environmental values of the coastal water in question
- the catchment that discharges to that coastal water
- the water quality issues (e.g. algal blooms, sedimentation, high coliform concentrations causing beach closures) and subsequent water quality objectives
- the total maximum load of pollutant/s to be achieved to attain and maintain the water quality objectives
- the allocation of the total maximum load of pollutant/s to diffuse and point sources of pollution
- the river flow objectives to protect identified environmental values, having regard for matters such as natural low flows, flow variability, floodplain inundation, interactions with water quality and the maintenance of estuarine processes and habitats
- management measures, timelines and costs in implementing the plan

- the grounds for a 'reasonable assurance' from jurisdictions to provide security for investments to achieve the specified pollutant-load reduction and environmental flow targets.

1.5 Reporting catchments

This water quality improvement plan provides information about nutrient sources, nutrient targets and recommended management approaches for the Geographe catchment. Much of this information has been presented on a subcatchment basis to aid the implementation of local-level projects. Subcatchments within the plan reflect the catchment areas of the major waterways. These are referred to as 'reporting catchments' in the plan because it is envisaged that each will be monitored individually over time and progress reported against their own specific targets. This approach will enable management information and recommendations for each area to be tailored for use by state government agencies, small-scale catchment or community groups, Land Conservation District Committees, agricultural user groups and local-government planning staff alike. Figure 2 illustrates the location of these reporting catchments.

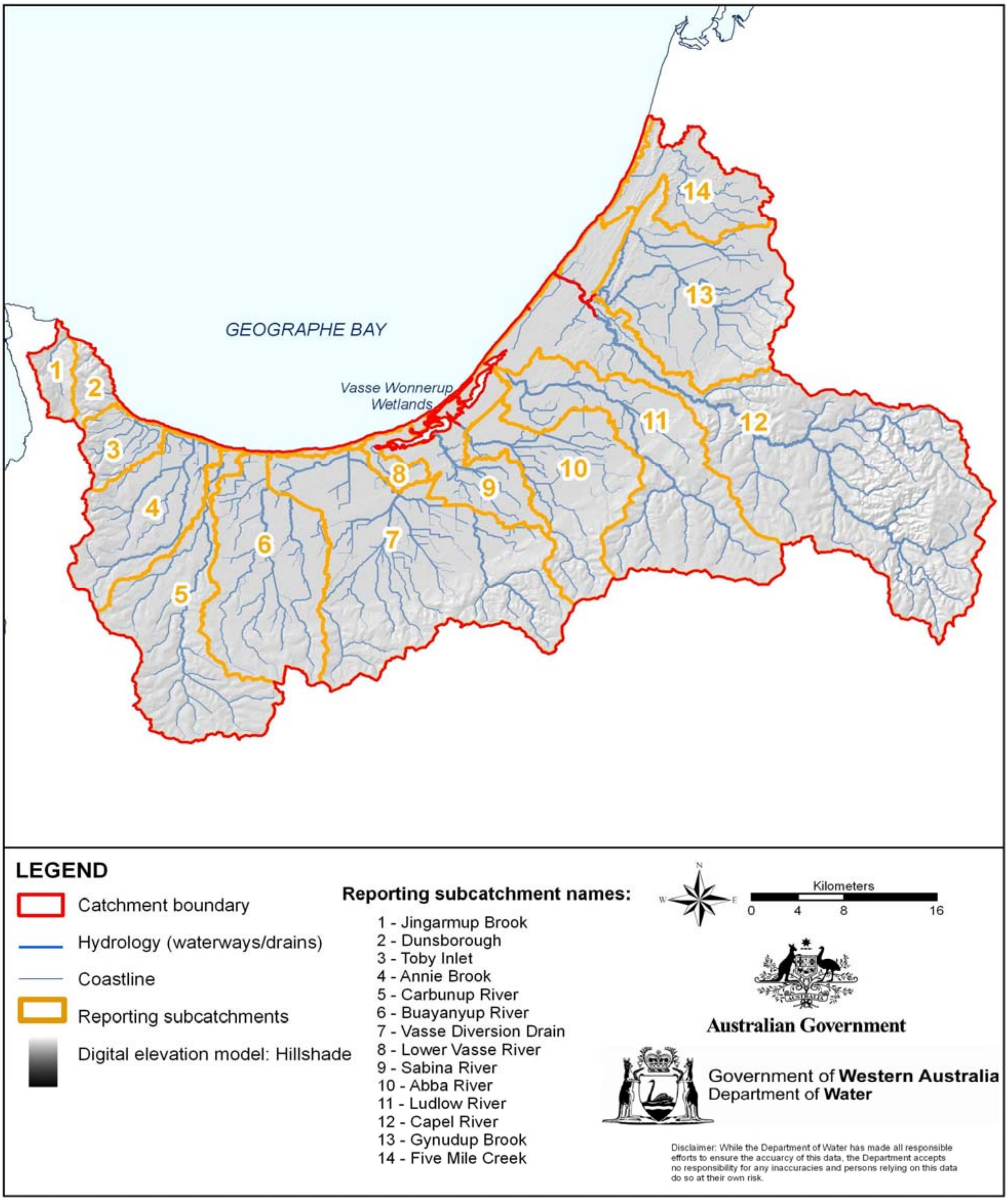


Figure 2: Reporting catchments of the Geographe catchment.

1.6 Stakeholder engagement process

Engagement with organisations likely to undertake nutrient management initiatives in the catchment began early in the plan's development phase. A steering committee of government agencies and natural resource management organisations was formed – many members of which were also part of the Swan Canning water quality improvement plan's steering committee. Joint meetings were therefore held to maximise efficiency and to help integrate nutrient management initiatives across the Swan coastal plain.

The following organisations were represented on this water quality improvement plan's steering committee:

- Geographe Catchment Council
- South West Catchments Council
- Department of Water
- Department of Agriculture and Food
- Department for Planning and Infrastructure
- Department of Environment and Conservation
- Western Australian Local Government Association
- Water Corporation
- Shire of Busselton.

2 Catchment characteristics

2.1 Location and landscape

The Geographe catchment occupies an area of approximately 2000 km^2 between Bunbury and Cape Naturaliste in Western Australia. The catchment is bounded by the Darling Range, the Whicher Range and the Leeuwin-Naturaliste Ridge. Below these ridges lies the southern-most part of the Swan coastal plain extending south and west to Dunsborough. The coastal plain is characterised by predominantly sandy-loam surfaced soils as well as poorly drained flats and palusplain wetlands. It has been extensively cleared and developed for agriculture and is becoming more urbanised. The ranges and ridges around the coastal plain retain a larger area of native vegetation, of which a significant proportion has been protected within areas of national park and state forest. These higher areas also contain gravelly and loamy soils and therefore have a better nutrient-retention capacity than much of the coastal plain.

The shires of Busselton and Capel cover much of the catchment's land area, though very small portions of the Donnybrook–Balingup and Augusta–Margaret River shires are also included.

2.2 Historical and current land use and demography

French explorers were the first-recorded European visitors to Geographe Bay aboard the ships *Naturaliste* and *Geographe* in 1801. Agriculture and settlement began in the 1830s when settlers such as the Molloy, Bussell and Layman families established farms in the Vasse River area, while the Chapman family settled the Bunker Bay area. These settlers grew wheat, barley and oats and raised livestock such as sheep, pigs and cattle. They began exporting as early as 1858. Inshore and estuarine fishing became important local industries and whaling began from 1846 to 1872, with operations based at Castle Bay near Dunsborough. Whalers traded supplies with local settlers and helped stimulate the Busselton town site's development. During the same period the timber industry was established and a mill built at Quindalup. The industry boomed when port facilities became available after the Busselton Jetty was constructed in 1864, and this supported steady population growth in the area through to the early 1920s.

The area's dairy industry began in the 1920s and 1930s when the British and Western Australian governments jointly formed the Group Settlement Scheme (WAPC 1998). The scheme failed to instigate the expected population growth in the area, mainly due to the settlers' inexperience and the economic hardships of 1930s depression. Despite these failings, the scheme opened up land for further agricultural development through land clearing and the extensive drainage works undertaken in coastal areas (WAPC 1998). Today agriculture still dominates the catchment's land area, with dairy and beef grazing the most widespread and intensifying (Figure 3). Viticulture has expanded in the western part of the catchment while production horticulture such as potato growing is also undertaken in these areas. Sheep and horses are grazed in many parts of the catchment. While the dairy industry struggled in the early years, milk now provides the highest ‘gross value of agricultural product’ in the Shire of Busselton, followed by viticulture (Shire of Busselton 2007).

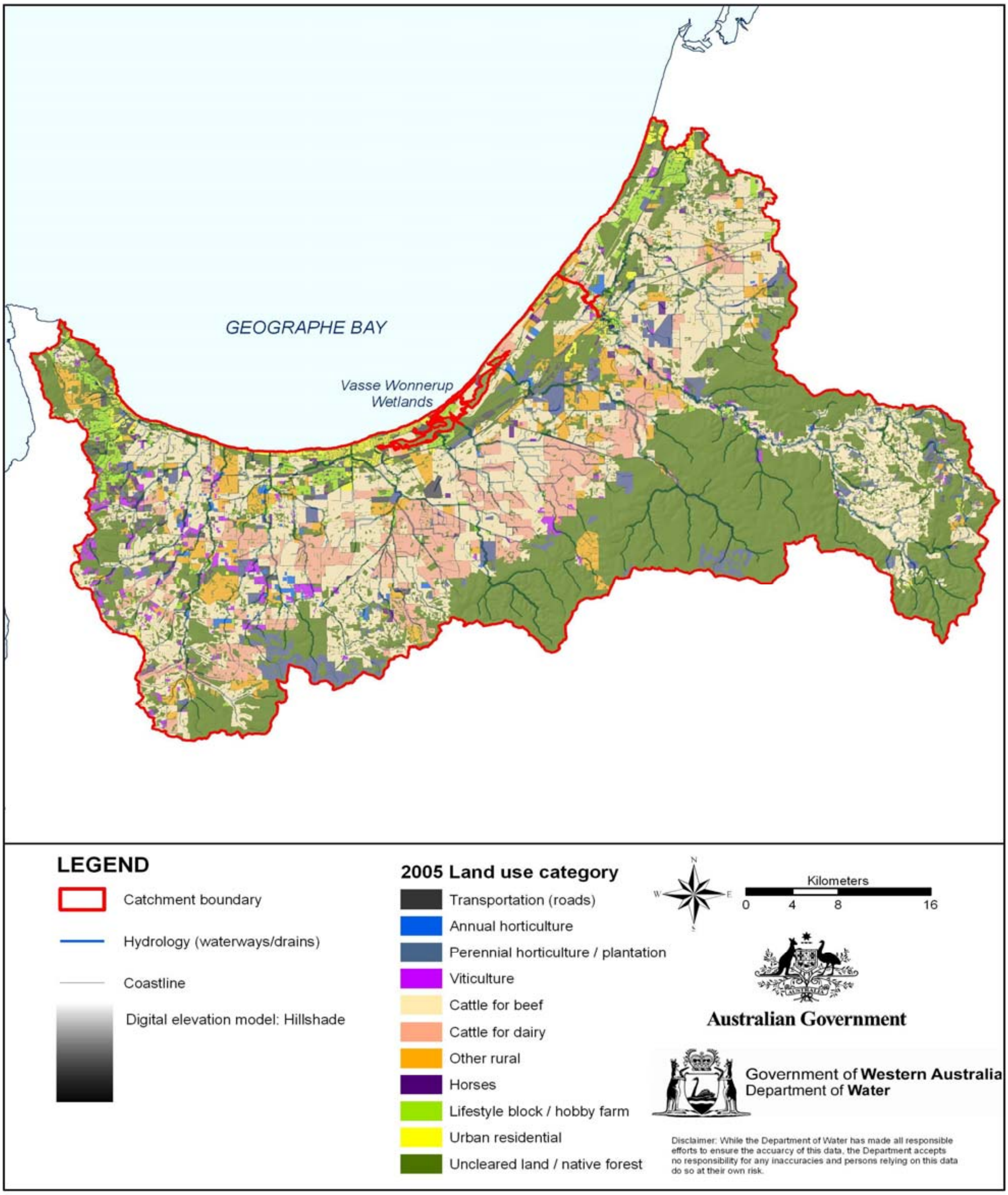


Figure 3: 2005 land use in the Geographe catchment[3].

[3] Categories used in this land-use map have been extensively summarised. For a full list of the land-use categories from the original data source, see Appendix G.

From the mid-1960s urban expansion and infrastructure changes became more dominant than changes brought about by primary production. Resource development projects increased in the region, including mineral-sands mining near Capel. Tourism expanded in the coastal areas, which led to a trend of increasing population that has heightened over the past few decades. Current urban areas within the catchment include the Busselton, Dunsborough and Capel town sites; the western portions of Boyanup; and the Eagle Bay, Peppermint Beach and Carbunup River hamlets. The Port Geographe canal development near Wonnerup directly borders the Vasse Estuary. The Vasse village near Busselton is growing, while in the catchment's northern extremity, the Dalyellup estate represents a southern expansion of the Bunbury urban area. Rural-residential lifestyle lots have developed around the Dunsborough and Busselton town sites and also occur at Gelorup and Stratham in the catchment's north. Urban land use is changing at the greatest rate, although agriculture and tourism remain economically important and agriculture still dominates the catchment's physical space.

Economic prosperity in the state, combined with a strong local tourism industry and the area's popularity as a 'sea change' location, has led to substantial population growth in the catchment in recent years. Both the Capel and Busselton shires are experiencing growth well above the state average and are among the fastest-growing rural shires in Australia. Population projections for both shires illustrate the magnitude of the expected growth (Figures 4 and 5). Most of the projected growth for the Capel shire will occur within the Geographe catchment from expansions of the Capel and Boyanup town sites and southern extensions of the Dalyellup estate (Iliya Hastings, Shire of Capel, pers. comm.)

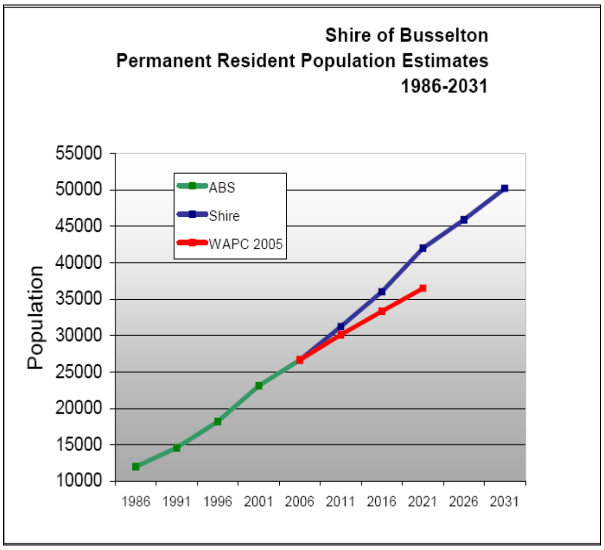


Figure 4: Current and projected population growth for the Shire of Busselton (Shire of Busselton 2007).

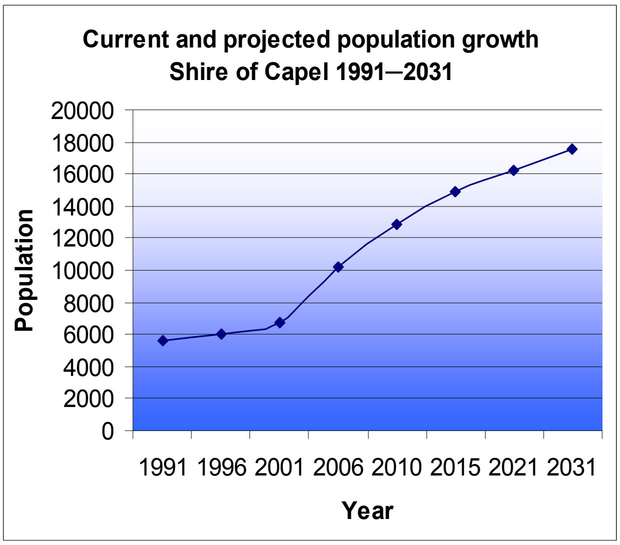


Figure 5: Current and projected population growth for the Shire of Capel (ABS 2006).

2.3 Hydrology

Geographe Bay receives ephemeral surface flow from 16 waterways that dissect the catchment (Figure 6). Of these, only the Lower Vasse, Lower Sabina, Abba and Ludlow rivers drain into the Vasse Wonnerup Wetlands before discharging through the Wonnerup Inlet into Geographe Bay. A network of seasonal streams flow into the Toby Inlet before draining into the bay. All other waterways flow directly into Geographe Bay either through their natural outlets or artificially constructed drains, with the exception of Gynudup Brook and Tren Creek, which flow first to the Capel River.

European settlement has seen many changes to the catchment's hydrology. Before these changes occurred, very few waterways flowed directly into Geographe Bay. They instead flowed first into an extensive chain of wetlands stretching along the coast that emptied into the Vasse or Wonnerup estuaries (Lane et al. 1997). Hydrological change in the catchment started as early as the 1880s when the Capel River was diverted from the Wonnerup Inlet into Geographe Bay through the Higgins Cut. From this time until the 1950s, a series of hydrological alterations were made, with drainage works escalating during the 1920s and again in the 1950s (WRM 2007). These works included the construction of floodgates to prevent saltwater incursion, a network of small drains to remove water from farmland, and a series of large arterial drains and river diversions to discharge surface flow directly to Geographe Bay (English 1994). These changes enabled farming of coastal areas that were previously inundated during winter, reduced saltwater incursion into pasture that bordered the estuaries, and protected the growing town of Busselton from flooding – thereby allowing it to expand into floodplain areas. However, these works also resulted in removal of the nutrient settlement and filtration functions once served by coastal wetlands, an increase in the velocity of water transport, reduced flushing of estuarine systems and increased sedimentation. Geographe Bay and the Vasse Wonnerup Wetlands now receive large loads of nutrient-laden flow delivered by the waterways during winter.

Geographe Bay is one of only a few sheltered north-facing marine embayments in Western Australia and is protected from summer swells. In winter the north-westerly swells push into the bay and reduce the overall flushing time from about 15 days to four (Fahrner & Pattiaratchi 1995). These flushing times are slow compared with open marine systems such as Whitfords lagoon in the Marmion Marine Park, which takes seven to two days to flush (Fahrner & Pattiaratchi 1995); though are more rapid than Cockburn Sound where flushing takes as long as 44 days in summer and 22 in winter (DA Lord & Associates 2001). Since all waterways aside from the Capel River are seasonal, nutrient loads are delivered to Geographe Bay primarily during winter, with little or no flow occurring during summer. The Mediterranean climate combined with a prevalence of seasonal waterways may be providing some protection to Geographe Bay. The largest loads of nutrients are delivered only at a time when the water is cold; there is little light within the water column to assist algal growth; and water discharged from streams is flushed out to sea quickly, thereby dissipating and diluting over a short time.

The Vasse Wonnerup Wetlands are comprised of the Vasse and Wonnerup estuaries and their exit channels; the Wonnerup Inlet; and the seasonal connection between the two estuaries known as Malbup Creek. The Dead Water and Swan Lake are also associated wetlands. Today only the Lower Vasse, Lower Sabina and Abba rivers flow into the Vasse Estuary, while the Ludlow River flows into the Wonnerup Estuary. Floodgates were installed near the mouths of the Vasse and Wonnerup estuaries during the early 1900s to prevent flooding of the surrounding agricultural land with salt water. These floodgates have since enabled the Busselton town site to expand into land that was previously inundated during winter. The floodgates have also served to maintain fresh–brackish water within the system for a longer period than would have occurred under ‘natural’ conditions. Large areas of the wetland system dry out during summer, though some water is retained in both estuaries that provides important summer refuge habitat for thousands of waterbirds.

Geographe Bay also receives flow from groundwater sources. The catchment is underlain by the Superficial aquifer, which is approximately 10 m thick. Below this lies the Leederville aquifer, which in turn is underlain by the older and larger Yarragadee aquifer. Both the Leederville and Yarragadee are confined aquifers that are recharged by direct infiltration of rainfall on the Blackwood Plateau. In thickness the Leederville aquifer varies from 50 m in the west to approximately 500 m in the east, while the Yarragadee aquifer ranges from 600 m to 1600 m. All three of these aquifers flow towards the coast (WAWA 1995). The Capel River is the only waterway that actually intersects the Leederville aquifer, which is the reason it is a perennial river system. All other waterways receive contributions only from the Superficial aquifer and surface runoff.

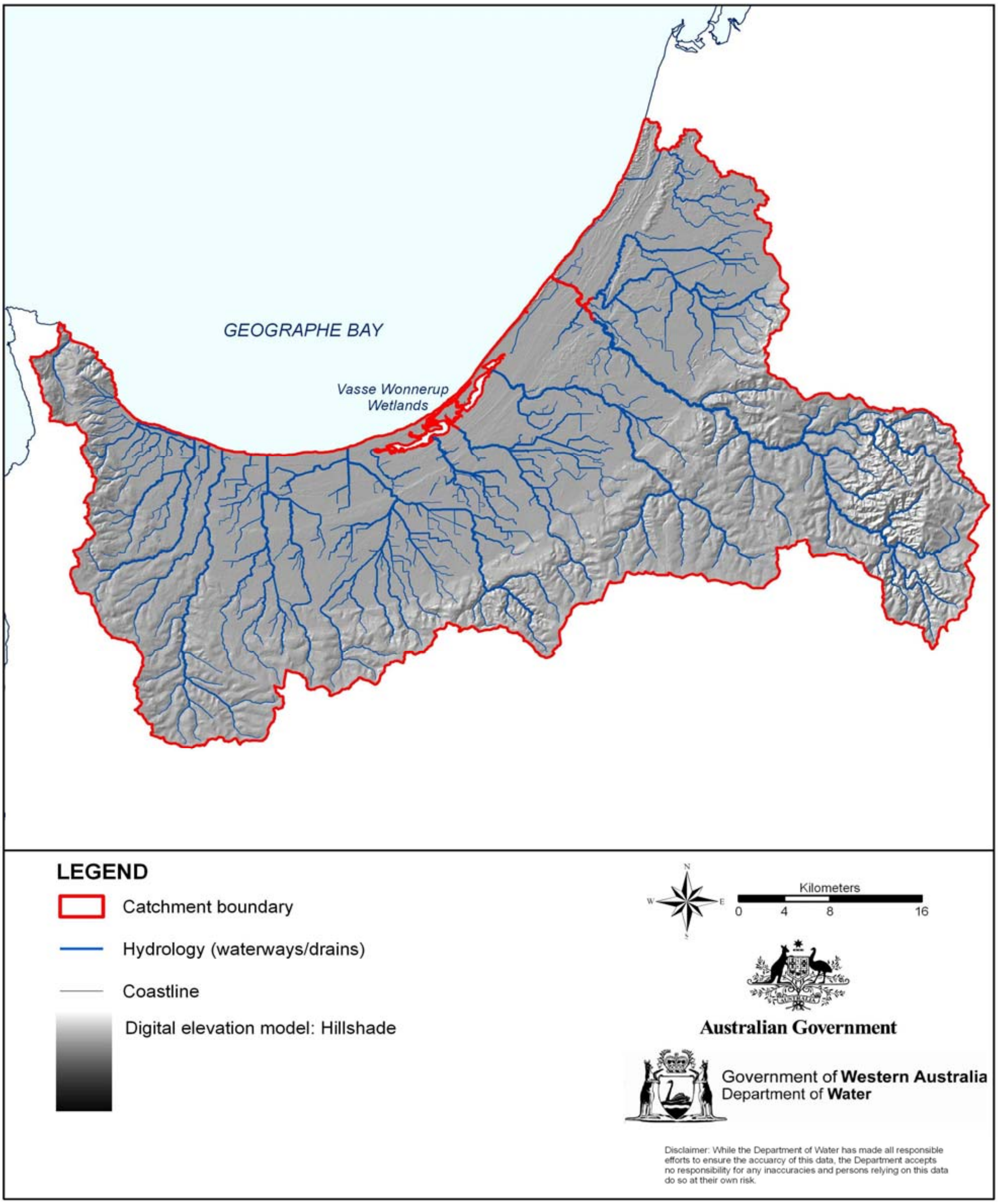


Figure 6: Surface-water hydrology of the Geographe catchment.

3 Ecological values

3.1 Vasse Wonnerup Wetlands

Waterbirds and the Ramsar Convention

The Vasse Wonnerup Wetlands are recognised as one of the most important waterbird habitats in Western Australia. More than 30 000 waterbirds comprising 90 different species make use of the habitat provided by the wetlands each year. These include a range of migratory and resident species in addition to the largest breeding colony of black swan in Western Australia (WAPC 2005). The only waterway in the state to support larger numbers of waterbirds is the Peel Harvey Estuary, though this is close to 13 times the size of the Vasse Wonnerup Wetlands (WRM 2007).

Many of the species recorded in surveys of the Vasse Wonnerup Wetlands have special conservation value (WRM 2007). These include:

- 40 species with priority conservation status at a state, national or global level, including 22 migratory waterbird species
- 61 resident Australian species, including large numbers of Australian pelican, great egret, yellow-billed spoonbill, Eurasian coot, black-winged stilt and red-necked avocet
- species that regularly occur in numbers greater than or equal to one per cent of the estimated Ramsar populations (back-winged stilt, red-necked avocet, Australian shelduck and Australasian shoveler)
- species that in some years occur in numbers greater than one per cent of the East Asian–Australasian Flyway population (wood sandpiper, sharp-tailed sandpiper, long-toed stint, curlew sandpiper and greenshank).

Owing to these significant waterbird values, since 1990 the Vasse Wonnerup Wetlands have been included in a list of wetlands of international importance under the Ramsar Convention. Australia is one of 158 countries that are contracting parties to this international convention, which was ratified in Ramsar, Iran, in 1971. Among other responsibilities, contracting parties are required to implement measures to promote wetlands conservation, ensure wise use of the listed wetlands, and to protect migratory waterbirds and their habitats.

Macrophytes such as the estuarine seagrass species *Ruppia megacarpa* grow throughout both estuaries and provide an important food source for waterbirds. The black swan, which breeds in large numbers on the wetlands, feeds directly on this species. Maintenance of macrophyte populations within the wetlands is important to ensure the long-term availability of feeding habitats for waterbirds.

The Vasse Wonnerup Wetlands Ramsar site currently covers approximately 1115 ha and includes the non-freehold and seasonally inundated floodplains and marshes of the Vasse and Wonnerup estuaries and Wonnerup Inlet. Recent extensions encompass the lower reaches of the Sabina River, Abba River and sections of the

Tuart Forest (Government of Western Australia 2000). An Ecological Character Description for the wetlands (WRM 2007) – prepared as part of the Coastal Catchments Initiative project – provides a summary of the wetlands' ecological values relevant to the Ramsar listing. Threatening processes affecting the wetlands and potential thresholds for change are also identified in this document. A copy of the draft Ecological Character Description is provided in Appendix D.

Other values

Aside from providing waterbird habitat, the Vasse Wonnerup Wetlands are also used by a wide variety of other fauna that play an important part in the wetland ecosystem. Twelve marine and estuarine fish species have been recorded in the wetlands, and of these, seven species use the system as a nursery area. Black bream and mullet are also fished commercially on a seasonal basis (WRM 2007). The western school prawn and blue swimmer crab appear occasionally, while a wide variety of frogs and snakes make use of the wetlands – as do long-neck tortoises and water rats.

The values of the Vasse Wonnerup Wetlands are not limited to ecological functions. They play an important flood-protection role for the surrounding low-lying coastal properties by providing water storage to buffer storm surges and peak river flows (WAPC 2005). The fringing vegetation and open water areas of the wetlands also hold important aesthetic landscape values for the town of Busselton. These values, together with the huge number of waterbirds that visit each year, provide the site with enormous potential for ecotourism that is unrealised as yet.

Photo 1: Scenic values of the Vasse Estuary.

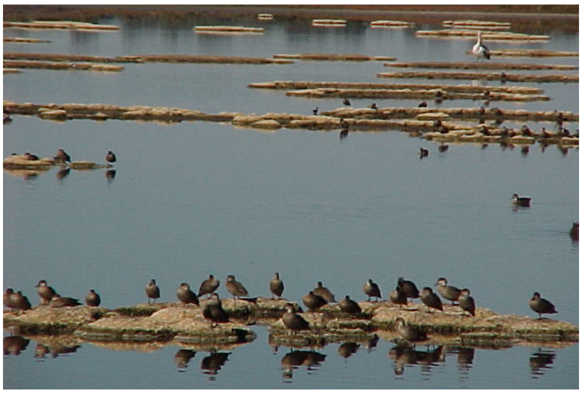


Photo 2: Waterbirds congregating on the estuary.

3.2 Geographe Bay

Proposed marine park

Geographe Bay is highly valued and used extensively for recreation by the local community and visitors to the area. The sheltered waters provide a range of opportunities such as safe boating, fishing and swimming; whale watching; and many other water-based pursuits.

Geographe Bay is predominantly north facing and provides sheltered conditions from the prevailing south-westerly swells for much of the year. The embayment is formed by a broad, shallow intercontinental shelf and has a mainly sandy base overlying limestone, of which much has been colonised by seagrass meadows. The influence of the Leeuwin Current enables a combination of tropical and temperate fauna species to occur. The combination of these features has created a marine embayment with an unusually diverse combination of marine flora and fauna that is still being explored.

These values have been recognised by the bay's inclusion in a proposed marine park that will extend from the eastern boundary of the Busselton shire and west to Cape Naturaliste and south to include the Cape to Cape coastline and the Hardy Inlet.

Photo 3: An aerial view of Geographe Bay at Busselton, showing the Busselton Jetty, Geographe Bay Yacht Club, the outlet of the Vasse Diversion Drain, and (in background) the Vasse Wonnerup Wetlands (courtesy GeoCatch 1999).

Seagrass meadows

Geographe Bay supports the most extensive seagrass meadows in temperate Western Australia (DEC 2006). Larger meadows occur in Shark Bay in the state's north, but these contain a range of tropical as well as temperate species. The seagrass meadows of Geographe Bay are not only large but also highly diverse, with 10 species from the five genera *Amphibolis*, *Posidonia*, *Halophila*, *Heterozostera* and *Thalassodendron* being identified (Elscott & Bancroft 1998; Walker et al. 1995). Most of the meadows in Geographe Bay are comprised of *Posidonia sinuosa* but mixed meadows of *P. angustifolia*, *Amphibolis graffiti* and *A. antarctica* also occur. A further feature of note is that some seagrass species are found at unusually great depths in Geographe Bay. *Thalassodendron pachyrhizum* has been found growing at 45 m, while *Posidonia* and *Amphibolis* species have both been recorded at 27 m (Elscott & Bancroft 1998).

Seagrass meadows provide many important ecological functions that make them vital components of the ecosystems of which they form a part. The leaves of seagrass provide a refuge for fish and invertebrates, as well as a substrate for the growth of algae – which in turn provides an important food source for many marine animals (Orth & Van Montfrans 1983). Following annual senescence (shedding) of leaves, the detritus formed by the leaves also provides a food source, primarily for aquatic invertebrates. Some fish and invertebrate species also consume seagrass leaves directly. Seagrass plants provide an important stabilising role for sediment in their environment: *Posidonia* species are particularly good at this since their large underground biomass is very resistant to wave action (Edgar 2001). Seagrass meadows also directly help nutrient cycling by taking up nutrients through their leaves and rhizomes, and indirectly when the algae that colonise their leaves absorb nutrients (Short 1986).

Coral and reef habitats

Well-developed coral communities occur between Dunsborough and Cape Naturaliste among low-relief rocky substrate. This area supports 14 species of seven genera – of which two species are endemic to Western Australia (Elscott & Bancroft 1998). Ten of those species are tropical and of these, five have their southern limit at Cape Naturaliste. In addition to these natural occurrences, the Busselton Jetty has created conditions for the colonisation of various soft coral species that would normally only occur under rock ledges where they are protected from light.

As well as the coral communities, numerous patches of low-relief limestone reef occur throughout Geographe Bay interspersed among the seagrass meadow (DEC 2006). These corals and patch reefs provide important and well-used fish and invertebrate habitat in the bay. Both the coral and reef communities have the potential to be adversely affected by elevated nutrients should algal assemblages cause the smothering of corals or substrate.

Photo 4: Soft coral colonising pylons of the Busselton Jetty (courtesy Annaleisha Sullivan 2004).

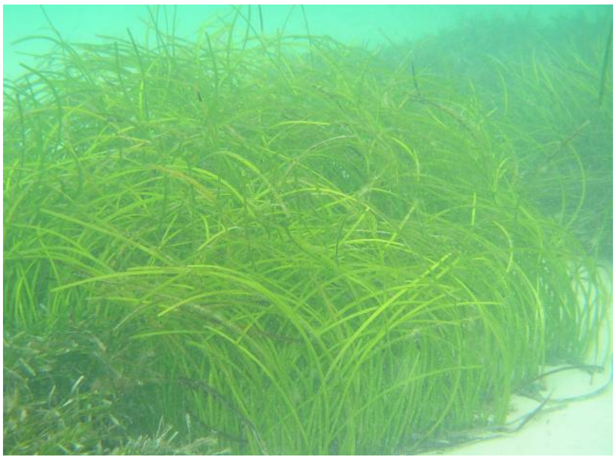


Photo 5: A Posidonia sinuosa *seagrass meadow growing in shallow water close to Dunsborough, Geographe Bay (courtesy Kirrily White 2006).*

Marine fauna

Geographe Bay supports an extensive array of marine fauna – ranging from the large and charismatic humpback whales to highly diverse and unusual species of sponges. A recent survey of fish in Geographe Bay using Baited Remote Underwater Video recorded 76 species of fish from 54 genera (Westera et al. 2007). The same research project recorded seven sea-star species and 12 ascidian species. In addition, an incredibly diverse array of sponges was collected, with an expectation that 40 to 60 species will be identified. Marine mammals known to use the bay include the New Zealand fur seal, which has a colony at Cape Naturaliste, and large populations of resident bottlenose dolphins. A variety of whale species including the humpback and southern right whale shelter their young and feed in the bay's protected waters during their annual southern migration in spring. The rare and endangered blue whale, the largest living mammal on earth, also feeds in the bay during November. Many other marine fauna species also occur in the bay including shark, octopi, squid and crabs. Elevated nutrients have the potential to impact on a wide range of marine fauna through disruptions to food-web linkages. Such disruptions can result from disturbance of important habitats such as seagrass meadows and coral communities.

*Photo 6: Yellowtail scad (*Trachurus novaezelandiae) *recorded in Geographe Bay using Baited Remote Underwater Video (courtesy Mark Westera 2007).*

3.3 The waterways

The waterways that flow to the Vasse Wonnerup Wetlands and Geographe Bay all retain important aquatic values of some kind. Marron, freshwater fish and freshwater mussels are all sensitive to poor water quality, especially if this results in low oxygen conditions. There are records of freshwater fish occurring in eight Geographe catchment waterways; marron in two waterways; and freshwater mussels in three waterways (Table 1). These are all predominantly larger systems where deep pools provide important summer refuges. Allowing water quality to decline further may pose risks to the long-term survival of these species in the local area.

Many of the smaller waterways in the catchment support gilgies and koonacs. The critically endangered Dunsborough burrowing crayfish, *Engaewa reducta,* occurs near the headwaters of some western systems. While this species does not live within the main stream channel, it may be sensitive to hydrological change and soil disturbance. All of these aquatic fauna play an important role in riverine ecosystems and so managing stream water quality is also an important objective of this plan.

Photo 7: Healthy foreshore vegetation on the Dandatup Brook, Dunsborough (courtesy Kirrily White 2005).

Table 1: Matrix of ecological values for Geographe waterways.[4]

Waterway/ catchment	Freshwater fish	Marron	Freshwater mussels	*Engaewa reducta*	Gilgies or koonacs	Riparian veg >10% A
Jingarmup					√	
Meelup		√			√	√
Dandatup					√	√
Dugalup					√	√
Toby Inlet				√	√	
Annie				√	?	
Carbunup	√	√	?	√	√	√
Buayanyup	√	√	?		√	√
Upper Vasse/ Sabina	√	√	√		√	√
Lower Vasse	√		√			
Lower Sabina	√				?	
Abba	√				?	
Ludlow	√				√	
Capel	√	√	√			
Five Mile	?				?	

[4] (A √ symbol represents that the value is present while a gap represents its absence; ? indicates that the value may be present but survey work is lacking.)

4 Water quality

4.1 Water quality issues

The severity of water quality issues in the Geographe catchment varies widely depending on the waterway and receiving waterbody. In some locations the problems are clearly expressed by visible algal blooms and fish kills or noxious odours. In other locations signs of ecosystem decline from nutrient enrichment have not yet visibly presented, though problems could be underlying and emerge with time.

The Vasse Wonnerup Wetlands have been experiencing symptoms of nutrient enrichment for many years. Instances of sudden mass fish kills have been recorded since the early 1900s and became more regular during the 1980s and 1990s (Lane et al. 1997). The majority of fish kills occurred immediately upstream of the Vasse and Wonnerup floodgates and have been attributed to low oxygen conditions in the water column (Lane et al. 1997). Blooms of macroalgae and phytoplankton have also regularly occurred, though some of these have been isolated to the immediate area of the floodgates. The Lower Vasse River, which flows to the Vasse Estuary, is also suffering from elevated nutrients and experiences toxic blooms of phytoplankton every summer for most of the season.

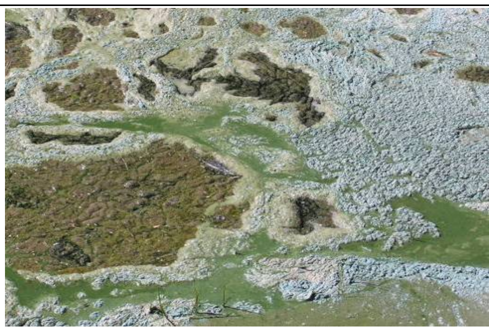
Extensive meadows of macrophytes within the wetlands, such as the estuarine seagrass *Ruppia* sp., are an important food source for waterbirds – especially for the black swan that feeds directly on this species. Surveys of the macrophytes, macroalgae, phytoplankton and water quality in the wetland system have highlighted that *Ruppia* meadows may be at risk should blooms of macroalgae and phytoplankton become more dominant in the estuary (Wilson et al. 2007; Wilson et al. 2008). A recent study identified that sediments in the lower reaches of both the Vasse and Wonnerup estuaries contain high levels of nutrients, which may be contributing to these blooms (Wilson et al. 2008). The authors state that there is 'an urgent requirement to reduce the nitrogen and phosphorus loads to the Vasse Wonnerup system' and that increasing nutrient loads to the system may 'cause loss of seagrass and associated bird life vital to the Vasse Wonnerup lagoons remaining a Ramsar wetland'. A long-term focus on the protection of macrophyte communities in the estuaries is needed in nutrient management programs for the wetland system.

Assessing the current impact of large nutrient loads on the Geographe Bay ecosystem is a complex task. Seagrass was certainly lost from Geographe Bay between 1958 and 1976, though the cause is unclear (Searle & Logan 1978; Conacher 1993). This was a period that coincided with intensive agricultural development in the catchment, but it is also possible that erosion processes within the bay were responsible for the change. Losses of seagrass cover that ranged from 17 to 45 per cent (depending on the location) were followed by a gradual recovery in most offshore areas between 1978 and 1993 (Conacher 1993).

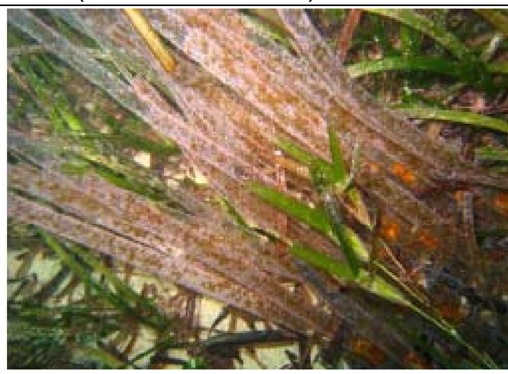
Inshore, scientists are not yet able to confirm the status of the seagrass. At sites close to nutrient-rich-water input such as Wonnerup, Quindalup and near Dunsborough, a reduction in seagrass cover may still be occurring but this seems to be balanced by gains in other areas (DAL Science and Engineering 2004). It is possible that these nearshore losses of seagrass cover are related to shoreline changes rather than elevated nutrients or are simply a reflection of natural variability, though these issues require further research. The techniques used to monitor changes in seagrass cover to date are not well suited to measuring small changes, since there are large errors associated with the mapping processes. Researchers from the University of Western Australia are currently establishing ecological benchmarks so that changes in the seagrass ecosystem can be more closely monitored and assessed over time (Westera et al. 2007).

A summary of the present water quality issues for the Vasse Wonnerup Wetlands, Geographe Bay and the waterways that flow to these systems is presented in Table 2.

Table 2: Summary of water quality issues recorded in the Vasse Wonnerup Wetlands, Geographe Bay and Geographe waterways.

Location	Issue	Example
Vasse Wonnerup Estuary – upstream of the Vasse and Wonnerup floodgates	Sudden mass fish deaths at the Vasse and Wonnerup floodgates have a long history. They were reported as early as 1905 before the floodgates were installed, with other large kills recorded in the 1930s, 1960s, 1980s and late 1990s (Lane et al. 1997). Fish kills have often been attributed to low oxygen conditions resulting from the closure of the sand bar at Wonnerup Inlet, or to algae decomposing within the estuary exit channel (Lane et al. 1997). The incidence of fish kills has reduced since the upgrade of both the Vasse and Wonnerup floodgates in 2004. The new floodgates included design modifications to better facilitate fish movements on both sides of the gates.	 Dead fish in Vasse Estuary, 1998 (courtesy Colin Bywaters, Busselton).
Vasse Wonnerup Estuary – Vasse Estuary	Regular blooms of phytoplankton occur at the floodgates (*Anabaena, Lyngbya* and *Oscillatoria* spp.) (WRM 2007). The visibility of both estuary exit channels upstream of the floodgates has led to heightened community concern about these issues.	 *Anabaenopsis* scum upstream of the Vasse Estuary floodgates (courtesy Chris Webb, Department of Water, December 2006).

Location	Issue	Example
Vasse Wonnerup Estuary — Vasse Estuary	Residents of the Estuary View Drive area have complained of regular odour problems from the Vasse Estuary when water levels are low (Jim Lane, Department of Environment and Conservation, pers. comm.) Decomposing *Ruppia* seagrass also contributes to these odours. Accumulated *Ruppia* on the foreshore when water levels are high has also smothered foreshore rehabilitation, frustrating the efforts of local residents to replant these areas (Veronica Piper, Department of Water, pers. comm.)	 Low water levels at the Vasse Estuary foreshore at Estuary View Drive exposing sediments that release noxious odours (courtesy Veronica Piper, Department of Water, 2007).
	There is anecdotal evidence that macroalgae is increasing in the Vasse Estuary, and this is currently the subject of further investigations. Several genera have been identified – *Ulva*, *Cladophora*, *Rhizoclonium* and *Chaetomorpha* (Wilson et al. 2007). Blooms of the potentially toxic macroalgal species *Lyngbya* have also been recorded in the Vasse Estuary in the vicinity of the Port Geographe development (Wilson et al. 2007).	 A bloom of sea lettuce (*Ulva)* in the Vasse Estuary near the floodgates (courtesy Annaleisha Sullivan, Department of Water, 2003).
Vasse Wonnerup Wetlands – wider wetland areas	The estuarine seagrass *Ruppia* sp. provides an important food source for waterbirds. There is concern that increasing blooms of macroalgae and phytoplankton may smother this macrophyte with resulting impacts on waterbirds (Wilson et al. 2007; Wilson et al. 2008).	 *Ruppia megacarpa* in the Vasse Estuary (courtesy Alan Clarke, Department of Environment and Conservation).

Location	Issue	Example
Vasse Wonnerup Estuary – wider wetland areas	Nuisance populations of mosquitoes are problematic in some areas. The Shire of Busselton is tackling this issue by putting larvae control measures in place (Shire of Busselton 2008). It monitors mosquito larvae numbers to help inform the need for aerial spraying, which uses a mosquito growth regulator to control populations.	 Mosquito larvae sampling (courtesy Shire of Busselton).
Vasse Wonnerup Estuary and Wonnerup lagoon – sediment	High concentrations of nitrogen and phosphorus are present in fine sediments (clays and silts) of the Vasse Estuary exit channel and the north-western shore of the Wonnerup lagoon. Release of nutrients from these sediments is highly likely to be occurring (Wilson et al. 2008).	 Measurement of sediment depth in the Vasse Wonnerup Estuary, February 2008 (Wilson et al. 2008).
Geographe Bay	Historical assessment of aerial photos has revealed losses of seagrass cover from nearshore areas of 17 to 45 per cent between 1958 and 1976, but most of these have now recovered (Conacher 1993). Only a few comprehensive studies of the effects of nutrients on Geographe Bay have been done and most have used different methods, making comparisons of results difficult. A current study aims to establish a benchmark against which future change in seagrass ecosystems can be measured.	 Artificial seagrass units being used to monitor growth of algal epiphytes, showing growth after eight weeks in Geographe Bay (courtesy Mark Westera, UWA, 2007).

Location	Issue	Example
Geographe Bay	Seasonal blooms of *Trichodesmium* algae have occasionally been reported at a number of beaches along the Geographe Bay foreshore. These have included the Meelup, Port Geographe, Quindalup and Abbey beaches (Veronica Piper, Department of Water, pers. comm.). Anecdotal reports of skin rashes arising from contact with *Trichodesmium* have been made in other locations in the state (Chambers et al. 2005).	 *Trichodesmium* bloom at the Port Geographe beach (courtesy Matt Price, Shire of Busselton, April 2008).
Toby Inlet	Toby Inlet experiences regular blooms of macroalgae and phytoplankton during the summer months. Phytoplankton blooms have been linked to low dissolved oxygen levels in the inlet and have caused fish to congregate near the inlet mouth in shallow water, leading to deaths as a result of sunburn and low oxygen (Veronica Piper, Department of Water, pers. comm.) Non-biting nuisance midges and seasonal odour associated with decomposition of algae are sometimes problematic for properties surrounding Toby Inlet (Veronica Piper, Department of Water, pers. comm.)	 A bloom of green filamentous algae (*Enteromorpha)* at Toby Inlet (courtesy Veronica Piper, Department of Water, November 2006).
Lower Vasse River	The Lower Vasse River has experienced regular blooms of toxic phytoplankton in summer for many years: common species are *Microcystis* and *Anabaena* (Paice 2005). Seasonal odour arising from the decomposition of algae has long been a problem in the river. Loss of amenity has also occurred due to restrictions in recreational contact when toxic species of phytoplankton are present. Such occurrences have disrupted traditional festival activities in the town that involved the river.	 A bloom of *Eugleophyte sanguinea* (red colouration) mixed with *Microcystis* and *Anabaena* blue-green algae (green colouration) in the Lower Vasse River (courtesy Veronica Piper, Department of Water, December 2006).

Location	Issue	Example
Other catchment waterways	Blooms of *Trichodesmium* algae have been reported within the exit channels and mouths of some Geographe waterways. The most recent occurrence was at the mouth of the Buayanyup Drain.	 *Trichodesmium* algae enlarged under a microscope (courtesy Sarah Grigo, Department of Water, April 2008).

4.2 Current water quality status

The current water quality of the Geographe catchment's waterways is highly variable and depends on the status of the individual reporting catchments. Historical water quality information is patchy and differences in the reporting limits of the data sets have complicated comparisons of the catchments. Some reporting catchments such as Gynudup, Annie, Dunsborough and Jingarmup were not included in previous regular water quality monitoring programs. Owing to these limitations, fortnightly monitoring of most Geographe waterways was undertaken during 2006 and 2007 at the locations shown in Figure 7. Regular water quality monitoring data was not available for the Five Mile Brook and Toby Inlet waterways. Accordingly, data for these systems was generated using a water quality model (as explained in Section 1.3 and Appendix A). The resulting sets of data from recent monitoring and modelling have been combined with historical water quality data, as well as data from other government agencies, to provide valuable information about the likely nutrient status of each waterway.

Figures 8 and 9 illustrate the extent of the variability in nutrient status across the reporting catchments. Waterways in the west of the catchment (Carbunup River and west) together with the Capel River generally have much lower phosphorus concentrations than all other Geographe waterways. These observed results are likely to have been influenced by a variety of factors such as land use and vegetation, although the higher phosphorus retention index (PRI) soils in the west of the catchment may be a strong contributing factor. A similar pattern is displayed by the nitrogen data, though some western catchments such as Annie Brook and Jingarmup Brook also maintain elevated nitrogen concentrations.

Waterways with the poorest water quality included the Ludlow River, Lower Sabina River, Lower Vasse River, Gynudup Brook, and the Upper Vasse/Sabina Diversion. The first three of these flow into the Vasse Wonnerup Wetlands. The Dunsborough streams of Meelup, Dugalup and Dandatup consistently demonstrated the best water quality in the catchment.

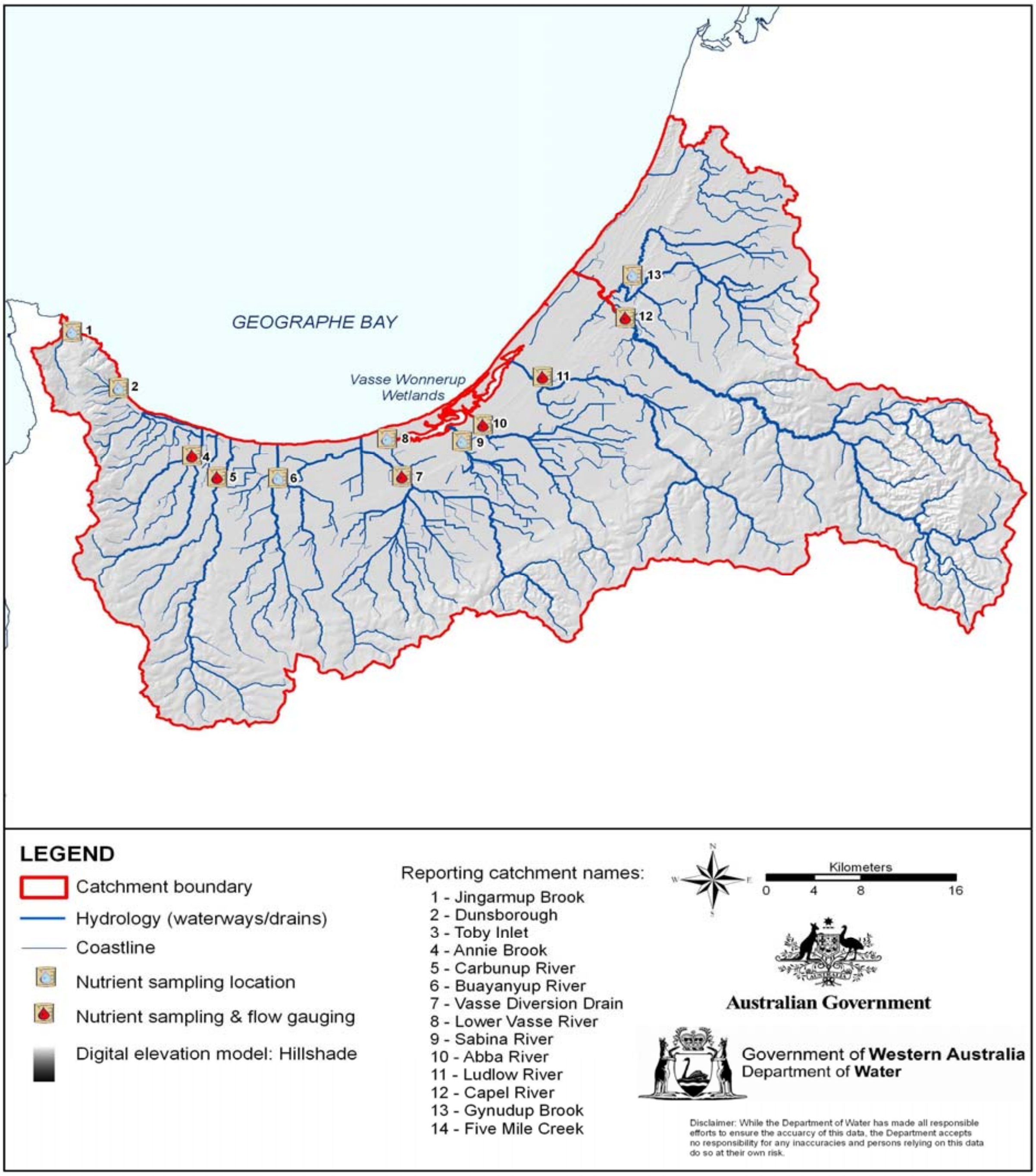


Figure 7: The location of water quality monitoring points in the Geographe catchment sampled for the Coastal Catchments Initiative project.

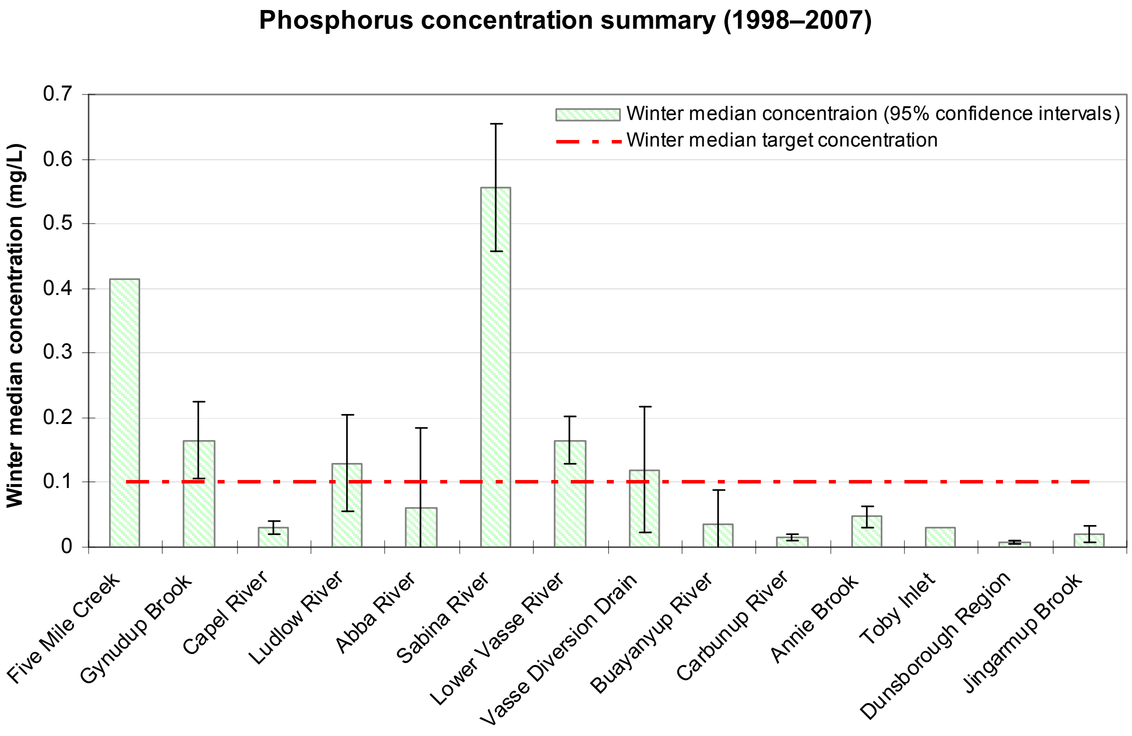


Figure 8: Median winter phosphorus concentration of Geographe waterways from fortnightly sampling between 1998 and 2007.

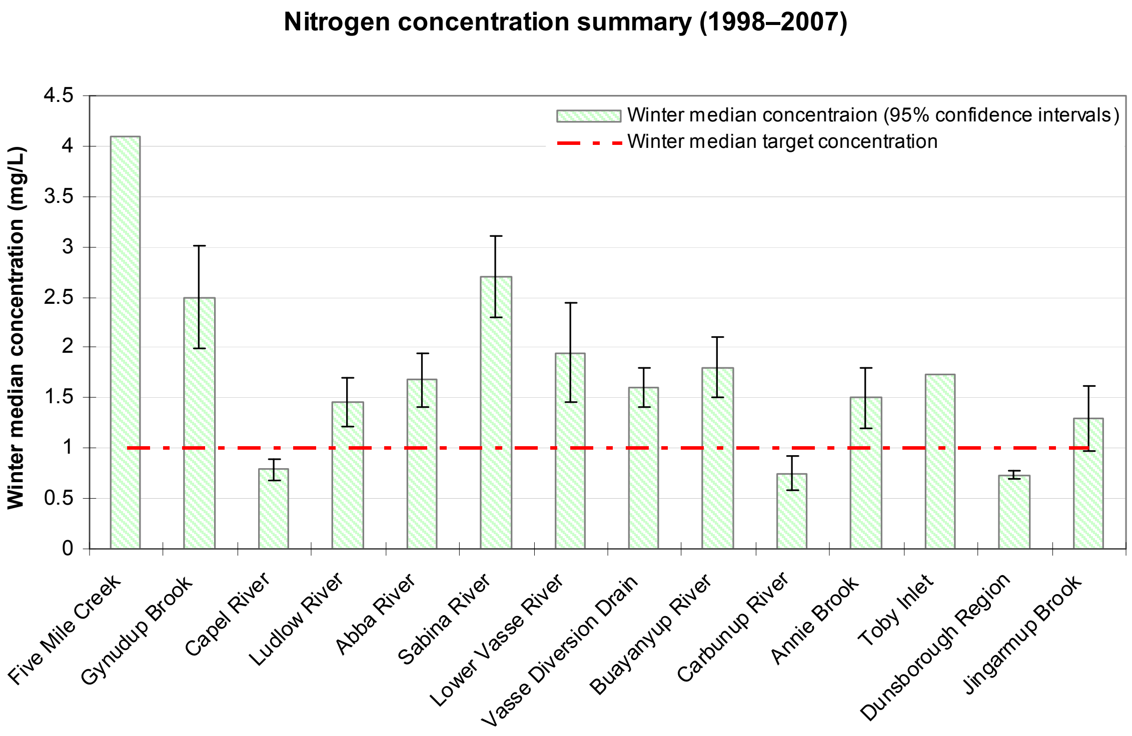


Figure 9: Median winter nitrogen concentration of Geographe waterways from fortnightly sampling between 1998 and 2007.

4.3 Water quality objectives

Background to water quality objectives

An important stage in this plan's development has been the setting of water quality objectives and targets for the waterways. Nutrient targets are typically used as numerical 'management goals' to reflect the nutrient concentration or loads that management actions aim to achieve. Such targets have been in place for many years in the Swan Canning and Peel Harvey catchments, but had not previously been established for the Vasse Wonnerup Wetlands or Geographe Bay.

Water quality objectives need to be set before targets are determined. A water quality objective, as defined in the *Framework for marine and estuarine water quality protection* and based on the Global Program of Action (Environment Australia 2002) for the Coastal Catchments Initiative program means:

> a numerical concentration limit or narrative statement that has been established to support and protect the environmental values of water at a specific site. It is based on scientific criteria or water quality guidelines but may be modified by inputs such as social or political constraints.

Load or concentration?

In setting water quality objectives for waterways, a common debate is whether to use nutrient concentrations or nutrient loads. The former measures the concentration of a particular nutrient in the waterway at any one time, while the latter measures the total weight (load) of a particular nutrient delivered to or by a waterway over a given time period (usually an annual average over a number of years) and is a function of both concentration and flow. Both have particular advantages and applications to various nutrient management situations.

The total load of nutrients is important when dealing with closed estuarine systems that have the potential to accumulate nutrients attached to sediment particles and then release nutrients back into the water column. This is particularly the case for phosphorus because it readily attaches to sediment, but less so for nitrogen as it is generally delivered in a soluble form. Nutrient loads are difficult to measure because they require installation of expensive flow-gauging stations and are associated with a high degree of error, particularly under high-flow conditions. Nutrient loads are also less relevant to the management of marine systems, which tend to flush such loads on a regular basis.

Where control of algal growth is the management goal, the concentration of nutrients is very important since algae responds to water quality conditions. Nutrient concentrations are simpler to measure than loads and are also associated with less error. It is for these reasons that the Department of Water uses water quality objectives and targets that are primarily based on the *concentration* of particular nutrients. This plan also presents those targets in terms of the calculated load of nutrients that each waterway would deliver if it were to meet the defined concentration targets.

Water quality objective process and framework

In developing water quality objectives for this plan, the Department of Water considered whether the objectives could achieve the following attributes:

- they could easily be incorporated into a monitoring program to regularly track progress over time
- they were based on sound science and were statistically rigorous
- they responded to the management needs of the receiving waterbody
- they were achievable.

The process to determine water quality objectives for the Geographe waterways firstly involved an assessment of each reporting catchment against Swan coastal plain water quality criteria: 0.1 mg/L for total phosphorus and 1.0 mg/L for total nitrogen. These concentration values have been used as targets for both the Peel Harvey and Swan Canning systems for many years, and are considered appropriate guidelines for other systems on the Swan coastal plain. Scientific review of water quality data on the Swan coastal plain has indicated that receiving waterbodies will be protected from nuisance water quality problems (such as algal blooms) when waterways that flow to them achieve nitrogen and phosphorus concentrations at or below these levels.

The assessment of waterways against these concentration values resulted in three groupings of reporting catchments that related to their current nutrient status, as follows:

- ‘protection’ – for all waterways that currently meet both the nitrogen and phosphorus criteria
- ‘intervention’ – for all waterways that currently meet the phosphorus criteria, but do not meet the nitrogen criteria
- ‘recovery’ – for all waterways that do not meet either of the nitrogen or phosphorus criteria.

The management objectives for each category are further defined in Table 3.

Table 3: Categories of water quality objectives for the Geographe waterways.

	Protection	Intervention	Recovery
Management objective	Maintain current good water quality.	Prevent P rising; reduce N to criteria levels.	Reduce N and P to criteria levels.
Waterways: flowing to Vasse Wonnerup Estuary		Abba River	Lower Vasse River Sabina River Ludlow River
Waterways: flowing to Geographe Bay	Dunsborough streams Carbunup River Capel River	Jingarmup Brook Toby Inlet streams Annie Brook Buayanyup River	Vasse/Sabina Diversion Gynudup Brook Five Mile Brook
Assessment against Swan coastal plain criteria of 0.1 mg/L P and 1.0 mg/L N	Meets both N and P criteria.	Fails N criteria; meets P criteria.	Fails both N and P criteria.
Water quality objective nitrogen	Prevent further increases from current median winter concentrations.	Decrease median winter concentrations to 1.0 mg/L N.	Decrease median winter concentrations to 1.0 mg/L N.
Water quality objective phosphorus	Prevent further increases from current median winter concentrations.	Prevent further increases from current median winter concentrations.	Decrease median winter concentrations to 0.1 mg/L.

The above process results in a framework for water quality management in the Geographe catchment which:

1 uses ecologically relevant concentration criteria for receiving waters on the Swan coastal plain

2 recognises the importance of preventing a shift from acceptable water quality to poor water quality while achieving improvements in areas that have already declined

3 aims to manage the integrity of the waterways themselves as well as the receiving waters, given that freshwater fish and marron occur in some of these systems

4 places a high value on protecting water quality flowing into the Ramsar-listed Vasse Wonnerup Wetlands

5 recognises that a precautionary approach to nutrient management is needed for catchments flowing to Geographe Bay (since current knowledge about the bay's responses to nutrients is still developing), keeping in mind that the bay:

   a is likely to have a higher assimilative capacity for nutrients than the Vasse Wonnerup Wetlands, but this cannot currently be quantified

   b supports extensive seagrass meadows that are known to be sensitive to high nutrient loads

   c is soon to become a marine park.

With one exception, all the Vasse Wonnerup Wetlands' reporting catchments fall within the recovery category, reflecting the poorest water quality and the greatest need for management action. The Abba River reporting catchment is the exception and has been placed in the intervention category along with most of Geographe Bay's reporting catchments. The intervention category reflects a need to reduce nitrogen concentrations while also preventing further increases in phosphorus. Only the Dunsborough streams, Carbunup River and Capel River reporting catchments maintain current water quality that is better than the Swan coastal plain criteria – protection of this good water quality is a key aim of this plan.

Figure 10 illustrates the location of the reporting catchments in each of the three management categories. It should be noted that water quality monitoring points are located only at the drainage point of each reporting catchment. Concentrations of nutrients in each catchment generally become greater further down the catchment, as distance from sampling points to the discharge point (at the coast) is reduced. The categories displayed in this figure therefore do not reflect the likely water quality in the upper reaches of each system because they are simply a reflection of the water quality just before it discharges to the receiving environments of Geographe Bay or the Vasse Wonnerup Wetlands.

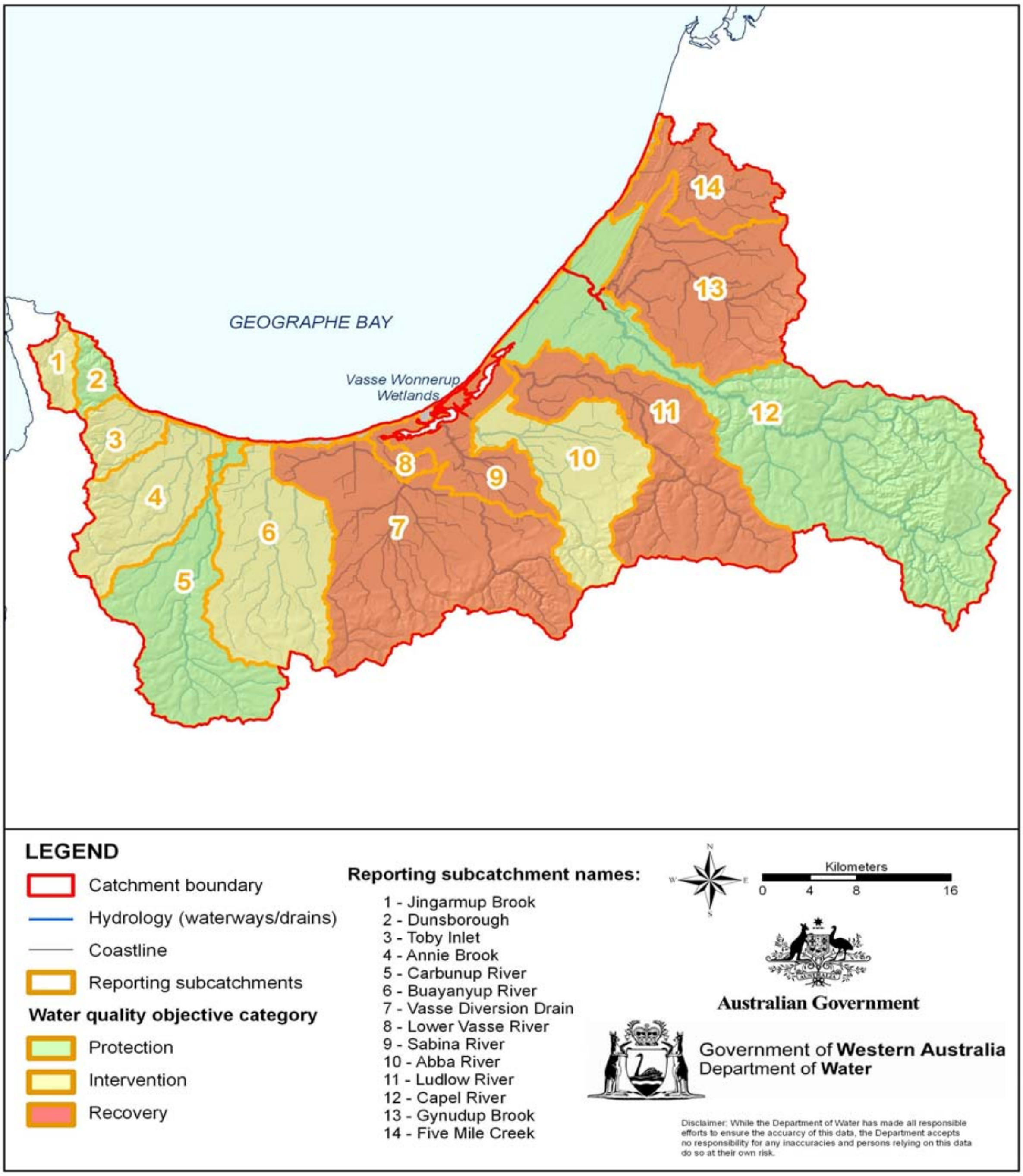


Figure 10: Location of reporting catchments within each water quality objective category.

4.4 Integrating values, issues and objectives

An integration of the values, issues and water quality objectives for each catchment waterway is presented in Table 4. This integration clearly displays the high values and wide range of water quality issues associated with the Vasse Wonnerup Wetlands. Recovery of the water quality in this system is clearly required. For Geographe Bay, a wide range of values are present, but as yet only a few water quality issues have occurred. A watching brief and preventative action is needed for this system. Values and issues for the waterways vary considerably.

Table 4: Integration of environmental values, water quality issues and water quality objectives.

Waterway	Environmental values	Are values being achieved?	Water quality Issues	Nutrient pollutant indicators	Water quality objectives (long term)
Vasse Wonnerup Ramsar wetlands	Ecosystem health	Not consistently	Nutrient enrichment. Phytoplankton blooms (toxic species). Regular sudden mass fish kills near Vasse and Wonnerup floodgates. Macroalgal blooms, possibly increasing. Seasonal odour from decaying algae and exposed sediment near Estuary View Drive. Potential remobilisation of nutrients from sediments. Nuisance mosquitoes. Possible loss of macrophytes (seagrass and chara) that are an important waterbird food source. Possible switch from macrophyte to phytoplankton/macroalgal-dominated system.	High nutrient concentrations. High chlorophyll levels, phytoplankton cell counts or macroalgae biomass. Low oxygen conditions. High colour, suspended solids and turbidity.	Phosphorus concentration of 0.1 mg/L. Nitrogen concentration of 1.0 mg/L in waterways flowing to the estuary. Total phosphorus load of 6 tonnes/year (or 41% less than current load). Total nitrogen load of 74 tonnes/year (or 55% less than current load).
	Maintain waterbird use of wetlands. High abundance (>20 000) and richness (>60 species) of waterbirds. >1% of Ramsar populations of blackwinged stilt, red-necked avocet, Australian shelduck and Australasian shoveler. Largest known breeding colony of black swan in WA (50–150 pairs).	Yes			
	Harvesting of fish for human consumption	Not consistently			
	Cultural and spiritual	Not consistently			

Waterway	Environmental values	Are values being achieved?	Water quality Issues	Nutrient pollutant indicators	Water quality objectives (long term)
Geographe Bay	Marine ecosystem health	Yes	History of seagrass loss during 1950s – 1970s, now recovered in offshore areas though some losses may still be occurring in some nearshore areas. Cause of seagrass losses unknown. Receives large annual loads of nitrogen and phosphorus. These loads seem to be increasing. Low light conditions during winter in some locations due to high turbidity.	High nutrient concentrations. High epiphyte load on seagrass. High periphyton growth. High turbidity.	Total phosphorus load of 20 tonnes/year (or 38% less than current load). Total nitrogen load of 177 tonnes/year (or 43% less than current load).
	Maintain seagrass meadows	Yes			
	Recreational (contact, active)	Yes			
	Harvesting of fish for human consumption	Yes			
	Cultural and spiritual	Yes			
	Highly diverse sponge, coral and invertebrate communities	Yes			
Toby Inlet	Aquatic ecosystem health	No	Nutrient enrichment. Regular blooms of phytoplankton and macroalgae. Seasonal odour from decomposition of algae. Nuisance mosquitoes and midges.	High nutrient concentrations. High chlorophyll levels, phytoplankton cell counts or macroalgae biomass. Low oxygen conditions. High colour, suspended solids and turbidity.	Phosphorus concentration of 0.1 mg/L. Nitrogen concentration of 1.0 mg/L.
	Harvesting of fish for human consumption	Not consistently			
	Cultural and spiritual	Not consistently			
Protection catchment waterways Dunsborough streams Carbunup River Capel River	Aquatic ecosystem health	Yes	Some instances of high faecal coliform counts (septic contamination) in Dunsborough streams.	High nutrient concentrations. High chlorophyll levels or phytoplankton cell counts. Low oxygen conditions. High colour, suspended solids and turbidity.	Prevent increases in current nitrogen and phosphorus concentrations and loads.
	Freshwater fish and marron (Capel, Carbunup)	Yes			
	Recreational contact	Not consistently			
	Cultural and spiritual	Not consistently			

Waterway	Environmental values	Are values being achieved?	Water quality Issues	Nutrient pollutant indicators	Water quality objectives (long term)
Intervention catchment waterways Jingarmup Brook Toby Inlet streams Annie Brook Buayanyup River Abba River	Aquatic ecosystem health	Not consistently	Nutrient enrichment – elevated nitrogen. Seasonal odour at the mouths of drains arising from decomposition of algae and/or exposure of anoxic sediment. High turbidity.	High nutrient concentrations. High chlorophyll levels or phytoplankton cell counts. Low oxygen conditions. High colour, suspended solids and turbidity.	Prevent increases in current phosphorus concentrations. Reduce nitrogen concentrations to 1.0 mg/L.
	Freshwater fish and marron (Abba River and possibly Buayanyup River)	Yes			
	Recreational contact	Not consistently			
	Cultural and spiritual	Not consistently			
Recovery catchment waterways Vasse/Sabina Diversion Lower Vasse River Lower Sabina River Ludlow River Gynudup Brook Five Mile Brook	Aquatic ecosystem health	No	Nutrient enrichment – elevated phosphorus and nitrogen. Regular blooms of toxic phytoplankton in the Lower Vasse River. Seasonal odour from decomposition of algae in the Lower Vasse River. Loss of community uses such as festival activities on Lower Vasse River. High turbidity.	High nutrient concentrations. High chlorophyll levels or phytoplankton cell counts. Low oxygen conditions. High colour, suspended solids and turbidity.	Reduce phosphorus concentrations to 0.1 mg/L. Reduce nitrogen concentrations to 1.0 mg/L.
	Freshwater fish	Yes			
	Recreational contact	Not consistently			
	Cultural and spiritual	No			

4.5 Water quality modelling

Much of the data presented in the upcoming sections has been generated using water quality modelling techniques undertaken by the Department of Water. Such techniques have enabled the assimilation of complex sets of data to inform the management directions of this plan. A process-based conceptual model – SQUARE (stream quality affecting rivers and estuaries) – was chosen as the most appropriate model to produce the required outputs for the project. SQUARE was developed specifically to model water quality and management scenarios in large-scale catchments, and has the ability to deal with the unique hydrological characteristics of the Swan coastal plain (sandy duplex and seasonally waterlogged soils with ephemeral waterways).

The input requirements for the SQUARE model included:

- land-use maps (current, future and historical)
- fertilisation rates and monthly breakdowns of fertiliser application – provided by the Department of Agriculture and Food's rural surveys and the Department of Water's urban nutrient survey project (Kitsios & Kelsey 2008)
- point-source nutrient-load contributions
- vegetation characteristics (leaf-area index and deep-rooted vegetation)
- soil characteristics
- daily rainfall and evaporation
- a high-quality hydrological coverage and digital elevation model to delineate subcatchments, which are organised around the river network and are the basic building blocks of the model.

The model was calibrated and validated using flow data from gauging stations and nutrient-concentration data gathered from regular catchment sampling events. Phosphorus and nitrogen were modelled in both dissolved and particulate forms. A set of physically based mathematical equations was used to direct water and nutrients through the soil and groundwater stores and to distribute rainfall either into the stores or directly into the waterway. The resultant flows and loads were aggregated through the stream network to yield the catchment's response at the main outlet, and at any number of intermediate points on the stream network.

SQUARE outputs included daily flows and nutrient loads. When the model was calibrated, inputs could be modified and the data lumped accordingly, to yield the following catchment results:

- the flow and nutrient status of the catchment (loads and concentrations)
- load-reduction targets and maximum acceptable loads
- source separation of nutrient loads
- timing (annual or monthly) of nutrient loads

- catchment hotspots
- quantification of the impact of land-use change and climate change on the catchment's nutrient status.

For a detailed description of the model, refer to Appendix A.

4.6 Nutrient loads and targets

Current nutrient loads

The total annual loads of nitrogen and phosphorus have been modelled for each Geographe waterway using monitored and modelled data on flows and nutrient concentrations. By comparing these loads it is possible to identify those reporting catchments that contribute the greatest proportion of nutrients to the wetlands and bay, thereby helping to prioritise where management action is most urgent.

The Lower Vasse and Sabina rivers are both contributing a disproportionately large share of the nutrient load to the Vasse Wonnerup Wetlands given their small catchment size (figures 11 and 12). The upper reaches of both systems have been diverted away from the wetlands into Geographe Bay through the Vasse Diversion Drain, leaving a much smaller proportion flowing to the wetland system. The remaining two reporting catchments of Abba River and Ludlow River still contribute substantial proportions of the balance of the phosphorus and nitrogen load, though these are more proportional to the size of the river catchments.

The Vasse Wonnerup Wetlands currently contribute a large load of phosphorus to Geographe Bay (Figure 13). Any actions to address nutrient loads in the wetlands will therefore have associated benefits for Geographe Bay. For the remainder of the catchment, the Vasse Diversion Drain catchment currently contributes by far the largest load of phosphorus to the bay. Other significant phosphorus loads are delivered by large catchments such as those of Capel River and Buayanyup River, although both of these waterways currently meet the phosphorus criteria of 0.1 mg/L. The proportion of the total phosphorus load contributed by the Dunsborough streams and Jingarmup Brook is so small that they are barely visible on the graphs.

The current sources of total nitrogen load delivered to Geographe Bay are more evenly spread across the reporting catchments than the phosphorus loads (Figure 14). While loads from the Vasse Diversion Drain and the Vasse Wonnerup Estuary still dominate the graph, there are substantial proportions of total nitrogen delivered by the Annie Brook, Carbunup River, Buayanyup River and Capel River reporting catchments.

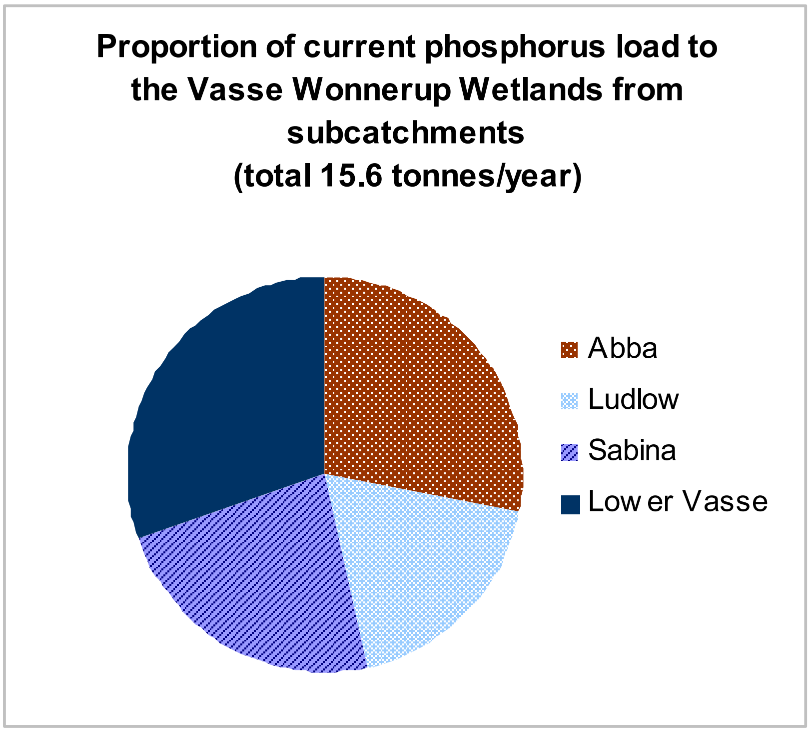


Figure 11: Current phosphorus load to the Vasse Wonnerup Estuary showing proportional contributions from reporting catchments.

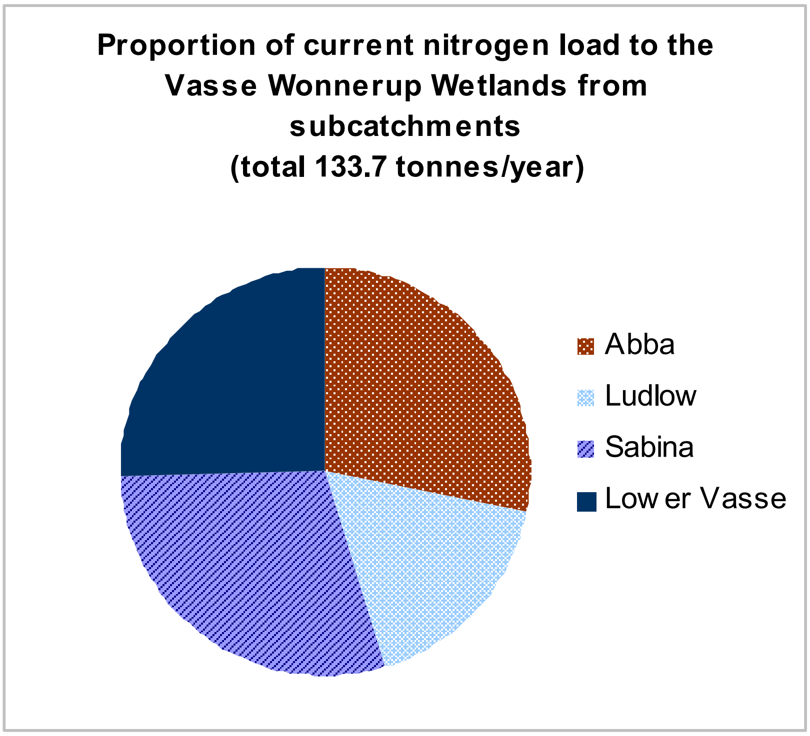


Figure 12: Current nitrogen load to the Vasse Wonnerup Estuary showing proportional contributions from reporting catchments.

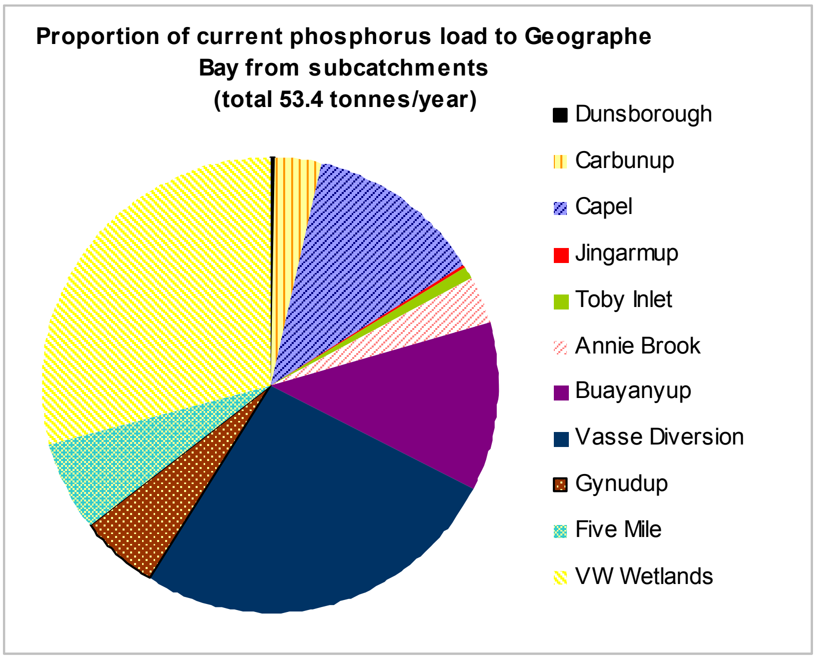


Figure 13: Current phosphorus load to Geographe Bay showing proportional contributions from reporting catchments.

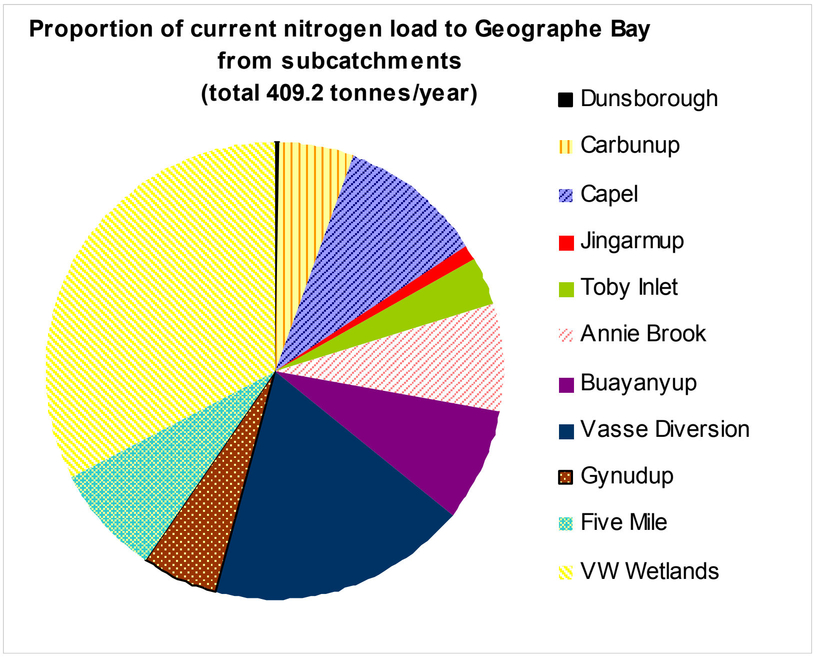


Figure 14: Current nitrogen load to Geographe Bay showing proportional contributions from reporting catchments.

Nutrient-hotspot maps have been created to show where loads of phosphorus and nitrogen are exported across the catchment (figures 15 and 16). These maps display the nitrogen and phosphorus exports as a measure of the weight of nutrients exported per unit area. These maps are useful for highlighting geographic areas of the catchment where potential exists for management interventions to deliver larger reductions in nutrient loads.

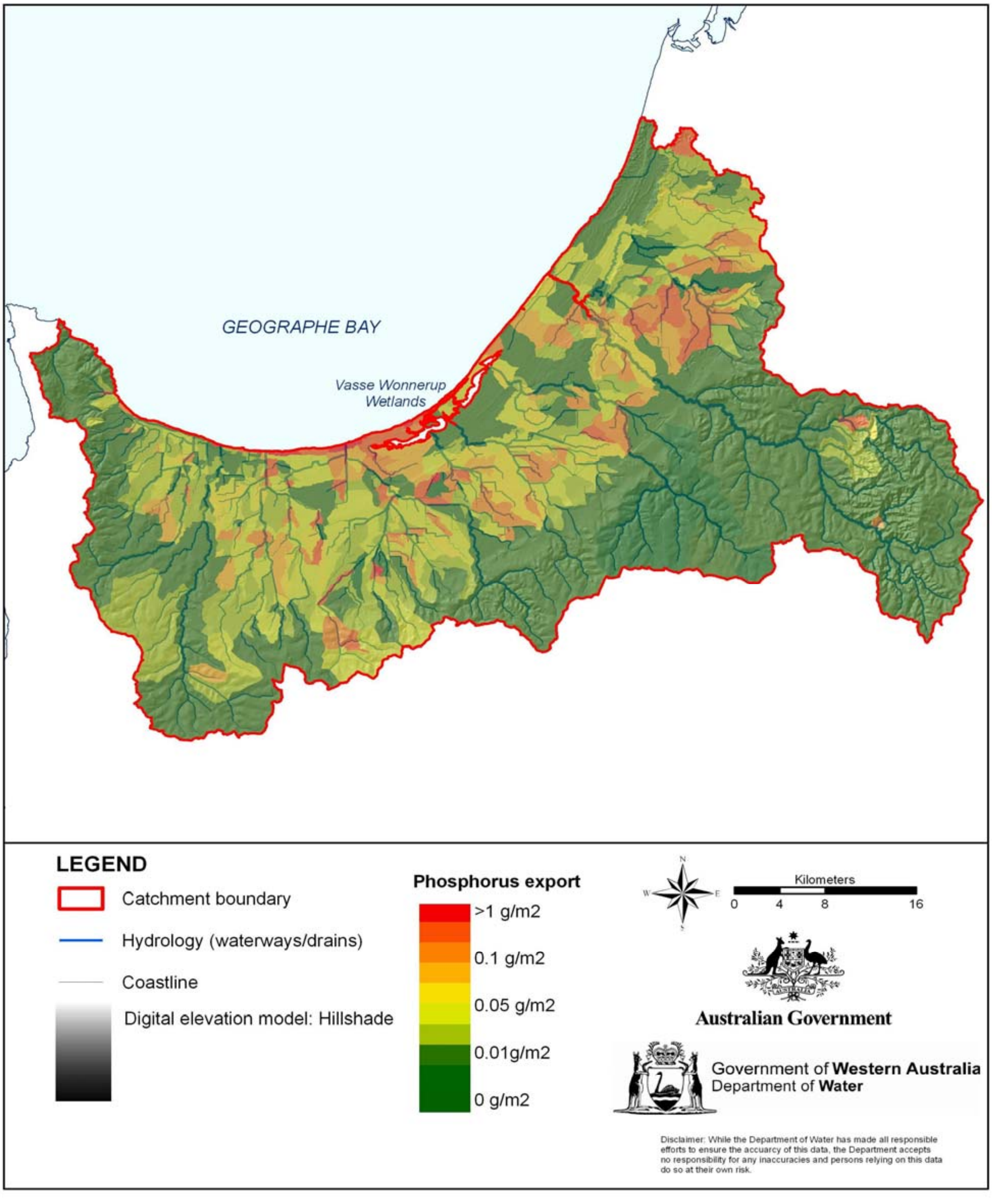


Figure 15: Phosphorus export hotspots in the Geographe catchment.

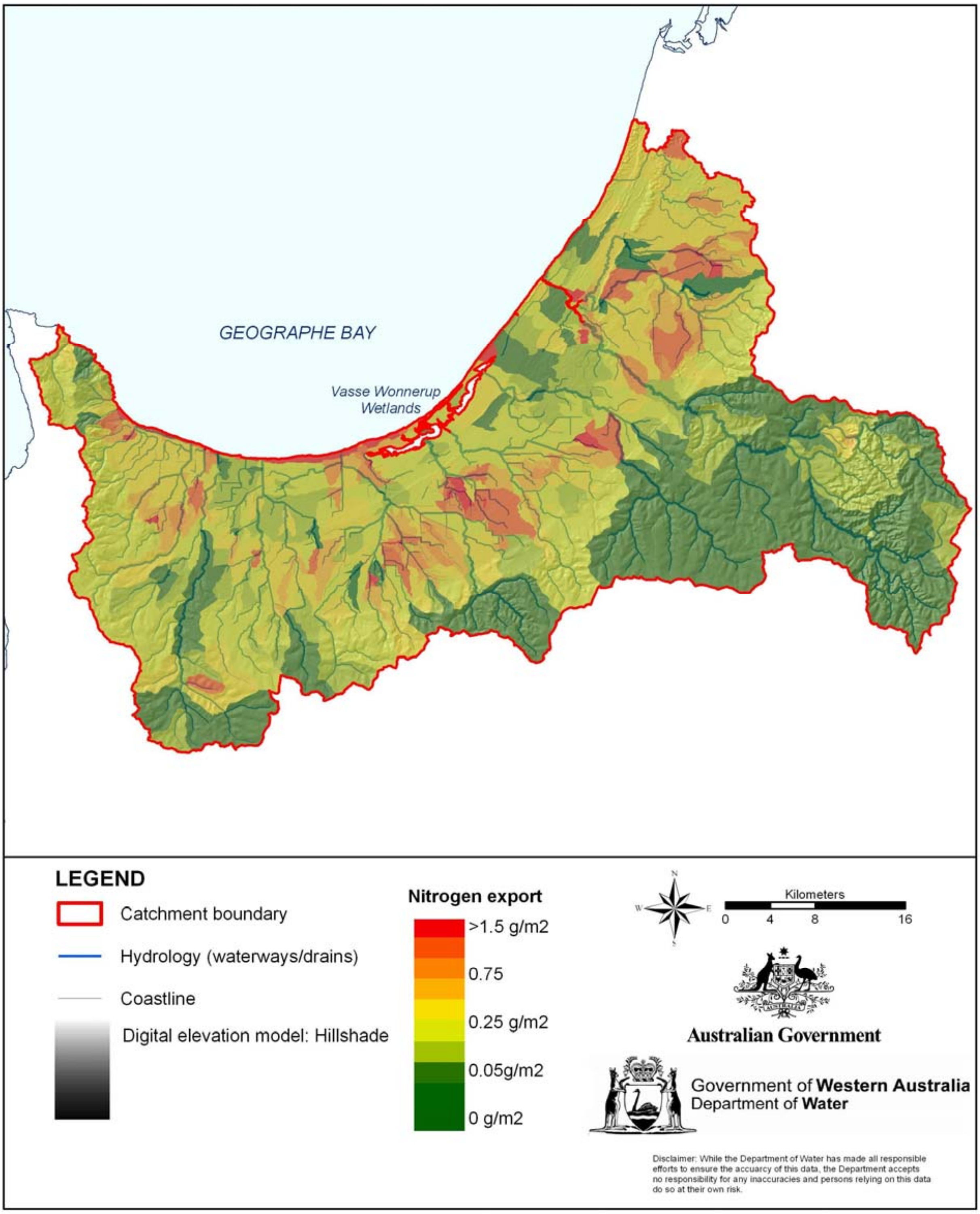


Figure 16: Nitrogen export hotspots in the Geographe catchment.

Calculating load reduction targets

To achieve its water quality objectives, this plan has used predictive water quality modelling tools to calculate the loads of nitrogen and phosphorus in the Vasse Wonnerup Wetlands and Geographe Bay subcatchments. The water quality objectives, presented in Section 4.3, were expressed using three categories that relate to the median winter concentrations of nutrients as follows:

- protection – prevent median winter concentrations of phosphorus and nitrogen from increasing above current levels
- intervention – reduce median winter concentrations of nitrogen down to 1.0 mg/L and prevent phosphorus increasing from current levels
- recovery – reduce median winter concentrations of nitrogen down to 1.0 mg/L and phosphorus down to 0.1 mg/L.

The water quality modelling tools have provided four useful sets of data on total nutrient loads that may be compared for each reporting catchment as follows:

1. the 'current' total load of phosphorus and nitrogen delivered by the waterway as averaged over the years 1996–2006
2. the 'projected' future load of phosphorus and nitrogen that will be delivered by the waterway once the predicted land-use changes over the next 20 years have occurred
3. the 'acceptable' load of phosphorus and nitrogen derived from the desired median winter concentrations of each nutrient according to the relevant water quality objective category
4. a 'load reduction target' calculated from the difference between the current load and the acceptable load of phosphorus and nitrogen.

Load reduction targets for the Vasse Wonnerup Wetlands

The current, projected and acceptable phosphorus and nitrogen loads and concentrations for the Vasse Wonnerup Wetlands reporting catchments are presented from figures 17 to 20. These modelled data indicate that the current and projected phosphorus loads for all reporting catchments except the Abba River are well above the acceptable load. The Sabina and Lower Vasse rivers are currently delivering over three times the acceptable phosphorus load. The Lower Vasse, Sabina and Ludlow rivers are contributing between 2 to over 3.5 times the acceptable nitrogen loads. The modelled future projections indicate that water quality may deteriorate even further in the Lower Vasse, Abba and Ludlow rivers as a result of the expansion of the Busselton town site.

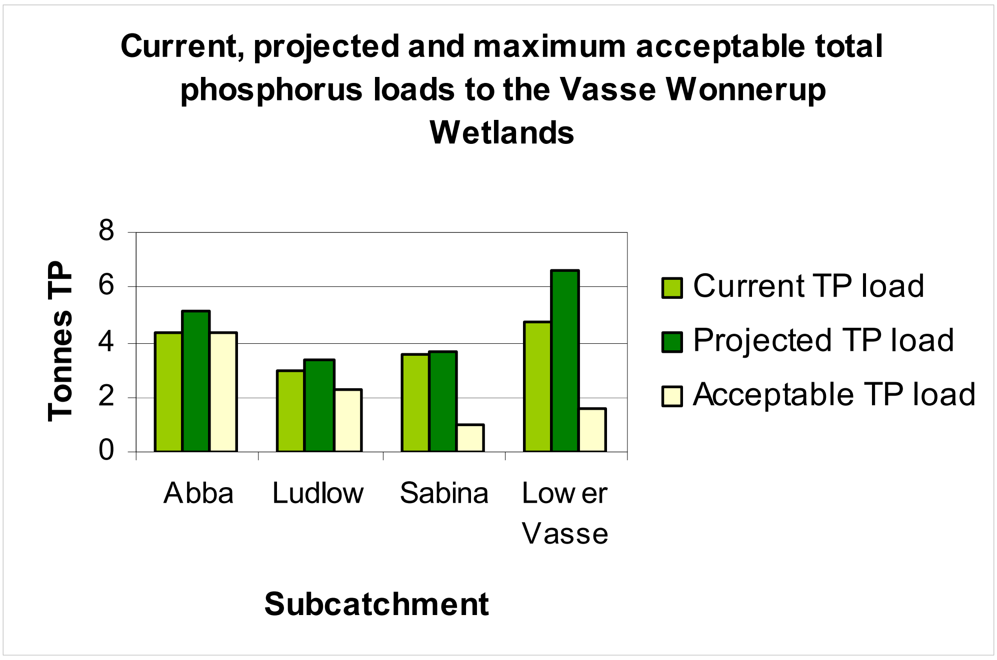


Figure 17: Current, projected and acceptable modelled phosphorus loads to the Vasse Wonnerup Wetlands.

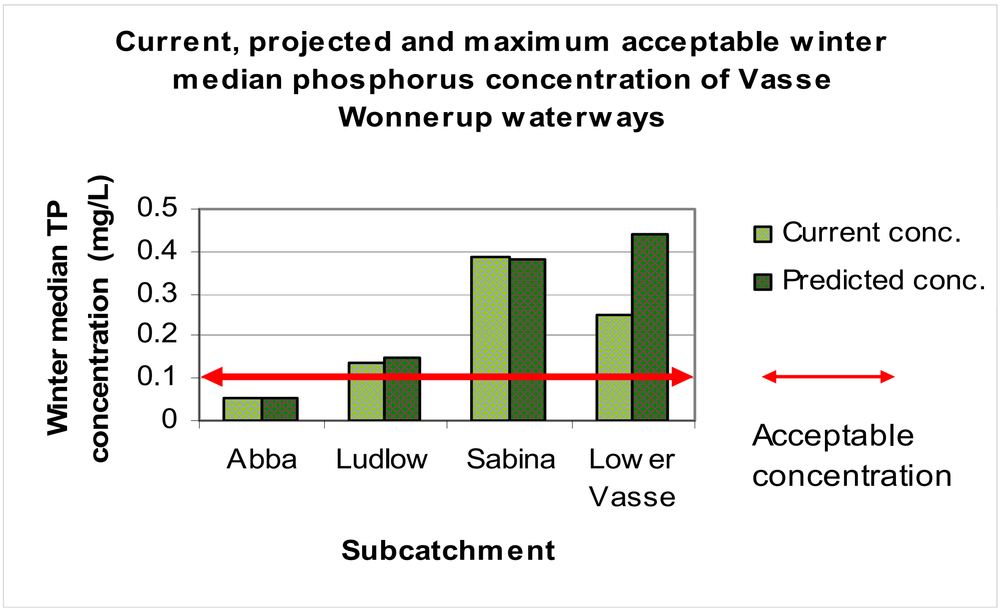


Figure 18: Current, projected and acceptable modelled phosphorus concentration at the drainage point of the Vasse Wonnerup reporting catchments.

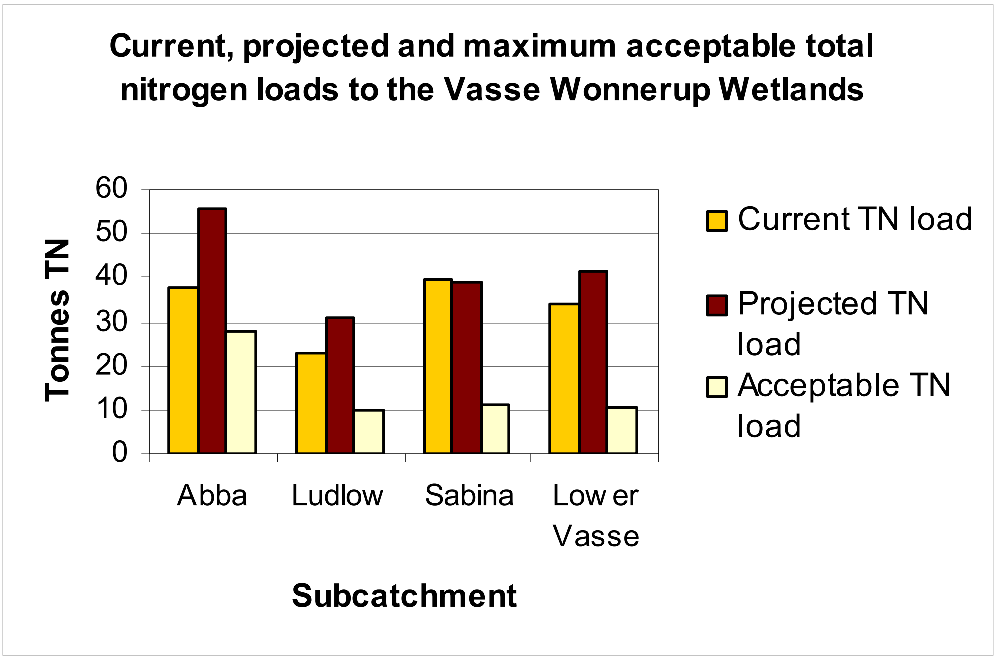


Figure 19: Current, projected and acceptable modelled nitrogen loads to the Vasse Wonnerup Wetlands.

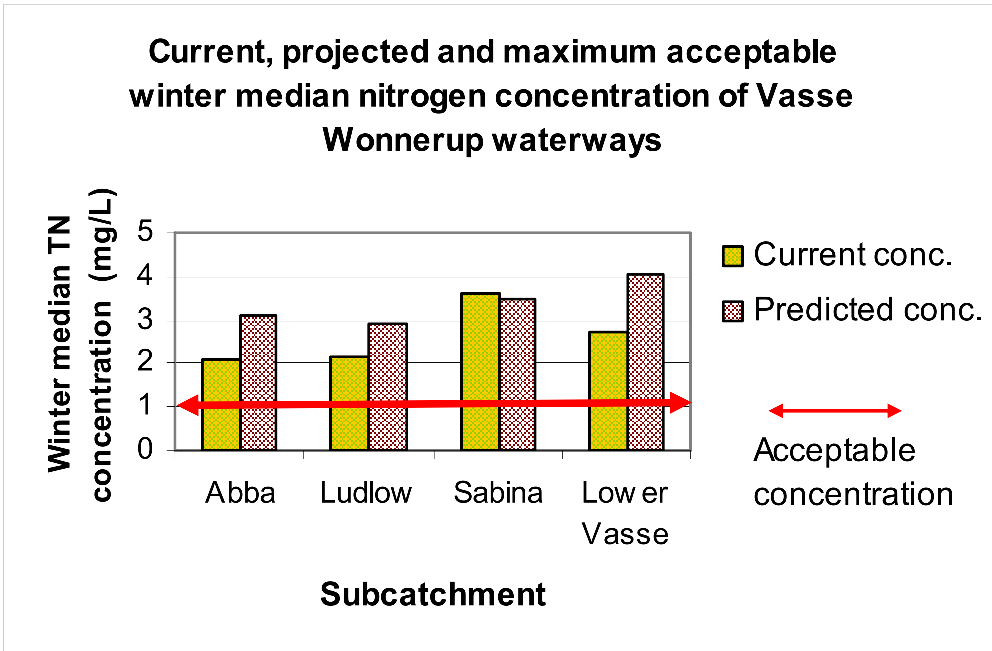


Figure 20: Current, projected and acceptable modelled nitrogen concentration at the drainage point of Vasse Wonnerup reporting catchments.

Summary statistics for the overall loads of phosphorus and nitrogen to the Vasse Wonnerup Wetlands are presented in tables 5 and 6. Overall the total acceptable phosphorus load to the Vasse Wonnerup Wetlands from all reporting catchments is 9.15 tonnes/year. This is 6.43 tonnes less than the current load to the wetlands. This difference is referred to as the 'total phosphorus load reduction target' for the wetlands. For nitrogen the total load reduction target is 74 tonnes. These figures equate to a requirement for a 41 per cent reduction in the total phosphorus load to the wetlands and a 55 per cent reduction in the total nitrogen load to the wetlands. Projections of the impacts of land-use change highlight a likely 20 per cent increase in the current phosphorus load and a 25 per cent increase in the nitrogen load to the wetlands if management interventions are not made.

The proportion of the total load of phosphorus and nitrogen that needs to be reduced from each reporting catchment is presented in figures 21 and 22. The bulk of the phosphorus load reduction is required from the Lower Vasse River catchment with most of the remaining required from the Sabina River catchment. The Lower Vasse River also needs to contribute the largest reduction in nitrogen load with the balance evenly divided between the Sabina, Abba and Ludlow reporting catchments.

Table 5: Summary of total phosphorus load reduction targets for the Vasse Wonnerup Wetlands from all reporting catchments.

Reporting catchment	**Current P load** (tonnes/year)	**Projected P load** (tonnes/year)	**Acceptable P load** (tonnes/year)	**P load reduction target** (tonnes/year)	**P load reduction target** (% reduction required from current load)
Intervention catchment					
Abba	4.35	5.18	4.35	0	0%
Recovery catchments					
Ludlow	2.94	3.38	2.31	0.63	21%
Sabina	3.57	3.61	0.94	2.63	74%
Lower Vasse	4.72	6.66	1.55	3.17	67%
Total	**15.58**	**18.83**	**9.15**	**6.43**	**41%**

Table 6: Summary of total nitrogen load reduction targets for the Vasse Wonnerup Wetlands from all reporting catchments.

Reporting catchment	**Current N load** (tonnes/year)	**Projected N load** (tonnes/year)	**Acceptable N load** (tonnes/year)	**N load reduction target** (tonnes/year)	**N load reduction target** (% reduction required from current load)
Intervention catchment					
Abba	37.5	55.4	28.1	9.4	25%
Recovery catchments					
Ludlow	22.9	30.9	10.2	12.7	55%
Sabina	39.5	39.1	11.3	28.2	71%
Lower Vasse	33.8	41.6	10.3	23.5	70%
Total	**133.7**	**167**	**59.9**	**73.8**	**55%**

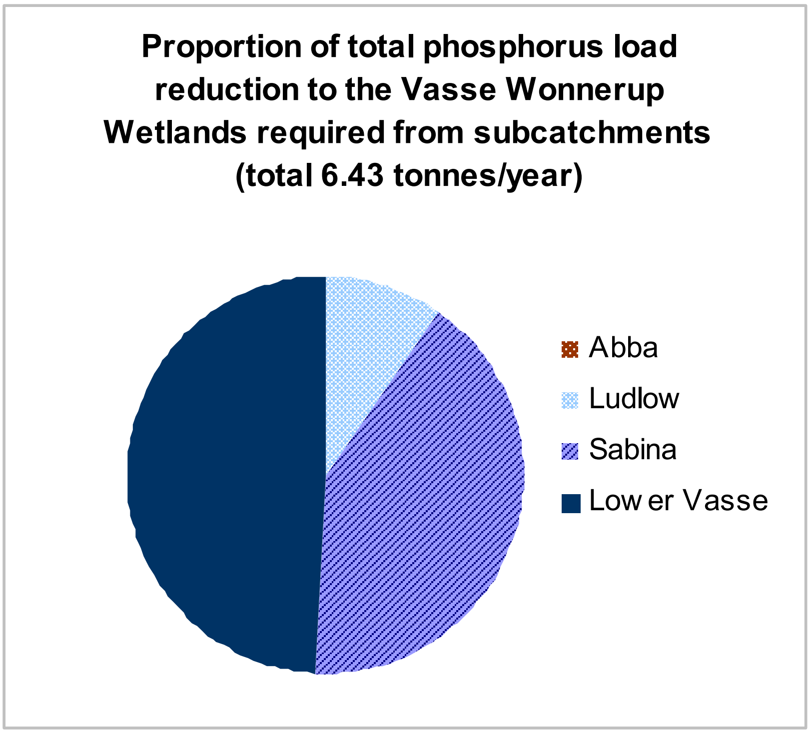


Figure 21: The proportion of total phosphorus load reduction target required from each Vasse Wonnerup reporting catchment.

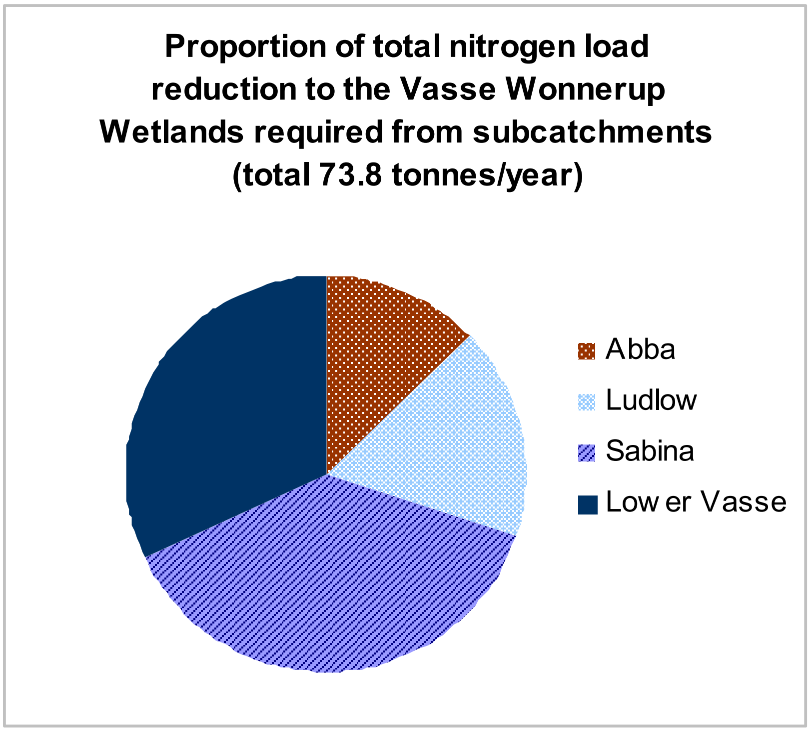


Figure 22: The proportion of total nitrogen load reduction target required from each Vasse Wonnerup reporting catchment.

Load reduction targets for Geographe Bay

Outcomes of the water quality modelling for the current, projected and acceptable phosphorus and nitrogen loads and median winter concentrations for the Geographe Bay reporting catchments are presented in figures 23 to 26. These data show that the Vasse Diversion Drain, Gynudup Brook and Five Mile Brook reporting catchments (those placed in the 'recovery' water quality objective category) are currently producing well above the acceptable load and concentration of both phosphorus and nitrogen[5]. The phosphorus load and concentration from the Vasse Diversion Drain is particularly high and is expected to dramatically increase as a result of land-use change. Other catchments expected to be similarly affected include those of Buayanyup River, Capel River and to a small degree Toby Inlet.

The phosphorus concentration data reveal an interesting west to east gradient. With the exception of Capel River, which is located in the catchment's east, all of the reporting catchments that currently meet the acceptable concentration standards for phosphorus are located west of the Vasse Diversion Drain. This pattern is likely to reflect the prevalence of soils with a high phosphorus retention index (PRI) in the Geographe Bay catchment's west. This west to east gradient is also present to some degree for the nitrogen concentration data.

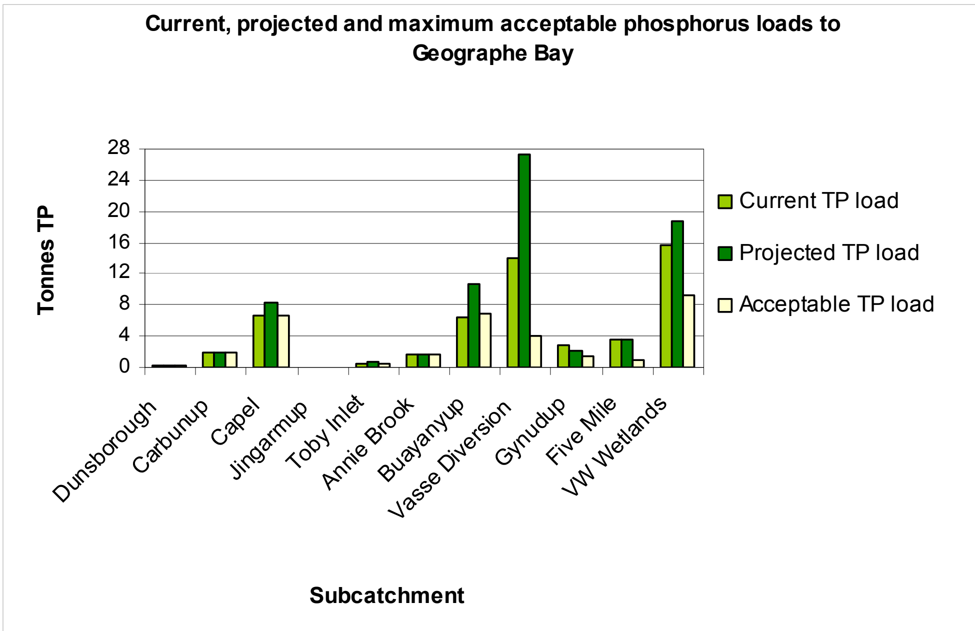


Figure 23: Current, projected and acceptable modelled phosphorus loads to Geographe Bay from all reporting catchments.

[5] Modelled data for the Vasse Diversion Drain are for the drainage point of the catchment. This point is below that of the water quality sampling point for which data is presented in figures 8 and 9. The modelled data therefore displays a higher current concentration of nutrients because the contributions from urban areas and the Busselton wastewater treatment plant have been included. These nutrient sources lie below the water quality sampling point and were therefore not able to be directly measured. Direct sampling at the discharge point was complicated by tidal influences.

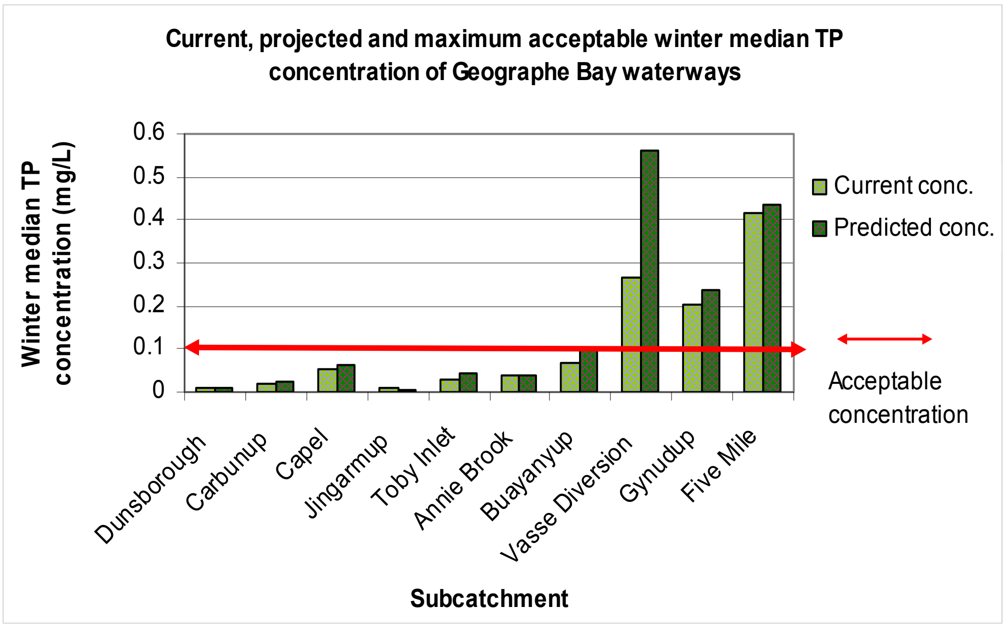


Figure 24: Current, projected and acceptable phosphorus modelled concentrations at the drainage point of Geographe Bay reporting catchments.

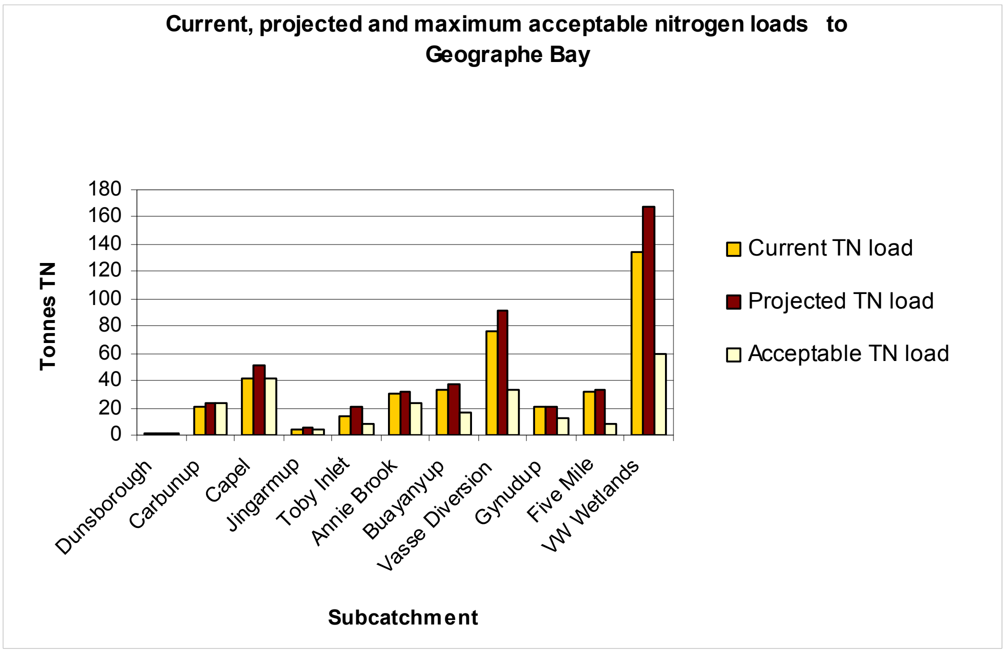


Figure 25: Current, projected and acceptable modelled nitrogen loads to Geographe Bay from all reporting catchments

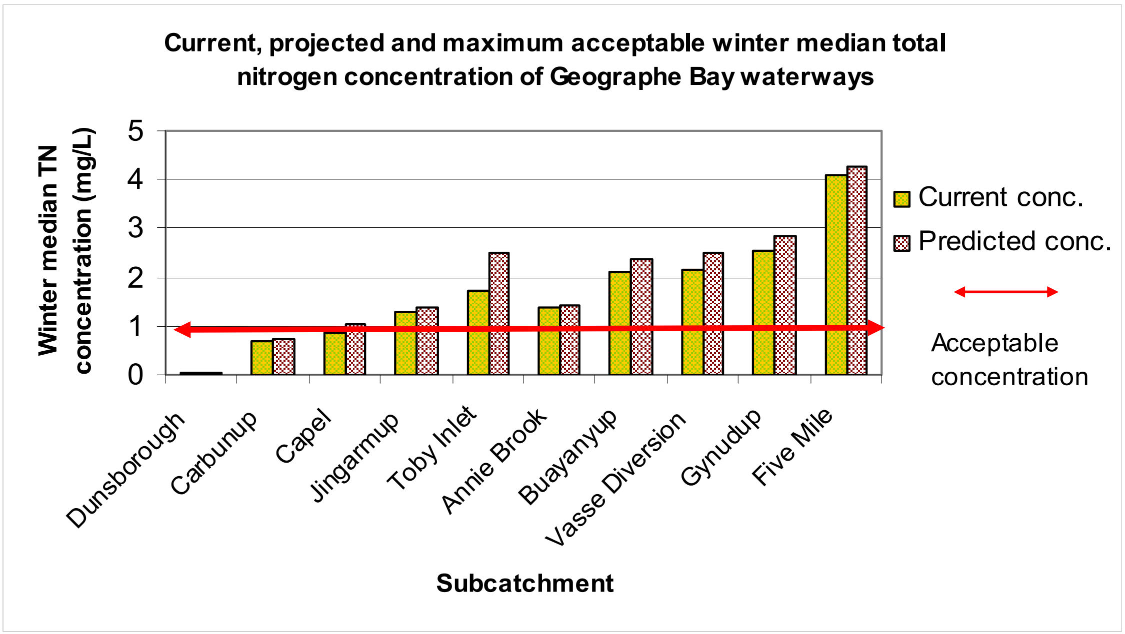


Figure 26: Current, projected and acceptable modelled nitrogen concentrations at the drainage point of Geographe Bay reporting catchments.

Summary statistics for the overall loads of phosphorus and nitrogen to Geographe Bay are presented in tables 7 and 8. Overall the total phosphorus load reduction required from all reporting catchments is 38 per cent of the current load. This may seem a potentially achievable target; however, it needs to be derived from large reductions in only four catchments. These include reductions of 71 and 76 per cent respectively from the Vasse Diversion Drain and Five Mile Brook reporting catchments. The overall nitrogen load reduction required is 43 per cent of the maximum acceptable load. This is required of eight of the 11 reporting catchments.

The proportions of the total phosphorus and total nitrogen load reduction targets required from each reporting catchment are presented in figures 27 and 28. Nearly half of the total phosphorus load reduction to Geographe Bay is required from the Vasse Diversion Drain catchment. A large load reduction is also required from the Vasse Wonnerup Wetlands catchment with a smaller overall reduction required from Five Mile Brook and Gynudup Brook.

The nitrogen load reduction requirement is spread across a larger number of the Geographe reporting catchments. Once again the largest load reduction is required from the Vasse Diversion Drain, Buayanyup River and Five Mile Brook. The Capel River, Toby Inlet, Gynudup Brook and Annie Brook reporting catchments require the next largest reduction in nitrogen load, while a small load reduction is also required from the Jingarmup Brook catchment. Only the Dunsborough streams, Carbunup River and Capel River reporting catchments require no reduction in current phosphorus and nitrogen loads.

Table 7: Summary of total phosphorus load reduction targets for Geographe Bay reporting catchments.

Reporting catchment	**Current P load** (tonnes/year)	**Projected P load** (tonnes/year)	**Acceptable P load** (tonnes/year)	**P load reduction target** (tonnes/year)	**P load reduction target** (% reduction required from current load)
Protection catchments					
Dunsborough	0.13	0.17	0.13	0	0%
Carbunup	1.81	1.9	1.9	0	0%
Capel	6.72	8.41	6.72	0	0%
Intervention catchments					
Jingarmup	0.09	0.09	0.09	0	0%
Toby Inlet	0.42	0.65	0.42	0	0%
Annie Brook	1.76	1.72	1.76	0	0%
Buayanyup	6.46	10.66	6.84	0	0%
Recovery catchments					
Vasse Diversion	14.08	27.17	4.04	10.04	71%
Gynudup	2.85	2.24	1.45	1.4	49%
Five Mile	3.47	3.55	0.84	2.63	76%
Vasse Wonnerup Wetlands	15.58	18.83	9.15	6.43	41%
Total	**53.37**	**75.39**	**33.34**	**20.03**	**38%**

Table 8: Summary of total nitrogen load reduction targets for Geographe Bay reporting catchments.

Reporting catchment	**Current N load** (tonnes/year)	**Projected N load** (tonnes/year)	**Acceptable N load** (tonnes/year)	**N load reduction target** (tonnes/year)	**N load reduction target** (% reduction required from current load)
Protection catchments					
Dunsborough	1.3	1.7	1.3	0	0%
Carbunup	21.1	23.1	23.1	0	0%
Capel	42.2	51.6	42.2	0	0%
Intervention catchments					
Jingarmup	4.5	4.9	3.7	0.8	18%
Toby Inlet	13.7	20.3	8.7	5	36%
Annie Brook	30.4	31.7	23.3	7.1	23%
Buayanyup	33.2	36.9	16.3	16.9	51%
Recovery catchments					
Vasse Diversion	75.6	91.6	33.2	42.4	56%
Gynudup	21.4	21.3	12.2	9.2	43%
Five Mile	32.1	32.7	7.9	24.2	75%
Vasse Wonnerup Wetlands	133.7	167	59.9	73.8	55%
Total	**409.2**	**482.8**	**231.8**	**177.4**	**43.35%**

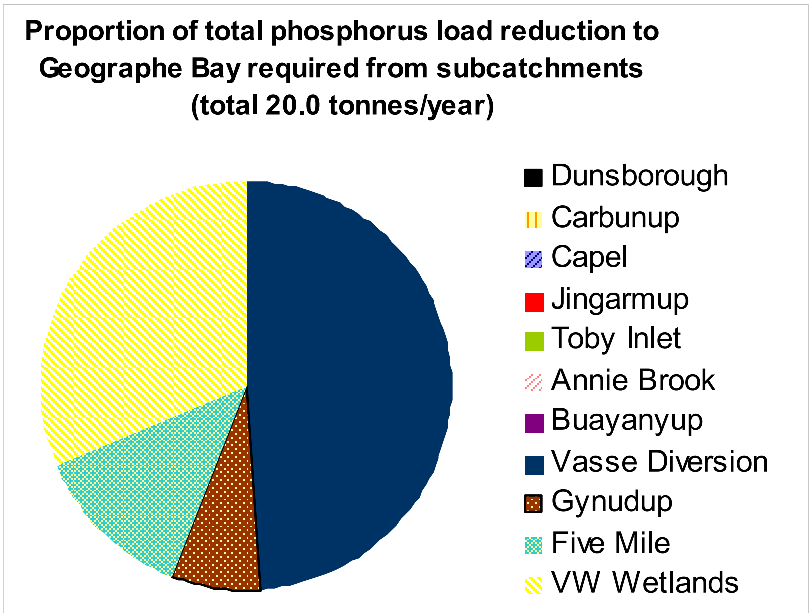


Figure 27: Proportion of the overall total phosphorus load reduction target required from Geographe Bay reporting catchments.

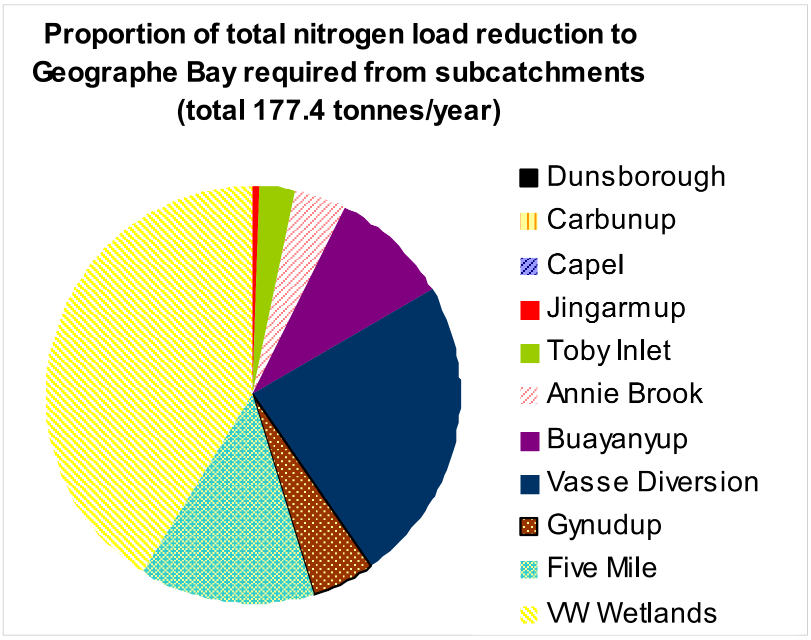


Figure 28: Proportion of the overall total nitrogen load reduction target required from Geographe Bay reporting catchments.

Accounting for seasonal variations in loads

All current loads and load reduction targets presented in this plan are medians calculated for the annual period. All assessments against concentration criteria have been based on the winter median concentration. There are no comparisons made with summer concentrations since all of the waterways except Capel River are seasonal systems that do not flow during summer, thereby contributing no nutrient loads to receiving waterbodies at this time. Summer water levels in the Lower Vasse River are artificially maintained using check boards but flow from the river does not pass into the Vasse Wonnerup Wetlands during summer. The water quality objectives and corresponding targets required to meet those objectives have been established specifically for the winter period, as this is the period appropriate for comparison with the Swan coastal plain water quality criteria (and most waterways in the catchment are dry during summer).

4.7 Load allocations to sources of nitrogen and phosphorus

Understanding the nutrient sources attributed to particular land uses is critical to prioritising the necessary management actions to reduce nutrient loading. Water quality modelling undertaken by the Department of Water has provided a breakdown of these nutrient sources by land use for the Geographe Bay and Vasse Wonnerup Estuary catchments and reporting catchments. The whole-of-catchment summaries of the sources for both receiving waterbodies are presented in figures 29 to 32. The nutrient-source breakdown for each reporting catchment is presented in Section 6.4 alongside the specific management recommendations to address these sources.

The catchment-wide summaries of source breakdown clearly show that agricultural sources provide the vast majority of nutrient loads to the Vasse Wonnerup Estuary and Geographe Bay. Of these, the combination of broadacre grazing for beef and dairy are dominant in each case. Comparing these two sources: cattle for dairy contributes larger loads of phosphorus and nitrogen to the wetlands and more nitrogen to Geographe Bay, but cattle for beef is a greater source of phosphorus to the bay. It should be noted that the cattle-for-dairy category only includes the grazing portion of nutrient loading. Dairy sheds and their associated effluent have been included within the point-source category. The dominance of diffuse sources of nutrients from broadacre grazing presents a management challenge in both catchments. Diffuse sources of nutrients from agriculture have traditionally been among the most difficult to mitigate.

Following grazing, the next largest contributor of phosphorus and nitrogen to both catchments is point sources. Most point sources are derived from the numerous dairy sheds that exist throughout the catchment. A number of other point sources are worth noting due to their comparative contributions of nutrients within individual reporting catchments (see Section 6.4 for reporting catchment graphs). These include:

- a feedlot in the Lower Vasse River catchment that is contributing the largest share of phosphorus in that reporting catchment
- a wastewater treatment plant in the Vasse Diversion Drain catchment for which predicted increases in treatment demand (and therefore volume of treated effluent flowing to the drain) – arising from urban expansion and the infill sewerage program – will contribute half of the expected large increase in phosphorus load from that reporting catchment

- industry point sources of nitrogen in the Gynudup Brook catchment.

Urban land use represents a comparatively small proportion of the overall nutrient load to both catchments. Yet urban sources are more dominant in some areas when viewed at the reporting-catchment level and some are predicted to increase substantially (see Section 6.4 for information on reporting-catchment source separation). Clearly nutrient management in these areas needs to focus on preventing further increases – a difficult task given the amount of urban growth predicted for some areas.

Although the proportion of septic sources of nutrients appears small on these graphs, the overall load of nitrogen and phosphorus that septic systems deliver is disproportionate to the small land area occupied by unsewered urban development. Horticulture is a significant source of phosphorus in the Geographe catchment, though not in all reporting-catchment locations.

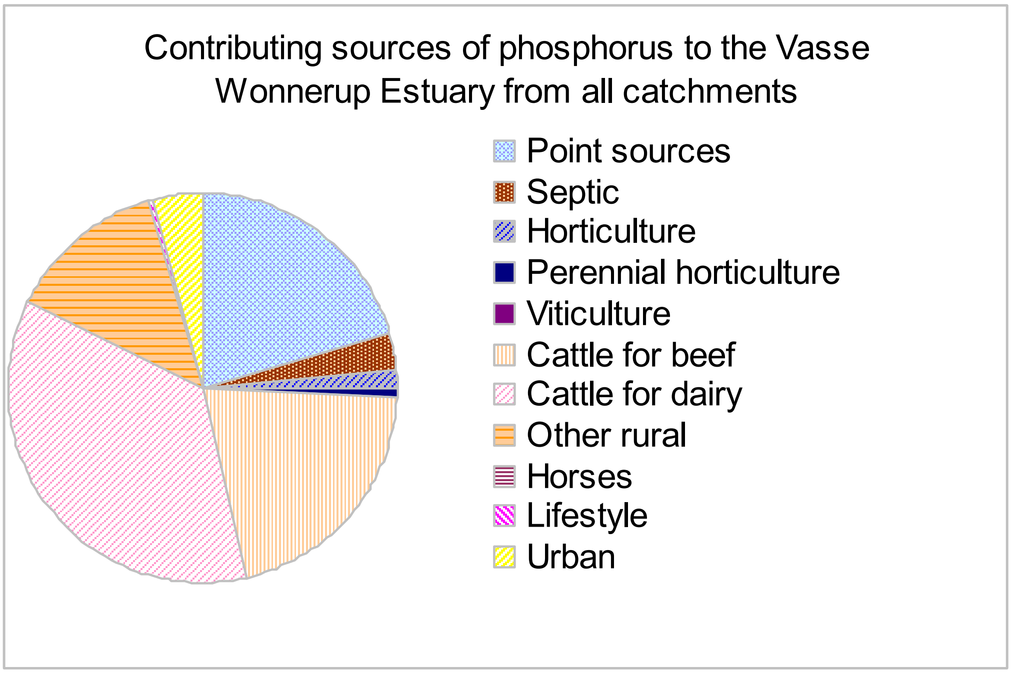


Figure 29: Sources of phosphorus to the Vasse Wonnerup Estuary by land use.

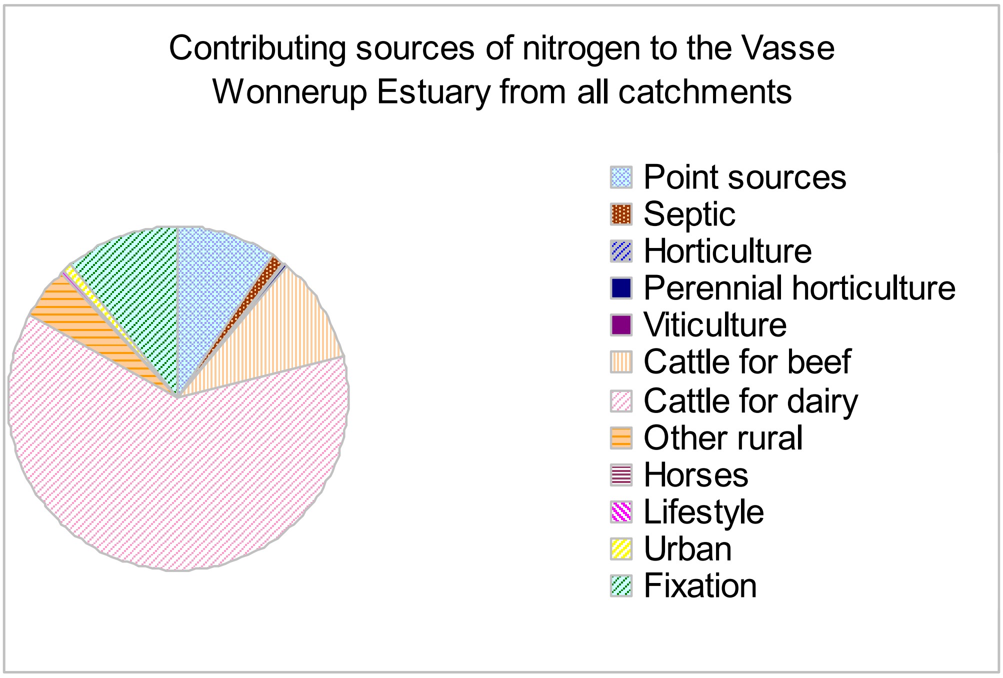


Figure 30: Sources of nitrogen to the Vasse Wonnerup Estuary by land use.

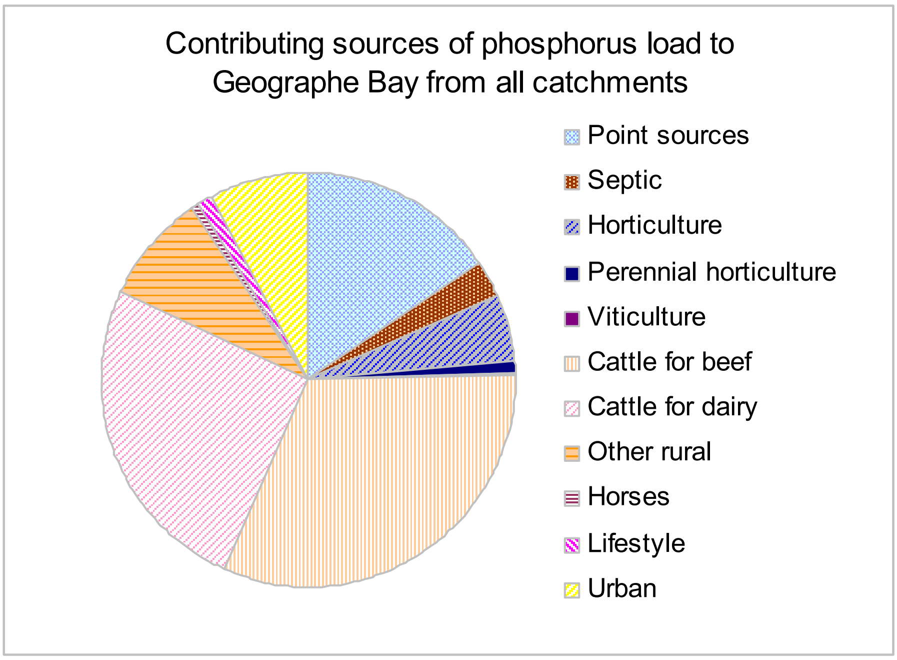


Figure 31: Sources of phosphorus to Geographe Bay by land use.

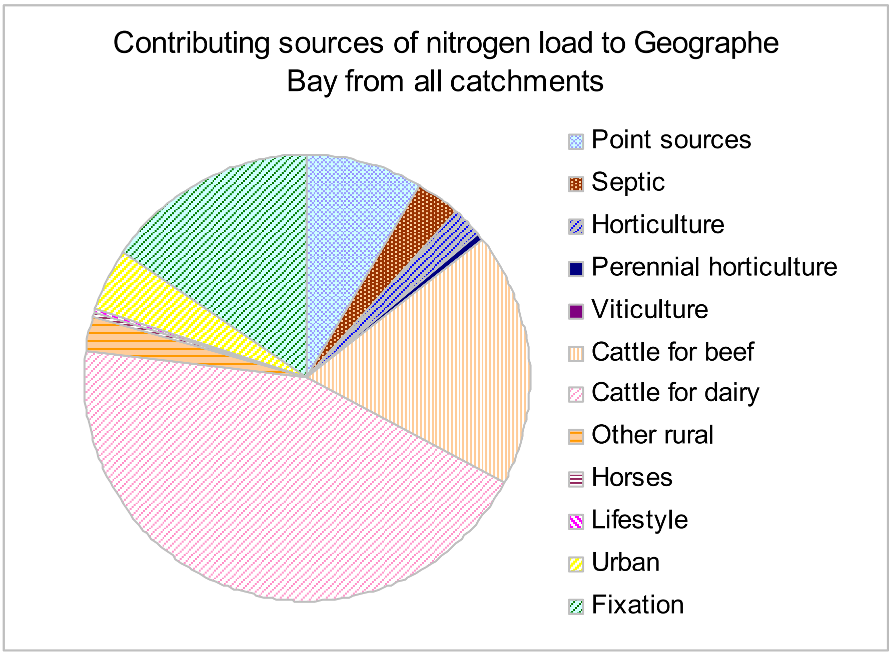


Figure 32: Sources of nitrogen to Geographe Bay by land use.

4.8 Margin of safety

For catchments where limited data on water quality is available, it is important to apply a margin of safety to the targets that are developed. Without a margin of safety there is a risk that load-reduction targets may be set too low and therefore not protect the receiving waterway from future land use or climatic changes. The converse also has inherent risks: if targets are set too high then work may be prioritised in reporting catchments that don’t require remediation at the detriment of those that do.

This plan's targets have a built-in margin of safety generated by a very conservative approach to establishing the water quality objectives, as well as by the best-available knowledge and data about suitable criteria to use for this purpose.

The water quality objectives chosen for this plan recognise that some reporting catchments already meet the standard Swan coastal plain winter median concentration criteria of 0.1 mg/L for phosphorus and 1.0 mg/L for nitrogen. Rather than establishing objectives and targets that would allow water quality in these better-quality catchments to deteriorate, targets have been set at current conditions for all areas that currently meet those standards. A further margin of safety has been provided by including information about the projected *future* loads of nutrients. This enables the identification of catchments that are at risk of further water quality decline and helps justify additional nutrient management measures in these areas.

The overall approach to establishing the water quality objectives and targets in this plan has been to stay ahead of changes in the catchment that will occur during the course of its implementation. It is envisaged that this approach will enable the plan to have a long and relevant shelf life for nutrient managers in the catchment, although an ongoing adaptive approach and continued monitoring of these waterways will also be necessary as part of reviews of the plan.

5 Environmental flows

5.1 Flow management in the Geographe catchment

An integral part of many Coastal Catchment Initiative programs around Australia has been the identification of environmental flow objectives, environmental flow regimes and the management recommendations to achieve them. In the Geographe catchment, most waterways have been heavily modified by an artificial drainage network that enables agricultural use of areas that were previously palusplain wetlands, sumplands or floodplain areas. The only true river system in the catchment is the Capel River, which is fed by groundwater through its lower reaches. All other systems are ephemeral and therefore do not flow during summer. Many of these other waterways are very small systems that do not retain any summer pool refuges for aquatic fauna. A strong reliance on groundwater for agricultural irrigation and domestic use has arisen because summer flow is absent from these waterways and the topography and soil is unsuitable for dam construction in much of the coastal plain area. Some waterways in the catchment's western part have, however, been developed with numerous on-stream dams. Over time some of these systems may risk exceeding environmental water requirements in the absence of appropriate management arrangements.

The Department of Water directly manages the flow regimes of surface-water resources through the surface-water allocation and licensing process. The Whicher area surface water allocation plan (DOW 2009) sets out a framework for surface-water allocation in the Whicher area, encompassing all waterways in the Geographe catchment. To protect the environmental flows of the area's waterways, the draft plan applies a precautionary approach that takes into account the drier climate experienced in the Whicher area since the mid 1970s. The draft plan:

- addresses security of surface-water supply both for the environment and for current users
- identifies where water is available for use
- sets out policies and rules for managing surface water in the area
- allocates the amount of surface water available for new commercial and private users.

The Whicher area surface water allocation plan (DOW 2009) uses up-to-date scientific information to aid the management of environmental flows in the catchment and will establish the formal direction for surface-water management in the Geographe catchment. The environmental flow objective defined in the draft plan for all waterways is as follows:

> Objective 1: Protect key ecological, cultural and social values at an acceptable level of risk from surface-water use.

Summary information about the draft plan and its implications in terms of surface-water availability is provided in the sections that follow.

5.2 Monitoring and modelling of river flows

Understanding current flow volumes and regimes is essential when managing flows for any waterway. Only a few gauging stations are currently measuring flows from Geographe catchment waterways, with these limited to the following systems (Hall 2006):

- Carbunup River
- Vasse Diversion Drain and Upper Vasse River
- Upper Sabina River
- Ludlow River
- Abba River
- Capel River.

Flow modelling for the catchment's other waterways has become possible as part of the Coastal Catchments Initiative project and calibrated flow data from the catchment's gauged waterways is now available (figures 33 to 44).

For all systems the average monthly flows are presented for the years 1980 to 2006. This period was chosen to best represent current day-rainfall patterns and associated flows (reflecting the drying climate trend), while also including a good variation of extreme wet and dry years within the data set. Gauging station data was used wherever it was available, while modelled data was used to fill gaps in time-series or to complete data sets for waterways where no gauging stations existed.

The flow data illustrates the seasonal nature of most Geographe waterways. The Capel River displays a continual year-round flow, while other waterways show a strongly seasonal pattern in the monthly flow. This pattern is typical of ephemeral systems, although the data shows some variation in the onset of low flow and dry periods.

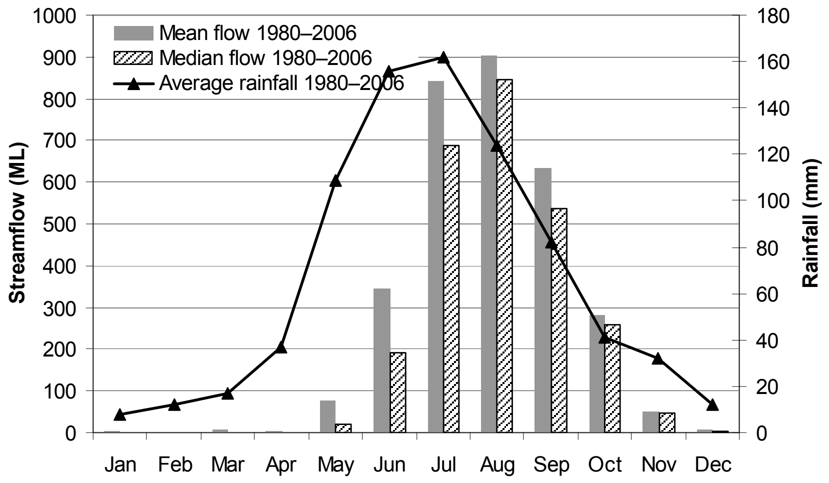


Figure 33: Jingarmup Brook modelled monthly flow 1980—2006.

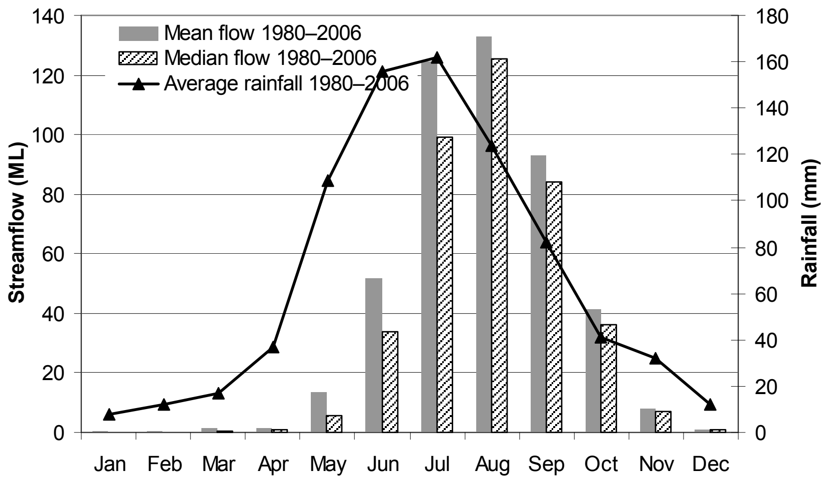


Figure 34: Dandatup Brook modelled monthly flow 1980—2006.

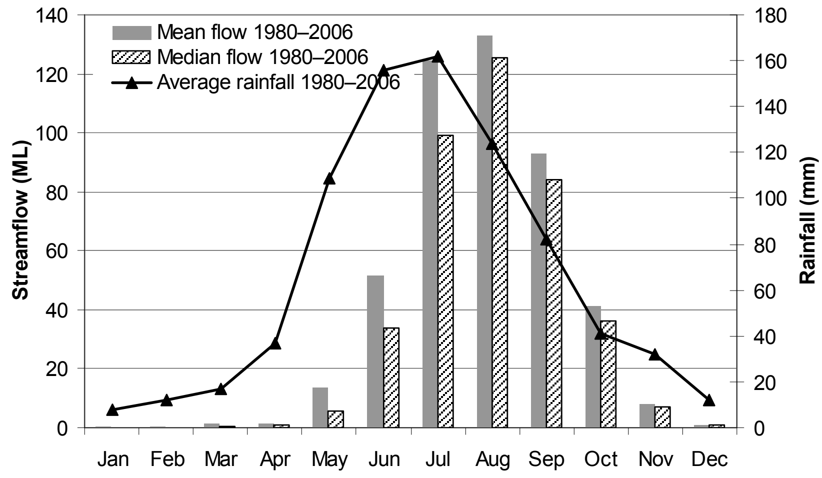


Figure 35: Dugalup Brook modelled monthly flow 1980—2006.

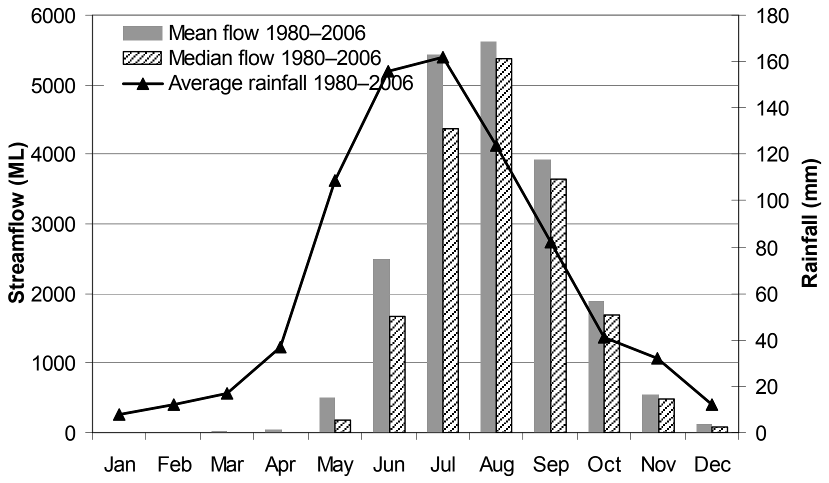


Figure 36: Annie Brook modelled monthly flow 1980—2006.

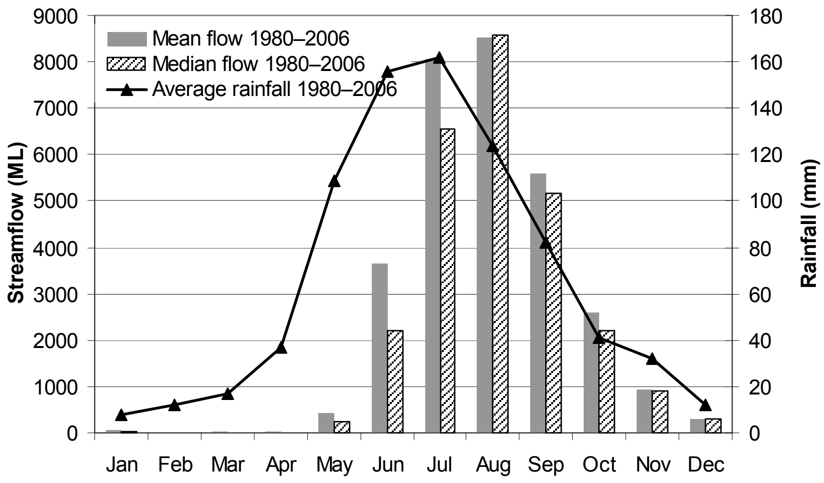


Figure 37: Carbunup River modelled monthly flow 1980—2006.

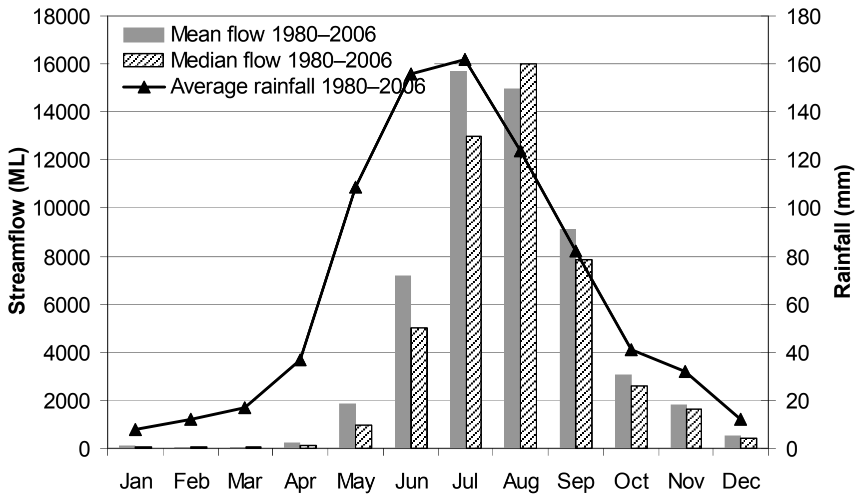


Figure 38: Buayanyup River modelled monthly flow 1980—2006.

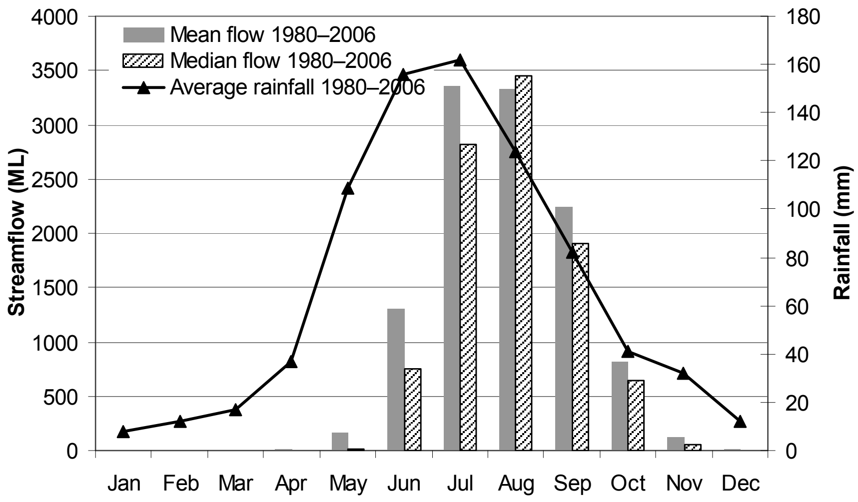


Figure 39: Vasse Diversion Drain modelled monthly flow 1980—2006.

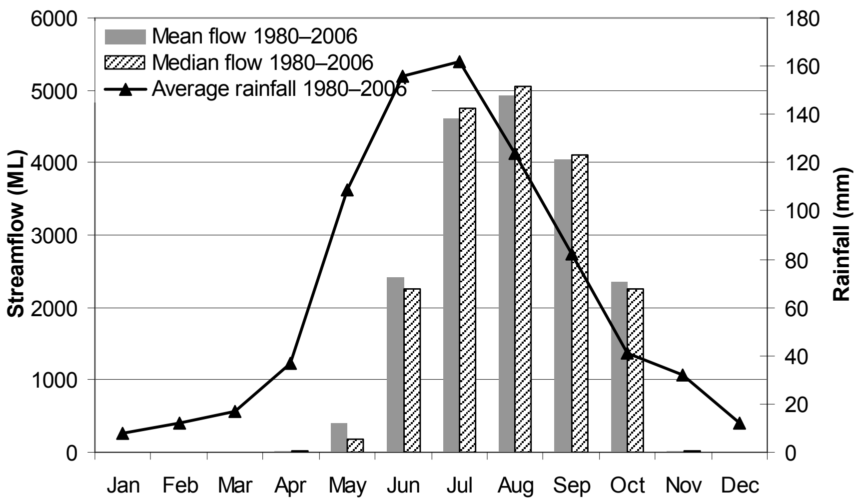


Figure 40: Lower Vasse River modelled monthly flow 1980-2006

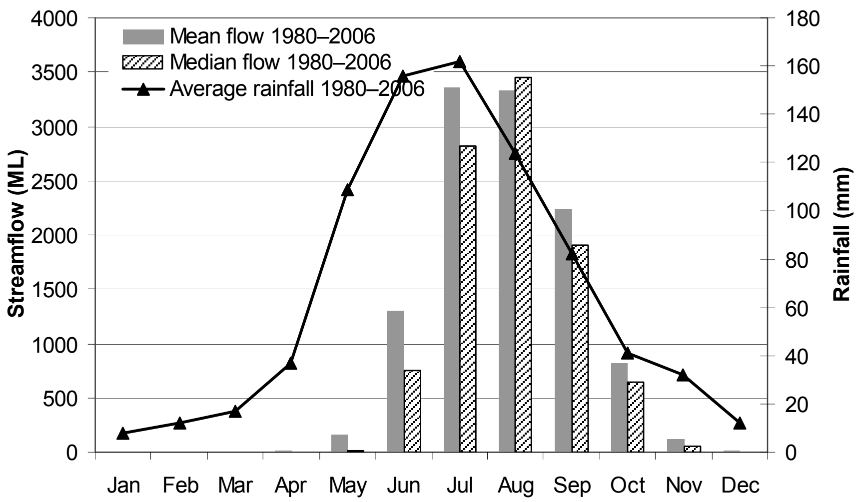


Figure 41: Sabina River modelled monthly flow 1980—2006.

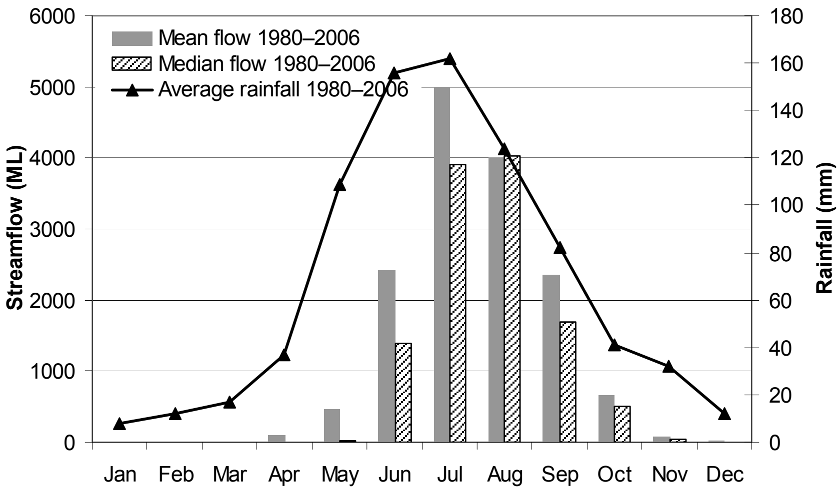


Figure 42: Abba River modelled monthly flow 1980—2006.

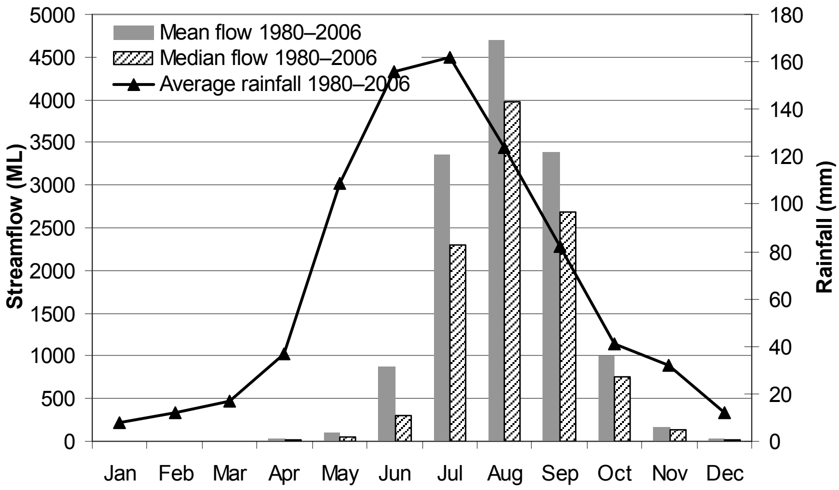


Figure 43: Ludlow River modelled monthly flow 1980—2006.

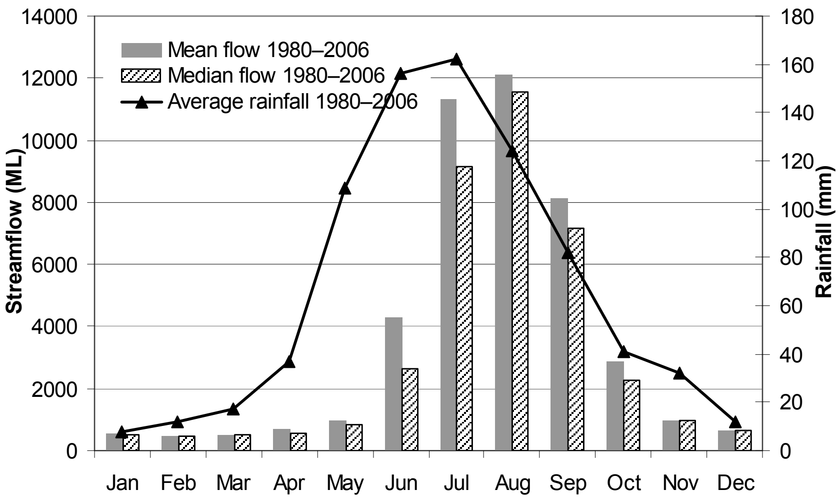


Figure 44: Capel River modelled monthly flow 1980—2006.

5.3 Proclamation of surface-water resources in the catchment

In September 2007, Jingarmup Brook and the upper portions of the Geographe waterways located between Dunsborough and the Ludlow River were formally proclaimed under the *Rights in Water and Irrigation Act 1914* (WA) (Figure 45). Within the Geographe catchment only the Capel River had previously been proclaimed. Water users now require authorisation from the Department of Water to interfere with or take water from these newly proclaimed watercourses. Historical use of surface water in these areas will be progressively licensed according to the Department of Water's priority schedule. The department will assess applications for new surface-water use from proclaimed areas under the Whicher area surface water allocation plan (DOW 2009).

The lower portions of the Geographe waterways flowing through the Swan coastal plain have not been proclaimed. Water supply in these areas is predominantly obtained by groundwater extraction because the seasonal nature of surface flows – combined with the flat topography of the coastal plain – limits surface-water extraction. The Department of Water manages and licences the Geographe catchment's groundwater resources through the *Southwest groundwater areas management plan – allocation* (DOW 2008c).

Figure 45: Surface-water resources in the Whicher area including proclaimed areas (DOW 2009).

5.4 Allocation of surface-water resources

The Whicher area has been divided into three surface-water management areas: Capel River, Busselton Coast and Lower Blackwood. These areas are further divided into surface-water management subareas. It should be noted that these subareas differ from the reporting catchment areas defined in this water quality improvement plan. An allocation limit, or annual volume of water set aside for use, has been defined for each subarea. Each allocation limit has been set with consideration for the environmental, cultural and social water requirements for each system and how much water can sustainably be taken. Allocation limits for the Geographe waterways are summarised in Table 9 and illustrated in Figure 46.

Table 9: Allocation limit and available surface water in the Geographe catchment (DOW 2008b).

Surface-water management area	Surface-water management subarea	Area (km^2)	Allocation limit (ML/year)	Available water for new developments
Busselton Coast (Cape to Cape north)	Naturaliste	64	310	Yes
Busselton Coast (Geographe Bay rivers)	Buayanyup	201	3540	Yes
	Carbunup	165	4320	Yes
	Dunsborough coast	158	3000	Yes
	Vasse Diversion Drain	283	3340	Yes
	Wonnerup	477	4240	Yes
Capel River	Capel River Central	111	980	No
	Capel River North branch	88	4700	No
	Capel River South branch	168	2730	Limited
	Capel River West	81	490	No
	Five Mile Brook	87	270	Yes
	Gynudup Brook and Tren Creek	188	1380	Yes

A

Figure 46: Surface-water availability in the Whicher area (DOW 2009).

5.5 Management measures to address environmental flows

Management of environmental flows is an integral part of the Whicher area surface water allocation plan (DOW 2009). To protect the ecology of river pools, the department will in general not support 'take' (including direct pumping) from watercourses during periods of low flow. The allocation limits in the plan are specifically designed to protect the river systems both now and in the future. Requests for surface water for new developments and/or the expansion of existing developments will not be approved if they result in total use being above those limits. New and existing commercial water users will need to consider how they can use water more efficiently, use alternative supplies, find fit-for-purpose water or trade water. The allocation limits were established using a precautionary approach to protect the environment and low allocation limits have been set for areas with high environmental value.

Further work is underway to increase our understanding of surface-water resources in the area, so that surface-water management can be continually improved. Future planning for surface-water management in the area will consider the potential for further climate change. In addition, studies on the ecological water requirements for key surface-water systems are in progress. The studies will identify important values that need to be protected and the flow regimes that need to be maintained.

In the Geographe catchment, data on the ecological values of the Carbunup and Capel river systems is limited though a fish survey of the Carbunup River has recently been undertaken. Given that these two river systems are likely to be the most pressured in the catchment – from a surface-water-use perspective – the Department of Water recommends these be prioritised for further development of environmental water requirements and formal surface-water-use management.

5.6 Integrating management of water quality and flow

Addressing water quality issues through the allocation process

Integrated management approaches can achieve positive water quality outcomes. The Department of Water considers water quality as part of its water allocation licensing process and conditions-of-license approvals can include requirements for the development of nutrient management plans. Such management arrangements can be streamlined through policy and/or strategy directions, particularly where water quality objectives have been clearly identified through a target-setting process. The department has therefore made the following recommendation to aid the integration of surface-water and groundwater management with water quality management in the catchment:

> Develop complementary policy and on-ground strategies to achieve integrated management of water allocation and water quality.

Flow manipulations in the Lower Vasse River

It is believed that severe water quality problems in the Lower Vasse River have been exacerbated by the altered hydrological regimes of the river system. These alterations include the diversion of the upper reaches of the river to Geographe Bay through the Vasse Diversion Drain and, in summer, the artificial maintenance of water levels in the lower reaches with the use of check-board structures. These changes have resulted in a river system that functions more like a lake. A large volume of flocculent sediment has accumulated in the river bed and these stores release additional nutrients to the river system during summer.

Some stakeholders have suggested the river's water quality could be improved with increased flushing of the system using additional flow from the Vasse Diversion Drain, which is already controlled by a valve structure. To assess the potential benefits of this option, the Department of Water modelled this management scenario (Appendix A). The model predicted that by releasing additional flow down the Lower Vasse River, the nutrient load to the river would increase and the concentration would decrease. The concentration, however, would not decrease to criteria levels of 0.1 mg/L phosphorus and 1.0 mg/L nitrogen but would level out at about 0.13 mg/L for phosphorus and 1.4 mg/L for nitrogen (which are the concentrations in the Vasse Diversion Drain). In summary, the additional flow would not be expected to provide any benefits for managing water quality problems in the river for the following reasons:

- the scenario involves flushing the river with high nutrient water – increasing the flow is therefore not going to improve nutrient concentrations down to levels that will prevent algal blooms
- the additional flow will increase the nutrient load being delivered to the river system
- during summer when the river's water quality is most problematic, there is no water in the Vasse Diversion Drain available to provide flushing
- the highest flushing velocities possible are unlikely to scour and purge the nutrient-rich sediment from the river system, although this could be the subject of further investigation.

6 Management measures to address nutrient loads

6.1 Management directions arising from water quality modelling

The Department of Water's monitoring and modelling of land-use sources of nutrients in the Vasse Geographe catchment have generated the following key messages with implications for water management:

1. The vast majority of nutrient loads to the Vasse Wonnerup Wetlands and Geographe Bay are currently derived from diffuse agricultural sources. Of these sources, grazing of cattle for beef and dairy are the most dominant, with a combined contribution of 57 per cent and 62.5 per cent of all phosphorus and nitrogen loads.
2. Point sources of nutrients contribute 15 per cent of phosphorus and eight per cent of nitrogen to Geographe Bay, but up to 20 per cent of the phosphorus load to the Vasse Wonnerup Wetlands. These are primarily comprised of dairy shed effluent, with smaller contributions from other sources in individual reporting catchments such as wastewater treatment plants and feedlots.
3. While urban sources are currently contributing only eight and four per cent of phosphorus and nitrogen respectively, these sources are predicted to increase substantially over the next 20 years as a result of planned urban expansions in Busselton. Urban land use also contributes a disproportionate load of nutrients given the comparatively small area of this land use in the catchment.
4. The growth of the Busselton town site will lead to a larger volume of effluent being discharged to the Vasse Diversion Drain from the Busselton wastewater treatment plant. The treatment plant's technology will need to be upgraded to avoid an increase in nutrient-load discharge.
5. In total the contributions from septic systems are very low (two to three per cent); yet within some reporting catchments, such as the Lower Vasse River and Toby Inlet, these contributions can be much larger (approximately 10 per cent).

The key messages above underpin this plan's five most important management directions. They are to:

1 focus on diffuse agricultural sources of nutrients as a first priority for remedial nutrient management action and investment

2 further improve effluent management at dairies and feedlots

3 prevent further increases to current nutrient loads from new urban developments (critically important)

4 reduce nutrient export from existing urban areas in some reporting catchments where there are significant nutrient contributions from diffuse urban sources

5 reduce contributions from septic systems in some reporting catchments to address local-level water quality problems.

6.2 Catchment-wide nutrient management recommendations

In 2008 Ecotones and Associates undertook cost-benefit analyses and scenario modelling of a range of nutrient management practices. The Department of Water has used the results to guide the selection of the practices recommended in this plan. The modelling indicates that even a comprehensive range of treatments implemented with high levels of adoption will not achieve all targets. Modelling of a realistic rate of implementation and adoption has revealed the need to establish interim targets for some reporting catchments. Even then, implementation of these treatments will require substantial investment and a range of barriers to uptake by landholders will exist.

The recommended strategies to address specific sources of nutrients throughout the catchment are outlined below. These are presented in order of importance within each source category based on the modelled cost benefit; estimates of likely uptake; and, based on currently available information, the likelihood that the action will reduce nutrient loads.

- **Managing diffuse agricultural nutrients:**
  1 improving fertiliser management throughout the catchment
  2 implementing riparian management and stock control on streams and drains
  3 using soil amendments on sandy soils
  4 using perennial pastures in suitable locations and situations.
- **Managing point-source agricultural nutrients:**
  5 improving effluent management at dairy sheds and feedlots.
- **Managing diffuse nutrients from the urban landscape:**
  6 reducing nutrient use and export risk in urban areas
  7 ensuring new urban developments incorporate water sensitive urban design
  8 achieving no net increase or a net reduction in nutrient loads from large new urban developments
  9 undertaking strategic retrofitting of water sensitive urban design in existing urban areas.
- **Managing urban point sources**:
  10 achieving no net increase in nutrient loads from wastewater treatment plants in recovery catchments
  11 developing solutions to large nutrient loads delivered by septic systems in specific reporting catchments.

Addressing diffuse agricultural nutrient pollution

1. Improve fertiliser management throughout the catchment

Best-management practices for fertiliser management include:

- conducting regular soil testing to determine the required nutrients to meet crop, pasture or animal needs (recommended to do every three years), and to ensure that soil-nutrient test levels do not exceed recommended agronomic thresholds
- conducting regular plant-tissue testing during the growing season to detect and correct nutrient deficiencies – this will ensure that nitrogen and phosphorus have the best-possible uptake
- applying fertiliser after the break-of-season, preferably in split applications
- applying fertilisers when nutrient requirements are greatest
- having unfertilised buffers between fertilised areas and watercourses
- using a calibrated fertiliser spreader to ensure even and accurate application rates
- avoiding fertilising when intense rainfall is forecast within the next two days
- avoiding fertilising firebreaks
- applying nutrients according to the recommendations of soil or tissue testing
- providing covered areas for stored fertiliser
- using a low-water-soluble phosphorus fertiliser on sandy soils
- applying sufficient lime to ensure that pH levels are above 5.5 in the top 10 cm of soil
- using nutrient budgeting to help make fertiliser decisions.

Benefits

Fertiliser management is the most widely applicable management practice and, according to the modelling, is also the second most cost-effective practice (Ecotones 2008). If all farmers adopted the recommended practices, phosphorus load reduction would range from five to 11 per cent depending on the reporting catchment, while nitrogen load reductions would be between three and 20 per cent (Ecotones 2008). However, there is greater uncertainty about the effectiveness of these practices at reducing nitrogen runoff – in comparison with phosphorus runoff – because of the interrelationships between nitrogen fertiliser use, nitrogen fixation, nitrogen efficiency and productivity (Don Bennett, Department of Agriculture and Food, pers. comm.). Yet it is likely that overcoming limiting factors such as nutrient deficiency in agricultural systems will help to optimise the use of nitrogen and phosphorus (Weaver et al. 2008).

The modelling indicated that best-practice fertiliser management delivers a net financial benefit to farmers across all catchments, with a very low capital cost of implementation.

Current uptake

There is room for farmers within the Geographe catchment to make large improvements in fertiliser management. Surveys of landholders have revealed that although 73 per cent of landholders are currently soil testing, only 40 per cent actually follow the recommendations of the soil tests (Keipert 2007) and only 25 per cent indicated that they left buffers between fertilised areas and watercourses.

Uptake may be improved by the recent increase in fertiliser prices, which have doubled over the past 12 months. This would need to be confirmed in further surveys.

Barriers to adoption

- Lack of nutrient-budgeting tools and consistent advice from the fertiliser industry.
- Low-water-soluble phosphorus fertiliser is not commercially available at present, although this is likely to change should the Department of Environment and Conservation's proposed Fertiliser Action Plan be finalised and implemented.

Advice for implementation

- Develop tools to help farmers interpret soil tests.
- Provide farmers with regular educational opportunities to build their understanding of how to interpret soil-test results.
- Support the development of nutrient-accounting packages and other tools that allow farmers to independently assess their fertiliser and nutritional requirements.
- Undertake demonstrations and case studies associated with best-management practices, including low-water-soluble fertilisers, to help implement the proposed Fertiliser Action Plan.

Implications for investment

Implementation would involve a very low capital cost. Costs of implementation would be balanced by net financial gains by farmers, though up-front funding would be needed for:

- coordination of extension programs
- cost of redevelopment of soil phosphorus assessment tools
- development of farm fertiliser management plans
- workshops and other educational opportunities
- management, monitoring and reporting of demonstration projects and case studies.

Specific reporting catchments for implementation

All Vasse Geographe reporting catchments.

2. Implementing riparian management and stock control

Definition

Best-practice riparian management includes:

- the fencing of streams and drains
- their rehabilitation and revegetation
- stock exclusion
- construction of stock and vehicle crossings
- the provision of off-stream watering points.

Riparian management is needed on first-, second- and third-order streams and minor drains to be most effective at reducing nutrient loads. This is because these first and second (low order) streams tend to be nutrient-source areas; however, they also represent a high percentage (70–80 per cent) of the total stream length in the catchment.

It is recognised that achieving a high adoption rate for best-practice riparian management as defined above is very difficult. Because significant nutrient management benefits can be achieved with fencing alone (to exclude stock), three levels of riparian management have been described by Ecotones (2008b) and have been used a basis for the cost-benefit analysis of this management measure in Section 6.2. These are as follows:

- riparian management LOW – is stream fencing, with revegetation using paddock grasses only
- riparian management MODERATE – is stream fencing, with revegetation using trees and grasses
- riparian management HIGH – is fencing, revegetation using trees and grasses, provision of off-stream watering points, stock exclusion and stream crossings.

Benefits

Riparian management prevents stock access to streams and drains, thereby preventing direct fouling and erosion. Grass-based vegetation strips alongside streams and rivers act as sediment traps, helping to filter a proportion of the nutrient-rich soil particles washed off paddocks (Keipert 2007).

Scenario modelling has indicated that best-practice riparian management can potentially deliver large nutrient-load reductions – particularly for nitrogen – if implemented on first-order (minor) streamlines and drains and larger systems in the catchment (Ecotones 2008). The model predicts it is one of the few available nutrient management tools capable of significantly reducing nitrogen (while also reducing phosphorus loads) if widely implemented on all stream orders (Ecotones 2008). Further assessment and monitoring is, however, needed to confirm the range of potential nitrogen and phosphorus removal that could be achieved with riparian management in this catchment.

This management practice is not limited to particular land uses and has substantial ecological spin-offs in regard to habitat restoration. These are important considerations in the Vasse Geographe catchment where many streams retain significant ecological values such as freshwater fish and rare flora.

Current uptake

River action plans have already guided extensive riparian management work in the catchment. However, most of this work has been undertaken on the main stream channels. Uptake of riparian management on first-order streams is very important because these systems drain the largest part of each catchment.

Barriers to adoption

- Very high capital cost for implementation.
- A need for improved data to determine the accuracy of the modelled nutrient-removal efficiency (particularly nitrogen).
- Requires work on first-order streams, which means that farmers need to take land out of production with resulting financial losses (difficult to persuade farmers to do this work as there are few perceived on-farm benefits).
- Long-term maintenance costs and additional management requirements such as feral animal control, weed management, drain maintenance and fire management in excluded areas.
- May require farm-plan redesign on first-order streams.

Advice for implementation

- Implement a high-level cost-sharing arrangement for riparian management that includes contributions to farm re-fencing and infrastructure redesign.
- Widely promote the benefits of riparian management to farmers through awareness programs and demonstration sites on minor streams.

Implications for investment

Implementing riparian management requires very high up-front capital costs. It requires landholders to take land around streams out of production and also has ongoing maintenance and management costs.

The impact of riparian management on water quality has not yet been established, as few comprehensive studies have been undertaken in Western Australia. Two published studies, one on the state’s south coast and another on the Peel Harvey catchment, show widely varying water quality responses to the practice. Local data collected within the Vasse Geographe catchment would help to clarify the water quality response and reduce the risk associated with investment in riparian management. Since this data takes considerable time and expense to collect, average values from the two studies have been used for cost-benefit analysis scenarios.

Despite these costs and uncertainties, riparian management has other significant ecological benefits and is therefore a high-priority action. Given the high cost of implementation, a prioritised approach is likely to be required.

Specific catchments for implementation

Prioritise implementation as follows:

- first- and second-order streams in all reporting catchments draining to the Vasse Wonnerup Estuary in addition to the Toby Inlet reporting catchment
- first- and second-order streams in recovery catchments flowing to Geographe Bay (Vasse Diversion Drain, Five Mile Brook, Gynudup Brook)
- first- and second-order streams in intervention catchments
- first-, second-, and third-order streams based on landholder uptake.

Photo 8: LOW-level riparian management showing fencing to exclude stock and river banks are stabilised with grasses (courtesy Gemma Mincherton, Department of Water).

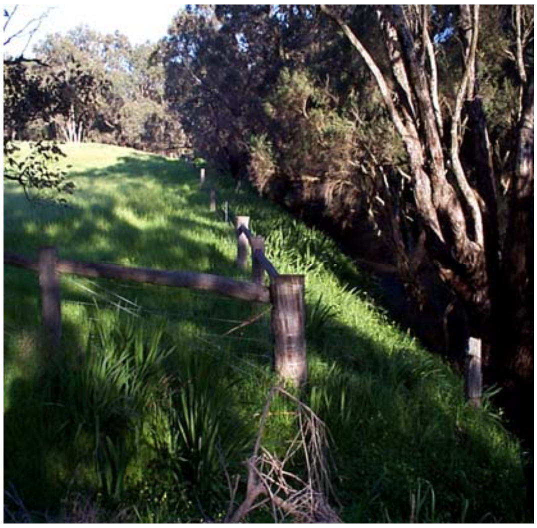


Photo 9: MODERATE-level riparian management showing fencing to exclude stock and banks are stabilised with trees and grasses (courtesy Rob Summers, Department of Agriculture and Food).

Photo 10: HIGH-level riparian management showing fencing to exclude stock, banks are stabilised with trees and grasses and a stream crossing is provided (courtesy Gemma Mincherton, Department of Water).

Photo 11: An off-stream watering point implemented as part of HIGH-level riparian management (courtesy Rob Summers, Department of Agriculture and Food).

3. Using approved soil amendments on sandy soils

Definition

This practice involves the application of high-phosphorus fixing materials to sandy soils to improve their phosphorus-retention capacity and thereby reduce phosphorus leaching.

A potential option in the Geographe catchment includes the use of Neutralised Used Acid (NUA), which is a by-product of synthetic rutile by the mineral-sand mining company Iluka Resources Pty Ltd.

Initial investigations of soil amelioration using subsoil delving has been encouraging. This involves mixing phosphorus-saturated topsoil into the higher phosphorus retention index (PRI) subsoils through soil tillage.

Benefits

Improvements in pasture condition on sandy, less-productive land can be expected, with commensurate increases in production levels and income.

Soil amendments can achieve a very high nutrient-load reduction in catchments with a high proportion of sandy soils. Examples are the Five Mile Brook and Gynudup Brook reporting catchments where the model predicts maximum application would achieve phosphorus reductions of 31 and 22 per cent respectively (Ecotones 2008). Some reporting catchments have a smaller proportion of sandy soils, and in these areas load reduction would be about five to seven per cent. Soil amendments aim to reduce phosphorus losses by improving the PRI of the topsoil. Accordingly, it does not impact significantly on nitrogen losses. With higher phosphorus retention, however, the use of other nutrients by pastures may improve – given that improved pasture growth tends to occur because soil-amending materials are used.

In addition, soil amendments can potentially be used within new urban developments where fill is required to be imported on-site. The use of this technique may have significant value in reducing phosphorus export from fertilised private gardens and public open space areas. This benefit would be particularly important when applied to large new urban developments in recovery catchments and subcatchments.

Soil amelioration involving subsoil delving has the potential benefit of increasing nutrient availability, potentially reducing fertiliser requirements.

Current uptake

The use of 'red mud' as a soil amendment in the catchment is currently not viable given the significant cost in transporting it. The Department of Agriculture and Food, CSIRO and Iluka are currently trialling the use of NUA. Widespread use of these products has not yet been approved as they are still in the product development phase. There are no other commercial applications of soil amendments in the catchment.

Barriers to adoption/limitations

- Alternative products (including 'red mud') that are already approved are not financially viable for use in the Geographe catchment due to the cost of transportation from the production location (ALCOA).
- There is a general lack of other soil amendment products available at a commercial scale.
- NUA products are not yet commercially available and the benefits are still being trialled. There is not yet a complete understanding of the productivity and phosphorus-reduction benefits or potential risks of this tool.
- Approval for commercial use of NUA is required from the WA Environmental Protection Authority, including assessment by the Department of Environment and Conservation.
- NUA will only reduce phosphorus export on soils with low PRI, so will have a low impact on loads from some Geographe reporting catchments and a limited impact on nitrogen loads overall.

Advice for implementation

- Continue trials of NUA to confirm phosphorus-export and pasture productivity benefits; establish feasibility; and identify potential limitations and risks.
- Encourage and assist Iluka to seek formal approval for targeted use of NUA in the Geographe catchment once the outcomes of trialling and testing have been confirmed.
- Undertake demonstration projects and promote the practice to farmers and developers if approval for use is obtained and a commercial product is made available. Large new urban developments within recovery catchments would be

ideal locations to demonstrate use of approved soil-amendment products and techniques.

- Continue trials of soil amelioration and soil delving to confirm nutrient/fertiliser application reduction potential and pasture productivity benefits; establish feasibility; and identify potential limitations.
- Undertake promotion, education and demonstration of approved products and techniques where clear benefits can be demonstrated and risks have been evaluated.
- Work with local councils to establish minimum PRI levels for proposed urban development sites as part of their water quality policies.

Implications for investment

Soil amendments can deliver significant phosphorus-load reductions on sandy soils with a low capital cost and strong economic returns for farmers over time. For example, a cost-benefit analysis of NUA applied at 10 tonnes/ha with 100 per cent adoption demonstrated a total capital cost of one million dollars with a return over 10 years of more than seven million dollars (Ecotones 2008).

Further experimental work is needed to establish approval for the widespread use of NUA in the Geographe catchment. Costs for implementation are therefore associated with:

- experimental trials and monitoring
- promotion, education and demonstration of approved products to farmers
- cost-sharing arrangements.

Specific catchments for implementation

Prioritise implementation as follows:

1 Sandy soils in the Five Mile Brook and Gynudup Brook reporting catchments (where widespread use can potentially achieve very large phosphorus-load reductions).

2 Sandy soils in the Lower Sabina reporting catchment (to maximise phosphorus-load reductions to the Vasse Wonnerup Estuary).

Photo 12: Spreading of NUA (courtesy Rob Summers, Department of Agriculture and Food).

Photo 13: NUA spread at 10 tonnes/ha (courtesy Rob Summers, Department of Agriculture and Food).

4. Using perennial pastures in suitable locations

Definition

This practice involves adding perennial grasses that live and grow continuously for more than two years to annual pasture. In non-irrigated situations perennial grasses include:

- kikuyu and paspalum – suited to wet depressions and drainage lines
- couch – suited to medium and higher sands
- Rhodes – drought tolerant and suited to soils ranging from deep sands and gravels to duplexes with at least 400 mm of sand to clay
- perennial veldt grass – dry sands (Ecotones 2008).

Benefits

Where established successfully, perennials take up more water than annual grasses and their deeper roots enable growth through summer, which can reduce erosion (URS 2008). They may be able to use nutrients that have leached below the level usually reached by annual pasture roots, thereby increasing nutrient-use efficiency (URS 2008).

Modelling indicates that reductions in nitrogen and phosphorus of about 15 per cent could be achieved if there was 100 per cent conversion of all annuals to non-irrigated perennials on all grazing land uses (except dairy where 20 per cent conversion is necessary) (Ecotones 2008). It should be noted, however, that high adoption rates are extremely unlikely given local sentiment that using perennials for broadacre grazing is unfeasible in this catchment.

Current uptake

Current uptake is low: about 4.4 per cent of the Geographe catchment area is covered by perennial pastures – over 70 per cent of which is used for horses or lifestyle blocks (Keipert 2007). Much of this area is likely to be comprised of irrigated pasture.

Barriers to implementation

- Loss of production for at least six months while some species establish and strict establishment procedures for certain species (Keipert 2007).
- Limited success of broadscale use for dairy and beef grazing in the local area.
- Current species suggested for non-irrigated areas do not provide the required level of nutrition for productive lactating dairy cows.
- The predominance of soil profiles that have low water-holding capacity – coupled with winter waterlogging, highly seasonal rainfall and high summer evaporation – means perennials are likely to be suited only to niche landscape/hydrological conditions in the catchment.
- Achieving higher-than-current uptake is expected to be difficult mainly due to limited previous success, time lags for establishment, repayment of capital cost and local distrust of the feasibility of using perennials in this catchment.

Advice for implementation

- Set up demonstration and/or experimental perennial-pasture sites in the local catchment to define areas where they will grow profitably and to clearly establish benefits and constraints to local implementation.
- Provide support to farmers that are willing to undertake replacement of annual pasture with perennial grasses in suitable locations.

Implications for investment

Implementation of perennial pastures at maximum adoption would require a capital cost of $21 million with a net cost over 10 years of about $9 million (Ecotones 2008). These factors combined with their limited applicability may lead to resistance to their implementation in this catchment. Thus perennial pastures have been given a lower priority in the management of diffuse nutrients.

Specific catchments for implementation

The focus for implementation will be recovery catchments in areas where perennial pastures will grow profitably, as well as the Abba River and Toby Inlet intervention catchments where the greatest nutrient-load reductions are required.

Photo 14: Horses on Rhodes grass (courtesy Rob Summers, Department of Agriculture and Food).

Photo 15: Perennial trial at Wagerup (courtesy Rob Summers, Department of Agriculture and Food).

Addressing point-source agricultural nutrient pollution

5. Improving effluent management from dairy sheds and feedlots

Definition

Effluent management includes the collection, conveyance, storage treatment and re-use of solid and liquid wastes (URS 2008). Best-practice dairy and feedlot effluent management should include the following elements as a minimum:

- containment of effluent
- settlement of solids from effluent in a pond or sump
- irrigation of effluent onto pasture or wood lots
- replacement of fertiliser with the irrigated effluent.

Please note: if ponds or sumps for removing solids from the waste stream are absent, then pump and sprinkler failure can occur. Such systems are not sustainable and are therefore not recommended as best practice.

Benefits

Approximately 10 to 15 per cent of nutrient problems arising from dairies is located in and around the dairy shed, with the remaining 85 to 90 per cent derived from diffuse nutrient transport from the farm (Keipert 2007). Therefore the maximum nutrient reduction from effluent management at the dairy shed is about 10 per cent of that produced on the whole farm. For fully shedded industries such as feedlots, as much as 100 per cent of effluent-produced nutrients could be managed.

Current uptake

Many dairy farmers in the Geographe catchment have upgraded effluent treatment systems in recent years as part of the Water Corporation’s environmental improvement initiative or the DairyCatch project. Despite these advances, not all of the effluent upgrades have met the best-practice standards identified above. This is because low-cost systems were installed when the dairy industry was not at its peak. Of the surveyed dairy farmers, about 10 per cent (18 people) said they had effluent ponds, and six per cent (11 people) said the effluent ponds leaked or overflowed. The dairy industry's recent growth combined with the availability of new technology now provides further opportunities for improvement in this area.

Barriers to implementation

- High up-front capital cost required to ensure low-maintenance systems are implemented.
- Most systems require some form of ongoing maintenance for effective operation.
- The success of wood lots is highly dependent on local hydrology and they also require substantial land areas and management/maintenance.

Advice for implementation

- Put cost-sharing arrangements in place to implement or upgrade to best-practice dairy effluent management.
- Widely promote the benefits of effluent management to farmers through awareness programs and demonstration projects.
- Adopt an industry-based approach to promote the implementation of best-management practices.
- Review and revise the dairy industry's codes of practice.

Please note: future programs involving cost-sharing arrangements for dairy effluent management should ensure maximum value is achieved – by only funding systems that meet best-practice effluent management standards. Lower-grade systems that exclude solids removal should not be funded. Furthermore, priority in funding should be given to systems that maximise winter storage of effluent.

Implications for investment

Dairy effluent management is the most cost-effective of all the best-management practices modelled by Ecotones (2008). Although the capital cost was high – estimated at over $1.9 million – the net *benefit* over 10 years was over $9.6 million.

Interestingly, the lower level of effluent management in which solid waste management is not incorporated into the system is the least cost effective of all the best-management practices modelled – with a net *cost* over 10 years of over $8.6 million (Ecotones 2008).

Implementation costs will involve:

- cost-sharing arrangements to help with the capital costs of putting best-practice dairy and feedlot effluent management into place (including upgrading/modifying systems without ponds and sumps)
- technical advice and extension to encourage uptake

- case study monitoring.

Specific catchments for implementation

Implementation should be targeted across the catchment but dairy farms and feedlots in recovery catchments should be first priority.

Photo 16: Trafficable sump with Rankin pump at the Vasse Research Station (courtesy Rob Summers, Department of Agriculture and Food).

Photo 17: Effluent being applied through a travelling irrigator (courtesy Rob Summers, Department of Agriculture and Food).

Managing diffuse nutrients from the urban landscape

6. Reducing nutrient use and export risk in urban areas

Definition

To reduce nutrient use and export in urban areas, community education and awareness programs need to be organised to achieve behaviour changes such as:

- reduced household fertiliser use and improved fertiliser management in the urban home environment and on fertilised areas of public open space
- increased use of indigenous plant species in urban gardens and public open space that have low nutrient and water requirements
- reduced export of nutrients through stormwater drainage systems
- 'cleaner production' practices by businesses within light-industrial areas
- locating new urban developments in low-risk areas for nutrient transport.

Reducing the transport of nutrients from the urban landscape can also be facilitated by:

- riparian management of streams and open drains in urban areas
- retrofitting existing urban areas with water sensitive urban design features (covered as a separate best-management practice recommendation).

Benefits

A nutrient survey of urban households on the Swan coastal plain (including the Busselton area) showed the median application of nitrogen and phosphorus by urban residents was about 1.5 times greater than previous estimates (Kitsios & Kelsey 2008). A small percentage of landowners were fertilising at higher rates than are commonly used in market gardens.

Urban land use in the catchment creates one of the highest nutrient loads per unit area of all land uses owing to the intensity of fertilisation. The close proximity of urban catchments to the receiving waters also gives nutrients from these areas less time to assimilate in-stream. Targeting urban land uses for remediation will therefore give the greatest load reduction per unit area (DOW 2008).

While the overall contribution of nutrients from urban areas is small for the whole catchment, these sources are dominant contributors in some individual reporting catchments. In local areas such as the Lower Vasse River and Toby Inlet, urban nutrient management will be a vital component of the measures required to meet nutrient-load reduction targets. In these areas urban fertiliser management can potentially reduce these loads by about 10 per cent (Ecotones 2008).

Improved nutrient management in urban areas can also result in less need for irrigation and more efficient watering practices within the community.

Current uptake

There is limited data available on the specific nutrient management practices of urban residents and businesses.

Barriers to implementation

- Limited resources currently available for large and comprehensive extension programs in urban areas.
- Wide range of education programs and media required to reach the full audience range.
- High cost of advertising material.
- Urban residents can experience ‘engagement fatigue’, given the wide range of education programs that state government agencies and natural resource management groups have in place.

Advice for implementation

- Implement a comprehensive education and awareness program to widely promote the benefits of urban nutrient management, highlight the ecological values of receiving waters, and raise awareness of how nutrients can degrade these values.
- Implement cost-sharing arrangements to improve adoption of nutrient management practices by businesses in light-industrial areas.

- Lead by example in the community by ensuring that facilities such as playing fields and landscaped town areas demonstrate best-practice nutrient management.
- Undertake further survey and auditing work to assess variations in urban nutrient management across the community and gauge changes in adoption rates.
- Develop and implement policies to ensure future landscaping of new urban areas and public open space uses indigenous plant species with low nutrient and water requirements.
- Facilitate the use of modelling and decision-support tools to help local councils to assess the nutrient-transport risk of proposed new urban expansion areas – as part of broad strategic planning and major urban structure planning.

Implications for investment

Implementation costs would include:

- funding for staff to organise education and awareness programs in the catchment to reduce nutrient use on private land as well as areas of public open space
- cost-sharing arrangements to promote and implement best-management practices in light-industrial areas
- further survey work to define the current management practices being used in urban areas and to monitor changes in the adoption rates of fertiliser management in urban areas.

Specific catchments for implementation

The first priority is the Lower Vasse River and Toby Inlet reporting catchments, where contributions from urban land uses are high and large reductions in nitrogen or phosphorus are needed. The remaining urbanised recovery catchments are the next priority.

Awareness programs can also be put into place across all urban areas in the catchment.

7. Ensuring new urban developments incorporate water sensitive urban design

Definition

Like many areas in Western Australia, the shires of Busselton and Capel are experiencing significant pressure for new urban and industrial areas. These developments are proposed to be located mostly within the recovery catchments of the Vasse Wonnerup Wetlands and Geographe Bay. Because these systems are already stressed, the impact of new developments on the existing water cycle needs to be managed appropriately. This will help ensure reductions in nutrient loads so that the catchment targets can be achieved as far as practicable.

The urban water cycle should be managed as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, groundwater, stormwater, wastewater, flooding, water quality, wetlands, watercourses, estuaries and coastal waters is recognised (Government of Western

Australia 2006). Water efficiency, re-use and recycling are integral components of total water cycle management, as outlined in the *Stormwater management manual for Western Australia* (DOW 2004–2007).

Water sensitive urban design was developed in Western Australia in the 1980s for urban planning and design. It provides a design framework for minimising the impact of urbanisation on the natural water cycle. Consideration of water issues must be integrated with other planning and development issues so that land and water planning are undertaken concurrently, rather than independently and consecutively.

Water sensitive urban design addresses water quality, water quantity and water conservation, together with broader social and environmental objectives – which are expressed as design objectives and criteria. Key objectives of water sensitive urban design are identified in *State planning policy no. 2.9: Water resources* (Government of Western Australia 2006) and *Better urban water management* (WAPC 2008).

The management of nutrients from urban areas is only one aspect of water sensitive urban design, which also deals with flood management, ecological protection and water conservation, efficiency, re-use and recycling.

Water sensitive urban design, in terms of water quality management only, aims to ensure that stormwater from hard surfaces such as roofs and roads is treated before it reaches receiving waterways and waterbodies, largely through the use of structural (or engineering) practices. Water sensitive urban design is also able to achieve improved outcomes through non-structural controls or policy and practices such as education programs, management and maintenance practices and programs, catchment management plans and activities, and town planning controls. These types of controls are able to influence the behaviours and practices of management and maintenance staff and the general community which can lead to, among other things, reduced application of fertilisers and improved building-site practices.

Benefits

Water sensitive urban design is recognised as having the ability to achieve multiple objectives. Although often considered only in the context of drainage, water sensitive urban design also offers opportunities for conserving drinking water as well as for catchment repair and improvements in the environmental health of our waterways, wetlands and other water-dependent ecosystems.

Water sensitive urban design is also about the planning of infrastructure and services to make the best use of infrastructure and water resources to maximise water re-use and recycling.

Addressing water resource issues ‘early’ in the planning system also ensures that solutions may be incorporated into the structure of urban areas, thereby facilitating more timely approvals and reducing bottlenecks at the subdivision and development-approval stages. This also provides more certainty for development outcomes.

Current uptake

The Swan coastal plain has seen significant advances in water sensitive urban design during the past few years. This has been primarily in greenfield development in the Swan Canning and Peel Harvey catchments, however structure planning for the Ambergate, Provence and Vasse Newtown developments will also incorporate water sensitive urban design best-management practices as far as possible.

Barriers to adoption

There are some impediments to achieving water sensitive urban design in Western Australia. These include:

- lack of clear governance structures, roles, responsibilities and accountabilities
- lack of understanding about the requirements for integrating water resource management with planning processes and decision making
- lack of understanding about catchment-scale ground and surface-water conditions and significant environments that need to be protected
- lack of appropriate water quality and quantity targets and tools to demonstrate compliance
- lack of local knowledge relating to performance, cost and maintenance requirements of best-management practices
- the need for increased awareness about the importance and effectiveness of water sensitive urban design actions.

Several projects are underway to address these barriers as part of the Coastal Catchments Initiative. They include:

- development of a framework for integration of water into the planning system, known as *Better urban water management*
- development of planning policies and provisions, technical guidelines, and decision-support systems including *Guidelines for the use of MUSIC on the Swan coastal plain*
- a capacity-building program for water sensitive urban design known as New Water Ways <www.newwaterways.org.au>.

Advice for implementation

The achievement of water sensitive urban design will be enhanced through the following general principles:

- Coordination: effective water sensitive urban design involves the existing disciplines of planning and urban design; engineering; landscape protection and design; and infrastructure and service provision. These functions have traditionally been delivered in isolation from each other, coming together only at the last stage in the development process – subdivision and detailed design. It is vital that integration of these activities occurs far earlier in the process if the best-possible water management solution is to be delivered.
- Consultation: a high level of consultation should occur with all stakeholders, particularly the Department of Water and local government. This should involve a

high level of technical support from the Department of Water for local government (particularly planning officers, given their role in reporting and decision making on urban proposals). Outcomes will be enhanced when this occurs early in the project planning process.

- Start simple but demonstrate continual improvement: water sensitive urban design solutions should be simple and respond to the conditions on-site. More complex solutions can be implemented during the development's later stages if desired.
- Document results and share learning: there is a lack of local information about the performance, cost and maintenance requirements of many best-management practices. This information should be made freely available by developers and local councils so that broader support and understanding is achieved.
- Support champions: there are many champions for water sensitive urban design across government and industry. These people play a vital role in facilitating improved outcomes and should be supported where possible.
- Educate the community: there is a need to ensure the public is aware of the importance of water quality treatment measures when they are incorporated into their residential developments, so that impediments to maintenance and function are minimised. The community should also be better informed about how their actions, particularly that of applying fertiliser, can affect the receiving waterbodies of the Vasse Wonnerup Wetlands and Geographe Bay.

Photo 18: Xeriscaped household garden, Sustainable Mandurah Home, Grandmere Parade, Meadow Springs (Courtesy Shelley Shepherd).

Photo 19: Flush kerbing to allow frequent stormwater events to flow to vegetated areas for treatment and infiltration, retaining natural bush where possible. Public open space, Seascapes, Halls Head.

Specific actions required to improve implementation of water sensitive urban design include:

- continue water sensitive urban design capacity-building programs and implementation of controls identified in the *Stormwater management manual* (DOW 2004–2007)
- develop assessment tools to aid local council decision making on the performance assessment of drainage management plans
- implement on-ground research into the performance of best-management practices for water sensitive urban design
- help local councils to adopt local water management planning policies and incorporate them into town planning schemes and/or local planning strategies.

Implications for investment

New developments will be required to provide appropriate information on the water resources in their development areas to support planning decision-making. This is likely to require field investigations and preparation of appropriate documentation, which has budgetary and timing implications.

The Department of Water and local councils will also need to have sufficient resources to assess and approve of water management information in a timely fashion and provide advice to the planning decision-maker as appropriate.

Additional funding is likely to be required for:

- ongoing capacity-building programs
- development of assessment tools
- on-ground research into the performance of best-management practices.

Specific catchments for implementation

All catchments with existing or proposed urban areas with a focus on recovery catchments.

8. Achieving no net increase or a net reduction in nutrient loads from large new urban developments

Definition

Projections of the impact of urban expansion suggest large increases in the load of phosphorus being delivered to Geographe Bay and the Vasse Wonnerup Wetlands. These projections have been based on the construction of ‘traditional’ urban developments; however, the use of best-practice water sensitive urban design is expected to reduce this overall load increase by about 60 per cent for phosphorus and 45 per cent for nitrogen.

Recent research (Kitsios & Kelsey 2008) has suggested that even if water sensitive urban design is implemented, an increase in nutrient load from each developed area may still occur, largely as a result of landowners using fertiliser on their lawns and gardens. This increase in nutrients to receiving waters is of concern, particularly as many areas proposed for urban expansion are in recovery reporting catchments where water quality is already poor and large nutrient-load reductions are necessary to protect the receiving waters. It may also counteract work undertaken in the rural part of the catchment to reduce loads from agricultural sources.

Achieving no net increase or a net reduction in nutrient loads from new developments over the long term, even with water sensitive urban design, is likely to require either of the following approaches or possibly a combination of the two:

1. Implementing a range of additional structural and non-structural controls within developments. Many examples of non-structural controls are listed in Chapter 7 of the *Stormwater management manual* (DOW 2004–2007), some of which include:
    - soil amendment within new urban developments located on sandy soils
    - landscaping rebate packages offered by developers to boost the number of nutrient- and water-wise gardens on suburban lots
    - community-based education programs to actively encourage a wide range of nutrient- and water-wise management practices
    - alternative water sources to enable the use of recycled or re-used water options
    - ‘smart’ irrigation and best-practice fertiliser management for public open spaces, schools and sporting ovals.
2. Using a nutrient-offset arrangement in which developers pay for or undertake equivalent nutrient-remediation works elsewhere in the same reporting catchment to mitigate the expected increase in nutrient load. The position and principles for application for nutrient offsets is discussed in Section 6.7.

Benefits

A net reduction approach to new developments in recovery catchments will prevent the projected increase in nutrient loads associated with urban expansion.

By implementing the measures proposed above, developers will become known as environmentally responsible. Should monitoring programs be established, they will be able to demonstrate this responsibility by showing a net improvement in nutrient impacts from their proposals. Where offset arrangements are considered, these could be targeted at the types of nutrient-remediation measures that might otherwise be difficult to do because of high up-front capital costs.

Current uptake

Many recent developments across the Swan coastal plain have included a range of non-structural stormwater management practices. In most cases, such inclusions have been on a voluntary basis.

Offset arrangements are not a new concept in the Vasse Geographe catchment. The Water Corporation implemented a five-year one-million-dollar nutrient-offset scheme as part of the upgrade of the Busselton wastewater treatment plant between 1999 and

2004. This scheme applied rural best-management practices to reduce the net nutrient load flowing to Geographe Bay.

To date nutrient-offset arrangements have not been applied to urban developments in the catchment; however, biodiversity offsets have been used to replace western ringtail possum habitat lost as a result of urban expansions or infill urban development. Such offsets have been negotiated with developers through the Australian Government's *Environmental Protection and Biodiversity Conservation (EPBC) Act 1999*.

Barriers to implementation

- Current lack of appropriate statutory or policy mechanisms to trigger requirements for nutrient offsets or mandatory use of non-structural stormwater controls to meet specific water quality targets.
- Limited timeframe available to negotiate nutrient offsets as part of the development process in the catchment, given planning for 20 to 30 years of projected growth is occurring now.
- Gaps in data on the nutrient-reduction benefits of some water saving urban design techniques complicate calculations of the expected nutrient loads for individual proposals.
- Industry expectations for equity in the way individual proposals are assessed (regardless of the location or scale) may pose a barrier to negotiations for non-structural controls or nutrient offsets.

Advice for implementation

Use of non-structural stormwater measures or nutrient-offset arrangements are currently negotiated with developers on a case-by-case basis. Wider application of these measures could be achieved with the adoption of an appropriate policy and/or regulatory framework.

Consistent application of the measures across a broad range of urban developments is also likely to encourage acceptance and uptake by the development industry and therefore achieve high-quality on-ground outcomes.

With regard to the use of nutrient offsets, more feasibility studies are needed. Currently offset arrangements can be sought through the provisions of the *Environmental Protection Act 1986* (WA) or through conditions of subdivision or development early in the planning process during rezoning. BDA (2008) recommends that further legal advice be sought on both options before attempting to implement them. The measures can also be put in place through the EPBC Act (Cwlth) where development is proposed in recovery catchments flowing to the Vasse Wonnerup Wetlands. While there is more certainty about the legal framework for this option, more formal guidelines for implementation need to be established with the Australian Government to ensure that best-practice offset principles are followed.

Implications for investment

Achieving no net increase or a net reduction in nutrient loads from new urban developments will require additional resources from state and local governments (in terms of personnel) for:

- research and development into new urban water management practices
- scoping implementation options
- negotiating implementation with individual proponents
- developing policy and/or regulatory mechanisms
- managing implementation.

Specific catchments for implementation

The first priority for implementing these additional measures is large new urban developments (greater than 50 lots) in recovery catchments. These include:

- the Lower Vasse River, Sabina River and Ludlow River reporting catchments flowing to the Vasse Wonnerup Wetlands
- the Upper Vasse River/Sabina diversion, Gynudup Brook and Five Mile Brook reporting catchments flowing to Geographe Bay.

9. Undertaking strategic retrofitting of water sensitive urban design in existing urban areas

Definition

Retrofitting is the process of installing or undertaking additional or alternative stormwater management devices or approaches in an existing developed area (DOW 2004–2007). Opportunities for retrofitting arise when redeveloping or upgrading existing developments and infrastructure, and can occur at the lot, street, estate or catchment scale.

Most urban areas have a traditional piped and drained system to manage flooding and groundwater tables. This type of system does not effectively manage the nutrients contained in stormwater or groundwater that enters the network of pipes and drains.

Traditional drainage systems modify natural water balances: retrofitting minimises the impact of this by increasing the amount of rainfall that is recharged to the groundwater and restoring natural surface-water systems where possible.

Retrofitting techniques include:

- Increasing temporary storage of stormwater to reduce peak flows and increase infiltration. Storage areas may also be used to remove pollutants by incorporating bioretention systems or garden beds with amended soil.
- Reducing impermeable areas by installing permeable surfaces or disconnecting hard surfaces (such as roads or car parks) with the use of broken kerbing, side entry pits, soakwells, raingardens or bioretention basins, swales, garden beds and vegetated open spaces.

- On-site capture and re-use of water with rainwater tanks or soakwells and garden bores.
- Rehabilitation of open drainage systems or removing sections of subsurface pipe and replacing them with vegetated swales or 'living streams'.
- Erosion and sediment control.

Benefits

As well as reducing flood risk and improving water quality, retrofitting can achieve many other objectives, such as: reduced potable water use through re-use of stormwater, improved public health and safety, catchment repair and restoration, creation of more attractive and liveable neighbourhoods and public spaces, reduced irrigation needs in public open spaces, retention or enhancement of cultural values, and increased community awareness about the need for better management of the water cycle. This ability to meet multiple objectives demonstrates the cost effectiveness of retrofitting, particularly when compared with conventional capital works programs.

Current uptake

Due to changes in state government policy, most redevelopment projects are required to incorporate water sensitive urban design. Most local councils are also supportive of the principles of water sensitive urban design and are starting to incorporate them into their capital works programs.

Barriers to adoption

Retrofitting is most effective if planned for at a catchment scale. To achieve this, however, funding is required for a stormwater management plan and then additional funding is needed to implement works that cannot be incorporated into capital works programs (due to scheduling and age of infrastructure). In addition, it is often difficult to identify opportunities for retrofitting until a catchment/local government-scale plan is undertaken.

Redevelopments and infill developments are constrained by the size of the land parcel and existing systems and capacity. This is particularly relevant in areas already at capacity (for flood risk) and where the watertables are high.

Advice for implementation

Nutrients are most effectively managed when a combination of solutions are implemented in a 'treatment train'. This includes minimising generation of pollutants (at source), disconnecting pollutant transport pathways (in-system) and capture or treatment of nutrients before they reach the main drain or receiving waterbody (end-of-pipe). Developing a comprehensive system of management requires a planning approach that looks at the whole catchment (or local government area).

All redevelopments and infill/brownfield developments should address the principles of water sensitive urban design, consistent with *State planning policy 2.9: Water resources* (Government of Western Australia 2006).

Specific advice for implementation includes:

- development of stormwater management plans for local government areas to help identify opportunities and priorities for undertaking water sensitive urban design retrofitting projects
- use of strategic monitoring to evaluate the best-management practices associated with retrofitting projects.

Implications for investment

Retrofitting should be included as an outcome of any local council capital works program. It is also appropriate in redevelopment and infill circumstances, provided the site is not completely constrained by its size or existing systems and capacity.

Where capital works are not proposed, additional funding would be required for retrofitting as well as to develop a stormwater management plan.

Specific catchments for implementation

Urbanised recovery catchments (Lower Vasse River, Vasse Diversion Drain and Five Mile Brook) are the highest priority for retrofitting.

Managing urban point sources

10. Achieving no net increase in nutrient loads from wastewater treatment plants

Definition

The expansion of the catchment's urban areas will eventually lead to higher effluent volumes from existing wastewater treatment plants and, in some cases, these plants will need to be upgraded to meet the increased demand.

The Water Corporation's growth projections for Dunsborough and Busselton are outlined below (Peter Spencer, Water Corporation, pers. comm.).

Treatment plant	Current average daily flow	Current wastewater treatment plant capacity	Next upgrade planned
Dunsborough	1.3 ML/d	2 ML/d	4 ML/d (2012)
Busselton	3.6 ML/d	4.5 ML/d	9 ML/d (2011) 18 ML/d (beyond 2020)

Preventing net increases in nutrient loads from wastewater sources can be facilitated by:

- nutrient-offset arrangements in which the Water Corporation would pay for or undertake equivalent nutrient-remediation works elsewhere in the reporting catchment to mitigate the expected nutrient-load increase
- implementing improvements in wastewater treatment technology to enable an increased volume of effluent to be treated without increasing the overall load

- increasing re-use of treated wastewater effluent as an alternative to direct disposal to the waterways or Geographe Bay.

Any of these options or a combination of the three can be used to prevent net increases in nutrient loads from recovery catchments.

Benefits

The Busselton wastewater treatment plant currently discharges treated wastewater to the Vasse Diversion Drain in Busselton. This reporting catchment has very high nutrient-reduction targets with further nutrient-load increases expected as a result of planned urban expansion. Preventing any further increases in nutrient loads from the plant either through improvements in treatment technology, re-use strategies or a nutrient-offset scheme will be part of a catchment-wide approach to meet phosphorus and nitrogen targets.

Current uptake

The Water Corporation instigated the Busselton environmental improvement initiative in the catchment between 1999 and 2004 to offset the nutrient loads from the plant. This program resulted in an investment of one million dollars to reduce nutrient loads from the rural catchment.

Current plans to upgrade the Busselton wastewater treatment plant include the use of new technology to reduce the current nutrient load from the plant despite the increase in the volume of effluent to be discharged.

Barriers to implementation

- Notwithstanding the planned use of improved technology, continued rapid growth in the catchment may eventually lead to higher nutrient loads being discharged.
- High capital costs for upgrades to wastewater treatment plants and competition for funding priorities from other regional areas in the state.
- High groundwater levels in Busselton make some alternative wastewater treatment options unfeasible, such as irrigated wood lots.
- The shallow bathymetry[6] of Geographe Bay and the presence of sensitive and extensive seagrass meadows create environmental limitations and potentially high capital costs for the construction of an ocean outfall in Busselton.

Advice for implementation

- Maintain a policy of ‘no net increase in nutrient loads’ in relation to wastewater treatment plant upgrades. This can be facilitated through the Environmental Protection Authority approvals process and may include technology upgrades and/or re-use options.
- In the event that nutrient-offset arrangements are negotiated as part of the approvals process for wastewater treatment plant upgrades, develop partnerships

[6] The measurement of water depth in oceans, seas or lakes.

between the Department of Water, GeoCatch and the Water Corporation to identify options for nutrient-offset projects.

Implications for investment

Funding for upgrades of wastewater treatment plants and any potential offset arrangements will be included within annual Water Corporation financial budgets.

Specific catchments for implementation

Reporting catchments with wastewater treatment plants include the Vasse Diversion Drain, Annie Brook and Capel River catchments.

11. Developing solutions to large nutrient loads delivered by septic systems in specific reporting catchments

Definition

Water quality modelling indicates that from septic tanks alone, the Busselton light-industrial area delivers approximately 0.45 tonnes of phosphorus (9.4 per cent of the total phosphorus load) and 1.3 tonnes of nitrogen (3.7 per cent of the total nitrogen load) to the river annually (Hall 2008). In the Toby Inlet reporting catchment, septics contribute 6.5 and 7 per cent of phosphorus and nitrogen loads respectively.

The Water Corporation's infill sewerage program began on 1 July 1994 with the aim to provide a sewerage service to 100 000 properties state-wide (80 000 properties within metropolitan Perth and 20 000 properties in country towns) at an estimated cost of $800 million. Large areas of the Busselton town site have already been serviced with infill sewers as part of the program. At this stage, there are no plans to expand the program any further in Busselton or Dunsborough beyond that required to service new urban developments (Peter Spencer, Water Corporation pers. comm.).

Further expansions to the infill sewerage program beyond those already planned would require the allocation of additional funding. In some cases, other viable alternatives to alleviate nutrient loads from septic tanks may exist, such as replacement with alternative treatment units (ATUs) where this is practical and viable.

Benefits

Removal of nutrient loads contributed by septic tanks through connections to deep sewerage has immediate and long-term positive effects. The reductions would be significant in only a few reporting catchments, yet there is much to be gained from a focused and strategic approach to implementation.

Current uptake

Extensive infill sewerage works have already been undertaken within the Busselton town site, though at this stage there are no plans to extend the program further.

Barriers to implementation

- High capital cost for implementation.
- Competing priorities from other areas in the state.

- No current plans or available funding to extend the infill sewerage program in Busselton or Dunsborough.

Advice for implementation

- Negotiate additional funding to expand the infill sewerage program to include urban residential land in the Toby Inlet catchment and the Busselton light-industrial area in the Lower Vasse River catchment.
- To help negotiations and feasibility assessments: undertake an audit of waste streams from the Busselton light-industrial area using the Water Corporation's criteria for acceptance of industrial waste.
- Investigate the feasibility of alternative options such as replacement of septic tanks with ATUs.

Implications for investment

The existing infill sewerage program would require additional funding to extend the service any further within Busselton or Dunsborough (beyond that which is set aside for new urban developments).

Cost-sharing arrangements are likely to be required for other options such as replacement of septic tanks with ATUs.

Specific catchments for implementation

The Toby Inlet and Lower Vasse River reporting catchments are high priorities, given that nutrient loads from septic tanks are large and likely to be making a sizeable contribution to existing severe water quality problems.

6.3 Cost-benefit analysis and interim targets

A cost-benefit analysis over a 10-year hypothetical period was completed using the computer-based Support System for Phosphorus and Nitrogen Decisions (SSPND). The Department of Agriculture and Food developed SSPND as part of the Coastal Catchments Initiative project. Further information about SSPND is provided in Appendix B and the results of a range of other catchment-wide best-management-practice scenarios undertaken by Ecotones (2008) are presented in Appendix E. Results of the Department of Water's scenario modelling using SQUARE (outlined in Appendix A) provided data on the predicted benefits of implementing recommendation 10.

Recommendations 7, 8, 9 and 11 could not be included in this cost-benefit analysis due to insufficient data about implementation costs or because the rates of nutrient removal associated with their implementation varied widely according to site-specific factors.

Recommendations 1 to 6 and 10 capture all of the agricultural nutrient management recommendations and two urban recommendations as follows:

- **Managing diffuse agricultural nutrients:**
  1 improving fertiliser management throughout the catchment

2 implementing riparian management and stock control on streams and drains

3 using soil amendments on sandy soils

4 using perennial pastures in suitable locations and situations.

- **Managing point-source agricultural nutrients:**

5 improving effluent management at dairy sheds and feedlots.

- **Managing diffuse nutrients from the urban landscape:**

6 reducing nutrient use and export risk in urban areas.

- **Managing urban point sources**:

10 achieving no net increase in nutrient loads from wastewater treatment plants in recovery catchments (example for Busselton wastewater treatment plant only).

Given that the vast majority of the current nutrient load is derived from agricultural sources, the above recommendations are likely to include most of the capital investment required to address current nutrient export in the catchment.

The cost-benefit analysis was performed by making selections of appropriate best-management practices and rates of uptake for each reporting catchment that would be suitable for implementation over a 10-year period. The SSPND model was then applied to these scenarios. The model provided data about the estimated load of nitrogen and phosphorus removed, the capital cost of implementation and a breakdown of the land uses that contributed to the load reduction. Selected scenarios were adjusted in SSPND until the nutrient-removal rates either roughly matched the required targets, or such rates were maximised without exceeding the likely achievable rates of best-management-practice adoption within a 10-year period. In undertaking these selections consideration was given to:

- ratios of individual reporting catchment land uses
- physical characteristics of each reporting catchment such as prevalence of low phosphorus retention index (PRI) soils
- theoretically achievable rates of adoption over a 10-year period assuming innovation in maximising uptake of best-management practices is applied
- the size of the nutrient-reduction targets in each reporting catchment
- the capital cost of best-management practices compared with the net return provided to farmers (low-cost, high-return options were favoured as a first step followed by higher-cost best-management practices to improve rates of nutrient removal where needed).

Results of the cost-benefit analysis are presented for each recommendation in Table 11. This summary includes a description of the relevant rate of adoption that was applied for the scenario and the reporting catchments it was applied to.

Across the whole catchment SSPND predicted that the selected management scenarios could reduce the total phosphorus load by 27 per cent and the nitrogen load by 36 per cent. A gross return of $24 million was estimated for this outcome. This needs to be balanced against the capital cost for implementation, which was over $14.6 million or $1.46 million annually over 10 years. This results in a net return of $9.4 million, with the major factors being improved productivity and more efficient use of fertilisers.

Individually, each of the agricultural nutrient management recommendations resulted in net financial returns for farmers with the exception of riparian management and perennial pastures, which were associated with an overall net cost. On balance, however, the model suggested there was potential for costs associated with these tools to be balanced by gains associated with putting the remaining recommendations in place. Initial test scenarios also demonstrated that in many reporting catchments the nutrient-reduction targets could not be met without implementation of extensive riparian management works. Furthermore, the primary benefit of riparian management is for nitrogen removal and there are few other available rural best-management practices for nitrogen management. The high capital costs associated with riparian management include maintaining fences and undertaking weed control, as well as the value of lost production from fenced-off areas.

The nutrient-load reduction predicted by SSPND for each reporting catchment is summarised in Table 12. This summary illustrates that implementation of the selected management scenarios could achieve or be within 15 per cent of the targets for all protection and intervention catchments – except the nitrogen target for the Buayanyup River reporting catchment. For recovery catchments, only the Ludlow River phosphorus target and Gynudup Brook nitrogen targets were achieved or within 15 per cent. For all other catchments (shaded red in the table) the targets could not be reached and therefore the load reductions predicted to be achieved are presented as 10-year interim targets. In some cases these interim targets are substantially lower than the original long-term targets proposed. Interim targets were identified for the following reporting catchments and are summarised on a catchment basis in Table 10.

Vasse Wonnerup reporting catchments

- Lower Vasse River (phosphorus and nitrogen)
- Lower Sabina River (phosphorus and nitrogen)
- Ludlow River (nitrogen)

Geographe Bay reporting catchments

- Buayanyup River (nitrogen)
- Vasse Diversion Drain (phosphorus and nitrogen)
- Gynudup Brook (phosphorus)
- Five Mile Brook (phosphorus and nitrogen)

Table 10: Summary of long term and interim nutrient targets.

Loads and targets	Vasse Wonnerup Wetlands	Geographe Bay
Total phosphorus		
Current load (tonnes/yr)	15.6	53.4
Long-term reduction targets (reduce by x tonnes/yr)	6.4	20.0
Long-term reduction targets (% of current load)	41%	38%
Interim 10-yr reduction targets (reduce by x tonnes/yr)	3.7	10.3
Interim 10-yr reduction targets (% of current load)	23%	19%
Total nitrogen		
Current load (tonnes/yr)	133.7	409.2
Long-term reduction targets (reduce by x tonnes/yr)	73.8	177.4
Long-term reduction targets (% of current load)	55%	43%
Interim 10-yr reduction targets (reduce by x tonnes/yr)	48.7	124.9
Interim 10-yr reduction targets (% of current load)	36%	30%

Despite the requirement for interim targets for seven of the 14 subcatchments, the 10-year management scenarios presented in this cost-benefit analysis are considered both realistic and encouraging in terms of the potential achievement of overall nutrient-load reduction and net financial benefits. Accordingly, these scenarios have been used as a basis for developing specific reporting catchment recommendations as presented in Section 6.4. Should funding and resources be limited even further, an additional prioritisation process may be required. There are many different ways to prioritise such works, including:

1 Actions with a low capital cost per kilogram of phosphorus and nitrogen removed. It should be noted that such costs are highly dependent on the selections made for management scenarios – both in terms of the management practice and the location – and accordingly may not be a reliable indicator for priorities when used in isolation.

2 Actions within subcatchments facing the greatest increases in nutrient loads over the next 20 years. Examples include the Vasse Diversion Drain and the Lower Vasse River subcatchment.

3 Actions within subcatchments or catchments with the highest natural values under threat. Examples include all subcatchments draining to the Vasse Wonnerup Wetlands and other wetlands such as Toby Inlet.

4 Priorities that fit well with available sources of funding or that can be linked with other initiatives such as the Fertiliser Action Plan*.*

The first scenario above has already been evaluated by Ecotones (2008), as presented in Appendix E.

Table 11: Results of the cost-benefit analysis using SSPND

Management intervention	Description	Reporting catchments for implementation	TP removal kg (% of current total load from all catchments)	TN removal kg (% of current total load from all catchments)	$ / kg nutrient removed		Total capital cost	Annual cost over 10 yrs[7]	10-yr net benefit
					TP	TN			
1. Agricultural fertiliser mgt	100% uptake of best-practice agricultural fertiliser mgt on cattle for beef and dairy, mixed grazing and horses and 75% uptake on lifestyle lots. Low-water-soluble fertiliser on low PRI soils.	All reporting catchments	5107 (9.2%)	20 228 (4.6%)	$170	$43	$870 670.00	$87 067.00	$15 313 664
2. Riparian mgt	**Level 1** • 50% adoption riparian mgt 'low'[8] on 1st order streams • 70% adoption 'moderate' on 2nd order streams • 100% adoption 'high' on 3rd order streams	Lower Vasse, Lower Sabina, Ludlow, Vasse Diversion, Gynudup, Five Mile	4984 (9%)	68 591 (15.7%)	$1195	$87	$5 958 793.00	$595 879.30	-$10 724 042

[7] This figure represents the difference between the capital and ongoing costs and benefits

[8] Definitions for low, medium and high riparian management implementation are provided in Section 6.2.

Management intervention	Description	Reporting catchments for implementation	TP removal kg (% of current total load from all catchments)	TN removal kg (% of current total load from all catchments)	$ / kg nutrient removed	Total capital cost	Annual cost over 10 yrs[9]	10-yr net benefit	
	Level 2 • 35% adoption 'low' on 1st order streams • 50% adoption 'moderate' on 2nd order streams • 100% adoption 'high' on 3rd order streams	Abba, Toby Inlet, Annie, Buayanyup	1642 (2.9%)	25 059 (5.7%)	$1510	$98	$2 479 865.00	$247 986.50	-$4 377 059
	Level 3 • 20% adoption 'low' on 1st order streams • 35% adoption 'moderate' on 2nd order streams • 70% adoption 'high' on 3rd order streams	Jingarmup	14 (0.03%)	733 (0.17%)	$3164	$60	$44 291.00	$4429.10	-$77 118
3. Soil amendment	50% adoption of 10 tonnes/ha NUA plus LWS fertiliser	Lower Sabina, Gynudup, Five Mile	1171 (2.10%)	998 (0.23%)	$291	$341	$341 256.00	$34 125.60	$2 384 584
4. Perennial pastures	**Level 1** • 35% adoption on beef cattle; 5%	Lower Vasse, Lower Sabina, Ludlow, Vasse	1446 (2.60%)	11 210 (2.56%)	$2044	$263	$2 956 282.00	$295 628.20	-$1 239 102

[9] This figure represents the difference between the capital and ongoing costs and benefits

	adoption on dairy	Diversion, Gynudup, Five Mile							
	Level 2 • 20% adoption on beef cattle	Buayanyup	114 (0.20%)	957 (0.22%)	$3302	$393	$376 455.00	$37 645.50	-$157 788
5. Dairy effluent mgt	**Level 1** • 100% uptake of best-practice dairy effluent mgt	Abba, Annie, Buayanyup, Vasse Diversion, Lower Vasse, Lower Sabina, Ludlow, Gynudup	410 (0.74%)	2359 (0.54%)	$3725	$647	$1 527 500.00	$152 750.00	$7 681 267
	Level 2 • 50% uptake of best-practice dairy effluent mgt	Carbunup, Capel	24 (0.04%)	140 (0.03%)	$4739	$812	$113 750.00	$11 375.00	$572 009
6. Urban fertiliser mgt	50% urban fertiliser program with 100% adoption on urban residential and 50% on lifestyle and rural residential	Toby Inlet, Lower Vasse, Vasse Diversion, Five Mile	1797 (3.23%)	13 682 (3.13%)	Not costed		Not costed	Not costed	Not costed
10. No net increase from wastewater treatment plants	Upgrading technology at the Busselton wastewater treatment plant to prevent future increases in load.	Vasse Diversion	Prevents predicted increase of 2630 kg P	Prevents predicted increase of 3100 kg N	Not costed		Not costed	Not costed	Not costed
Total			15 244 (27.38%)	157 161 (35.95%)	N/A		$14 668 862.00	$1 466 886.20	$9 376 415

Table 12: Predicted target achievements (and interim targets) in reporting catchments following implementation of management recommendations

Reporting catchment	Management scenario modelled	% P reduction predicted	P target (% reduction required)	% N reduction predicted	N target (% reduction required)
Protection catchments					
Dunsborough	• Agricultural fertiliser mgt	13.7	0	17	0
Carbunup	• Agricultural fertiliser mgt • Dairy effluent mgt (medium)	5.3	0	6.2	0
Capel	• As for Carbunup	5.46	0	8	0
Intervention catchments					
Abba	• Agricultural fertiliser mgt • Dairy effluent mgt (high) • Riparian mgt (medium)	19.5	0	28.2	25
Toby Inlet	• Agricultural fertiliser mgt • Riparian mgt (medium) • Urban fertiliser mgt	23.3	0	32.9	36
Jingarmup	• Agricultural fertiliser mgt • Riparian mgt (low)	11.2	0	18.6	18
Annie	• As for Abba	17.1	0	28	23
Buayanyup	• Agricultural fertiliser mgt • Riparian mgt (medium) • Perennial pastures (medium) • Dairy effluent mgt (high)	20.6	0	32.9	51
Recovery catchments					
Lower Vasse	• Agricultural fertiliser mgt • Riparian mgt (high) • Perennial pastures (high) • Dairy effluent mgt (high) • Urban fertiliser mgt	44.2	67	56.2	70
Lower Sabina	• Agricultural fertiliser mgt • Riparian mgt (high) • Perennial pastures (high) • Soil amendment • Dairy effluent mgt (high)	27	74	32	71
Ludlow	• Agricultural fertiliser mgt • Riparian mgt (high) • Perennial pastures (high) • Dairy effluent mgt (high)	23	21	34	55
Vasse Diversion	As for Lower Vasse • Upgrade Busselton wastewater treatment plant	27	71	37.7	56
Gynudup	As for Lower Sabina	38.3	49	37.4	43
Five Mile	• Agricultural fertiliser mgt • Riparian mgt (high) • Perennial pastures (high) • Soil amendment • Urban fertiliser mgt	50.5	76	45	75

Key:

Target exceeded or achieved	Within 15% of target	> 15% of target, interim target proposed

6.4 Recommendations for reporting catchments

Protection catchments

Dunsborough streams

Water quality objective: Protection – maintain good water quality				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	0.13	0.17	0	0
Nitrogen	1.3	1.7	0	0

Summary of status and trends

The Dunsborough streams include the Meelup, Dandatup and Dugalup brooks. They currently maintain very good water quality in terms of both nitrogen and phosphorus, despite having a large proportion of urban land use in the overall catchment. The high PRI of soils in the catchment combined with good quality riparian vegetation and low stocking rates on agricultural land are likely reasons for this water quality status. Water quality modelling indicates that further urban expansion has potential for some increases in both phosphorus and nitrogen loads, and accordingly management will need to focus on preventing any further decline in water quality.

Nutrient sources

Diffuse urban pollution and septic systems are the dominant sources of nutrients from this subcatchment.

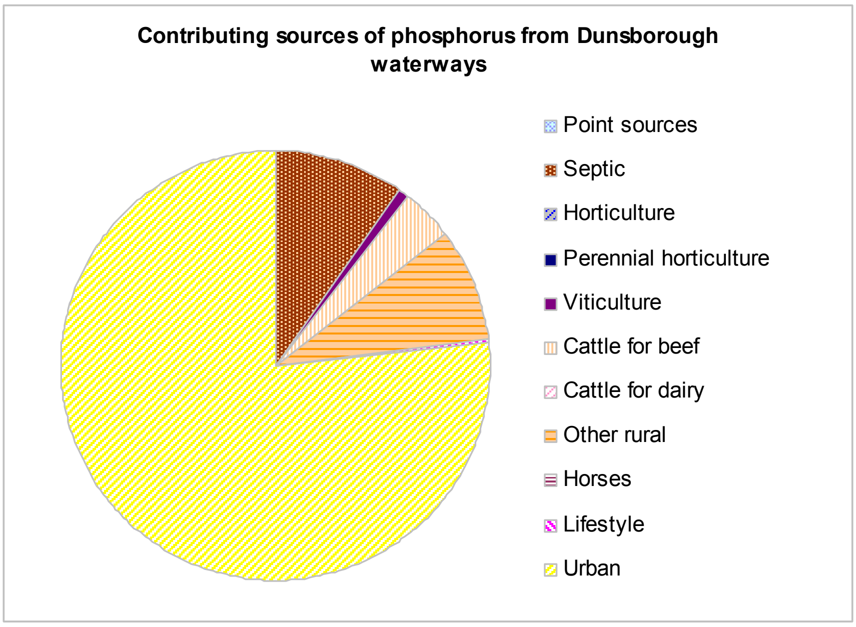


Figure 47: Contributing sources of phosphorus to the Dunsborough streams.

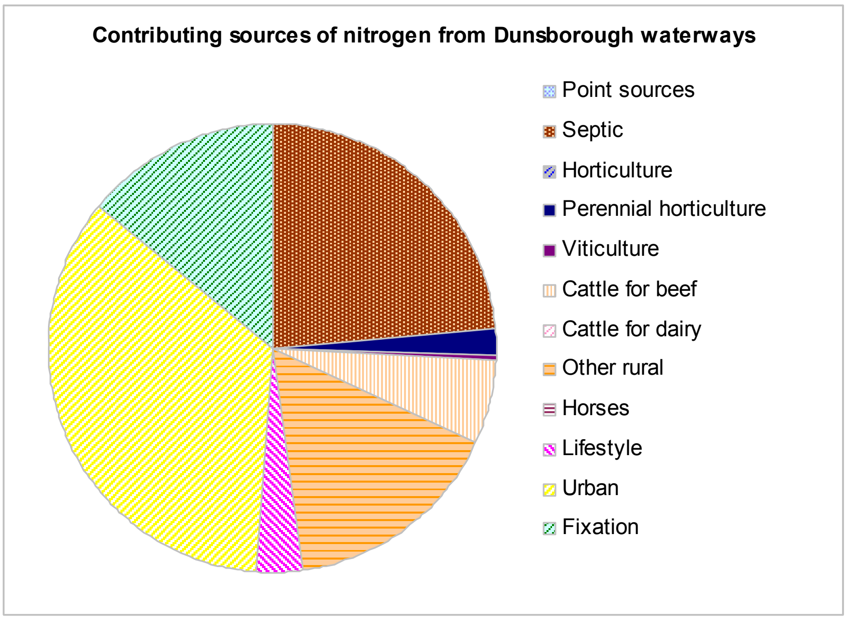


Figure 48: Contributing sources of nitrogen to the Dunsborough streams.

Prioritised nutrient action and goals

Action	Ten-year management goal
Undertake awareness programs to ensure community recognition of existing values.	High level of community awareness about catchment values.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than is currently delivered by the existing land use on the land in question.
Promote adoption of best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Continue monitoring of this subcatchment to assess for changes in nutrient status.	No significant increase in the winter median concentration of nitrogen and phosphorus concentrations in the Dunsborough streams.

Challenges for nutrient management

- Rapid urban growth.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient offset arrangements.
- Incremental loss of riparian vegetation.

- Balancing groundwater and surface-water extraction and environmental flows with nutrient management targets.

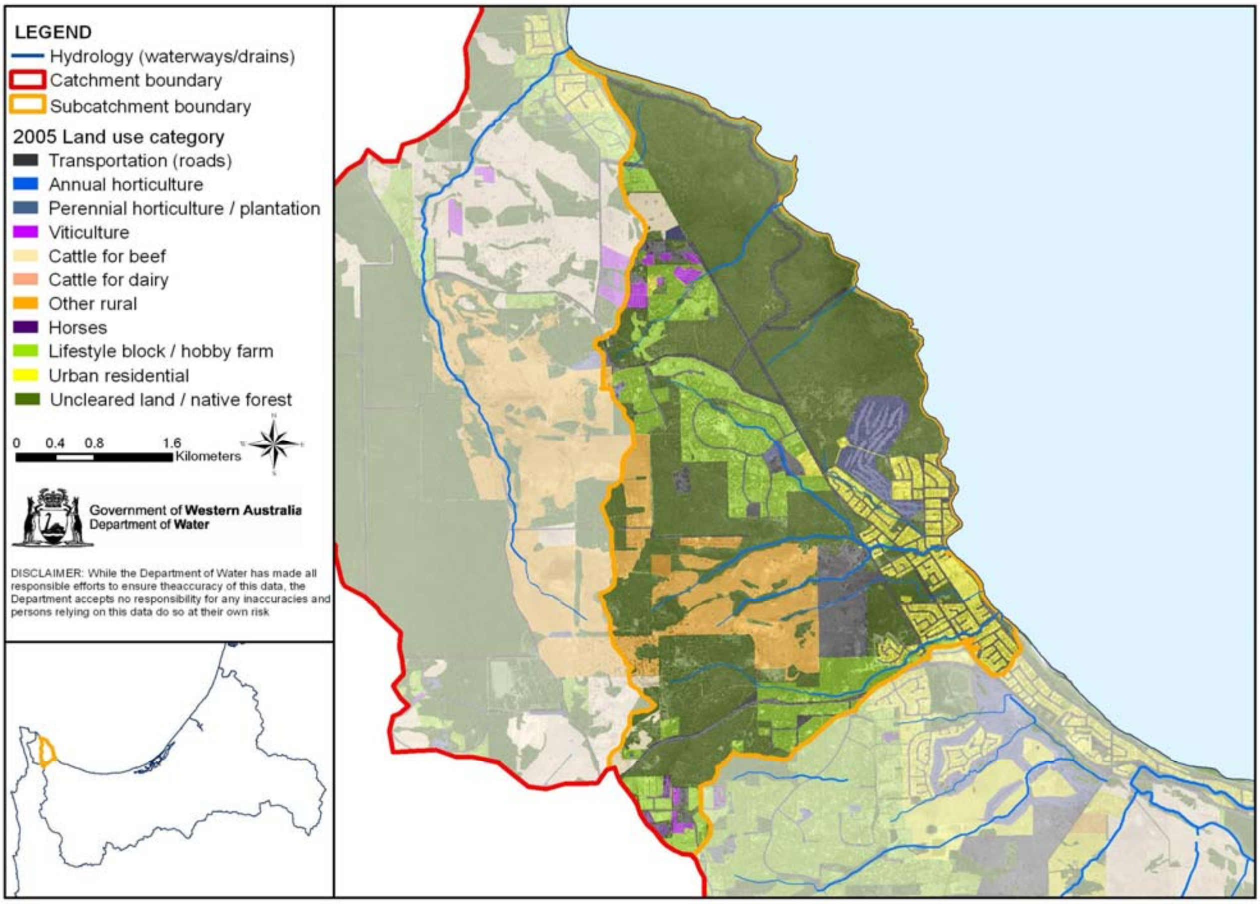


Figure 49: Location and land use of the Dunsborough streams reporting catchment[10].

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[10] Land-use categories have been extensively simplified for this and all the following subcatchment land-use maps for the purposes of visualising the major land uses. Detailed land-use maps with all categories included as part of the water quality modelling process are presented in Appendix A. To view the sub-categories used in each land-use class for the above and following maps, please refer to Appendix G.

Carbunup River

Water quality objective: Protection – maintain good water quality				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	1.81	1.9	0	0
Nitrogen	21.1	23.1	0	0

Summary of status and trends

The Carbunup River currently has very good water quality in terms of both nitrogen and phosphorus. The PRI of soils in this catchment combined with good quality riparian vegetation on the river and many of its tributaries are likely to have contributed to this status.

Nutrient sources

Diffuse agricultural sources from beef and dairy grazing are contributing the largest proportion of phosphorus and nitrogen to the Carbunup River. Point sources (from dairy sheds) and a small number of horticulture farms are also significant contributors of both nitrogen and phosphorus.

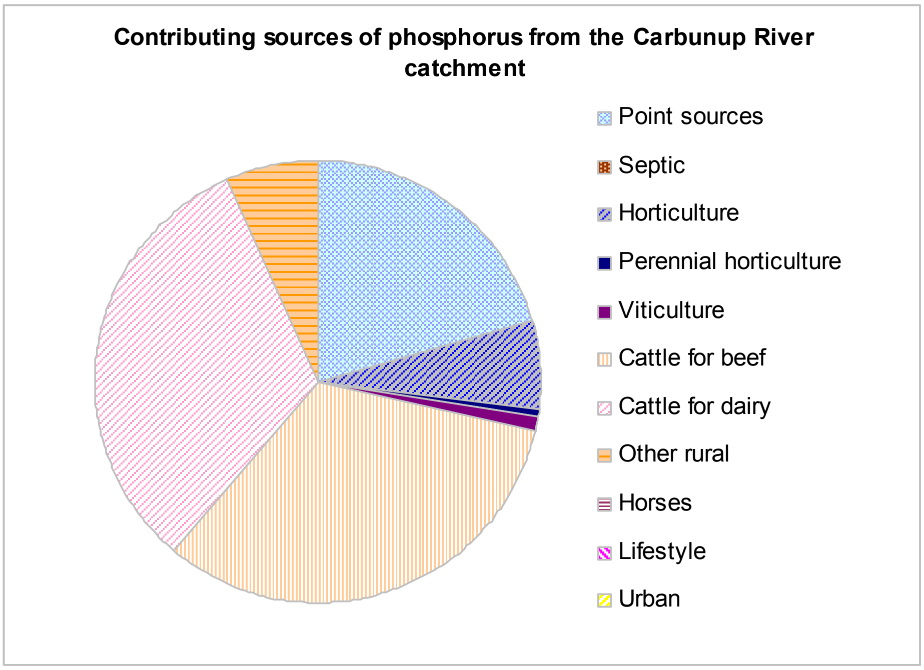


Figure 50: Contributing sources of phosphorus to the Carbunup River.

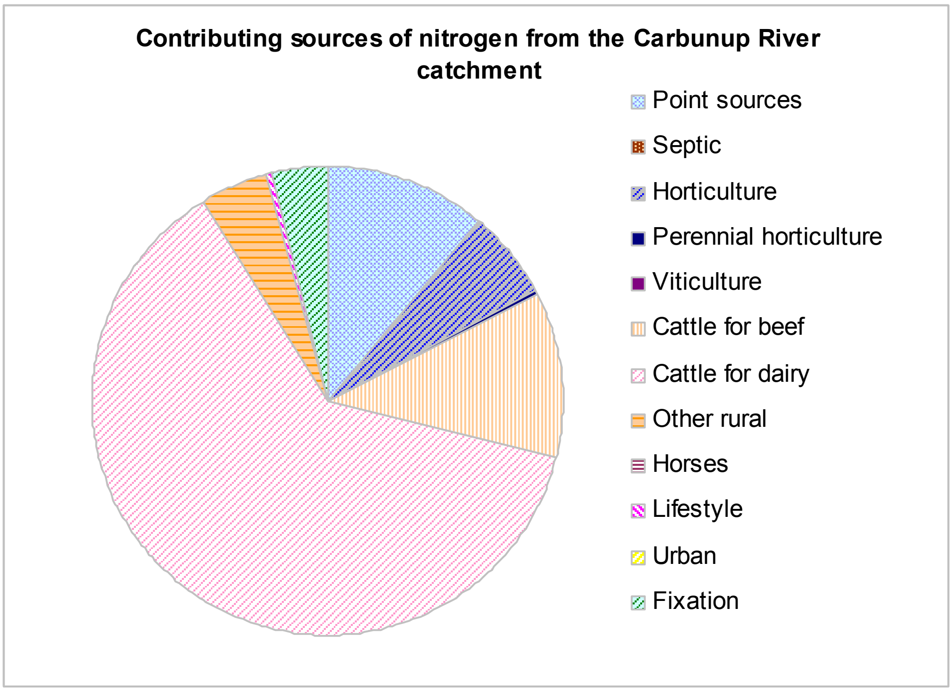


Figure 51: Contributing sources of nitrogen to the Carbunup River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Undertake awareness programs to ensure community recognition of existing values.	High level of community awareness about catchment values.
Promote adoption of best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Promote best-practice dairy effluent management.	50 per cent adoption of best-practice dairy effluent management.
Continue monitoring of this reporting catchment to assess for changes in nutrient status.	No significant increase in the winter median concentration of nitrogen and phosphorus concentrations in the Carbunup River.

Challenges for nutrient management

- Incremental loss of riparian vegetation.
- Limited historical monitoring data.
- Few available best practices in nutrient management that are relevant for local horticultural industries.
- Balancing groundwater and surface-water extraction and environmental flows with nutrient management targets.

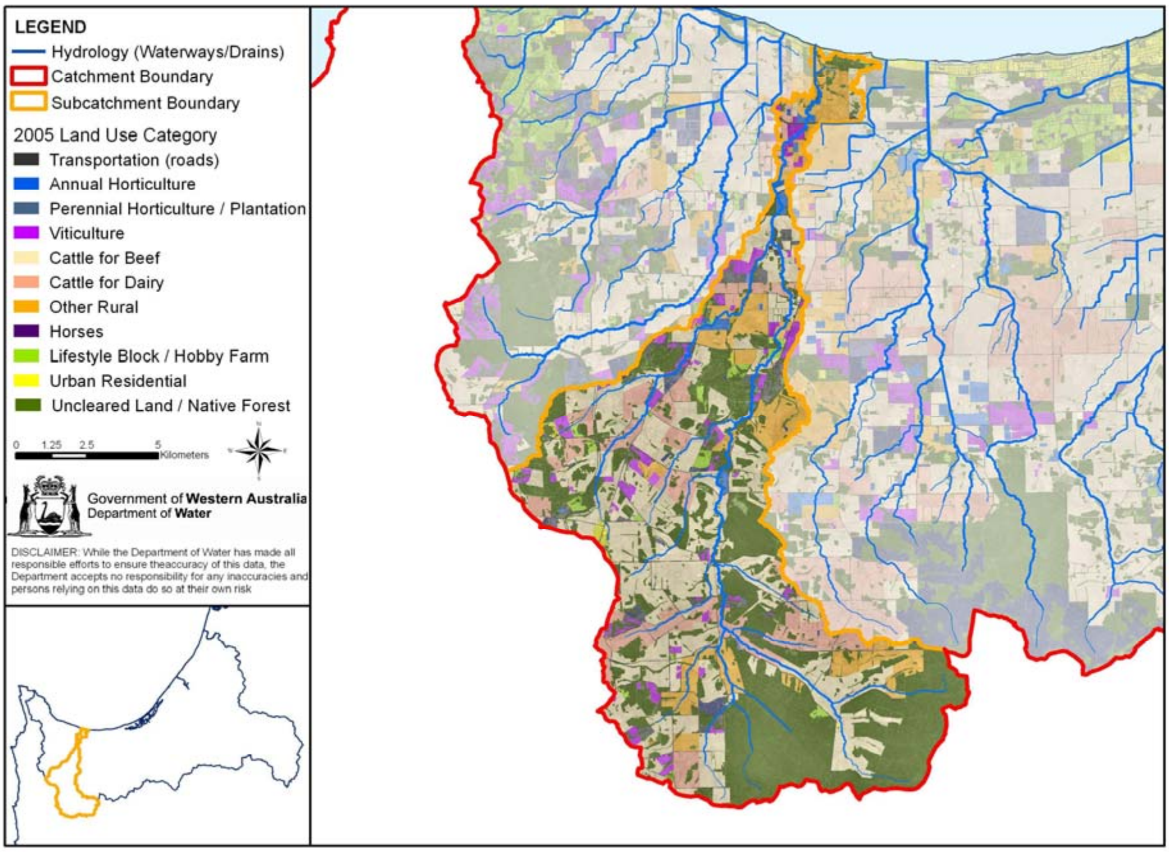


Figure 52: Location and land use of the Carbunup River reporting catchment.

Capel River

Water quality objective: Protection – maintain good water quality				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	6.72	8.41	0	0
Nitrogen	42.2	51.6	0	0

Summary of status and trends

The Capel River currently has good water quality. Despite meeting the nutrient-concentration limits of 0.1 mg/L phosphorus and 1.0 mg/L nitrogen, the Capel River still discharges a large load of nutrients to Geographe Bay compared with many other reporting catchments. The Capel River is the only groundwater-fed waterway in the catchment, and it is likely that dilution of nutrients by the groundwater has contributed strongly to this system meeting the acceptable nutrient-concentration limits. Water quality modelling has predicted that urban expansion of the Capel town site will lead to an increase in the load and concentration of both phosphorus and nitrogen. Without management, the nutrient status of the Capel River may shift into the 'intervention' category due to a predicted increase in nitrogen concentration and load.

Nutrient sources

Nutrient sources in the Capel River subcatchment are highly diverse. Diffuse pollution from grazing for cattle and beef are the largest contributors of both phosphorus and nitrogen, though point sources are also significant for both nutrients. Horticulture is another important phosphorus source and septic systems contribute large nitrogen loads to the system. Urban contributions are currently small, yet these sources are predicted to increase substantially.

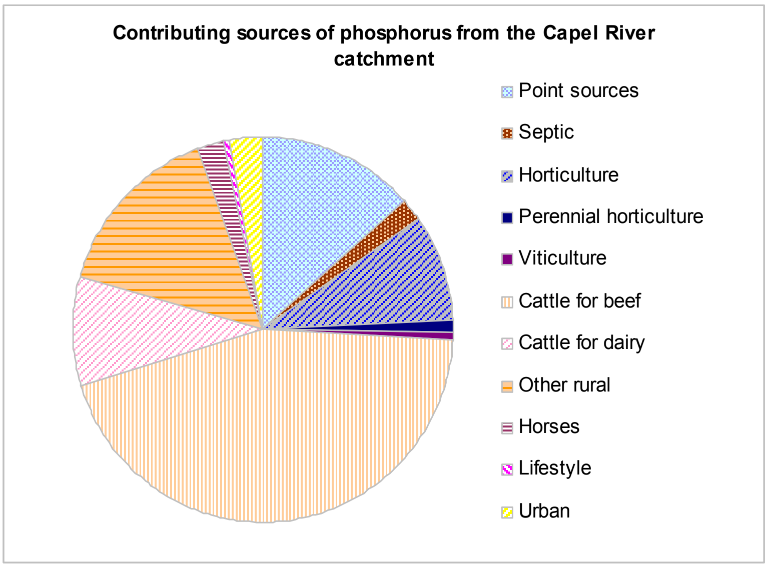


Figure 53: Contributing sources of phosphorus to the Capel River.

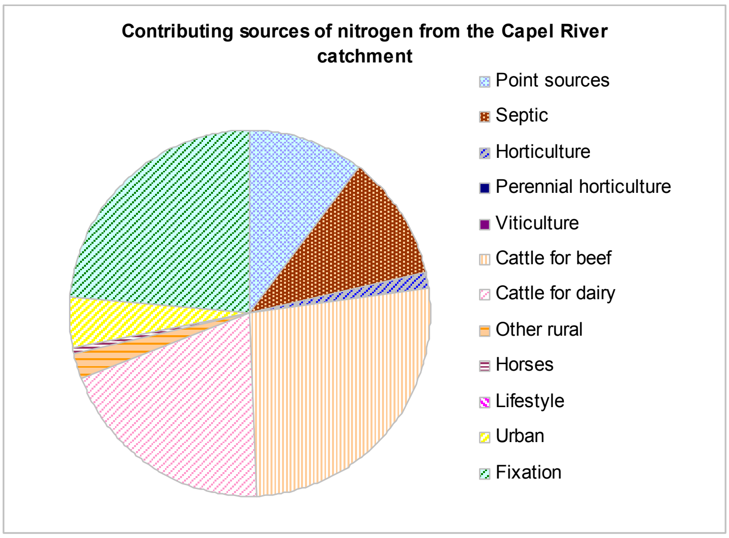


Figure 54: Contributing sources of nitrogen to the Capel River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Undertake awareness programs to ensure community recognition of existing values.	High level of community awareness about catchment values.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than is currently delivered by the existing land use on the land in question.
Promote adoption of best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Promote best-practice dairy effluent management.	50 per cent adoption of best-practice dairy effluent management.
Continue monitoring of this subcatchment to assess for changes in nutrient status.	No significant increase in the winter median concentration of nitrogen and phosphorus concentrations in the Capel River.
Maintain a no net increase in nutrient load approach to upgrades of the Capel wastewater treatment plant.	No net increase in nutrient loads discharged from the Capel wastewater treatment plant.

Challenges for nutrient management

- Extensive urban growth planned.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient-offset arrangements.

- Incremental loss of riparian vegetation.
- Few available best practices in nutrient management that are relevant for local horticulture industries.
- Balancing groundwater and surface-water extraction and environmental flows with nutrient management targets.

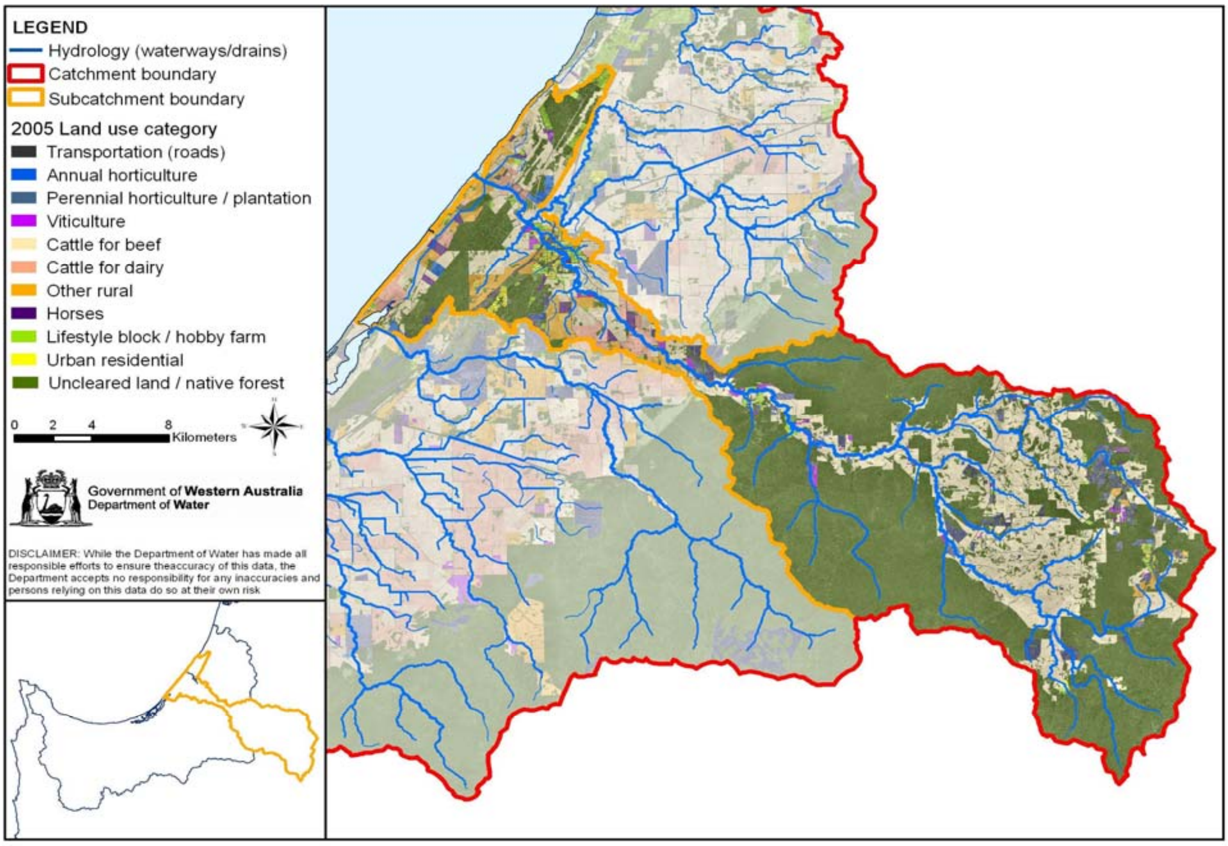


Figure 55: Location and land use of the Capel River reporting catchment.

Intervention catchments

Abba River

Water quality objective: Intervention – prevent P rising, reduce N to target				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	4.35	5.18	0	0
Nitrogen	37.5	55.4	9.4	25%

Summary of status and trends

Water quality in the Abba River currently meets the concentration criteria of 0.1 mg/L for phosphorus, but regularly exceeds the nitrogen criteria of 1.0 mg/L. The Abba

River has significantly better water quality than the neighbouring Ludlow and Sabina rivers. It is believed that this is caused by the higher PRI of soils in the catchment, combined with a larger flow (and therefore greater dilution factor) than other reporting catchments. Given that the Abba River flows directly into the Vasse Estuary and maintains a large load of both nitrogen and phosphorus, management of both nutrients is likely to be needed.

Nutrient sources

All sources of nutrients delivered to the Abba River are derived from agricultural production. The largest contributors are diffuse sources of nitrogen and phosphorus from beef and dairy cattle grazing, though point-source dairy-shed effluent also delivers a large load of both nutrients.

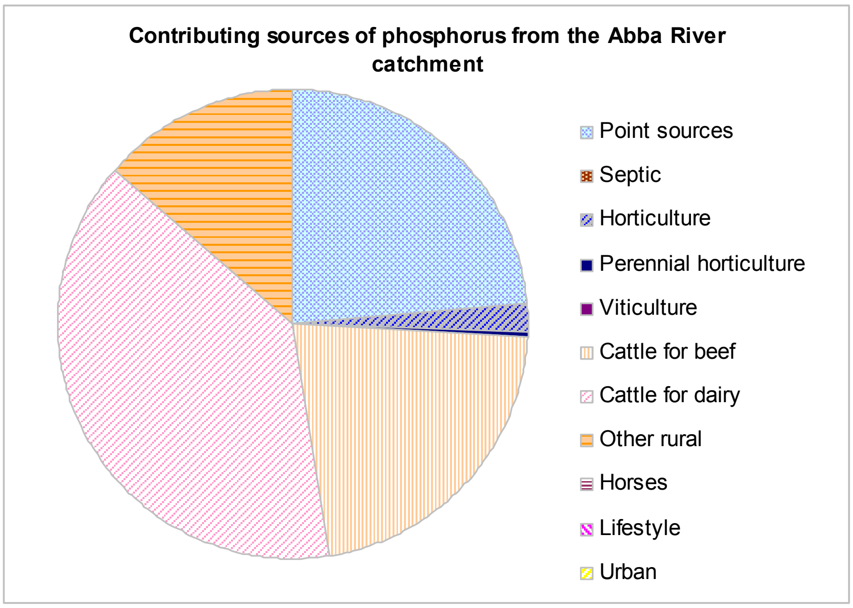


Figure 56: Contributing sources of phosphorus to the Abba River.

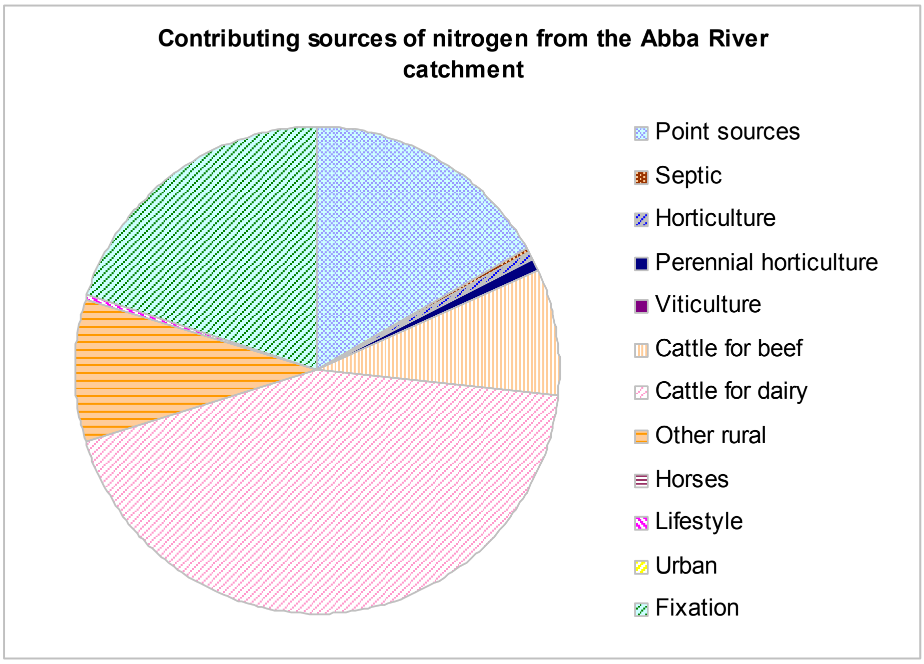


Figure 57: Contributing sources of nitrogen to the Abba River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	35 per cent adoption of riparian management 'low' on first-order streams. 50 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.

Challenges for nutrient management

- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.

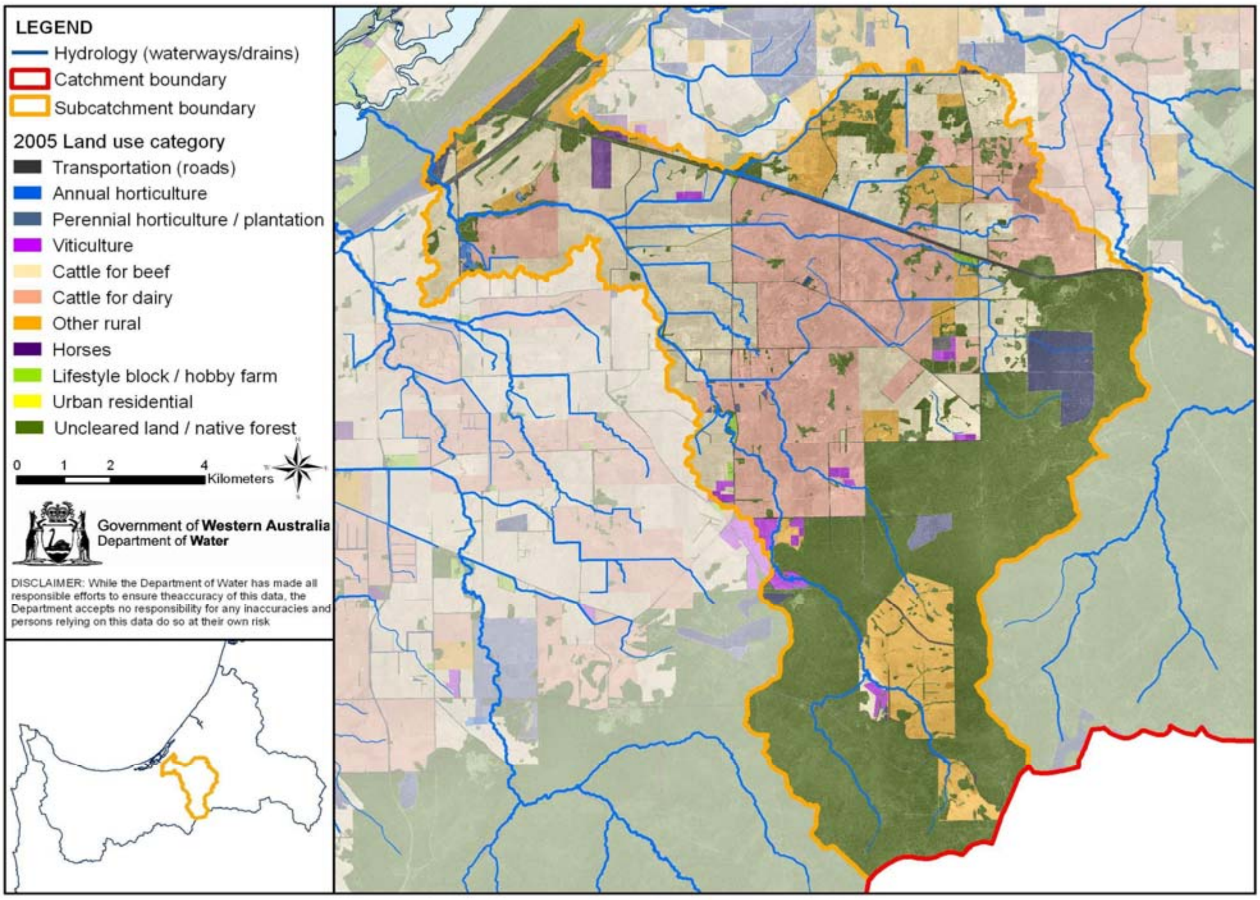


Figure 58: Location and land use of the Abba River reporting catchment.

Jingarmup Brook

Water quality objective: Intervention – prevent P rising, reduce N to target				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	0.09	0.09	0	0
Nitrogen	4.5	4.9	0.8	18

Summary of status and trends

Water quality in the Jingarmup Brook currently meets the concentration criteria of 0.1 mg/L for phosphorus, but exceeds the nitrogen criteria of 1.0 mg/L. The catchment's relatively small size means that the overall load of nitrogen delivered to Geographe Bay is still very small. The load of nitrogen is predicted to increase as a result of the Eagle Bay town site's expansion.

Nutrient sources

The vast majority of phosphorus load to the Jingarmup Brook is sourced from cattle for beef and other rural practices. A small proportion is derived from diffuse urban and septic tank sources from the Eagle Bay town site. In contrast, most of the nitrogen load to the brook is contributed from nitrogen fixation within the catchment. About half the balance of the load is derived from diffuse urban and septic tank sources. The remainder is contributed by cattle for beef and other rural land uses.

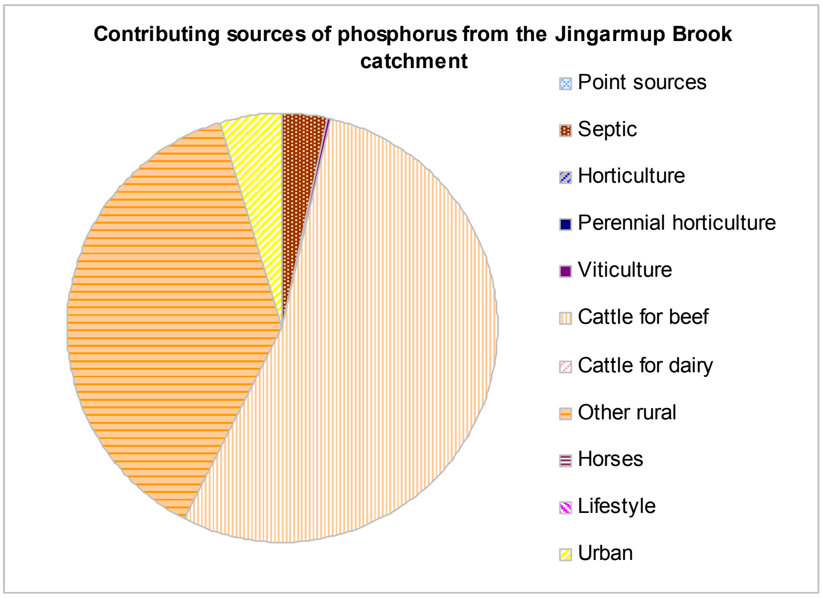


Figure 59: Contributing sources of phosphorus to Jingarmup Brook.

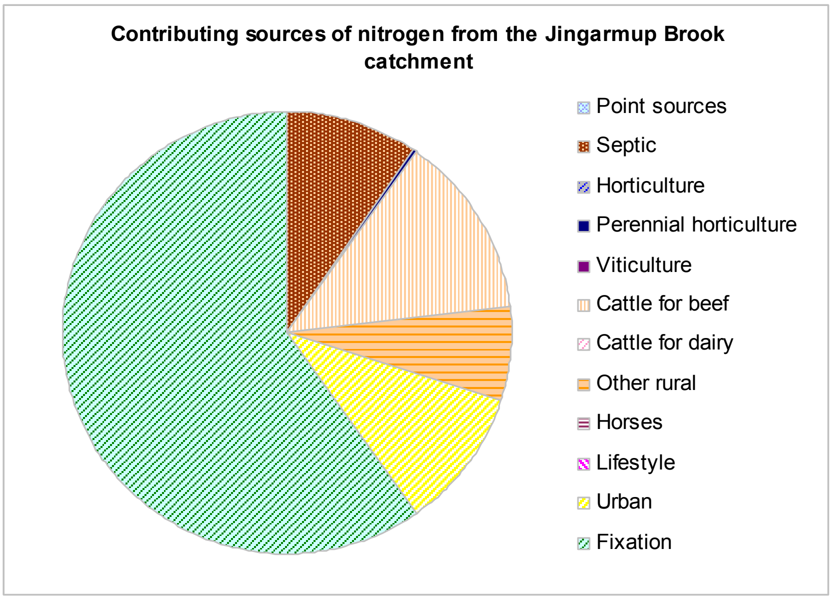


Figure 60: Contributing sources of nitrogen to Jingarmup Brook.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement targeted practice riparian management.	20 per cent adoption of riparian management 'low' on first-order streams. 35 per cent adoption of riparian management 'moderate' on second-order streams. 70 per cent adoption of riparian management 'high' on third-order streams.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than is currently delivered by the existing land use on the land in question.

Challenges for nutrient management

- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- Further urban expansion in the catchment.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient offset arrangements.

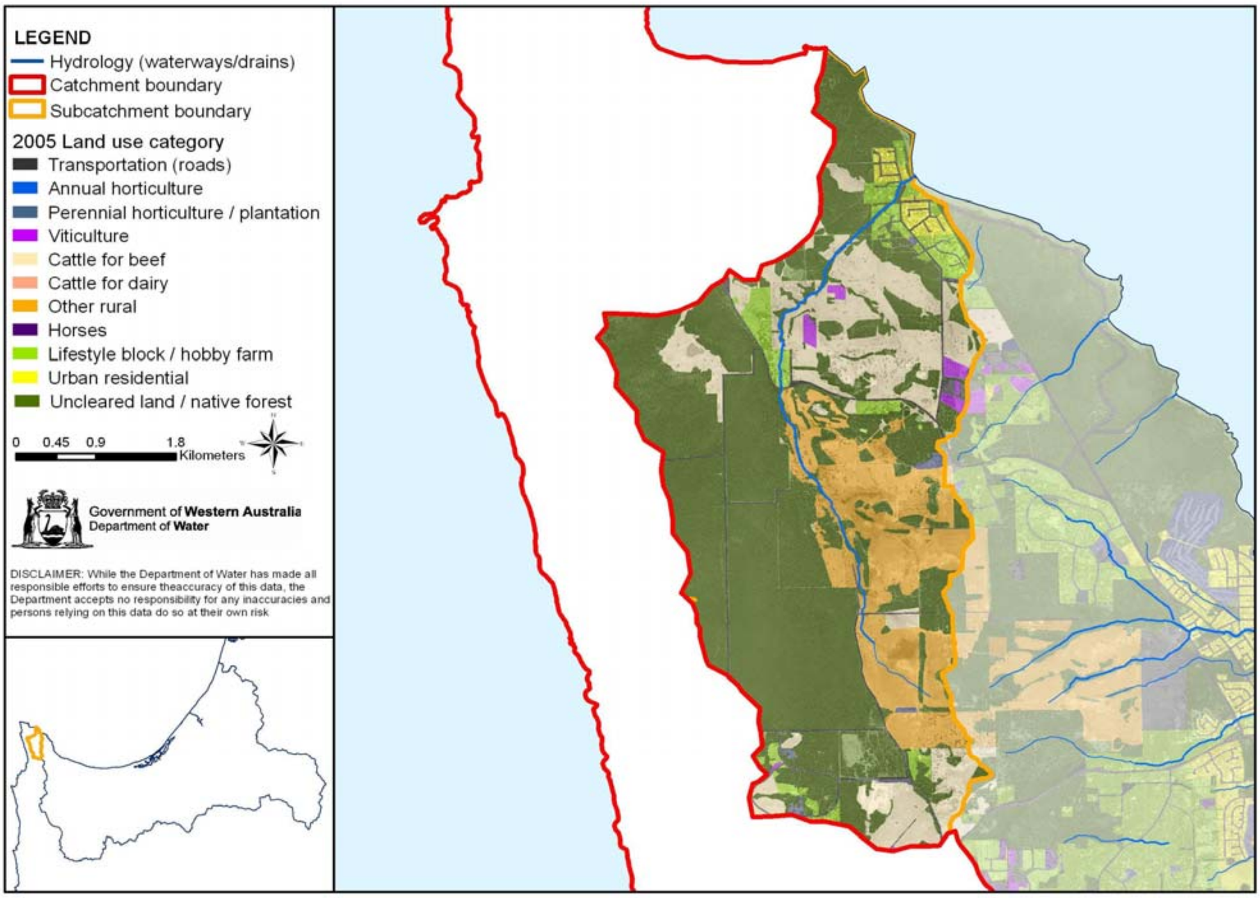


Figure 61: Location and land use of the Jingarmup Brook reporting catchment.

Toby Inlet streams

Water quality objective: Intervention – prevent P rising, reduce N to target				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	0.42	0.65	0	0
Nitrogen	13.7	20.3	5	36%

Summary of status and trends

Sufficient monitoring data was not available from this catchment, therefore computer modelling was used to estimate water quality. The model suggested that water quality in Toby Inlet was likely to meet acceptable concentration criteria for phosphorus, but nitrogen was likely to be elevated. The model suggested that nitrogen load needed to be reduced by 35 per cent, but without management could increase by about 48 per cent as a result of proposed land-use change in the catchment.

Nutrient sources

The most dominant source of phosphorus in the catchment is from beef cattle grazing, followed by urban land uses, and then septic systems. Beef cattle grazing is the largest source of nitrogen, though this is only slightly greater than the urban contribution. Septic systems are also a significant source of nitrogen: they may be the major nitrogen source during summer when other sources are not delivered due to an absence of flow. Other minor sources of nutrients include horses and lifestyle lots.

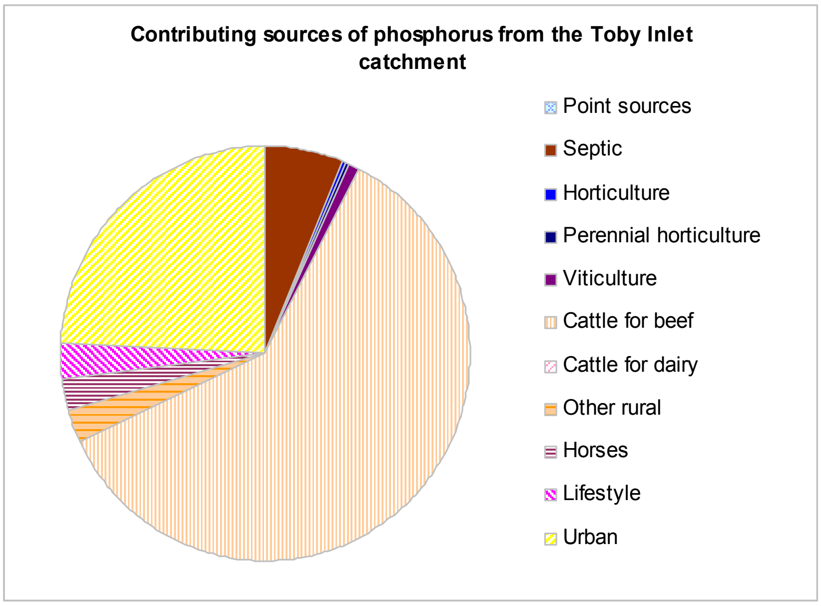


Figure 62: Contributing sources of phosphorus to Toby Inlet.

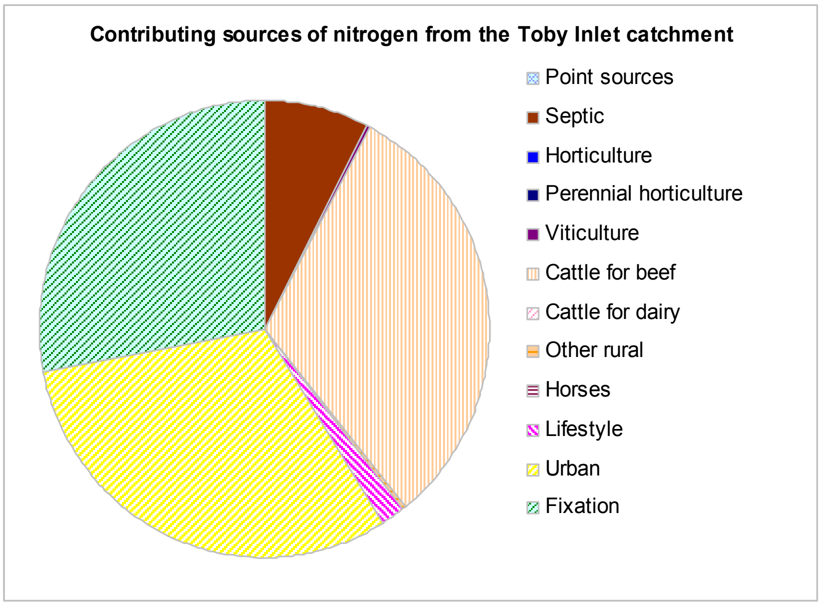


Figure 63: Contributing sources of nitrogen to Toby Inlet.

Prioritised nutrient action and goals

Action	Ten-year management goal
Undertake water quality monitoring at site to enable use of data for calibration of water quality models.	Fortnightly monitoring of water quality of flow to Toby Inlet at a suitable site for compatibility with water quality models.
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement targeted practice riparian management.	35 per cent adoption of riparian management 'low' on first-order streams. 50 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	10 per cent adoption of perennial pastures.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than is currently delivered by the existing land use on the land in question.
Develop solutions to the contribution of nutrients from septic tanks in urban areas.	Septic sources of nutrients from urban areas have been removed through sewer connection or replacement with ATUs.
Implement an urban fertiliser management program.	50 per cent adoption of fertiliser management on urban and lifestyle lots in the catchment.

Challenges for nutrient management

- With the exception of new urban developments, currently there are no plans to extend the infill sewerage program to this catchment. The contribution of septic systems to nutrient loads in summer will be much higher than that displayed by the annual source separation data above. Given algal blooms are at their worst in summer, this nutrient source requires urgent management.
- Rapid urban growth.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new urban developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient-offset arrangements.
- Incremental loss of riparian vegetation.
- High capital cost of management measures (such as infill sewer and riparian management) to address the nitrogen loads in this catchment.

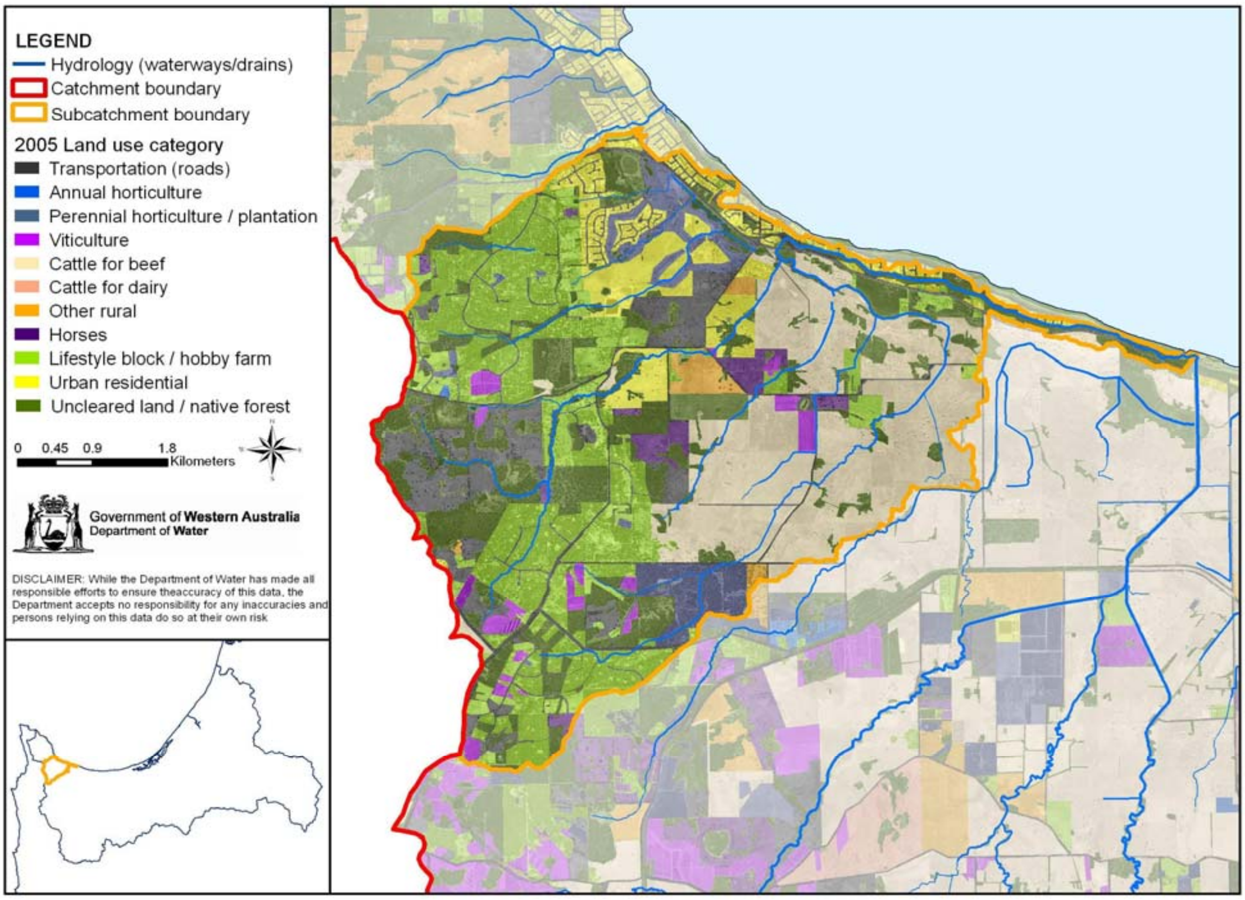


Figure 64: Location and land use of the Toby Inlet reporting catchment.

Annie Brook

Water quality objective: Intervention – prevent P rising, reduce N to target				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	1.76	1.72	0	0
Nitrogen	30.4	31.7	7.1	23

Summary of status and trends

Water quality of flow to Annie Brook currently meets acceptable concentration criteria for phosphorus, but nitrogen is elevated. The nitrogen load needs to be reduced by 23 per cent.

Nutrient sources

Both the phosphorus and nitrogen loads to Annie Brook are sourced from agricultural land uses. Cattle for beef contributes the vast majority of the overall nutrient load, followed by cattle for dairy, and then horticulture. Other rural sources and horses also contribute a small proportion.

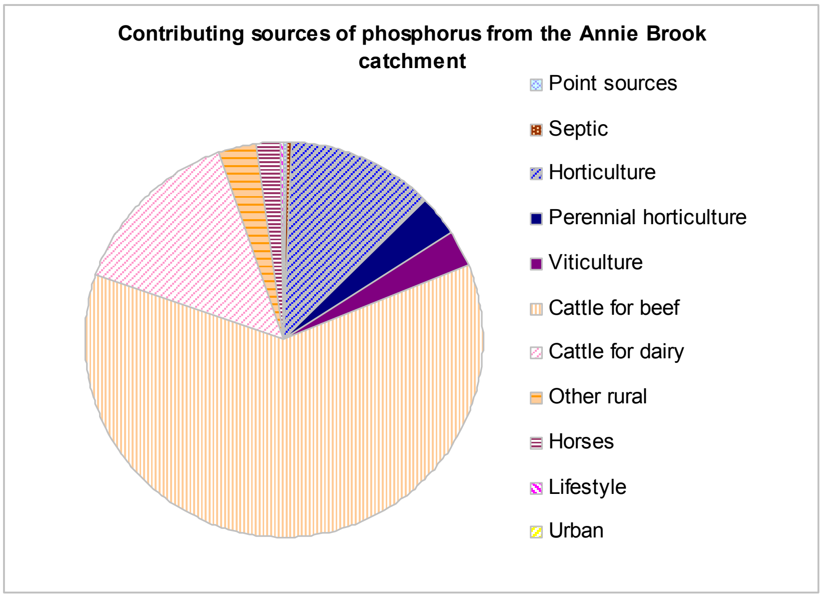


Figure 65: Contributing sources of phosphorus to Annie Brook.

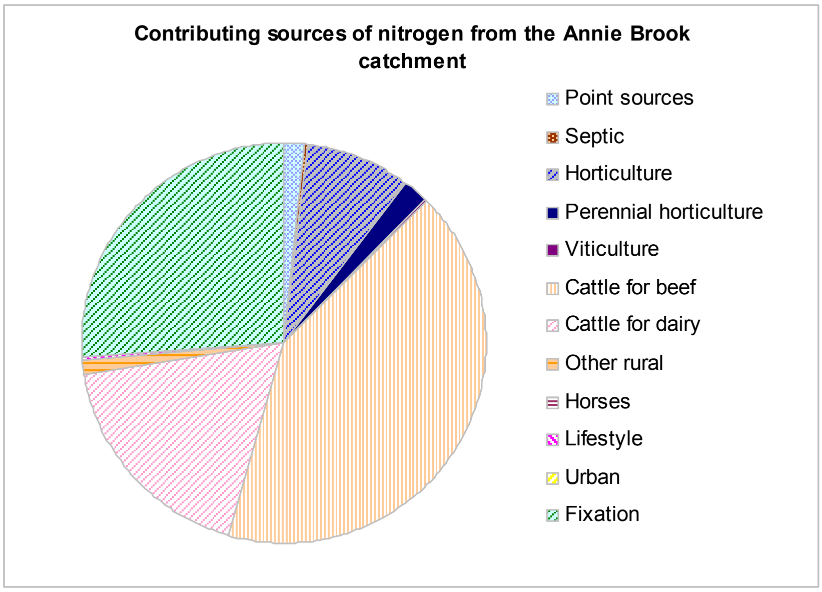


Figure 66: Contributing sources of nitrogen to Annie Brook.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	35 per cent adoption of riparian management 'low' on first-order streams. 50 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Maintain a no net increase in nutrient-load approach to upgrades of the Dunsborough wastewater treatment plant.	No net increase in nutrient loads discharged from the Dunsborough wastewater treatment plant.

Challenges for nutrient management

- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.

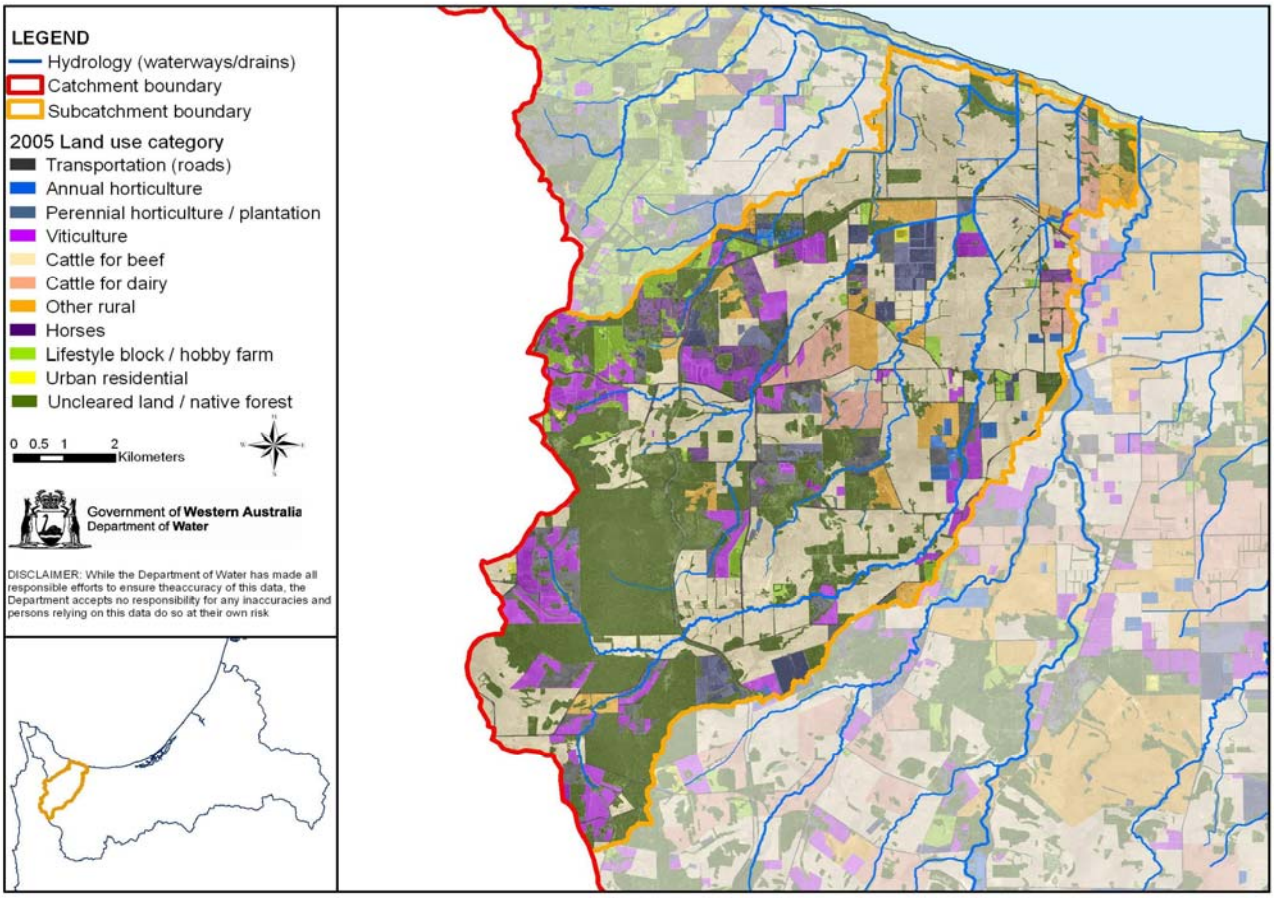


Figure 67: Location and land use of the Annie Brook reporting catchment.

Buayanyup River

Water quality objective: Intervention **– prevent P rising, reduce N to target**

	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	6.46	10.66	0 1	0
Nitrogen	33.2	36.9	Long term: 16.9 10-yr interim: 11	Long term: 51% 10-yr interim: 33%

Summary of status and trends

Water quality flowing to the Buayanyup River currently meets the acceptable concentration criteria for phosphorus, but nitrogen is highly elevated and needs to be reduced by 51 per cent in the long term and by 33 per cent within 10 years. Predictions of the impact of Vasse village's urban expansion indicate that both the phosphorus and nitrogen loads could increase substantially. This situation would result in this catchment being reclassified as a recovery catchment – unless management interventions are applied.

Nutrient sources

The largest sources of both phosphorus and nitrogen in this catchment are cattle for dairy, followed by horticulture. Point sources of nutrients (from dairy sheds) and cattle for beef also contribute significant proportions of the load. Other rural and urban diffuse sources also contribute a small amount of the phosphorus load. The predicted increases in nutrient loads are expected to be primarily from the urban expansion of the Vasse village.

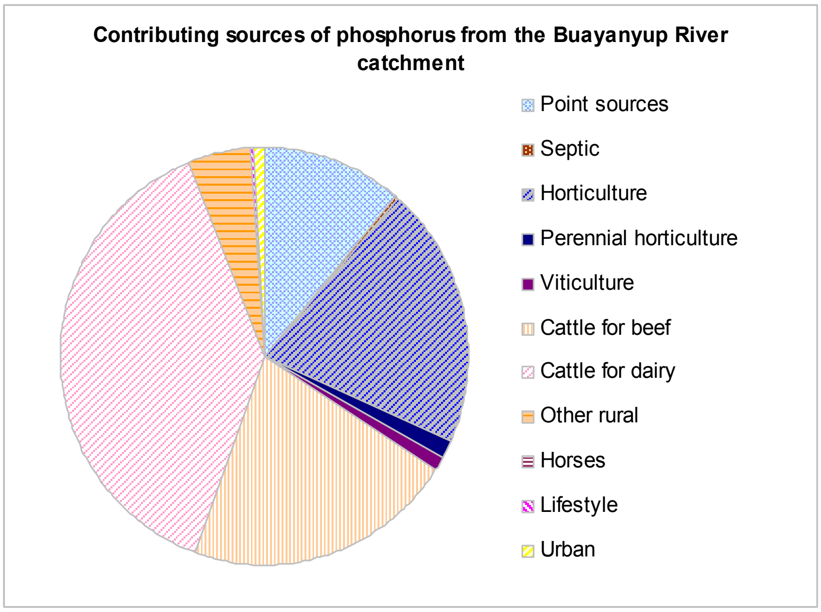


Figure 68: Contributing sources of phosphorus to the Buayanyup River.

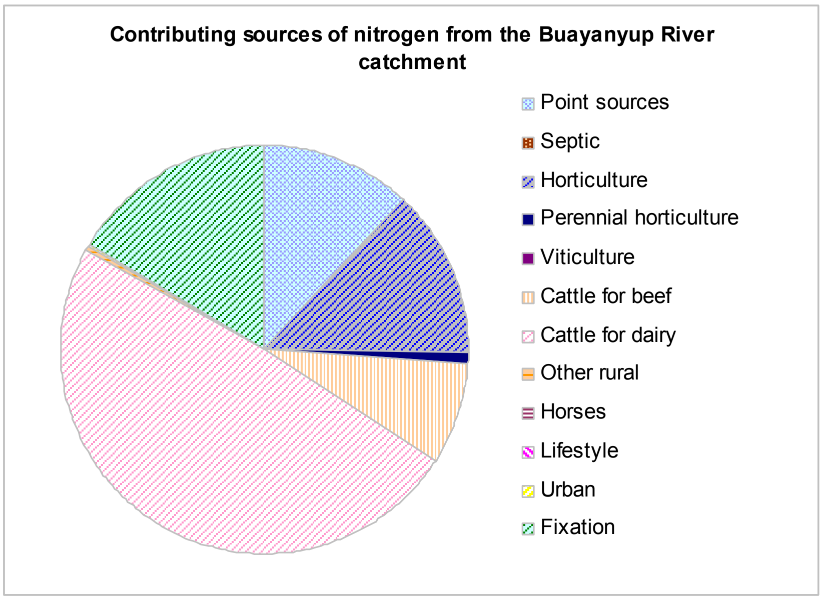


Figure 69: Contributing sources of nitrogen to the Buayanyup River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	35 per cent adoption of riparian management 'low' on first-order streams. 50 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	20 per cent adoption of perennial pastures on cattle for beef properties.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than is currently delivered by the existing land use on the land in question.

Challenges for nutrient management

- Extensive urban growth planned.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new urban developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient offset arrangements.
- Incremental loss of riparian vegetation.
- Few available best practices in nutrient management that are relevant for local horticulture industries.
- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- Effective dairy effluent management requires dairy farmers to make a long-term commitment to maintain effluent management systems.
- Balancing groundwater and surface-water extraction and environmental flows with nutrient management targets.

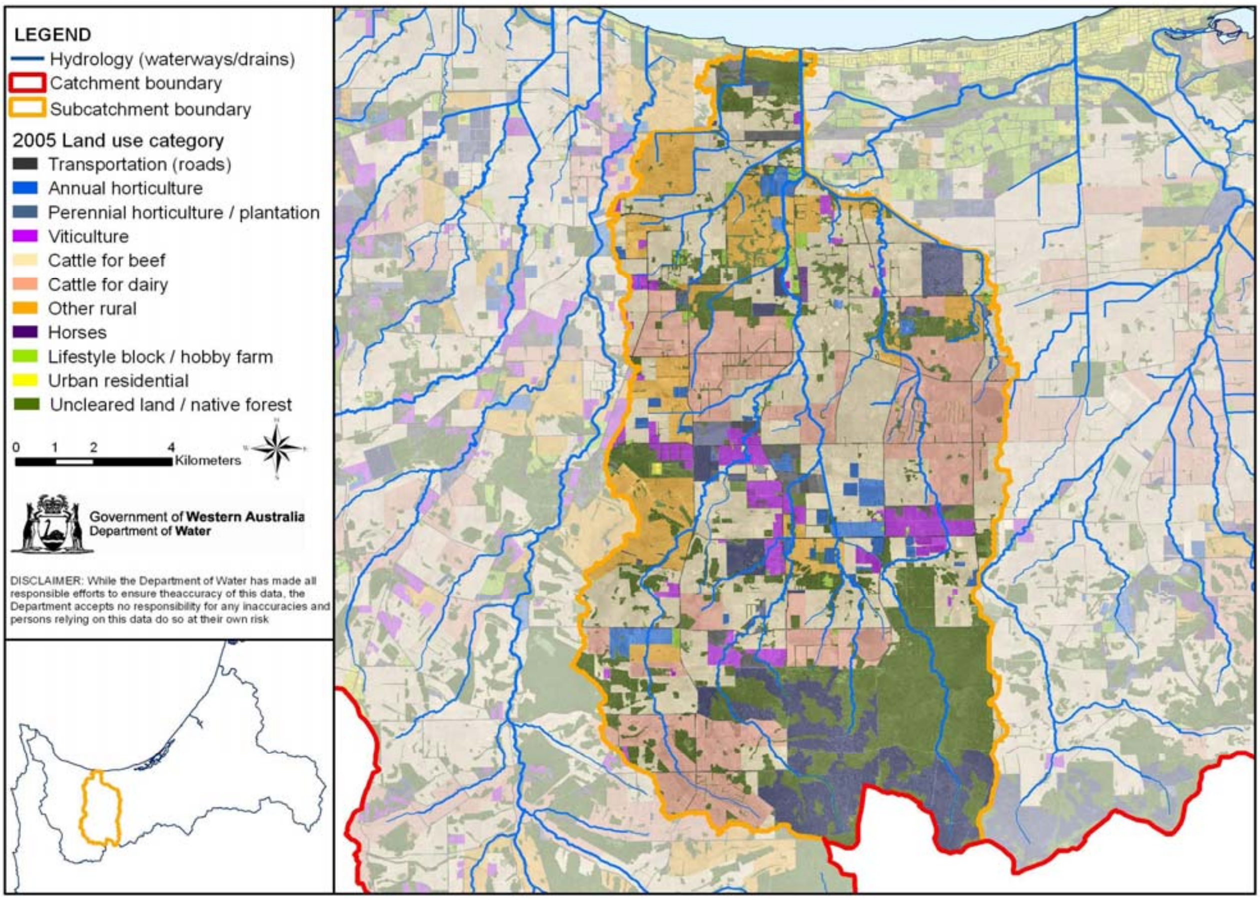


Figure 70: Location and land use of the Buayanyup River reporting catchment.

Recovery catchments

Lower Vasse River

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	4.72	6.66	Long term: 3.17 10-yr interim: 2.0	Long term: 67% 10-yr interim: 44%
Nitrogen	33.8	41.6	Long term: 23.5 10-yr interim: 18.9	Long term: 70% 10-yr interim: 56%

Summary of status and trends

Water quality in the Lower Vasse River substantially exceeds criteria for both phosphorus and nitrogen. Long-term load reductions are required: 67 per cent for phosphorus and 70 per cent for nitrogen. Interim 10-year targets include a 44 per cent reduction in phosphorus and a 56 per cent reduction in nitrogen. Water quality modelling suggests that without management intervention, planned urban expansions in the catchment could potentially cause a 41 per cent increase in phosphorus load and a 23 per cent increase in nitrogen load. The Lower Vasse River flows to the Vasse Estuary, which forms part of the Ramsar-listed Vasse Wonnerup Wetlands.

Nutrient sources

The Lower Vasse River receives flows from the immediate subcatchment area as well as a proportion of flow from the Vasse Diversion Drain when the valve connection to the drain is open.

Point sources make the largest contribution of total phosphorus to the river. They include a feedlot located in the immediate subcatchment area and dairy sheds in the Vasse Diversion Drain catchment. Other large sources of phosphorus are from cattle for beef and dairy, diffuse urban pollution, septic tanks and other rural uses. A small load of phosphorus is also contributed by horticulture. Cattle for dairy contributes the largest source of nitrogen, followed by cattle for beef, and then point sources. The balance of the nitrogen load is roughly equally sourced from other rural sources, septic tanks and diffuse urban land uses. The contribution of septic systems to nutrient loads in summer will be much higher than that displayed by the annual source separation data, since other sources are primarily delivered only during winter when flow is received.

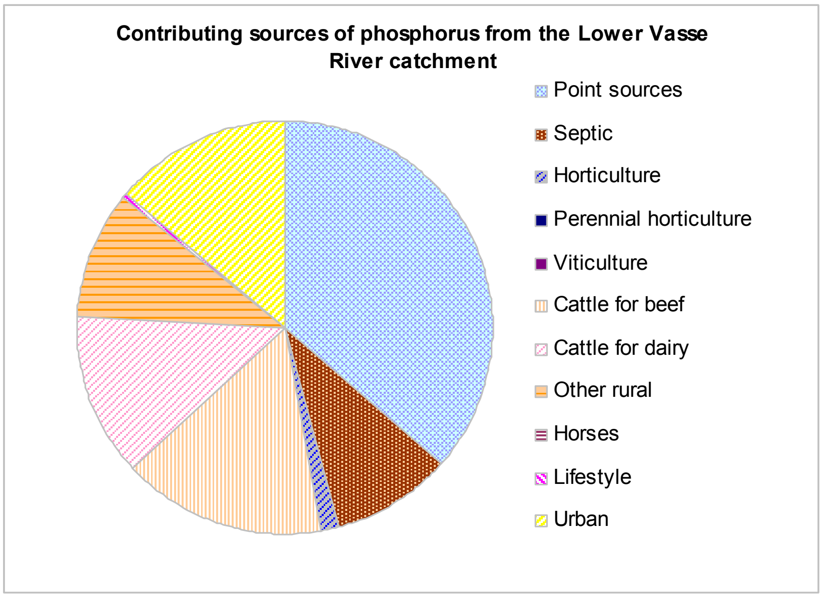


Figure 71: Contributing sources of phosphorus to the Lower Vasse River.

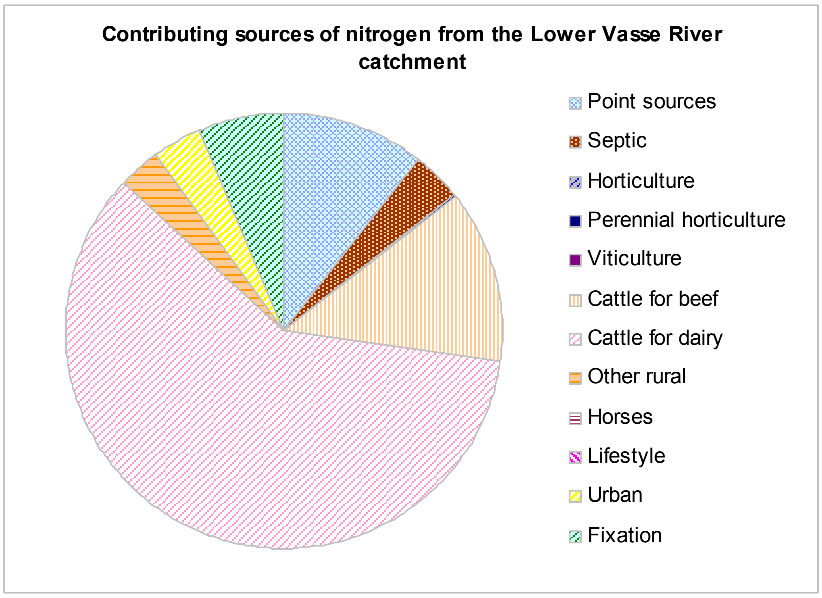


Figure 72: Contributing sources of nitrogen to the Lower Vasse River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy and feedlot effluent management.	100 per cent adoption of best-practice dairy and feedlot effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy.
Implement an urban nutrient management program.	25 per cent adoption of fertiliser management in urban residential and light-industrial areas.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Implement targeted retrofitting of water sensitive urban design.	High-priority retrofitting projects identified and implemented in existing urban areas (including light industrial).
Develop solutions to the contribution of nutrients from septic tanks in urban areas.	Septic sources of nutrients from urban areas have been removed through sewer connection or replacement with ATUs.

Challenges for nutrient management

- Owing to hydrological changes to the river system, it now functions more as a lake than a river. Summer conditions promote algal growth because the water in the river is warm and still.
- Water quality modelling has indicated that increasing flow to the Lower Vasse River through the Vasse Diversion Drain will not sufficiently improve water quality to reduce algal blooms. While nutrient concentrations would decrease slightly, the overall load would increase and over time exacerbate problems further. This situation is unlikely to change until the water quality in the Vasse Diversion Drain has substantially improved (see Section 5.5 for further details).
- With the exception of new urban developments, there are currently no plans to extend the infill sewerage program to this catchment.
- Rapid urban growth.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new urban developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient-offset arrangements.
- Incremental loss of riparian vegetation.
- High capital cost of management measures (such as infill sewer and riparian management) to address the nitrogen loads in this catchment.
- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved.
- There are significant groundwater sources of nutrients in this subcatchment (e.g. from septic tanks): these sources of nutrients alone are sufficient to fuel algal blooms in the river.
- An additional source of nutrients is the large volume of sediment that has accumulated in the river. These sediments are very flocculant and have acid-sulfate-forming potential, which reduces the feasibility of their removal.

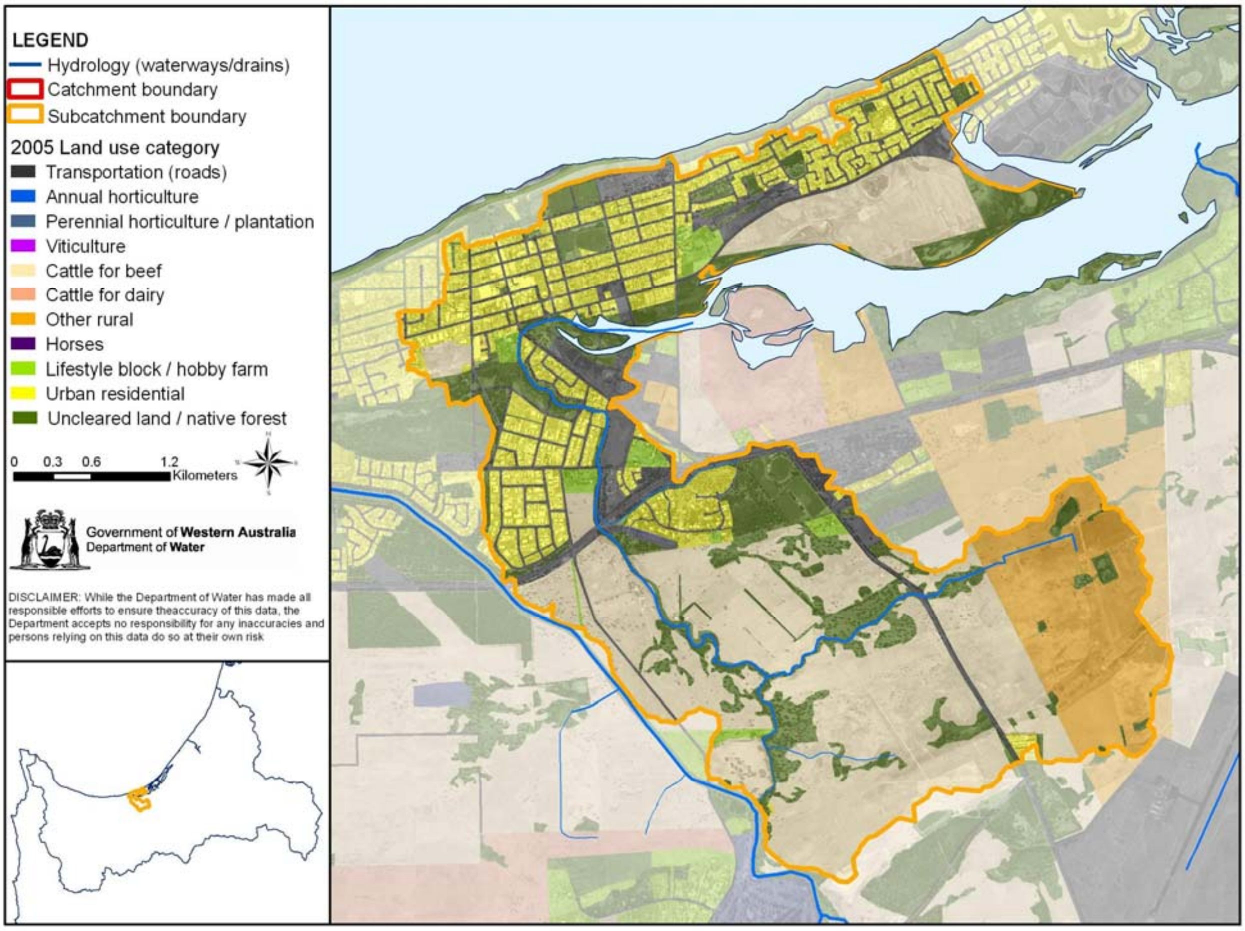


Figure 73: Location and land use of the Lower Vasse River reporting catchment.

Lower Sabina River

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	3.57	3.61	Long term: 2.63 10-yr interim: 0.96	Long term: 74% 10-yr interim: 27%
Nitrogen	39.5	39.1	Long term: 28.2 10-yr interim: 12.6	Long term: 71% 10-yr interim: 32%

Summary of status and trends

The Lower Sabina River currently has the poorest water quality of all of the Geographe waterways. The concentration of both phosphorus and nitrogen is over three times acceptable levels. A long-term load reduction of 74 per cent is required for phosphorus and 71 per cent for nitrogen, while 10-year interim targets are a 27 per cent reduction in phosphorus load and a 32 per cent reduction in nitrogen load. The

Lower Sabina River flows to the Vasse Estuary, which forms part of the Ramsar-listed Vasse Wonnerup Wetlands.

Nutrient sources

Both phosphorus and nitrogen loads in this subcatchment are contributed entirely by agricultural land uses. Cattle for dairy is the dominant contributor, followed by cattle for beef, and then point sources (dairy sheds). Other rural land uses also contribute a small load of phosphorus to the river. Urban uses are expected to contribute a greater proportion of loads due to the new Ambergate urban estate in the subcatchment's west.

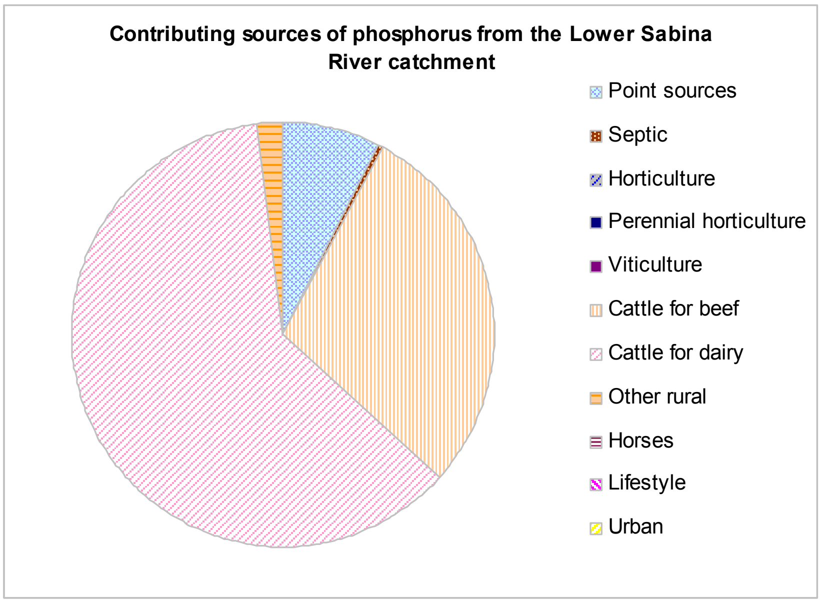


Figure 74: Contributing sources of phosphorus to the Lower Sabina River.

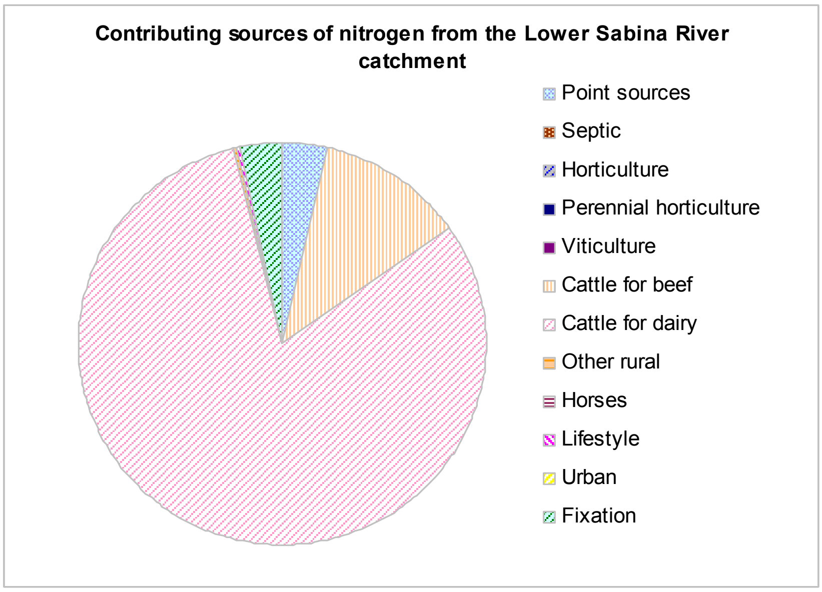


Figure 75: Contributing sources of nitrogen to the Lower Sabina River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy.
Implement targeted soil amendment on agricultural properties.	50 per cent adoption of soil amendment (10T.NUA and low-water-soluble fertiliser).
Implement an urban nutrient management program.	25 per cent adoption of fertiliser management in existing and future urban areas.
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Develop solutions to the contribution of nutrients from septic tanks in urban areas.	Septic sources of nutrients from urban areas have been removed through sewer connection or replacement with ATUs.

Challenges for nutrient management

- Incremental loss of riparian vegetation.
- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved.
- Substantial and ongoing urban growth.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new urban developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient-offset arrangements.

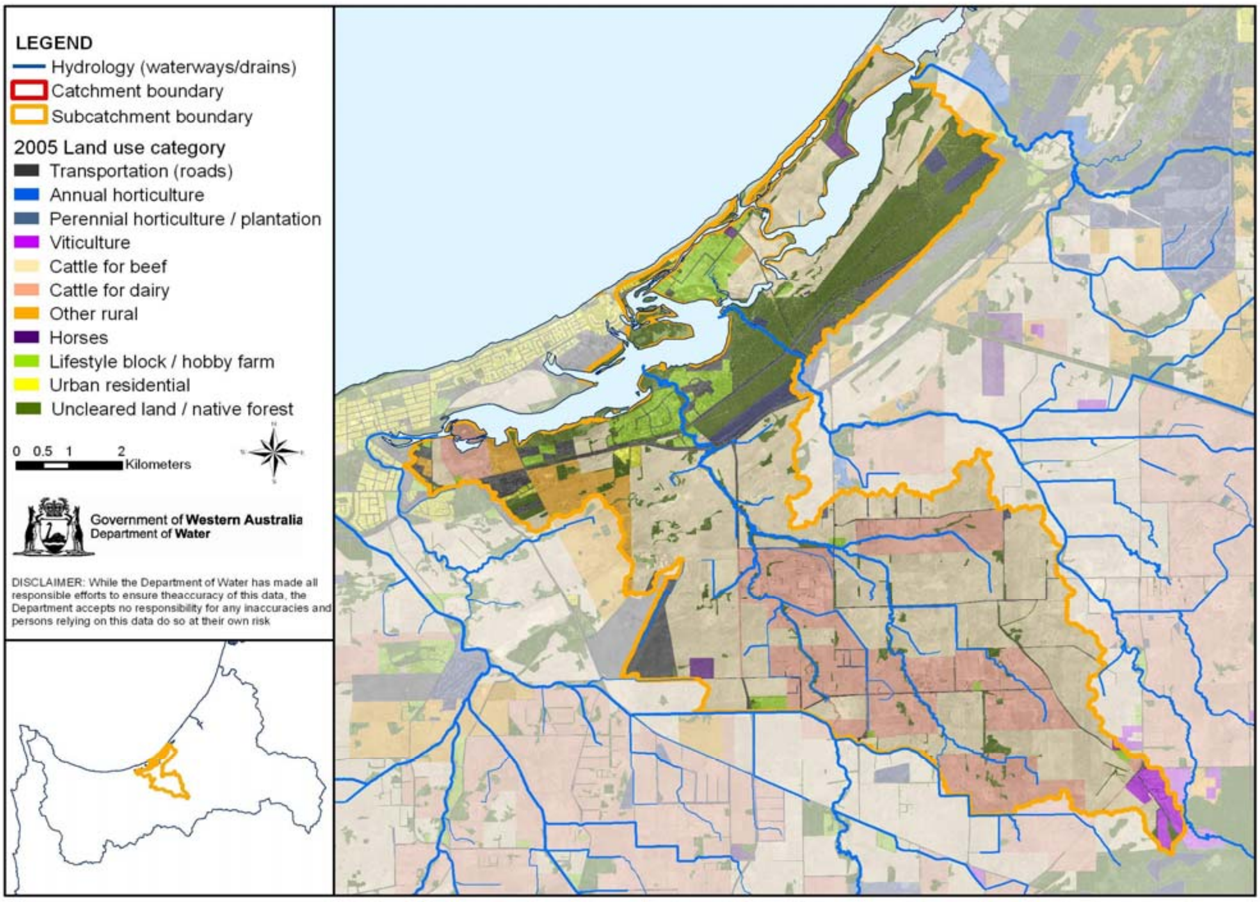


Figure 76: Location and land use of the Lower Sabina River reporting catchment.

Ludlow River

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	2.94	3.38	0.63	21%
Nitrogen	22.9	30.9	Long term: 12.7 10-yr interim: 7.8	Long term: 55% 10-yr interim: 34%

Summary of status and trends

Water quality in the Ludlow River substantially exceeds criteria for both phosphorus and nitrogen. A load reduction of 21 per cent is required for phosphorus and 55 per cent for nitrogen. Management scenario modelling indicates that the phosphorus target is achievable over 10 years, however an interim 10-year nitrogen reduction target of 34 per cent is required. Water quality modelling suggests that further increases in nutrient loads may occur as a result of soils in the catchment reaching their nutrient-retention limit. The Ludlow River flows to the Wonnerup Estuary, which forms part of the Ramsar-listed Vasse Wonnerup Wetlands.

Nutrient sources

Both phosphorus and nitrogen loads in this subcatchment are contributed entirely by agricultural land uses. Cattle for dairy and other rural land uses are the dominant contributors, followed by cattle for beef, and then point sources (dairy sheds). Annual and perennial horticulture also delivers small proportions of the phosphorus and nitrogen loads.

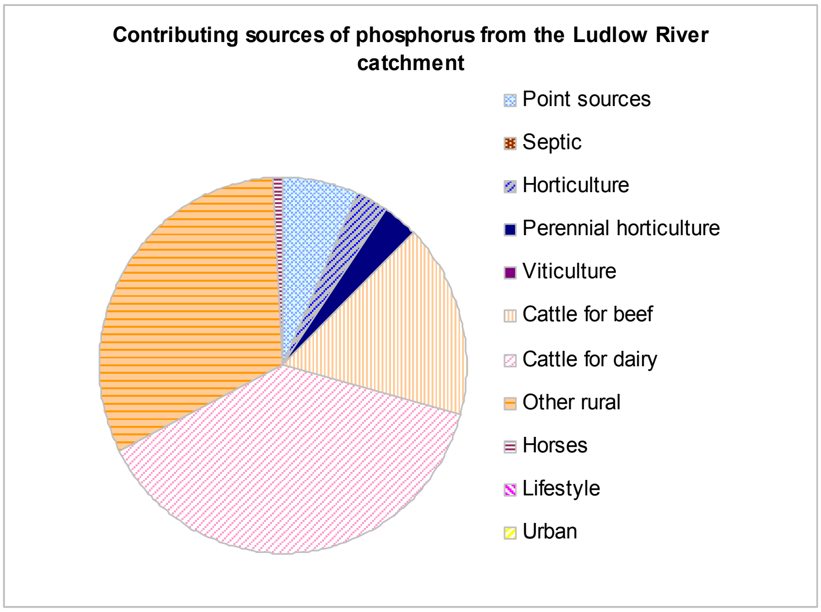


Figure 77: Contributing sources of phosphorus to the Ludlow River.

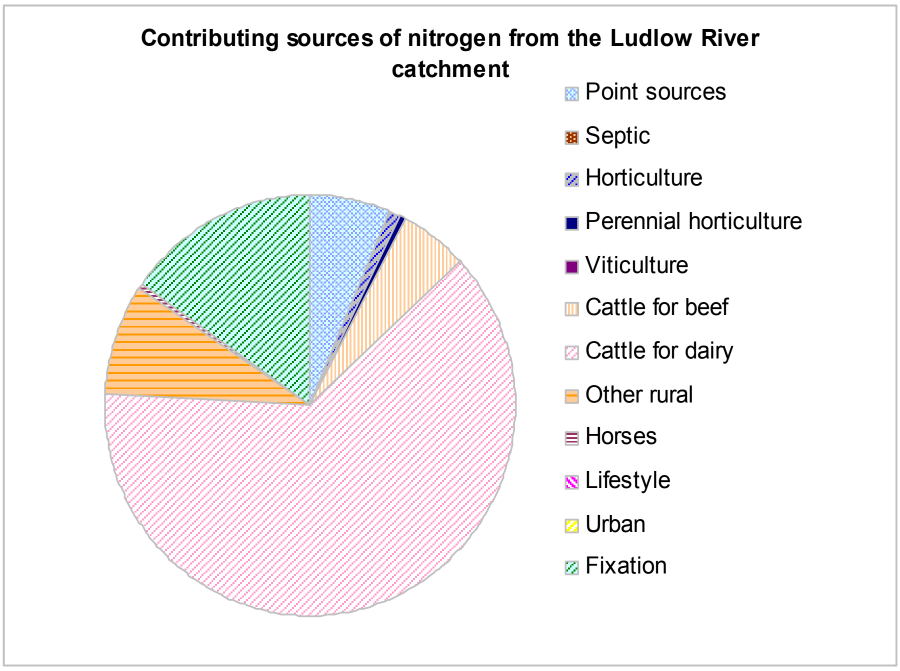


Figure 78: Contributing sources of nitrogen to the Ludlow River.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy.

Challenges for nutrient management

- Incremental loss of riparian vegetation.
- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved.

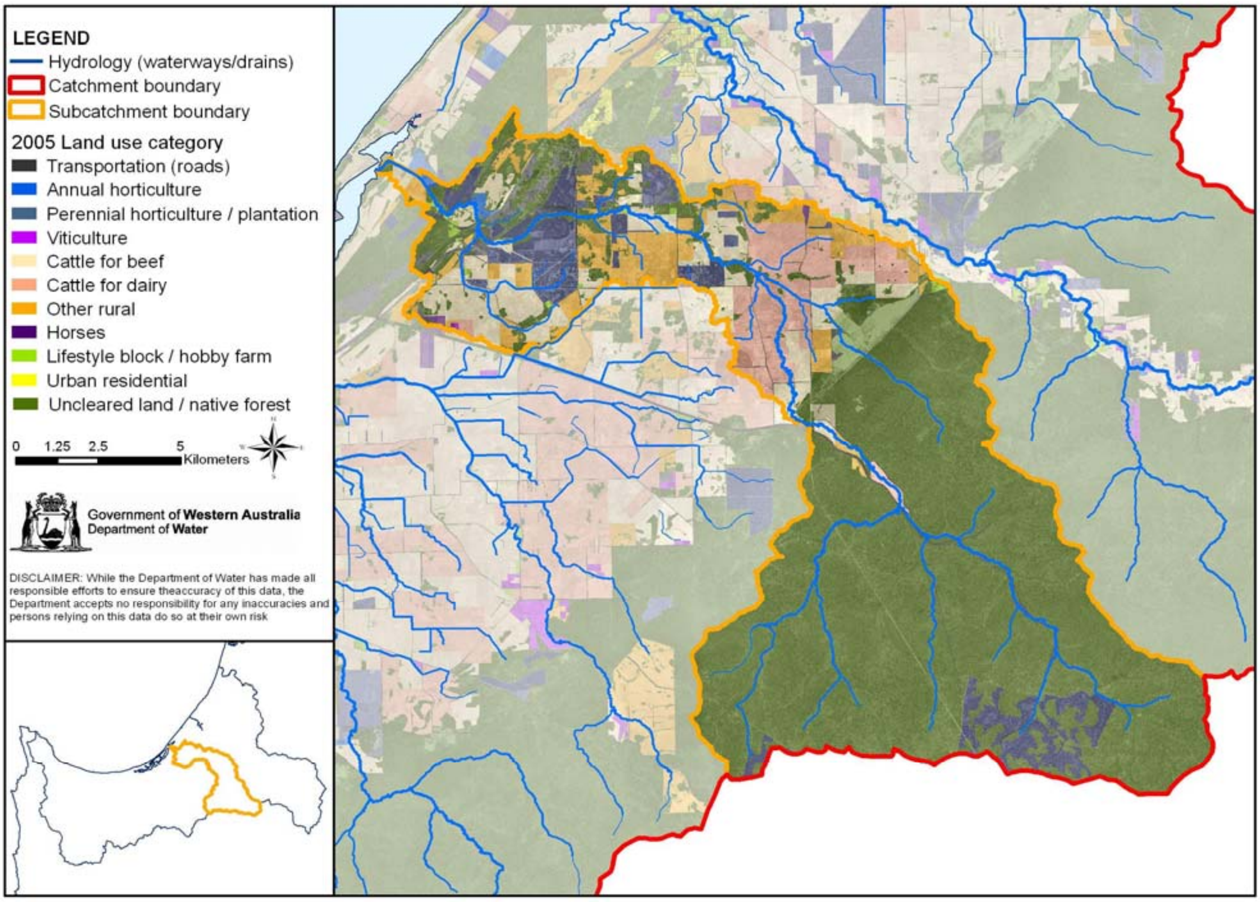


Figure 79: Location and land use of the Ludlow River reporting catchment.

Vasse Diversion Drain

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	14.08	27.17	Long term: 10.04 10-yr interim: 3.8	Long term: 71% 10-yr interim: 27%
Nitrogen	75.6	91.6	Long term: 42.4 10-yr interim: 28.5	Long term: 56% 10-yr interim: 38%

Summary of status and trends

Water quality in the Vasse Diversion Drain substantially exceeds criteria for both phosphorus and nitrogen. A long-term load reduction of 71 per cent is required for phosphorus and 56 per cent for nitrogen. Interim 10-year targets are a 27 per cent reduction for phosphorus and a 38 per cent reduction for nitrogen. Water quality modelling suggests that substantial further increases in both phosphorus and nitrogen loads may occur as a result of planned urban expansions in the catchment.

Nutrient sources

Sources of phosphorus and nitrogen from this subcatchment are highly varied. Cattle for beef and dairy are the dominant contributors, followed by point sources (dairy sheds), urban diffuse sources and discharge from the Busselton wastewater treatment plant. Annual and perennial horticulture also delivers a small proportion of the phosphorus and nitrogen loads. The largest predicted increases in nutrient loads are expected to be derived from the Ambergate urban expansion project and discharge from the Busselton wastewater treatment plant (without technology upgrades).

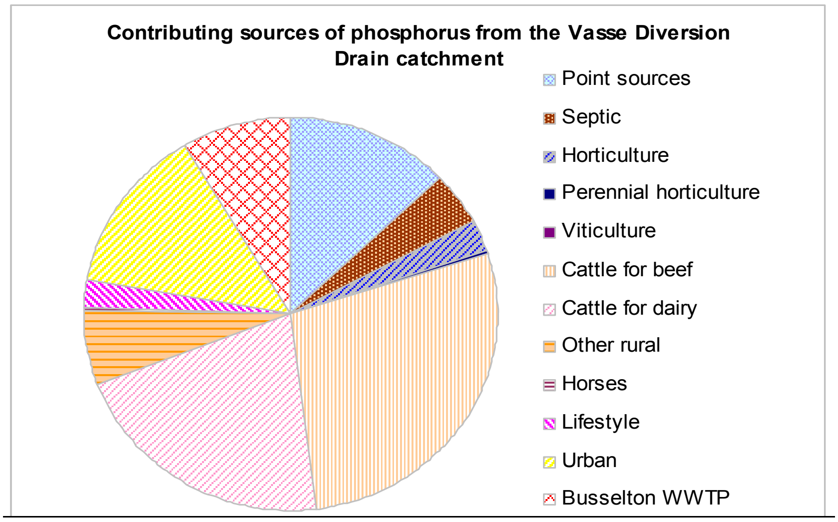


Figure 80: Contributing sources of phosphorus to the Vasse Diversion Drain.

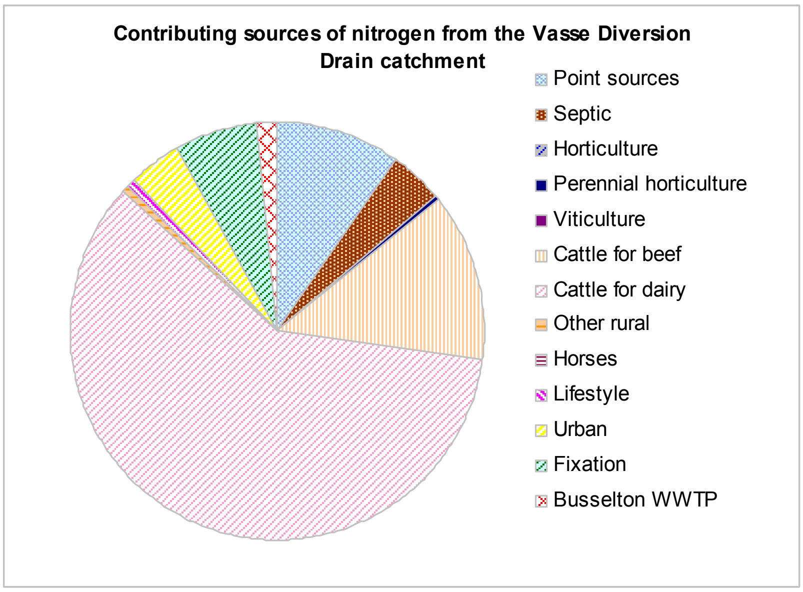


Figure 81: Contributing sources of nitrogen to the Vasse Diversion Drain.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy
Ensure new urban developments incorporate water sensitive urban design.	Water sensitive urban design incorporated in new developments and designed to achieve at least 60 per cent less phosphorus load and 45 per cent less nitrogen load export than conventional urban design.
Apply a no net increase approach to managing nutrient loads from large new urban developments (>50 lots).	Large new urban developments in the catchment have delivered no larger nutrient loads than are currently delivered by the existing land use on the land in question.
Maintain a no net increase in nutrient load approach to upgrades of the Busselton wastewater treatment plant.	No net increase in nutrient loads discharged from the Busselton wastewater treatment plant.
Implement an urban nutrient management program.	25 per cent adoption of fertiliser management in urban residential and light-industrial areas.
Implement targeted retrofitting of water sensitive urban design.	High-priority retrofitting projects identified and implemented in existing urban areas (including light-industrial).

Challenges for nutrient management

- Extensive urban growth planned.
- Structural controls used in water sensitive urban design can currently reduce nutrient loads from new urban developments by up to 60 per cent for phosphorus and 45 per cent for nitrogen in comparison with conventional urban design. The residual increase in nutrients from large new urban developments will still require management using non-structural controls to reduce transport from home gardens and public open space and/or nutrient-offset arrangements.
- Incremental loss of riparian vegetation.
- High capital cost of management measures (such riparian management) to address the nitrogen loads in this catchment.
- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved.

- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- The Water Corporation is planning to upgrade technology at the Busselton wastewater treatment plant to enable a doubling of effluent volume discharge without increasing nutrient loads. The next challenge will be to address growth post-2020 – when the capacity of the new plant is expected to be reached. Early planning is required to investigate all possibilities for effluent management, including re-use options for treated wastewater.

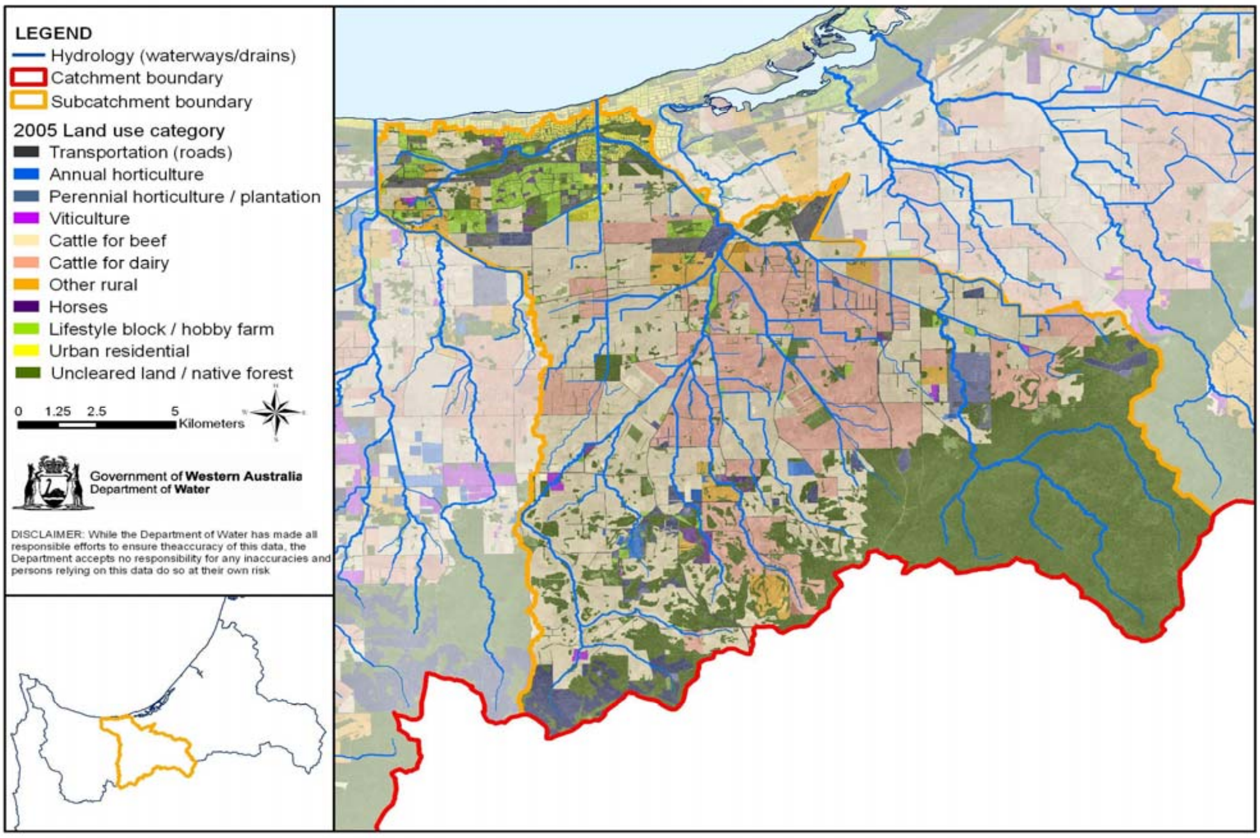


Figure 82: Location and land use of the Vasse Diversion Drain reporting catchment.

Gynudup Brook

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	2.85	2.24	Long term: 1.4 10-yr interim: 1.0	Long term: 49% 10-yr interim: 38%
Nitrogen	21.4	21.3	9.2	43%

Summary of status and trends

Water quality in the Gynudup Brook substantially exceeds criteria for both phosphorus and nitrogen. A long-term load reduction of 49 per cent is required for phosphorus and 43 per cent for nitrogen. An interim 10-year target of 38 per cent is also recommended.

Nutrient sources

Sources of both phosphorus and nitrogen from this subcatchment are contributed entirely by agricultural land uses. Cattle for dairy and beef are by far the most dominant contributors, followed by other rural land uses, and then point sources (dairy sheds) for nitrogen only. Annual and perennial horticulture, horses and lifestyle lots also deliver small proportions of the phosphorus and nitrogen loads.

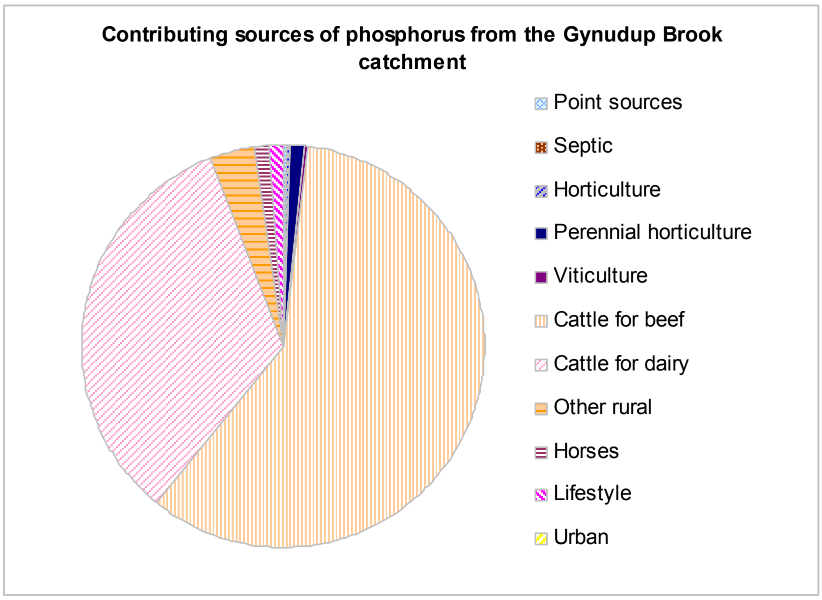


Figure 83: Contributing sources of phosphorus to Gynudup Brook.

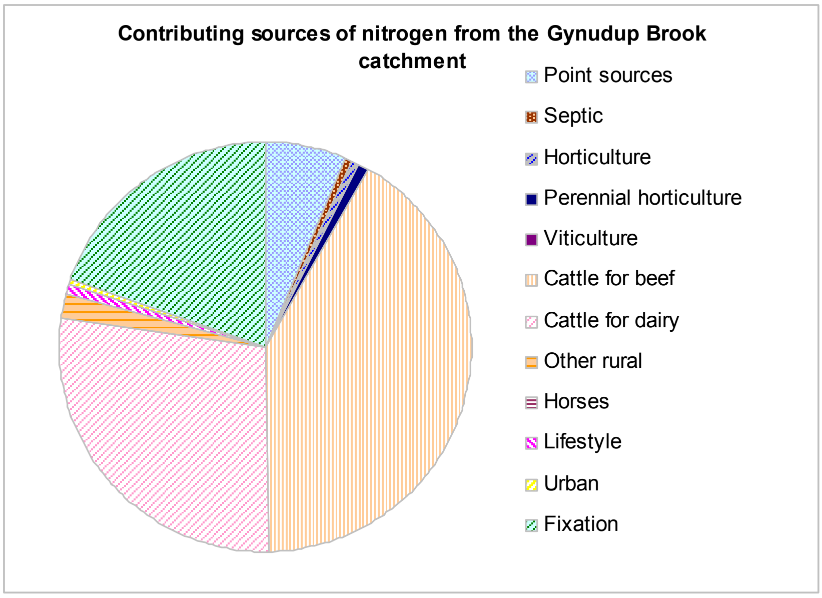


Figure 84: Contributing sources of nitrogen to Gynudup Brook.

Prioritised nutrient action and goals

Action	Ten-year management goal
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy.
Implement targeted soil amendment on agricultural properties.	50 per cent adoption of soil amendment (10T.NUA and low-water-soluble fertiliser).

Challenges for nutrient management

- Incremental loss of riparian vegetation.
- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.
- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved.

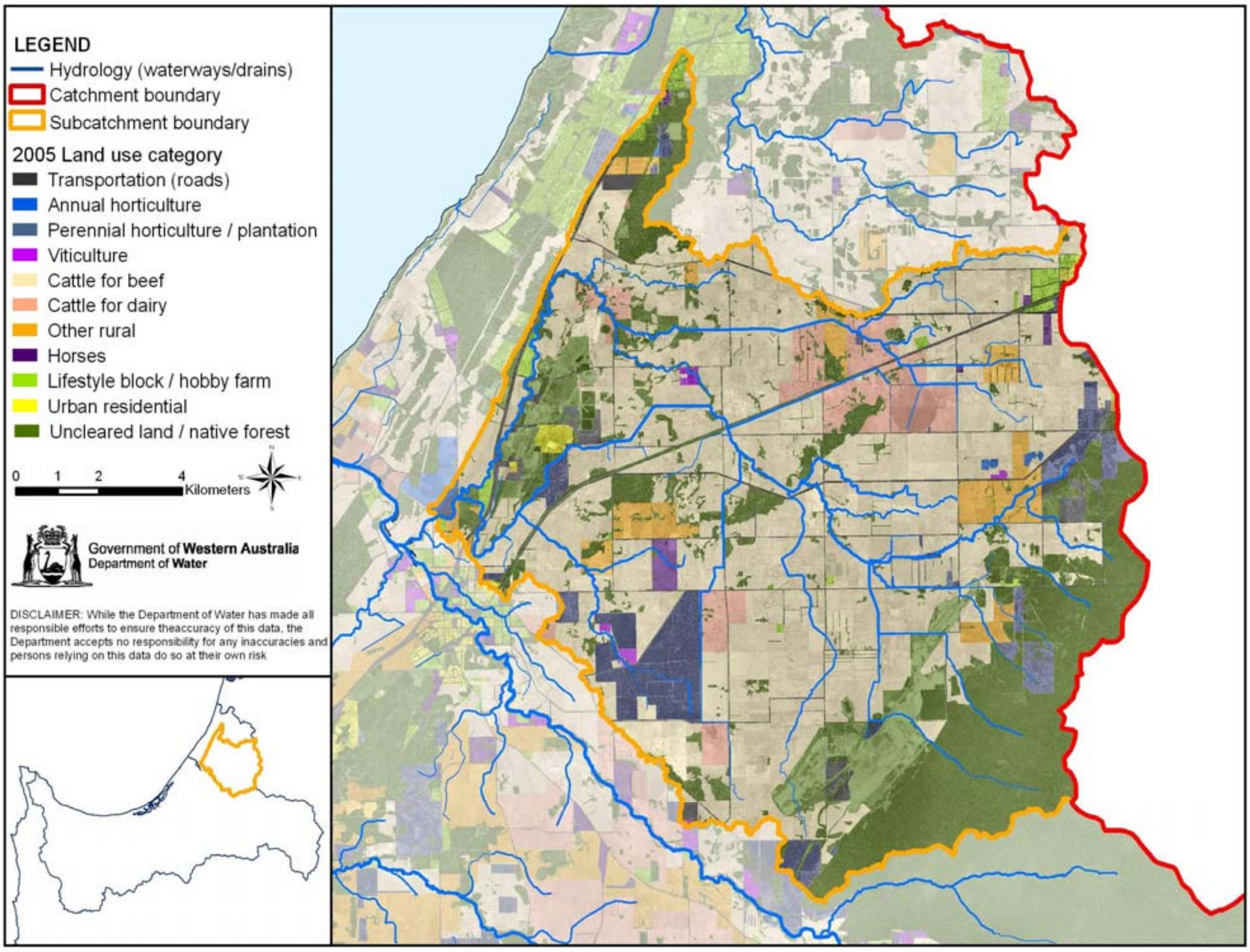


Figure 85: Location and land use of the Gynudup Brook reporting catchment.

Five Mile Brook

Water quality objective: Recovery – reduce N and P to targets				
	Current load (tonnes/pa)	Predicted load (tonnes/pa)	Load reduction target (tonnes/pa)	Load reduction target (% of current)
Phosphorus	3.47	3.55	Long term: 2.63 10-yr interim: 1.7	Long term: 76% 10-yr interim: 50%
Nitrogen	32.1	32.7	Long term: 24.2 10-yr interim: 14.4	Long term: 75% 10-yr interim: 45%

Summary of status and trends

Sufficient monitoring data was not available from this catchment. Computer modelling was therefore used to estimate water quality. Modelling for the waterway was based on the land use, hydrology and vegetation in the Five Mile Brook catchment, and the modelling parameters were adopted from the adjacent catchment where sufficient flow gauging and nutrient sampling regimes exist.

The model suggested that water quality in the Five Mile Brook is likely to substantially exceed criteria for both phosphorus and nitrogen. A long-term load reduction of 76 per cent for phosphorus and 75 per cent for nitrogen has been calculated, while the 10-year interim targets are a 50 per cent reduction in phosphorus and a 45 per cent reduction in nitrogen load.

A priority should be placed on the need for monitoring and revisiting of modelling for this waterway.

Nutrient sources

Cattle for beef is by far the most the dominant contributor of phosphorus and nitrogen in this catchment, followed by diffuse urban sources, and then septic tanks. Lifestyle lots, cattle for dairy, horses, horticulture and other rural land uses comprise the balance of the nutrient load.

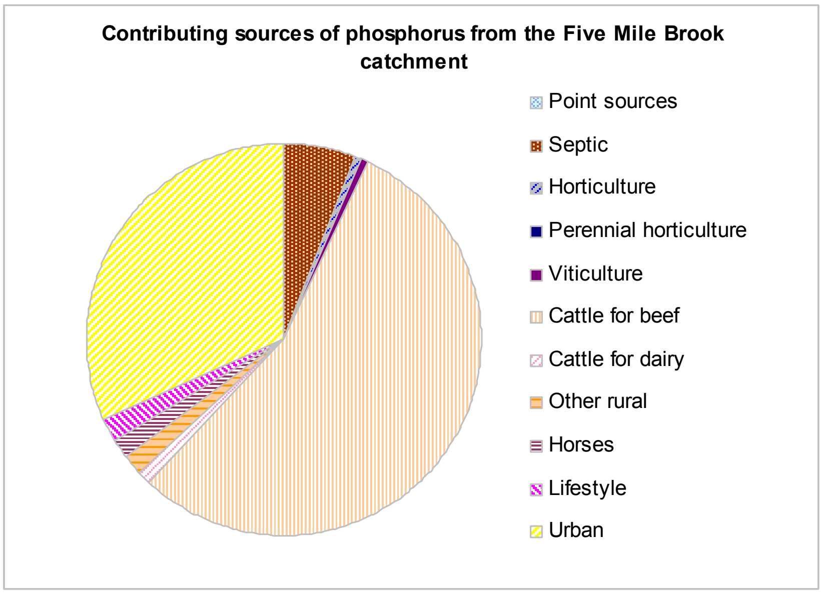


Figure 86: Contributing sources of phosphorus to Five Mile Brook.

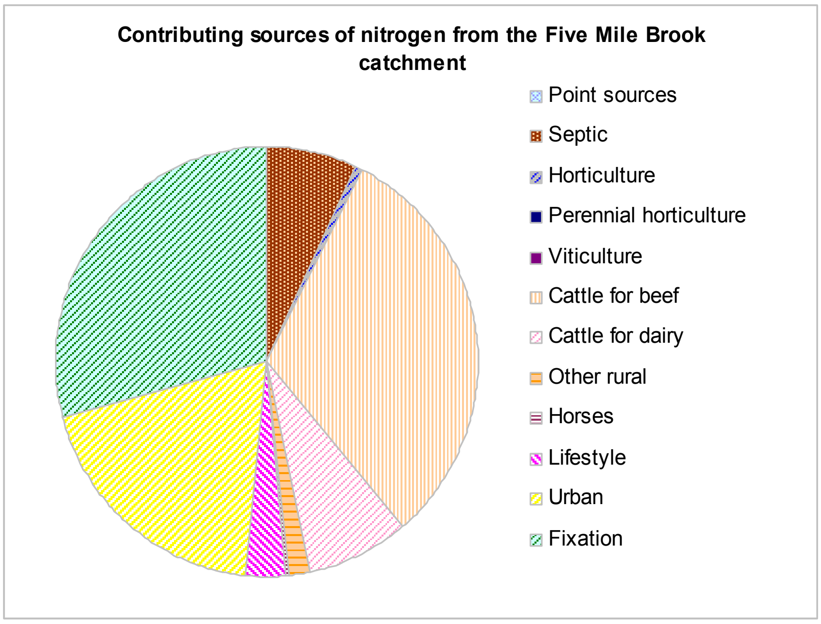


Figure 87: Contributing sources of nitrogen to Five Mile Brook.

Prioritised nutrient action and goals

Action	Ten-year management goal
Establish regular water quality monitoring in this catchment and revisit modelling based on this.	A comprehensive set of water quality data is available for assessment of water quality status.
Implement best-practice agricultural fertiliser management in the catchment.	100 per cent adoption of best-practice fertiliser management for agricultural industries.
Implement best-practice dairy effluent management.	100 per cent adoption of best-practice dairy effluent management.
Implement targeted practice riparian management.	50 per cent adoption of riparian management 'low' on first-order streams. 70 per cent adoption of riparian management 'moderate' on second-order streams. 100 per cent adoption of riparian management 'high' on third-order streams.
Implement targeted perennial pastures.	35 per cent adoption of perennial pastures on cattle for beef properties and 5 per cent on dairy.
Implement targeted soil amendment on agricultural properties.	50 per cent adoption of soil amendment (10T.NUA and low-water-soluble fertiliser).

Challenges for nutrient management

- Incremental loss of riparian vegetation.
- Implementation of the proposed agricultural-nutrient management actions currently relies on voluntary uptake by farmers, with encouragement through incentives, demonstrations and promotions.
- There are limited data available to demonstrate to farmers the effectiveness of some nutrient management practices, such as riparian management.

- The load reduction targets for this catchment are substantial. Even for the interim targets proposed, an intensive management effort is required if they are to be achieved. The targets will require re-checking once sufficient water quality data for this catchment is available.

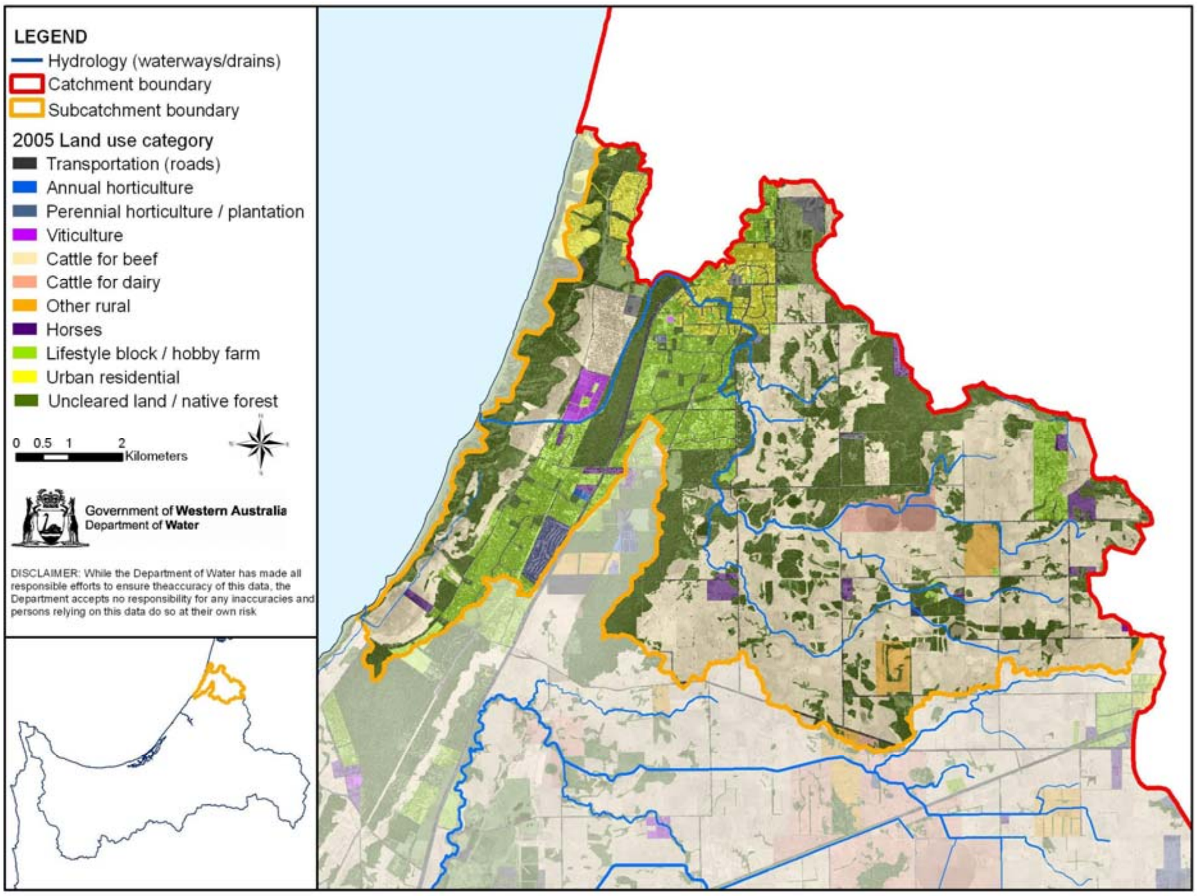


Figure 88: Location and aerial photo of the Five Mile Brook reporting catchment.

Managing the impacts of future urban expansion

Water quality modelling shows that the urban expansions planned in the Geographe catchment have the potential to substantially increase nutrient loads. Most of these increases would be a result of the expansion of the Busselton town site to accommodate an additional 20 000 people in the Provence, Ambergate and Vasse Newtown developments. These developments will drain into the Lower Sabina, Lower Vasse, Vasse Diversion and Buayanyup catchments, which will lead to increased nutrient loads without management intervention. The predicted increases have been illustrated in figures 15 to 18 and 21 to 24 as presented in Section 4.6. Given the challenges already presented by the need to significantly reduce current nutrient loads, the prevention of further increases from new developments is of critical importance.

Addressing the predicted increases in nutrient loads requires careful consideration of the component sources of those loads, and how each component can best be mitigated. Calculations of nutrient-load increases in the catchment have been based on the modelling assumption that urban development would be conventional in design; that is, would not incorporate water sensitive urban design (WSUD) principles. In practice such expansions are highly likely to incorporate these design principles as required by the recently developed *Better urban water management* framework and recommended in this plan.

Implementation of appropriately designed and constructed WSUD to treat flows in all new urban developments is expected to reduce the predicted load increase attributed to new diffuse urban sources. Assuming best-practice design is used, this would be up to 60 per cent for phosphorus and 45 per cent for nitrogen using structural controls. The balance of the predicted increase in load is comprised of two components. The first includes the residual load of 40 per cent for phosphorus and 55 per cent for nitrogen that remains from the urban diffuse contribution after application of WSUD. The second includes any increase in effluent discharged from wastewater treatment plants resulting from the additional sewer connections in new urban areas. For example, the Busselton wastewater treatment plant would have to double its load discharge during the urban growth period unless a significant upgrade of the treatment technology was implemented. All of these component sources need to be addressed to prevent nutrient loads in the catchment from rising further.

Three key recommendations of this plan specifically aim to achieve a zero increase in nutrient load resulting from urban expansions. These are listed below and are outlined in detail in Section 6.2:

- *Recommendation 7: Ensuring new urban developments incorporate water sensitive urban design* – this recommendation is supported by the recently developed *Better urban water management* framework (outlined in more detail in Appendix C).
- *Recommendation 8: Achieving no net increase or a net reduction in nutrient loads from large new urban developments* – this recommendation involves the implementation of additional non-structural controls within new developments or nutrient-offset arrangements. While both measures can currently be negotiated with developers, consistent regulatory and/or policy frameworks would substantially improve the feasibility and effectiveness of their implementation.
- *Recommendation 10: Achieving no net increase in nutrient loads from wastewater treatment plants in the catchment* – there are plans to upgrade technology at the Busselton plant to achieve this aim for the Vasse Diversion Drain reporting catchment.

The application of these recommendations to address individual components of the potential nutrient-load increase is illustrated in Figure 89 below. This figure provides a theoretical breakdown of the management approaches applied to each source of *future* load increase, as compared with management approaches addressing *current* nutrient load. While recommendations 7 and 10 are strong components in currently accepted approaches to nutrient management, recommendation 8 deals with a proportion of the residual nutrient-load increase that is frequently not considered or addressed as part of the development approval process. The example below has been based on modelled data of phosphorus load for the Vasse Diversion Drain catchment. The importance of implementing recommendation 8 is illustrated by noting that the proportion of load it would address is roughly equal in size to the total phosphorus load that would be considered 'acceptable' to flow down the Vasse Diversion Drain (one of the largest Geographe reporting catchments) into Geographe Bay.

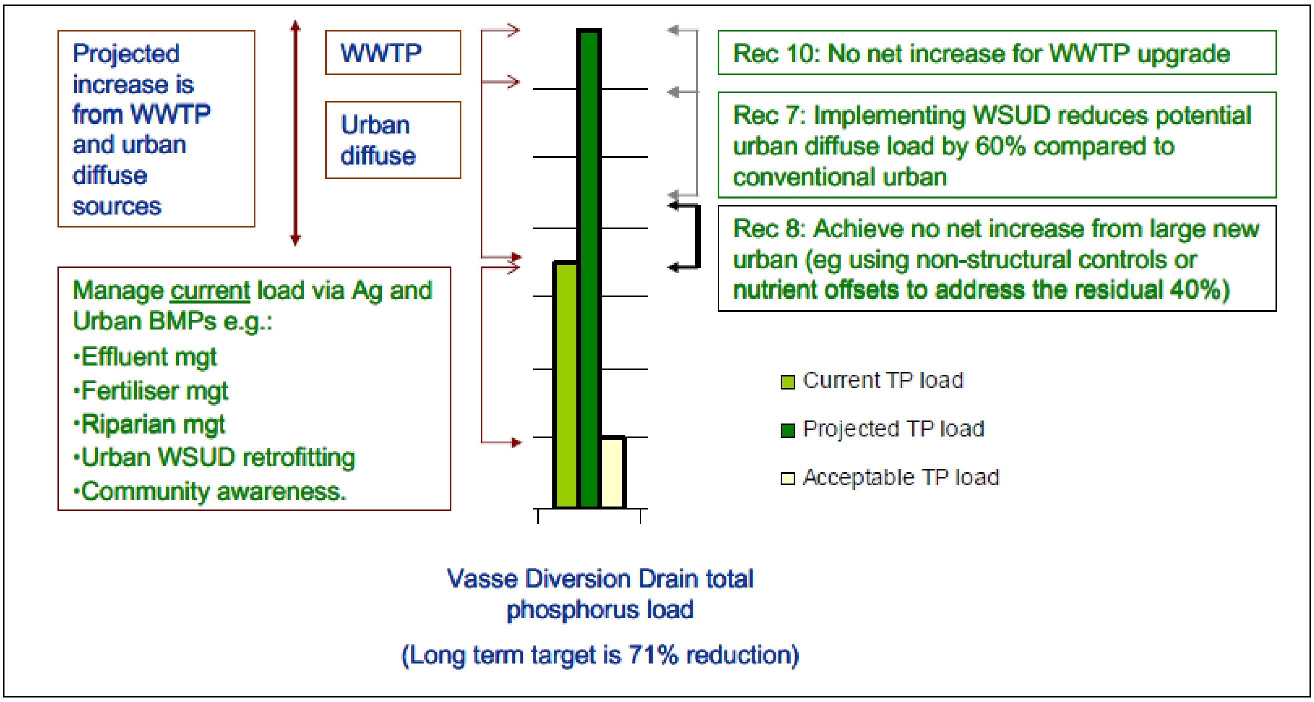


Figure 89: Components of the predicted phosphorus load increase resulting from urban development.

6.5 Further research needs

A long-term and adaptive approach to the management of nutrient problems in the Geographe catchment will be important as land use and rainfall patterns in the catchment change and as new management techniques become available. Current knowledge gaps on nutrient interactions in the bay and estuary ecosystems may also inform management directions as they are filled over time. The first step towards this adaptive approach is the ongoing monitoring and assessment of the status of the bay, estuary and waterways, as well as the implementation of a wide range of research projects to address currently unanswered management questions. Such research projects are just as important as the management interventions recommended in this plan, as they are needed to update our management approach, techniques and direction over time.

A number of important research priorities specific to the Vasse Wonnerup Wetlands have been identified in the *Ecological character description for the Vasse Wonnerup*

Estuary (WRM 2007) presented at Appendix D. Projects that specifically address current shortfalls in nutrient management information – both for the wetland system and Geographe Bay – are summarised below.

Understanding nutrient dynamics in the Vasse Wonnerup Wetlands

Recent surveys by Wilson et al. (2007) and Wilson et al. (2008) have identified large blooms of macroalgae and phytoplankton in the Vasse and Wonnerup estuaries, as well as significant stores of nutrients within the sediments in parts of each estuary. While these surveys have developed a good baseline for monitoring, extensive further research is required to develop an understanding of the changes that may be occurring within algal populations and how nutrient cycling between the water column, plants and sediment may influence their populations. Key projects that are required to progress this aim include:

- seasonal assessments of macrophytes, macroalgae, phytoplankton and water quality throughout the Vasse and Wonnerup estuaries
- further research into the successional dynamics and bloom formation of phytoplankton and macroalgae populations in the Vasse and Wonnerup estuaries
- further sediment studies in the Vasse Wonnerup Wetlands to assess the potential for the storage and release of nutrients from sediments throughout the wetland.

Understanding the ecological impacts of high nutrient loads in Geographe Bay

Current knowledge about thresholds for nutrient loading in Geographe Bay and other marine embayments in Western Australia and beyond is very limited. There have been numerous studies documenting the decline of seagrass ecosystems once impacts have become so severe that widespread loss of seagrass occurs (Cambridge & McComb 1984; Hillman et al. 1991). Unfortunately such cases have demonstrated that once seagrass loss has begun at a scale that can easily be measured, it is very difficult to arrest the problem to prevent further losses and ecosystem decline (Kirkman & Kuo 1990). Seagrass systems can certainly withstand a level of nutrient loading, but the point at which such loads become problematic – the ‘threshold’ level – is very difficult to predict. Monitoring programs that use ecological indicators as early warning signs of nutrient problems in the bay are needed. Further research is needed so that such programs can be established with confidence. To this end, the following research project is recommended:

- develop and evaluate ecological indicators to assess the impact of elevated nutrients at known nutrient hotspots within Geographe Bay.

Understanding groundwater sources of nutrients

Water quality modelling of nutrient sources used in this plan’s preparation has taken into account the contributions of flow and nutrients transported from the Superficial aquifer to individual waterways of the catchment. There was, however, limited data available on the transport of nutrients from the Superficial aquifer directly to the nearshore environment of Geographe Bay and the wetlands from land uses that drain directly to these areas. For the developed coastal strip along the Geographe Bay shoreline, this would also include a significant number of septic tanks that contribute nutrients to the Superficial aquifer during summer. The degree of connectivity between this aquifer and the bay's nearshore environment during the summer period is not known. To close this knowledge gap the following research project is recommended:

- detailed monitoring and assessment of the storage and transport of nutrients within groundwater resources to the wetlands and the nearshore environment of Geographe Bay.

Developing and evaluating nutrient best-management practices

The management scenario modelling presented in this plan used the best-available information and data on the nutrient-removal rates of a selected range of the recommended management measures. For other measures very little data exists and so they cannot be included within such scenario modelling. This is particularly the case for many urban best-management practices. This lack of data hinders the effective implementation of such management measures, since many stakeholders seek clear information about the particular benefits of nutrient management tools when considering their adoption. There are also knowledge gaps about nitrogen interactions in the catchment. There is a particular need for improved data on nitrogen-fixation processes and attenuation of nitrogen within streams. Developing a better understanding of these processes will help to clarify the effect of management measures such as reducing use of nitrogen fertilisers in the catchment and implementing riparian management as a means to treat nitrogen in runoff. As such, the following research projects are recommended:

- develop and undertake further monitoring and research into current and new agricultural nutrient best-management practices to improve understanding about their nutrient-removal rates and other benefits
- develop and undertake further monitoring and research into current and new urban nutrient best-management practices to improve understanding about their nutrient-removal rates and other benefits
- undertake further research and monitoring into the relationship between changes in management (such as the amount of nitrogen fertilisation), nitrogen fixation and nitrogen in runoff.

6.6 Monitoring and modelling

The preparation of this plan and the computer modelling that supports its targets and recommendations would not have been possible without the water quality monitoring data collected as part of the Coastal Catchments Initiative project. Additional data from other water quality monitoring programs coordinated by the Department of Water, the Department of Agriculture and Food and other agencies also supported the modelling process. Further updates to this plan will rely heavily on the availability of continued and updated water quality monitoring information. Failure to collect reliable water quality data for each waterway in the catchment in the years to come will preclude the ability to track the outcomes of implementing this plan.

While the best attempts have been made to ensure that a comprehensive data set was available for this project, there are always improvements that can be made. Gaps in water quality data increase the risk of errors in water quality modelling results. To provide an indication of the level of confidence in water quality monitoring information for each reporting catchment, a summary of the availability of data for each catchment was developed. This summary was then used to make an assessment of the confidence in the modelling results used within this plan. This assessment highlights the shortfall in monitoring data available for the Five Mile Brook and Toby Inlet catchments where there was low confidence in the modelled results due to these limitations. In contrast there was high confidence in the modelled results for the Ludlow, Carbunup, Capel and Vasse Diversion reporting catchments where the long-term data records for both flow and water quality are far more comprehensive.

A complete analysis of the water quality data requirements for calibration of water quality modelling tools used by the Department of Water is presented in the *Water quality monitoring program for the Vasse Geographe catchment* (Appendix F). This document outlines a comprehensive range of monitoring needs in the catchment, some of which have been fulfilled, but need to be continued. Other monitoring needs are still outstanding. The minimum monitoring requirements to enable updates of this water quality improvement plan are as follows:

1. Continued fortnightly water quality monitoring at all existing CCI monitoring sites (shown in Figure 7).

2. Addition of water quality monitoring sites at the discharge point of Five Mile Brook and the Toby Inlet waterways.

3. Continued flow and water quality monitoring at other existing Department of Water sampling sites in the catchment to aid calibration and comparison with upper reaches of relevant waterways.

Table 13: Rating of confidence in modelling results for reporting catchments based on the availability of monitoring data (DOW 2008).

	Five Mile	**Gynudup**	**Capel**	**Ludlow**	**Abba**	**Sabina**	**Lower Vasse**	**Vasse Diversion**	**Buayanyup**	**Carbunup**	**Annie**	**Toby Inlet**	**Dunsborough**	**Jingarmup**
Water criteria														
Flow gauging station on catchment	×	×	✓	✓	✓	×	×	✓	×	✓	✓	×	×	×
Secondary flow gauging station on catchment	×	×	×	✓	×	×	×	✓	×	×	×	×	×	×
Flow gauging station on nearby catchment	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
Catchment hydrology is understood and documented	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×
Flow has been estimated in other documents/models	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
Hydrological calibration > 0.8 Nash Sutcliffe efficiency	×	×	✓	✓	✓	×	×	×	×	✓	✓	×	×	×
Total water	**1**	**2**	**6**	**6**	**5**	**3**	**3**	**5**	**3**	**5**	**4**	**1**	**0**	**0**
Phosphorus criteria														
Nutrient sampling on catchment	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
Secondary nutrient sampling location on catchment	×	✓	✓	✓	×	×	✓	✓	×	✓	✓	×	✓	×
Nutrient sampling at flow gauging station	×	×	✓	✓	✓	×	×	✓	×	✓	×	×	×	×
Sampling record > 3 years	×	×	✓	✓	×	×	✓	✓	×	✓	×	×	×	×
Nutrient calibration > 0.5 Nash Sutcliffe efficiency	×	×	✓	×	×	✓	×	×	×	✓	✓	×	✓	×
Winter median concentration within error bounds of samples	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
Total phosphorus	**0**	**3**	**6**	**5**	**3**	**3**	**4**	**5**	**2**	**6**	**4**	**0**	**4**	**2**
Nitrogen criteria														
Nutrient sampling on catchment	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓
Secondary nutrient sampling location on catchment	×	✓	✓	✓	×	×	✓	✓	×	✓	✓	×	✓	×
Nutrient sampling at flow gauging station	×	×	✓	✓	✓	×	×	✓	×	✓	×	×	×	×
Sampling record > 3 years	×	×	✓	✓	×	×	✓	✓	×	✓	×	×	×	×
Nutrient calibration > 0.5 Nash Sutcliffe efficiency	×	×	×	✓	✓	✓	×	×	×	✓	×	×	✓	×
Winter median concentration within error bounds of samples	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×
Total nitrogen	**0**	**3**	**5**	**6**	**4**	**3**	**4**	**5**	**2**	**6**	**3**	**0**	**4**	**1**

Table 14: Interpretation of outcomes from the confidence assessment (DOW 2008).

Flow value	Confidence in results
5-6	High confidence that actual flows are well represented by modelled flows for the output of the catchments, on a daily and annual basis.
3-4	Modelled flows are likely to represent actual flows, but cross-checks with documented flow studies are required. If flow is not calibrated to gauging data, annual flow quantities will still have a relatively high degree of confidence.
1-2	Annual flows will be likely to have some error associated with them (plus or minus 20 per cent), which will be reflected in annual nutrient-load quantities. Cross-checks with other flow data is essential.
0	Flow quantities are likely to be associated with large errors (plus or minus 50 per cent), and priority in these catchments will be to improve the estimation and understanding of the flow, and to reassess the flow and subsequent load targets.
Nutrient value	**Confidence in results**
5-6	High confidence in modelled annual and seasonal loads. Loads are likely to be represented well in upper reaches of the catchment, and small errors will be associated with the annual load values.
3-4	Modelled annual loads are likely to be associated with a high level of confidence for the period over which the sampling has occurred. Past and future loads have lower confidence due to the length of the sampling record.
1-2	Annual loads will be likely to have some error associated with them (plus or minus 30 per cent), even if there is good flow quality. Error in loads will deteriorate to > 50 per cent if flow data quality is also poor.
0	Low confidence associated with the nutrient loads and concentration values in these catchments, and high errors in annual loads are likely (plus or minus 50—60 per cent). Priority is to begin a sampling regime in these catchments before remedial activities are conducted.

6.7 Nutrient offsets

Nutrient offsets are arrangements whereby developers pay for or undertake equivalent nutrient-remediation works elsewhere in the same reporting catchment to mitigate an expected increase in nutrient load. In accordance with a study by BDA (2008) – *Report on the applicability of a nutrient offset contributions scheme for the Vasse Geographe catchment* – it is recommended that opportunistic, site specific and targeted nutrient offsets be applied in the catchment consistent with the following principles:

- Nutrient discharges should first be avoided – and then minimised or reduced – before considering the use of offsets for any residual impact.
- Nutrient offsets should not be used to allow development in areas where it could not otherwise occur. Offsets should not replace or diminish existing environmental standards or regulatory requirements.
- Proposed offsets should directly reduce nutrient discharges.
- The nutrient being offset should be the same as the nutrient being discharged.

- The proposed measures must offset nutrient discharge in the same part of the system (e.g. ecological zone or reporting catchment) with a minimum time difference between the impact and the offset.
- To address uncertainty, the nutrient offset must achieve a better environmental outcome (the nutrient offset ratio should be greater than 1:1).
- Proposed offsets must be clearly defined, quantified and measurable.
- Proposed offsets must ensure a long-lasting benefit.

7 Implementation

7.1 Implementation framework

Statutory context

A review of the statutory and institutional arrangements to support implementation is included at Appendix I, along with an adaptive management and implementation strategy at Appendix H. The review looks at the existing institutional instruments and mechanisms available to facilitate the plan's implementation.

The Western Australian and Australian governments have a range of statutes and polices that support and will be relevant to the plan's implementation, including:

- National Water Quality Management Strategy
- National Water Initiative
- Australian Government's Coastal Catchments Initiative
- *State water plan*
- *State water strategy*
- *State planning policies*
    - *State planning policy no. 2: Environment and natural resources*
    - *State planning policy no. 2.5: Agricultural and rural land use planning*
    - *State planning policy no 2.7: Public drinking water sources*
    - *State planning policy no. 2.9: Water resources*
- *Better urban water management*
- Wetlands Conservation Policy for Western Australia

Implementation options

The review outlines options to aid implementation through an appropriate framework. These options include using existing agency coordination and cooperation arrangements and various programs and agreements to establish a catchment management authority. The review also proposes a number of small regulatory and institutional changes including:

- State environmental policy
- Planning and development approvals panel
- changes to Environmental Protection Regulations 1987

A further option would be to license dairy farms and feedlots under Part V of the *Environmental Protection Act 1986* (WA). This would require additional resources within the Department of Environment and Conservation to assess the license applications and then audit their performance.

Implementation committee

The review and the adaptive management and implementation strategy (Appendix H) both recommended that an implementation committee be formed. This is proposed to be a subcommittee of the Geocatch Catchment Council and include other lead agencies, stakeholders and community members.

7.2 Implementation principles

A clear set of principles is critical to ensure the plan's nutrient management measures and recommendations are implemented and ultimately the nutrient reduction targets achieved. These principles are strongly focused on the need for collaborative resourcing, as well as a joint agency, industry and all-of-government approach to achieving the plan's objectives. Given the broad range of measures proposed, the plan's success depends on such an approach. The following points outline the key implementation principles:

- Implementation will be based on an all-of-government approach with cross-agency cooperation, resourcing, support and involvement primarily between the Department of Water, Department of Agriculture and Food (DAFWA), Department for Planning and Infrastructure (DPI) and the Department of Environment and Conservation (DEC), local government and where relevant other government agencies and community and industry stakeholders.
- Agricultural-based management measures will generally be implemented in a collaborative manner between the Department of Water, DAFWA and relevant industry groups.
- Implementation of agricultural-based management measures will focus on an agency, industry and community program of research, demonstration sites and extension of existing programs.
- Urban-related management measures will generally be implemented in a collaborative manner between the Department of Water, DPI and local government.
- Implementation of urban-related management measures will focus on the outcomes and requirements of *Better urban water management* and the evaluation of best-management practices in the catchment.

This collaborative approach will need to support the following implementation priorities:

- Allocation of sufficient funds and resourcing to undertake the particular measures. This is particularly important for the monitoring, modelling, evaluation and test cases proposed.
- Priorities for monitoring will need to be clearly identified so that some work continues even in periods of low funding. Priority catchments are:

- reporting catchments that have limited or no monitoring (Five Mile Brook and Toby Inlet)
- catchments likely to undergo substantial land-use change (Buayanyup River)
- those identified as recovery catchments (e.g. Vasse Diversion Drain).

Detailed implementation plans need to identify such priorities based on resourcing and funding availability.

- A focus on evaluating best-management practices in the catchment will be critical to the plan's implementation at an early stage. The current lack of knowledge around certain management measures (e.g. riparian management and perennial pastures) in the catchment is a key limitation. When this shortfall is overcome, aspects of the plan may need reviewing.
- Establishment of case studies in both agricultural and urban settings will be critical to the plan's effective implementation.
- Incorporation of water quality issues into the planning framework.

7.3 Implementation of management measures

Implementing the recommended management measures will require a strategic and prioritised approach to allocating resources for individual recommendations and reporting catchments. Table 15 brings together the nutrient management recommendations that have been prioritised within their source categories and the flow management and research requirements also identified in this plan. Specific actions required for the implementation of these recommendations are also provided for a 10-year management scenario. Details about subcatchment priorities for implementation, levels of adoption and estimated capital have been based on the cost-benefit analysis presented in Section 6.3. Appropriate lead agencies or organisations to manage each recommendation have also been suggested.

In terms of costs, it should be noted that estimates have only been provided for capital costs of implementation. Significant additional costs will be associated with the extensive promotion and coordination tasks required to achieve on-ground implementation of all recommendations and these should be factored into any financial planning as separate items. Similarly, cost estimates have not been provided for recommendations that:

- rely on factors such as agency or private industry staff time for implementation
- are likely to vary significantly in cost depending on site-specific factors
- rely on development of regulatory or policy approaches
- relate to research and development projects for which budgets are likely to develop and change over time.

Table 15: Implementation strategy

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
Managing diffuse agricultural nutrients				
***1** Improving fertiliser management throughout the catchment*	**1.1** Develop tools to assist interpretation of soil tests by farmers. **1.2** Provide regular educational opportunities to farmers to build understanding of how to interpret soil-test results. **1.3** Undertake demonstrations and promote case studies on the benefits of best-practice fertiliser management and using low-water-soluble fertilisers to assist implementation of the *Fertiliser Action Plan.*		$88 000	DAFWA GeoCatch
***2**. Implementing riparian management and stock control*	**2.1** Implement a flexible and high-level cost-sharing arrangement for riparian management and stock control in the catchment that reflects subcatchment priorities for meeting targets. **2.2** Undertake rigorous local evaluation to determine effectiveness of riparian management and stock control on nutrient export including trials of native vegetation. **2.3** Widely promote the benefits of riparian management to farmers through awareness programs and demonstration sites on minor streamlines. **2.4** Develop links for implementation with nutrient-offset programs in the catchment.	**Level 1** Lower Vasse Lower Sabina Vasse Diversion Gynudup Five Mile	$595 000	GeoCatch DOW
		Level 2 Abba Toby Inlet Buayanyup	$250 000	
		Level 3 Jingarmup	$5000	

[11] Actions to aid implementation are listed in the further information about each management measure presented in Section 6.2.

[12] Location and level of implementation are outlined and defined as part of the cost-benefit analysis presented in Section 6.3.

[13] Estimated annual cost is based on the cost-benefit analysis presented in Section 6.3.

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
***3.** Using approved soil amendments on sandy soils*	**3.1** Continue trials of NUA to confirm phosphorus export and pasture productivity benefits; establish feasibility; and identify potential limitations. **3.2** Encourage and assist Iluka to seek formal approval for widespread use of NUA in the Geographe catchment. **3.3** Undertake demonstration projects and promote the best-management practice to farmers once approval for widespread use has been obtained. **3.4** Continue trials of soil amelioration and soil delving to confirm nutrient/fertiliser application reduction potential and pasture productivity benefits; establish feasibility; and identify potential limitations. **3.5** Undertake promotion, education and demonstration of approved products and techniques where clear benefits can be demonstrated and risks have been evaluated. **3.6** Investigate options for soil amelioration in new urban developments	Lower Sabina Gynudup Five Mile	$34 000	DAFWA GeoCatch
***4.** Using perennial pastures in suitable locations*	**4.1** Undertake demonstration and/or experimental implementation of perennial pastures in the local catchment to define areas where they will grow profitably and to clearly establish benefits and constraints to local implementation. **4.2** Provide support to farmers that are willing to undertake replacement of annual pasture with perennial grasses in suitable locations.	**Level 1** Lower Vasse Lower Sabina Ludlow Vasse Diversion Gynudup Five Mile	$295 000	DAFWA
		Level 2 Buayanyup	$38 000	

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
Managing agricultural point sources of nutrients				
***5.** Improving effluent management from dairy sheds and feedlots*	**5.1** Implement cost-sharing arrangements for implementation of or upgrades to best-practice dairy effluent management. **5.2** Widely promote the benefits of effluent management to farmers through awareness programs and demonstrations. **5.3** Adopt an industry-based approach to promoting implementation of BMPs. **5.4** In partnership with industry, review and develop dairy effluent code of practice. **5.5** Ensure all new dairies are assessed with conditions incorporating best practice dairy effluent and nutrient management.	**Level 1** Abba Annie Buayanyup Vasse Diversion Lower Vasse Lower Sabina Ludlow Gynudup	$153 000	Western Dairy DAFWA GeoCatch DOW
		Level 2 Carbunup Capel	$114 000	
Managing diffuse nutrients from the urban landscape				
***6.** Reducing nutrient use and export risk in urban areas*	**6.1** Implement a comprehensive education and awareness program to widely promote the benefits of urban nutrient management, highlight ecological values of receiving waters, and raise awareness of the impacts of nutrients on these values. **6.2** Implement cost-sharing arrangements to improve adoption of nutrient management practices by businesses in light-industrial areas. **6.3** Lead by example in the community by ensuring that facilities such as playing fields and landscaped town areas demonstrate best-practice urban nutrient management. **6.4** Undertake further survey and auditing work to assess variations in urban nutrient management and gauge changes in adoption rates.	Toby Inlet Lower Vasse Vasse Diversion Five Mile	Not costed	DOW GeoCatch Local councils

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
	6.5 Develop and implement policies to ensure future landscaping of new urban areas and public open spaces use local native species with low nutrient and water requirements. **6.6** Facilitate use of modelling and decision-support tools to help local councils to assess the nutrient-transport risk of proposed new urban expansion areas as part of broad strategic planning.			
***7.** Ensuring new urban developments incorporate water sensitive urban design*	**7.1** Continue water sensitive urban design capacity-building programs. **7.2** In consultation with the shires of Busselton and Capel develop assessment tools, plans and technical support to aid local government in decision making on urban proposals and implementation of *Better urban water management* in recognition of the outcomes of the water quality improvement plan. **7.3** Implement on-ground research into the performance of best-management practices for water sensitive urban design. **7.4** Assist local councils to adopt common/shared local water management planning policies and incorporate them into town planning schemes and/or local planning strategies.	All new urban developments regardless of location	Not costed	Local councils DOW WALGA DPI Development industry
***8.** Achieving no net increase in nutrient loads from new urban developments*	**8.1** Negotiate with proponents of new developments to implement non-structural stormwater controls (in addition to structural WSUD) and/or use nutrient-offset arrangements. **8.2** Develop and adopt a policy and/or regulatory framework to formally link non-structural stormwater measures or nutrient-offset arrangements with achievement of accepted nutrient targets. **8.3** Undertake research and development into new urban water management practices. **8.4** Investigate options for nutrient management programs within new	Large new urban developments (>50 lots)	Not costed	DOW DPI Local councils EPA

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
	developments through partnerships with developers and residents.			
***9.** Undertaking strategic retrofitting of water sensitive urban design in existing urban areas*	**9.1** Develop stormwater management plans for local government areas including identification of opportunities and priorities for implementation of WSUD retrofitting projects. **9.2** Implement strategic monitoring to evaluate best-management practices that are part of retrofitting projects.	Lower Vasse Vasse Diversion Toby Inlet Five Mile	Not costed	Local councils DOW
Addressing urban point sources of nutrients				
***10.** Achieving no net increase in nutrient loads from wastewater treatment plants in the catchment*	**10.1** Maintain a no net increase in nutrient-load policy approach to wastewater treatment plant upgrades. This could be facilitated through the Environmental Protection Authority approvals process and might include technology upgrades and/or re-use options. **10.2** In the event that nutrient-offset arrangements are negotiated as part of the approvals process for wastewater treatment plant upgrades, develop partnerships between the Department of Water, GeoCatch and the Water Corporation to identify potential options for nutrient-offset projects. **10.3** Investigate and support options for wastewater reuse that will result in a net nutrient reduction entering wetlands and/or Geographe Bay	Annie Vasse Diversion Capel	Not costed	Water Corporation EPA
***11.** Developing solutions to large nutrient loads delivered by septic systems in specific subcatchments*	**11.1** Negotiate additional funding to expand the infill sewerage program to include urban residential land in the Toby Inlet catchment and the Busselton light-industrial area in the Lower Vasse River. **11.2** To assist negotiations and feasibility assessments, undertake an audit of waste streams from the Busselton light-industrial area using the Water Corporation's criteria for acceptance of industrial waste.	Lower Vasse Toby Inlet	Not costed	Water Corporation DOW Local councils

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
	11.3 Investigate the feasibility of alternative options such as replacement of septic tanks with ATUs that reduce both phosphorus and nitrogen.			
	Managing environmental flows			
12. *Implement flow management assessments for the Carbunup and Capel rivers*	**12.1** Prioritise the Carbunup and Capel river systems within the Geographe catchment for further development of environmental water requirements and formal surface-water management.	Carbunup Capel	Not costed	DOW
13. *Integrate management of environmental flows with water quality management objectives*	**12.3** Develop complementary policy and on-ground strategies to achieve integrated management of water allocation and water quality.	Groundwater and surface-water resources	Not costed	DOW
	Research and development			
14*. Understanding nutrient dynamics in the Vasse Wonnerup Wetlands*	**14.1** Undertake seasonal assessments of macrophytes, macroalgae, phytoplankton and water quality throughout the Vasse and Wonnerup estuaries. **14.2** Undertake further research into the successional dynamics and bloom formation of phytoplankton and macroalgae populations in the Vasse and Wonnerup estuaries. **14.3** Undertake further sediment studies in the Vasse Wonnerup Wetlands to assess the potential for the storage and release of nutrients from sediments throughout the wetlands.	Vasse Wonnerup Wetlands	Not costed	DEC DOW GeoCatch Research organisations
15. *Understanding the ecological impacts of high nutrient loads in Geographe Bay*	**15.1** Develop and evaluate ecological indicators to assess the impact of elevated nutrients at known nutrient hotspots within Geographe Bay.	Geographe Bay	Not costed	DEC DOW GeoCatch

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
				Research organisations
***16.** Understanding groundwater sources of nutrients*	**16.1** Develop and implement detailed monitoring program and assessment of the storage and transport of nutrients within groundwater resources to the wetlands and nearshore environment of Geographe Bay.	Groundwater resources	Not costed	DOW
***17.** Developing and evaluating best-management practices (BMPs) for nutrients*	**17.1** Develop and undertake further monitoring and research into current and new agricultural nutrient BMPs to improve understanding about their nutrient-removal rates and other benefits.	Rural areas of the Geographe catchment.	Not costed	DAFWA
	17.2 Develop and undertake further monitoring and research into current and new urban nutrient BMPs to improve understanding about their nutrient-removal rates and other benefits.	Urban areas of the Geographe catchment.	Not costed	DOW
	17.3 Undertake further research and monitoring into the relationship between changes in nitrogen management (such as the amount of nitrogen fertilisation and riparian management), nitrogen fixation and nitrogen in runoff.	Rural areas of the Geographe catchment.	Not costed	DAFWA
Monitoring				
***18.** Undertaking extensive and ongoing monitoring and modelling in the catchment*	**18.1** Ongoing evaluation and implementation of the water quality monitoring program for the Vasse Geographe catchment, which should include as a minimum: – continued catchment-scale water quality monitoring at all existing CCI monitoring sites with priority given to the addition of water quality monitoring sites at the discharge point of the Five Mile Brook and Toby Inlet waterways. – water quality monitoring in subcatchments where			

Management measure	Actions to aid implementation[11]	Location and level of implementation[12]	Estimated annual capital cost (over 10 years)[13]	Lead agencies/ organisations
	management measures are being implemented and tested in order to evaluate progress in achieving nutrient reduction targets and the effectiveness of management measures – continued flow and water quality monitoring at other existing Department of Water sampling sites in the catchment to aid calibration and comparison with upper reaches of relevant waterways. **18.2** Revisit water quality modelling undertaken for Five Mile Brook and Toby Inlet based on monitoring data. **18.3** Formulation of a coordinated and jointly funded research and monitoring program between agencies responsible for agricultural and urban water management. **18.4** Ongoing maintenance and review of the catchment model to reflect changes in land use, water quality, knowledge of BMPs and management measures so that the plan's progress can be tracked and evaluated over time.			

7.4 Using a treatment train approach

To achieve best results, management practices need to be implemented using a 'treatment train' approach throughout the landscape. This approach recognises that some best-management practices act in parallel (concurrently) and others in series (sequentially – one after another) (Keipert 2007). Management practices that reduce the total nutrient load within farming systems (or urban developments) then need to be addressed by practices implemented beyond the farm or urban landscape. Achieving the complete treatment train within a catchment will maximise the overall nutrient-load reduction that may be achieved. For this reason, recommendations in this plan should be implemented concurrently across reporting catchments and farms, rather than tackling only a selection of the recommendations. The figure below illustrates the treatment train approach for the rural landscape.

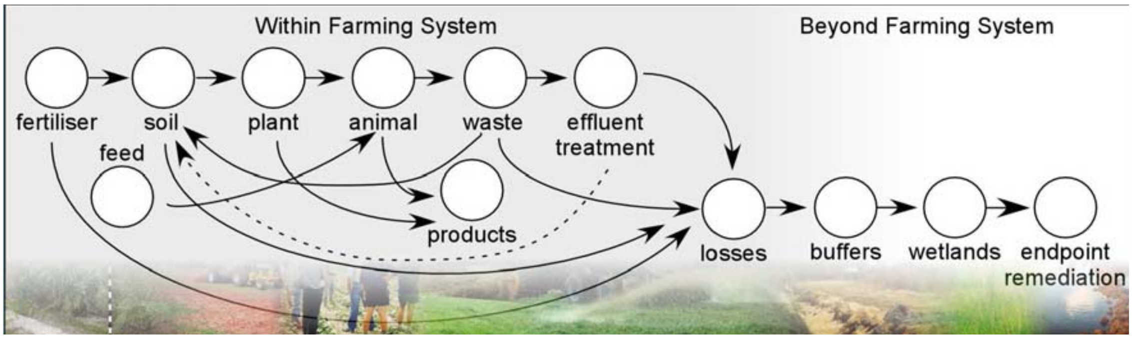


Figure 90: Treatment train that influences best-management practice options (Keipert 2007).

Increasing the adoption of agricultural best-management practices presents a challenge since these tools have been the subject of extensive effort by natural resource managers for many years. Keipert (2007) provides the following general advice for improving the uptake of agricultural best-management practices:

- raise farmer awareness of impacts they may be having
- provide practical demonstrations of particular best-management practices supported by appropriate nutrient-reduction data
- build understanding that their management practices could be improved
- provide good reasons for farmers to adopt best-management practices.

7.5 Using market-based approaches

Maximising the uptake of management practices may sometimes require innovation in areas where usual approaches have not achieved success, and where regulation is unavailable or unsuitable. Market-based approaches to the implementation of environmental management measures have been used extensively throughout Australia for many years. Six market-based options have been identified as being suitable for use in the Geographe catchment to maximise the uptake of this plan's management recommendations. These are summarised in Table 16.

Table 16: Market-based incentives suitable for use in the Geographe catchment.

Options for market-based approaches	Management measures with potential suitability	Explanation	Comments
Cost-sharing arrangements	Fertiliser management Riparian management In-stream management Soil amendment Perennial pastures Effluent management Irrigation techniques Drainage management Retrofitting septic tanks with ATUs	Grants to landholders to improve uptake of BMPs; for example, cost sharing can help landholders with: – improved access to independent interpretation of soil-test results – fencing, rehabilitation and stock crossings/watering points – upgrades to effluent management systems – improvements to irrigation systems – replacement of annual pasture grasses with perennials – soil amendment.	Industry partnerships should be maintained to maximise the long-term impact of grant programs. Implementation can be through individual direct grants or auction-based systems. Potential for links to be made with nutrient offsets for some of these works. Riparian management is likely to need full cost recovery on first- and second-order streams in high-priority catchments to improve uptake.
Increased cost of fertiliser	Fertiliser management	Recent and potential future rises in fertiliser prices may result in improved fertiliser management through increased need for farmers to reduce fertiliser expenditure.	May not result in improved management in situations where farmers are able to pass on the increased cost to consumers by increasing produce prices. Survey work should be used to confirm the effect of this current market situation. Lack of nutrient-budgeting tools and advice about interpretation may limit the impact of pricing on management.
Low interest loans	Increasing connections to existing deep sewer	Low interest loans offered to urban landholders that are not yet connected to an available deep sewer.	Currently being tested in the Perth metropolitan area by some local councils. Would enable a highly targeted approach in high-risk areas. Potential option for implementation of BMPs for which direct grants are not considered appropriate.

Options for market-based approaches	Management measures with potential suitability	Explanation	Comments
Opportunistic nutrient offsets	Achieving a net reduction in nutrient loads from urban developments in recovery catchments.	A requirement for proponents of large developments (or point-source upgrades) in recovery catchment areas to pay for nutrient management works elsewhere within the same catchment. This would be designed to provide a permanent nutrient-load reduction commensurate with the estimated nutrient load associated with the proposal.	Requires substantial feasibility assessment and evaluation. Clear and formalised guidelines for the implementation of opportunistic offsets are needed (some are suggested by BDA 2008). Requires established arrangements to ensure ongoing management, maintenance and evaluation of the implemented offsets. Independence in approval and selection of suitable offsets is needed.
Badging and branding	Potential applications for all nutrient management measures, both agricultural and urban.	Involves public recognition of the use of best-practice nutrient management through signage, accreditation or endorsement of some kind. Works on the basis that recognition of best practice will improve the marketability of a particular product (whether it be milk from a particular area or sale of lots from a particular subdivision).	True market-based applications would relate to use within rural industries or new urban developments (where there is a product to 'sell'). Other applications can provide community recognition for achievements such as improvements in sewer connections within particular suburbs. Potential benefits would be enhanced with wider implementation in some situations (e.g. state-wide rather than just catchment-based programs).
Industry-led management	Potential applications for a wide variety of nutrient management measures.	Involves self-regulation by an industry group to improve standards in nutrient management. An example is the nutrient management requirements for dairy farms providing milk to Fonterra Cooperative Group Limited in New Zealand. Fonterra specifies guidelines and targets for nutrient and carbon management for all of its milk suppliers.	Implementation is reliant on industry voluntarily seeing a marketing benefit in the guarantee that a product has been produced using best-practice nutrient management. Strong links could be made between this option and badging and branding techniques. Industry adoption of such systems could potentially be fast-tracked through badging and branding approaches.

8 Reporting and review

8.1 Reporting on implementation of this plan

The process for public reporting on the implementation of this water quality improvement plan is proposed to involve two stages:

1. reporting of progress toward meeting defined water quality and nutrient-load targets
2. reporting of progress toward implementation and adoption of management measures and control actions defined within the plan.

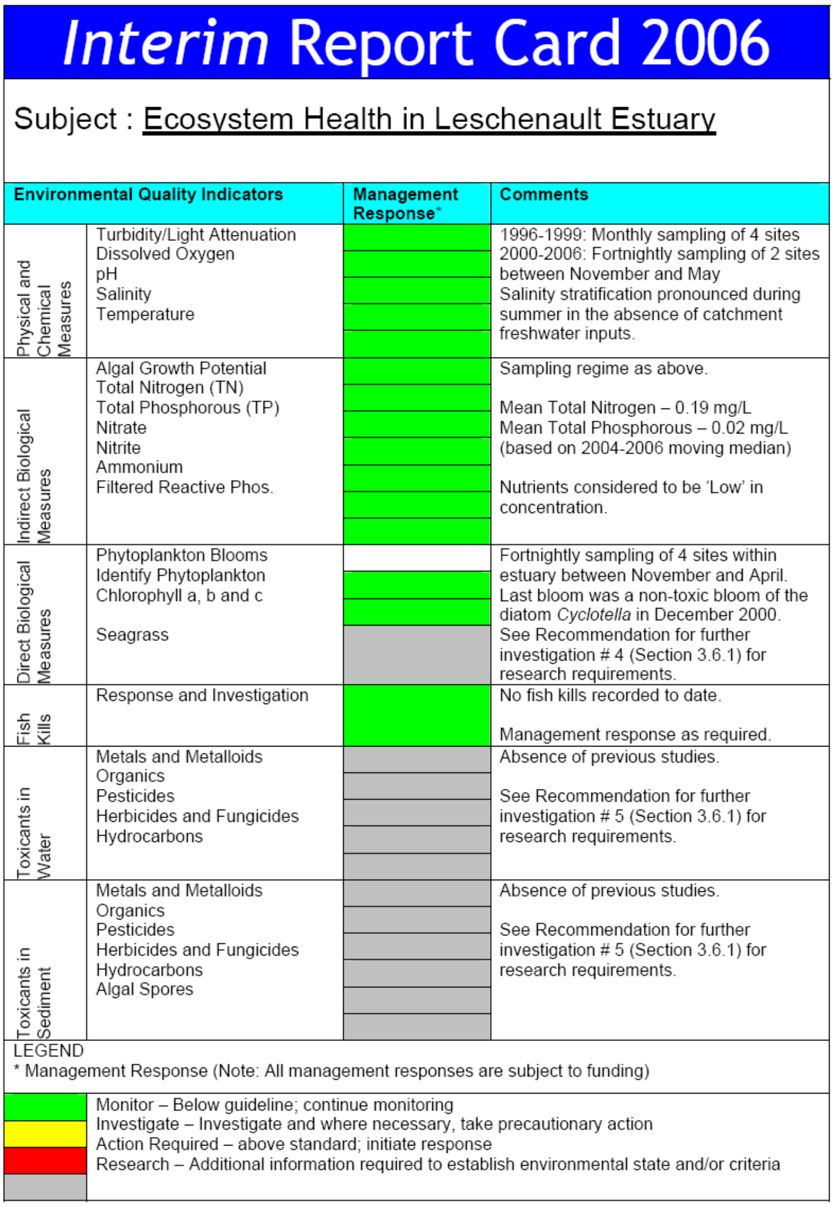
These two types of reporting are discussed below.

Progress toward targets

It is proposed that public reporting of progress toward water quality targets is undertaken every three years using report cards for individual reporting catchments. These report cards will provide subcatchment stakeholders with updates on how water quality in their subcatchment is changing based on water quality monitoring data and updates of the water quality model outputs. This will enable updates to be provided on:

- trends in nutrient status in terms of nutrient loads and nutrient concentrations in the waterways
- changes in the source separation within the subcatchment (reflecting known changes in management or reductions in point sources)
- changes in the management category of the subcatchment (e.g. over time with improvements, some intervention subcatchments may move into the protection category)
- a summary of the water quality monitoring results for the reporting catchment, including results of compliance testing against water quality criteria
- known incidents of algal blooms, fish deaths or other nutrient responses recorded within the reporting catchment.

Similar report cards have been produced for the Swan Canning, Cockburn Sound and Leschenault catchments. These other examples have used different report parameters depending on the local monitoring programs. An example report card from the Leschenault catchment is provided below. The approach to reporting presented in this example is expected to form the basis of the Geographe catchment’s report cards, though the categories of reporting will be adapted to align closely with this water quality improvement plan.



Interim Report Card 2006

Subject : Ecosystem Health in Leschenault Estuary

Environmental Quality Indicators		Management Response*	Comments
Physical and Chemical Measures	Turbidity/Light Attenuation Dissolved Oxygen pH Salinity Temperature		1996-1999: Monthly sampling of 4 sites 2000-2006: Fortnightly sampling of 2 sites between November and May Salinity stratification pronounced during summer in the absence of catchment freshwater inputs.
Indirect Biological Measures	Algal Growth Potential Total Nitrogen (TN) Total Phosphorous (TP) Nitrate Nitrite Ammonium Filtered Reactive Phos.		Sampling regime as above. Mean Total Nitrogen – 0.19 mg/L Mean Total Phosphorous – 0.02 mg/L (based on 2004-2006 moving median) Nutrients considered to be 'Low' in concentration.
Direct Biological Measures	Phytoplankton Blooms Identify Phytoplankton Chlorophyll a, b and c Seagrass		Fortnightly sampling of 4 sites within estuary between November and April. Last bloom was a non-toxic bloom of the diatom *Cyclotella* in December 2000. See Recommendation for further investigation # 4 (Section 3.6.1) for research requirements.
Fish Kills	Response and Investigation		No fish kills recorded to date. Management response as required.
Toxicants in Water	Metals and Metalloids Organics Pesticides Herbicides and Fungicides Hydrocarbons		Absence of previous studies. See Recommendation for further investigation # 5 (Section 3.6.1) for research requirements.
Toxicants in Sediment	Metals and Metalloids Organics Pesticides Herbicides and Fungicides Hydrocarbons Algal Spores		Absence of previous studies. See Recommendation for further investigation # 5 (Section 3.6.1) for research requirements.

LEGEND
* Management Response (Note: All management responses are subject to funding)

Monitor – Below guideline; continue monitoring
Investigate – Investigate and where necessary, take precautionary action
Action Required – above standard; initiate response
Research – Additional information required to establish environmental state and/or criteria

Figure 91: Example report card for the Leschenault Estuary (DOW 2007).

Progress toward implementation of management measures

Reporting of progress toward implementation of the management measures and control actions will be undertaken on an annual basis. Reporting of this nature will ideally be undertaken as a joint effort involving all responsible parties. Reporting will identify achievements toward implementing each management measure and control action.

These annual implementation progress reports will be supplemented by:

- Where possible, GIS mapping of best-management-practice implementation across the catchment to provide relevant spatial information.
- Farmer and urban nutrient surveys undertaken every five years to update information about best-management-practice adoption and nutrient use in the

catchment. These surveys will also be used to analyse trends in adoption rates and practices that can be reflected in reporting-catchment report cards.

8.2 Accounting for impacts of climate change

As implementation of this water quality improvement plan progresses, it will be important to ensure that regular reviews of the plan take account of the changes in rainfall that may result from climate change. The Intergovernmental Panel on Climate Change (IPCC) developed an updated set of long-term emission scenarios in 1996. These scenarios have been widely used in the analysis of possible climate change, its impacts and options to mitigate climate change (Nebojsa et al. 2000). For this plan, two of the emission scenarios have been analysed by DOW (2008):

- **A2 scenario:** a scenario describing a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continually increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other scenarios.

- **B1 scenario:** a scenario describing a world in which the emphasis is on local solutions and economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in other scenarios. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Using these scenarios, the Department of Water (2008) completed an analysis of the likely changes in the average annual load and average winter median concentration of phosphorus and nitrogen across waterways in the Geographe catchment. The results of this analysis indicate that both climate change scenarios would result in a decrease in annual load (figures 92 and 93). These changes were only slightly different from the future loads predicted using current rainfall data for the B1 scenario. In contrast the A2 scenario is predicted to have a dramatic effect – with a substantially lower load of phosphorus and a nitrogen load roughly equalling the current load. The implications of both climate change scenarios is that load reduction targets may be easier to meet as a result of reduced rainfall. It should, however, be noted that meeting those same load-reduction targets may no longer achieve the same outcomes in terms of winter median concentration of nutrients. Depending on local hydrological conditions, climate change may result in an increase in nutrient concentrations within some waterways and receiving waterbodies even though the overall load would be reduced. This can occur when lower volumes of water flow fail to provide the diluting effects that may currently be present. Given that algae responds to concentration and not load, this situation may result in a failure to prevent the range of nutrient issues currently experienced in some waterways, even when load reduction targets are met. Clearly, a process to review nutrient-reduction targets is needed, which reflects changes in rainfall resulting from climate and the need to meet the required concentration criteria for phosphorus and nitrogen.

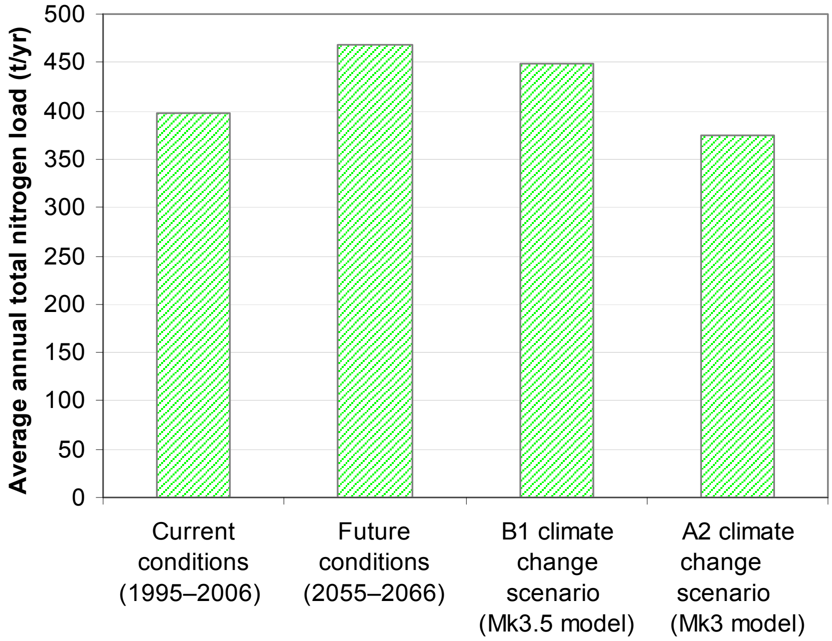


Figure 92: Modelled outcomes of nitrogen load from climate change scenarios.

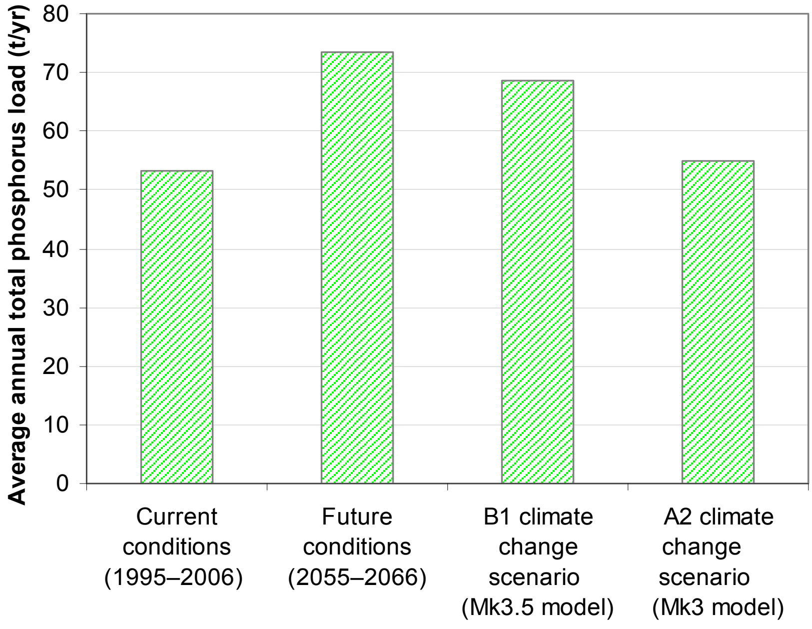


Figure 93: Modelled outcomes of phosphorus load from climate change scenarios.

To review the water quality targets in this plan to account for climate change, the following steps should be undertaken every five years:

1 review updated information about rainfall to determine whether trends indicate a change in rainfall regime
2 where changes in rainfall regime are detected, undertake recalibration of the water quality models to reflect these changes
3 using updated water quality monitoring data and the newly calibrated water quality models, undertake calculations of adjusted load reduction targets to meet concentration criteria
4 recalibrate decision-support tools using newly calculated load reduction targets and (where relevant) rainfall regimes and re-run scenario testing.

8.3 Water quality implementation plan review

Regular reviews of this water quality improvement plan will need to occur as new information becomes available. This new information has potential to stem from:

- outcomes of research and development projects that may lead to the need to adjust nutrient targets, flow regimes or management practices
- amendments to water quality targets resulting from ongoing monitoring
- changes in rainfall patterns resulting in a need to adjust load targets, recalibrate models and re-run management scenarios and cost-benefit analyses
- changing market conditions affecting financial returns from management practices
- responses to new government initiatives or policies that may affect the potential for implementation of a range of management recommendations.

The proposed structure for this review has been established in the adaptive management and implementation strategy which is shown as Appendix H. This proposes a comprehensive review every five years as well as review, consolidation and implementation on an ongoing and annual basis. The stages, responsibilities and nature of the review process are summarised in the Figure 94. This shows that the Department of Water and Geographe Catchment Council will be mainly responsible for future reviews.

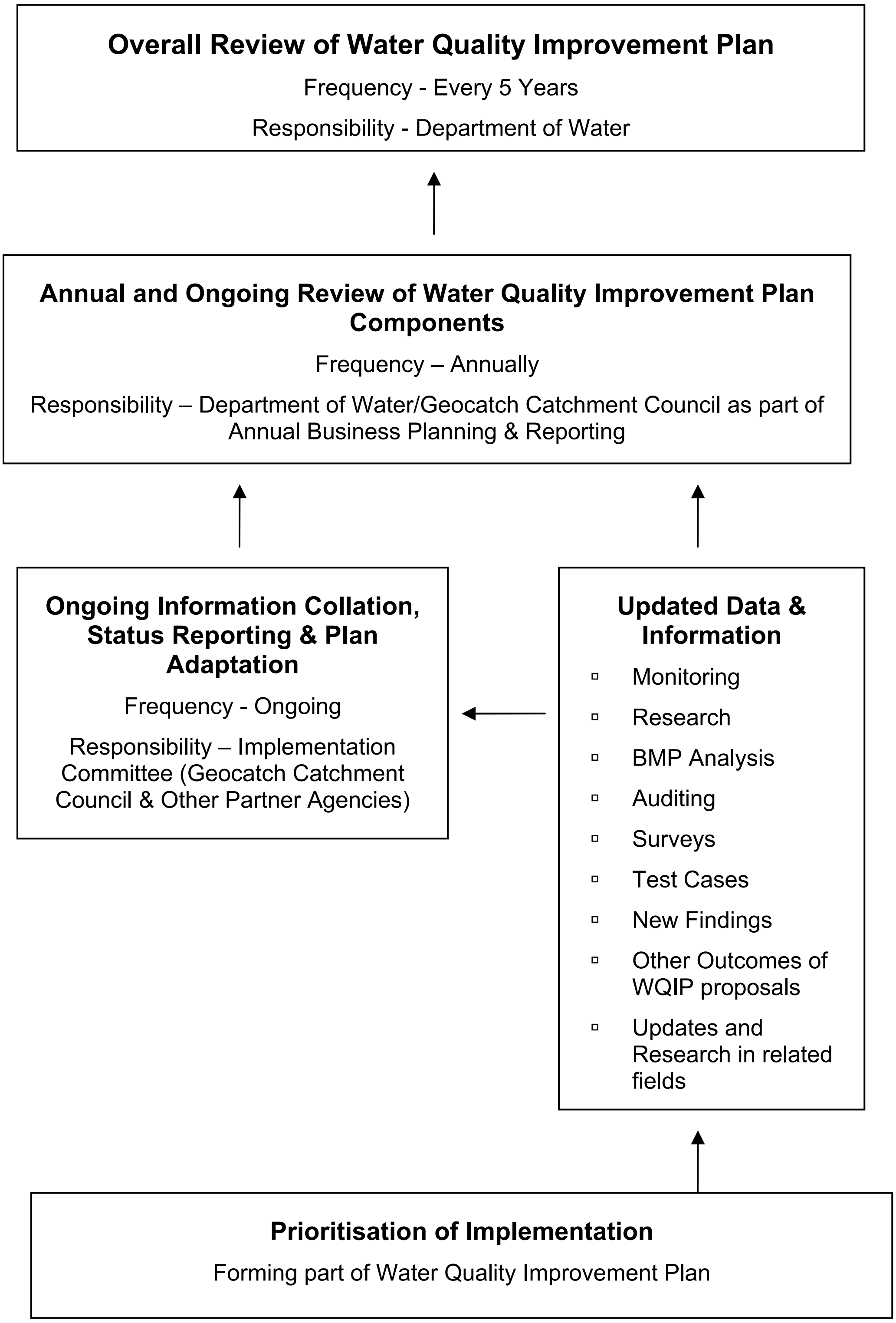


Figure 94: Framework for review

The five-yearly review would involve the following processes:

1 Collecting and compiling updated data on:
   - land-use and projected land-use changes
   - updated water quality monitoring information
   - outcomes from new surveys of farmers and urban landholders about nutrient use and rates of adoption of management practices
   - new information from research, development and evaluation of management practices
   - outcomes from research about nutrient thresholds in the receiving waterways
   - updated information on changes to rainfall regimes resulting from climate change
   - compiled information on achievements to date from progress reporting.

2 Updating and recalibrating water quality models and decision-support systems to reflect the new data or upgrading these tools as improvements become available over time.

3 Using outcomes from the model to update information in the plan about:
   - nutrient status
   - load-reduction targets
   - source separation analysis
   - cost-benefit analysis
   - management recommendations.

While the five-yearly review will represent a substantial culmination of information and outcomes affecting this plan, it is important that a structure is established that supports this broader review and deals with adaptive measures and implementation on a more regular basis.

It is proposed that the plan's management measures, recommendations and outcomes are integrated into the Geographe Catchment Council's business planning model. Business planning for Geocatch involves an annual reporting process that includes review, assessment and prioritisation of projects and adopted recommendations. This includes a consultation process with partner organisations such as DAFWA, DEC, DPI, the shires of Busselton and Capel, Land Conservation District Committees, universities and community organisations. Such consultation seeks to document and acknowledge the relevant actions of these other stakeholders which contribute to the business plan's key directions.

Glossary

Biodiversity	Biological diversity or the variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems.
Catchment	Area of land from which rainfall runoff contributes to a single watercourse, wetland or aquifer.
Climate change	A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
Ecological values	Natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	Water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. a lake. Includes all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environment	Living things, their physical, biological and social surroundings, and the interactions between them.
Extraction	Taking of water, defined as removing water from or reducing the flow of a waterway or from overland flow.
Flow	Streamflow in terms of m^3/yr, m^3/d or ML/yr. Also known as discharge.
Groundwater	Water that occupies the pores and crevices of rock or soil beneath the land surface.
Licence	A formal permit that entitles the licence holder to ‘take’ water from a watercourse, wetland or underground source.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Watercourse	a. Any river, creek, stream or brook in which water flows. b. Any collection of water (including a reservoir) into, through or out of which anything coming within paragraph (a) flows. c. Any place where water flows that is prescribed by local bylaws to be a watercourse. A watercourse includes the bed and banks of anything referred to in paragraphs (a), (b) or (c).

Water-dependent ecosystems	Those parts of the environment that are sustained by the permanent or temporary presence of water.
Water regime	A description of the variation of flow rate or water level over time. It may also include a description of water quality.
Waterways	All streams, creeks, stormwater drains, rivers, estuaries, coastal lagoons, inlets and harbours.
Xeriscaped	A landscaped area that has low-water-use plants such that supplementary irrigation is not required. Xeriscaped gardens also frequently have low nutrient requirements.

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Appendices

Appendix A: DOW 2008, SQUARE water quality modelling report

Appendix B: Ecotones 2008, Development of the decision-support system SSPND

Appendix C: Achieving better urban water management in Western Australia

Appendix D: Draft ecological character statement for the Vasse Wonnerup Wetlands

Appendix E: Ecotones 2008, BMP scenarios for the Vasse Geographe catchment

Appendix F: Water quality modelling and monitoring program for Vasse Geographe

Appendix G: Summary of land-use map categories

Appendices A to G are provided on the enclosed CD.

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