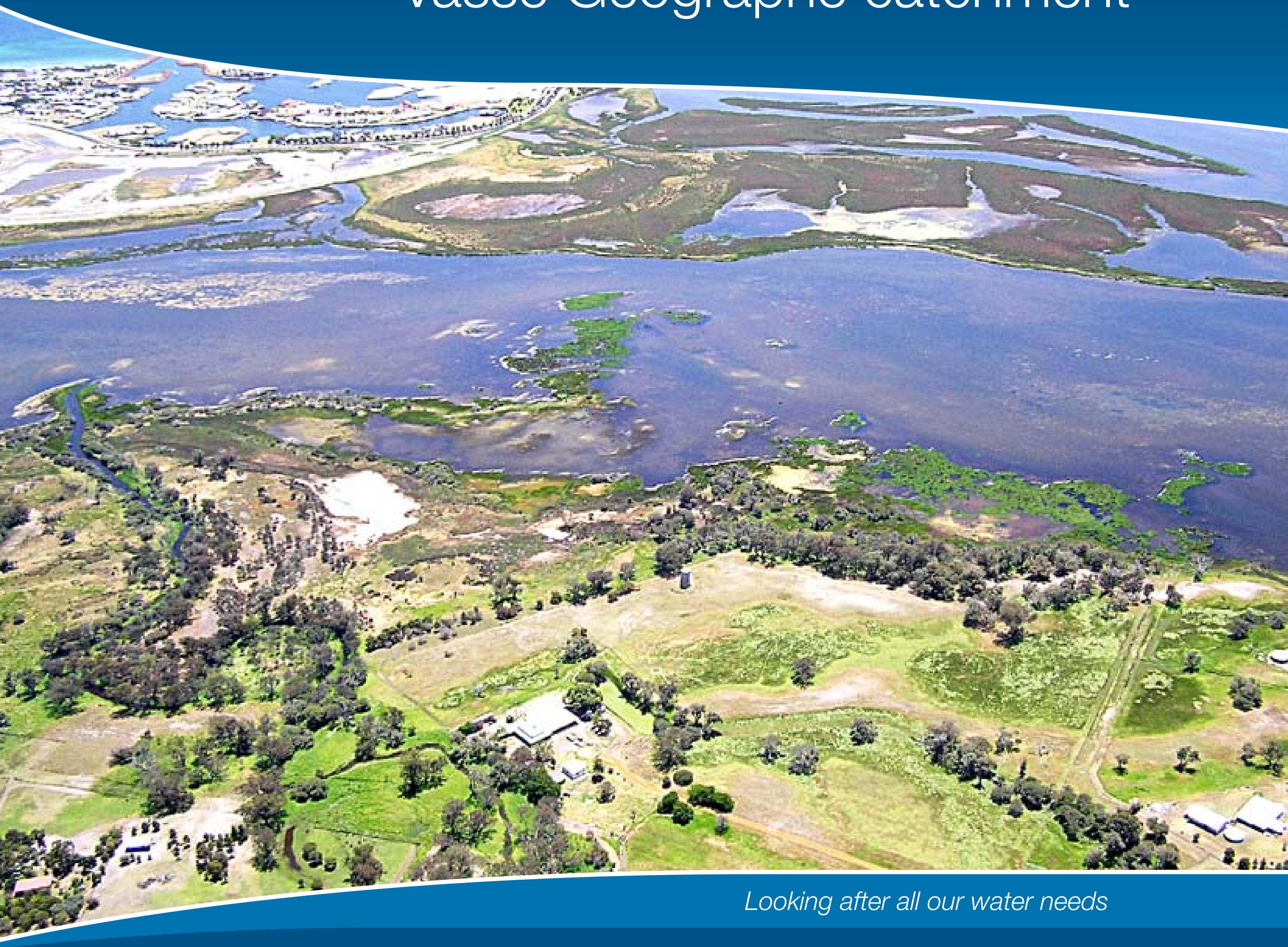
Government of Western Australia
Department of Water

Nutrient modelling in the Vasse Geographe catchment



Looking after all our water needs

Water*Science*
technical series

Report no. WST 2
April 2009

Nutrient modelling in the Vasse Geographe catchment

Department of Water
Water Science Technical Series
Report No. 2

April 2009

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.water.wa.gov.au

April 2009

ISSN 1836-2869 (print)
ISSN 1836-2877 (online)

ISBN 978-1-921549-48-9 (print)
ISBN 978-1-921549-49-6 (online)

Acknowledgements

This project was jointly funded by the Australian Government through the Coastal Catchment Initiative and the South West Catchments Council.

The Department of Water would like to thank the following people for contributing to the study. For assistance with modelling: Peta Kelsey, Artemis Kitsios, Christian Zammit, Water Science Branch, Department of Water, Western Australia. For assistance with spatial data development: Simon Neville, Ecotones & Associates Pty Ltd. For agricultural fertiliser information: David Weaver, Department of Agriculture and Food, Western Australia. For agricultural best-management information and advice: Dr Rob Summers, Don Bennett, Department of Agriculture and Food, Western Australia. For general advice and project steering: Kirrily White, Naturaliste Environmental Services, Bev Thurlow, Department of Water, Western Australia. For review and technical advice: Peta Kelsey, Belinda Quinton, Malcolm Robb and Tarren Reitsema, Water Science Branch, Department of Water, Western Australia.

Reference details

The recommended reference for this publication is: Hall, J 2009, *Nutrient modelling in the Vasse Geographe catchment*, Water Science Technical Series No. 2, Department of Water, Western Australia. This report was published in April 2009 as Appendix A in the *Draft water quality improvement plan for the Vasse Wonnerup Wetlands and Geographe Bay*

For more information about this report, contact Joel Hall, Water Science Branch, the Department of Water, Western Australia.

Cover photograph: Aerial view Vasse Wonnerup Wetlands and Geographe Bay, courtesy Geographe Catchment Council.

Contents

Figures

Tables

Executive summary

In 2006 the Geographe catchment – including the Vasse Wonnerup Wetlands[1] and Geographe Bay – was recognised through the Australian Government's Coastal Catchments Initiative (CCI) as a priority water quality 'hotspot'. This was due to the high levels of nitrogen and phosphorus entering the coastal environment from land-based sources. A dynamic hydrologic and nutrient model was used to determine current nutrient loads, load targets, load-reduction targets, nutrient sources and priority subcatchments for remediation.

The model predicted that on average, 53 tonnes of phosphorus and 397 tonnes of nitrogen enter Geographe Bay and the Vasse Wonnerup Wetlands annually. Load reduction targets of 20 tonnes per year of phosphorus and 167 tonnes per year of nitrogen are required to meet the water quality objectives established as part of this project (winter median concentrations of 0.1 mg/L for phosphorus and 1.0 mg/L for nitrogen). If these water quality objectives are met, a maximum of 33 tonnes of phosphorus and 230 tonnes of nitrogen per year would be delivered to the receiving water bodies.

The main sources of the nutrients are cattle grazing for beef and dairy, which together contribute approximately 60 per cent of the phosphorus and nitrogen loads. However, horticulture, septic tanks, and urban and point sources (wastewater treatment plants, dairy sheds, feedlots, landfills etc.) also make up significant proportions of the load. Priority regions identified for remediation included the Sabina River, Vasse Diversion Drain, Lower Vasse River, Ludlow River, Gynudup Brook and Five Mile Brook subcatchments. The model was used to predict the effect of various management scenarios on nutrient loads and concentrations, which included climate change, various land-use changes (including urban expansion), regional hydrological manipulations, and the implementation of best-management practices.

The predictive modelling results contributed to the preparation of a *Water quality improvement plan for the Vasse Wonnerup Wetlands and Geographe Bay* (DOW 2009) and a framework for its implementation. The Australian and Western Australian governments initiated a series of projects that led to the water quality improvement plan's development and the Vasse-Geographe CCI project was aimed specifically at reducing nitrogen and phosphorous inputs.

The Stream Quality Affecting Rivers and Estuaries (SQUARE) model was the tool used to deliver the predictive modelling component of the project. SQUARE is a physically-based conceptual model driven by meteorological and land-cover inputs.

[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'.

It was developed specifically to model 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 water quality improvement plan required load targets and load-reduction targets for all catchments. These were used to determine the type and scale of catchment remediation necessary to achieve the water quality objectives. A load-reduction target is defined as the average annual waterway load reduction required to meet a winter median concentration target, for a given rainfall sequence.

The Geographe catchment was divided into 14 reporting subcatchments. For each of the reporting subcatchments, the model was used to derive the following outputs:

- average annual loads and winter median concentrations
- predicted future loads (post urban expansion) and winter median concentrations
- maximum acceptable loads and load-reduction targets to meet water quality objectives, such as concentrations of nutrients entering the receiving water bodies
- source separation of export loads into land-use components
- contributions of point-source and diffuse-source loads
- the effect of climate change scenarios on catchment loads.

Scenarios for catchment remediation, management and climate change were developed in conjunction with stakeholders from catchment groups, community groups, landholders and various state government departments. The model was used to address these management scenarios, which were then analysed to generate the following key findings:

Waste from septic tanks accounts for a predicted average of 1.5 tonnes of phosphorus and 13.2 tonnes of nitrogen annually, which is 2.8 per cent of the total annual phosphorus load, and 3.2 per cent of the total annual nitrogen load that is delivered to the bay and estuary. The Busselton light industrial area was predicted to be responsible for over 90 per cent of the septic-tank nutrient contribution to the Lower Vasse River, and was predicted to deliver approximately 0.45 tonnes of phosphorus and 1.3 tonnes of nitrogen annually.

The major contributor of total load for both nitrogen and phosphorus is cattle grazing for beef and dairy. This is largely because these farms occupy the majority of the fertilised land area in the Geographe catchment. Point sources contribute a significant proportion of the total output load, especially when compared with the relative input load. Most point sources are discharged directly to the waterways, and as such the nutrients have little opportunity to be assimilated compared with fertiliser that is applied directly to the land. The land uses with the greatest nutrient load per unit area are urban and horticulture, due to fertilisation intensity.

Most point-source contributions are from dairy-shed effluent. An estimated 5.1 tonnes of phosphorus and 23.0 tonnes of nitrogen are discharged into the receiving water bodies each year. Wastewater treatment plants contribute significantly to the point-source loads, and are expected to double in capacity in the next 20 years. The model predicts an average annual discharge of 1.31 tonnes of total phosphorus and 1.33 tonnes of total nitrogen to the bay from the Busselton wastewater treatment plant. The Water Corporation plans to upgrade the treatment facility in 2009: the improved facility is expected to halve the nutrient concentration of the wastewater outflow to compensate for increased volumes.

The urban expansion scenario predicts that the phosphorus and nitrogen loads will increase during the next 25 years. The cause of the increase will primarily be land-use change – moving from beef grazing to urban land uses – which corresponds to an increase in fertiliser input rate. Water sensitive urban design measures will be required to minimise the load increase.

Nutrient-hotspot analysis revealed that the highest rates of nutrient export were located in the centre of the Geographe catchment – in the regions surrounding the Sabina River, the Vasse Diversion Drain, and the Buayanyup River. High exports also occur in the Gynudup Brook catchment, and are evident on the coastline in urban regions.

Beef grazing on the wetland fringes is predicted to be responsible for 10 per cent of the total phosphorus and five per cent of the total nitrogen loads to the Vasse Wonnerup Wetlands, with the majority of the nutrient load being delivered through the rivers that discharge into the wetlands.

Analysis of the timing of loads revealed that most of the nutrient load is delivered between May and October, with only a small fraction of the load delivered in the summer months. There are large variations in the timing of loads, and this is due to the variation in the monthly rainfall, and hence monthly flow. The annual catchment load is highly dependent on the rainfall, and high rainfall years (such as 1999) will generally deliver a load over five times the magnitude of low rainfall years (such as 1987 or 2006).

Two emission scenarios from the Intergovernmental Panel on Climate Change (IPCC) were investigated. The A2 (pessimistic) and B1 (optimistic) scenarios were modelled as part of the climate change scenario analysis. The A2 scenario is predicted to result in approximately 30 per cent reductions in load for both nitrogen and phosphorus, whereas the B1 scenario is predicted to result in five per cent reductions in load. Although nutrient loads are expected to decrease for climate change scenarios, flows will also decrease, resulting in lower groundwater levels, decreased flows to wetlands, and drying of permanent pools and waterways.

Increased flushing of the Lower Vasse River was analysed by modelling increased flow from the Vasse Diversion Drain into the river. Even if high levels of flushing were occurring from the Vasse Diversion Drain, algal problems would be likely to continue as current nutrient concentrations from the inflow would be sufficient to trigger algal blooms.

The modelling achieved in this project was based on best-available data, but in many cases where the data record is short or poor, it will be necessary to re-visit the modelling after collection of a few more years of data. It is important that a regular fortnightly sampling regime be undertaken at all reporting subcatchments to validate and update modelling results. Loads, load-reduction targets, and specific management recommendations should be reviewed in three to five years.

1 Introduction

The Australian Government's Coastal Catchments Initiative (CCI) aims to reduce the discharge of pollutants to coastal waterways. Priority catchments in Western Australia are the Swan-Canning and Geographe catchments, and pollutants of concern are nutrients – phosphorus and nitrogen in particular. Several projects have been undertaken to support the development of water quality improvement plans for these priority catchments. The Department of Water had a role in applying the Stream Quality Affecting Rivers and Estuaries (SQUARE) model to the Geographe catchment. This was a joint project funded by the South West Catchments Council and the CCI.

The Geographe catchment is an important productive agricultural area of Western Australia, with the main industries being dairy and beef cattle, forestry, horticulture and viticulture. The region has one of the highest rates of urban expansion in Australia. According to the Shire of Busselton, the population is projected to increase from approximately 28 000 residents in 2006 to approximately 46 000 residents by 2021 (Shire of Busselton 2005).

The receiving water bodies of the Geographe catchment exhibit highly valued and diverse ecological and social attributes. Geographe Bay is an important marine area with widespread seagrass meadows and diverse species of fauna and flora (Westera et al. 2007). The Vasse Wonnerup 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 (Government of Western Australia 2000). The intensifying agriculture and rapid urbanisation of recent years has led to increased levels of nutrients and hence algal activity. This in turn has led to an increased threat to the aquatic life in the bay and the Ramsar-protected wetlands.

Both the Lower Vasse River and the Vasse Wonnerup Wetlands experience phytoplankton (blue-green algae in the Lower Vasse River) and macroalgal blooms. Other waterways linked to catchment drainage such as the Toby Inlet also suffer from highly degraded water quality.

The model serves as a decision-support tool and uses existing data to provide the following information:

- the flow and nutrient status of the catchment (loads and concentrations)
- load-reduction targets
- the sources of the nutrient loads
- timing of the nutrient loads and flows
- quantification of the impact of land-use change and climate change on the nutrient status of the catchment

- quantification of the nutrient-load reduction due to implementation of various best-management practices (BMPs) and management scenarios.

SQUARE was developed specifically to model 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). It was developed by the Department of Water and is an extension of its predecessor – Large Scale Catchment Model (LASCAM) (Viney & Sivapalan 2001) – developed by the Centre for Water Research in partnership with the Department of Water.

Scenarios for catchment remediation, management and climate change were developed in conjunction with stakeholders from catchment groups, community groups, landholders and various state government departments. Two models were used in the CCI project to address the scenarios posed by stakeholders: the Department of Water's SQUARE model, and the Western Australian Department of Agriculture and Food's Support System for Phosphorus and Nitrogen Decisions (SSPND) model (Ecotones & Associates 2008).

SQUARE was used to provide results at catchment or subcatchment scales, as well as to predict changes in flow regimes (and associated nutrient loads) due to climate change or hydrological manipulations. SSPND operates at a farm scale, and uses detailed best-management practice implementation (such as riparian restoration, soil amendment and fertiliser efficiency) and pricing modules to provide cost-benefit analyses of management options. This report discusses the SQUARE modelling component of the CCI project.

2 The Stream Quality Affecting Rivers and Estuaries (SQUARE) model

SQUARE is a complex semi-distributed process-based conceptual model with a daily time-step. The basic building blocks are subcatchments organised around a river network. The model architecture is similar to its predecessor – Large Scale Catchment Model (LASCAM) – which was developed by Viney and Sivapalan (1996). All hydrological and water quality processes are modelled at the subcatchment scale, with the resultant flows and loads being aggregated through the stream network to yield the response of the catchment at the main outlet, and at any number of intermediate points on the stream network (Figure 2.1).

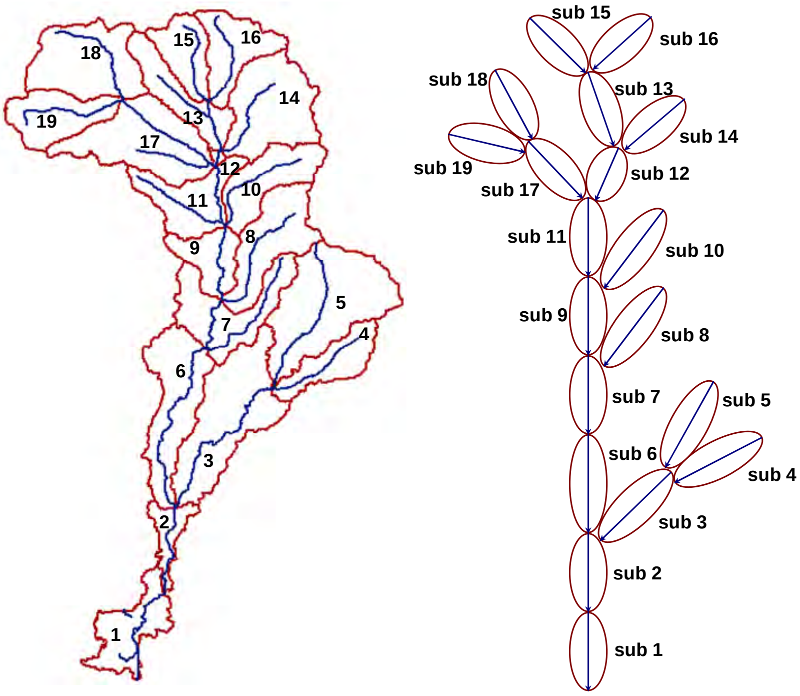


Figure 2.1. Subcatchment organisation (i.e. surface connection) based on a river network of 19 subcatchments.

Calculation of the daily fluxes of water, nutrients and sediments through the soil and discharge to the stream is based on three soil-moisture stores. They are the near-stream perched aquifer, or shallow ephemeral groundwater (the A store); the permanent deep groundwater system (the B store); and the intermediate unsaturated zone (the F store) (Figure 2.2). The hill slope model parameter definitions are displayed in Table 2.1. In addition, daily fluxes of nutrients through the soil are represented by the U store, which can be conceptualised as the root zone of shallow-rooted vegetation (Figure 2.3). Phosphorus and nitrogen are modelled in both dissolved and particulate forms. The soluble component of nitrogen is further discriminated into nitrate/nitrite-nitrogen, ammonium-nitrogen and dissolved organic nitrogen. For each subcatchment, a set of physically-based constitutive relations is used to direct water, soluble phosphorus, total phosphorus, nitrate/nitrite, ammonium, dissolved organic nitrogen and total nitrogen between stores and to distribute rainfall either into the stores or directly into the stream (Figure 2.3).

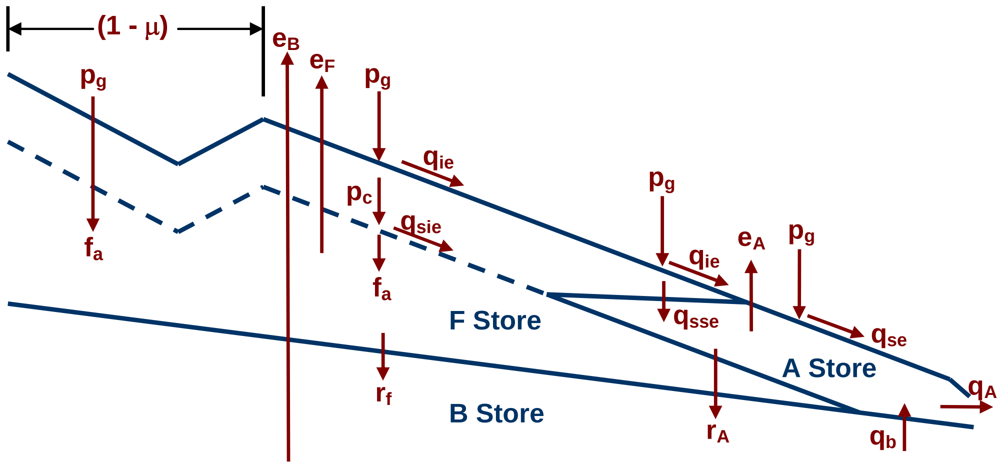


Figure 2.2. Schematic of a hill-slope cross-section assumed in SQUARE, and the definition of the subsurface water stores (Viney & Sivapalan 2001).

Table 2.1. Parameter definitions for the hill slope model used in SQUARE.

Symbol	Definition
e_A	Evaporation from A store
e_B	Evaporation from B store
e_F	Evaporation from F store
q_A	A store discharge to stream
q_B	B store discharge to A store
q_{se}	Saturation excess surface runoff
q_{ie}	Infiltration excess surface runoff
q_{sie}	Infiltration excess subsurface runoff
q_{sse}	Saturation excess subsurface runoff
p_g	Throughfall
p_c	Surface infiltration
f_a	Subsurface infiltration
r_A	Recharge from A store to B store
r_F	Recharge from F store to B store
μ	Upslope perching factore

The water, sediment and nutrient balance models have 92 parameters. The model is calibrated using a Shuffled Complex Evolution (SCE) algorithm (Duan & Gupta 1993) to optimise an objective function relating one or more pairs of observed and predicted fluxes.

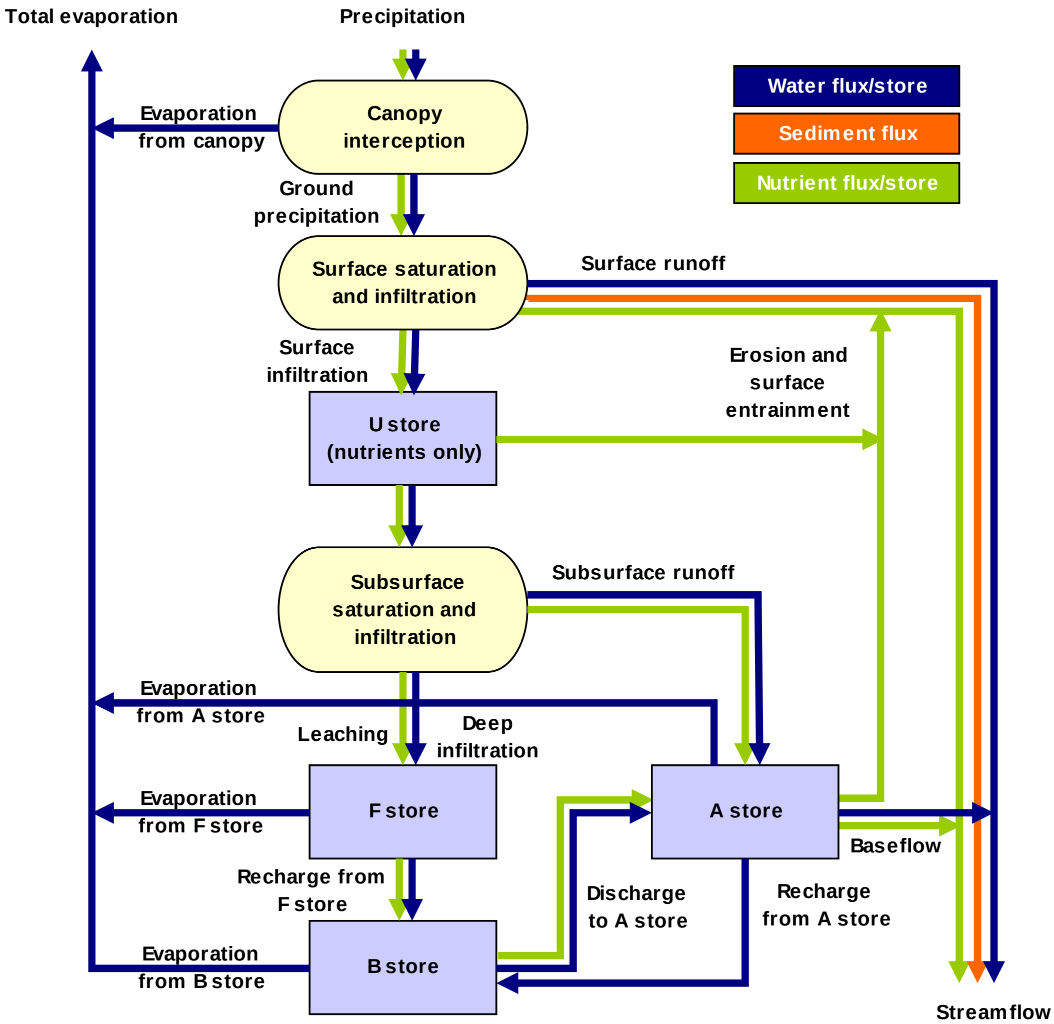


Figure 2.3. Small catchment model (building block model) in SQUARE for water, sediments and nutrients (Zammit et al. 2005).

Calibration of the hydrological component is undertaken initially and independently from the nutrient modules. The hydrological component has 32 parameters that are calibrated against observed data extracted from flow-gauging stations. When the hydrological calibration is complete, the sediment model is then calibrated (six parameters), followed by the models for phosphorus (16 parameters) and nitrogen (38 parameters). Observed data for the nutrient and sediment models is taken from nutrient-sampling data. The Nash-Sutcliffe estimator is used to determine the efficiency of the calibration, and each calibration produces a suite of results containing the highest efficiencies. The greatest mathematical efficiency does not necessarily correspond to the most physically correct model, and a suite of 20 sets of parameters are analysed for each calibration to determine the most appropriate, if any, to be used for scenario modelling and presentation of results.

Verification of the modelled data is undertaken by loading the modelled and observed data into a series of Matlab^{TM} scripts for visualisation and statistical analysis. Daily, monthly, annual and cumulative series are compared, with particular care taken to meet the total water balance for the hydrological model (Figure 2.4). If satisfactory time-series results are obtained, the soil store time-series are analysed, and the B-store results verified by comparing the signal with annual rainfall or nearby superficial-groundwater-bore signals. The flux paths and statistics are then analysed, not only to determine if the effect of over-cycling patterns is evident in the model, but also to check if evaporation, evapotranspiration and groundwater fluxes are physically plausible. If a satisfactory calibration is derived, the set of parameters is used for modelling scenarios and analysis of results. If not, inputs are investigated and changed if necessary, parameters are adjusted and the model is recalibrated.

If a catchment does not contain a flow-gauging station or a sampling point, a comparison of the geophysical, climatic and land-use attributes is undertaken with adjacent catchments that contain calibrated data, and the set of parameters from the most similar nearby catchment is adopted.

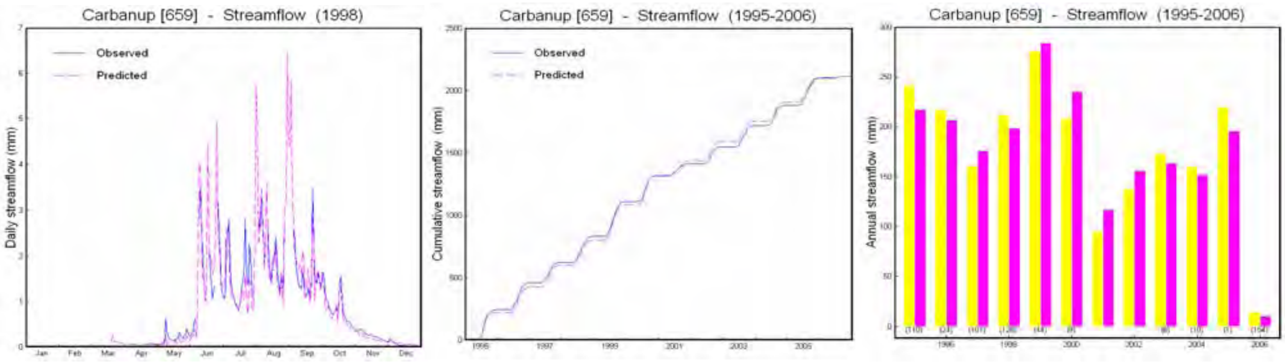


Figure 2.4. Examples of daily, cumulative and annual time-series comparisons used in model verification.

In the Geographe catchment, there are 11 gauging stations used for the hydrological calibration (Figure 2.5) and 34 water quality sampling sites, used either for model calibration or validation (Figure 2.6). A detailed calibration report is presented in Appendix A.

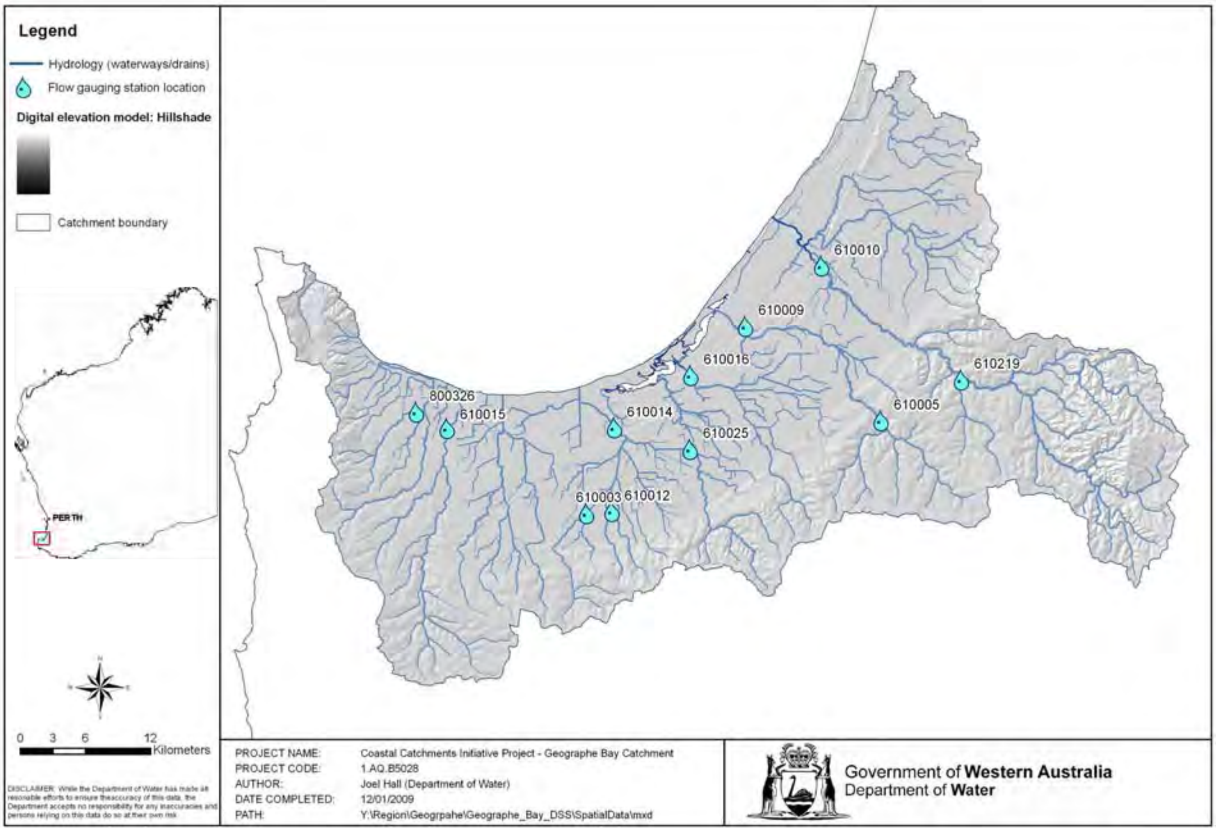


Figure 2.5. Locations of flow-gauging stations.

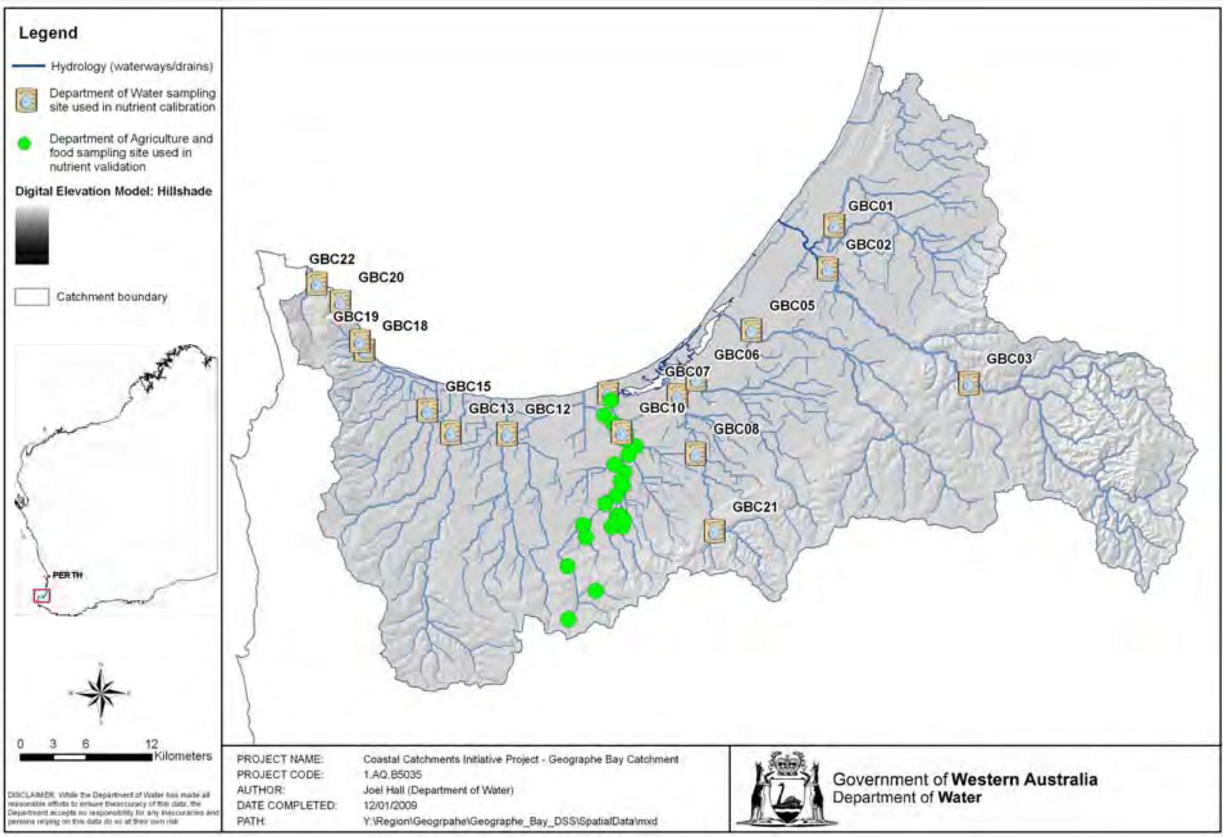


Figure 2.6. Locations of nutrient-sampling sites.

3 Catchment description

3.1 Location

The Geographe catchment is situated between Bunbury and Dunsborough in Western Australia's South West and covers an area of approximately 2000 km^2. The catchment is bounded by the Darling Range to the east, the Whicher Range to the south and south-east, and the Leeuwin-Naturaliste Ridge to the west. The majority of the catchment lies on the Swan coastal plain – an extremely low-lying floodplain characterised by sandy soils and a high watertable prone to waterlogging during the winter months. The Carbunup, Capel, Ludlow, Abba, Sabina, Vasse and Buayanyup rivers drain the Geographe catchment. Most of the catchment is within the Shire of Busselton, with smaller portions in the shires of Capel, Donnybrook–Balingup and Augusta–Margaret River. Figure 3.1 displays the catchment boundary and the watercourses (drains and natural waterways) within the catchment.

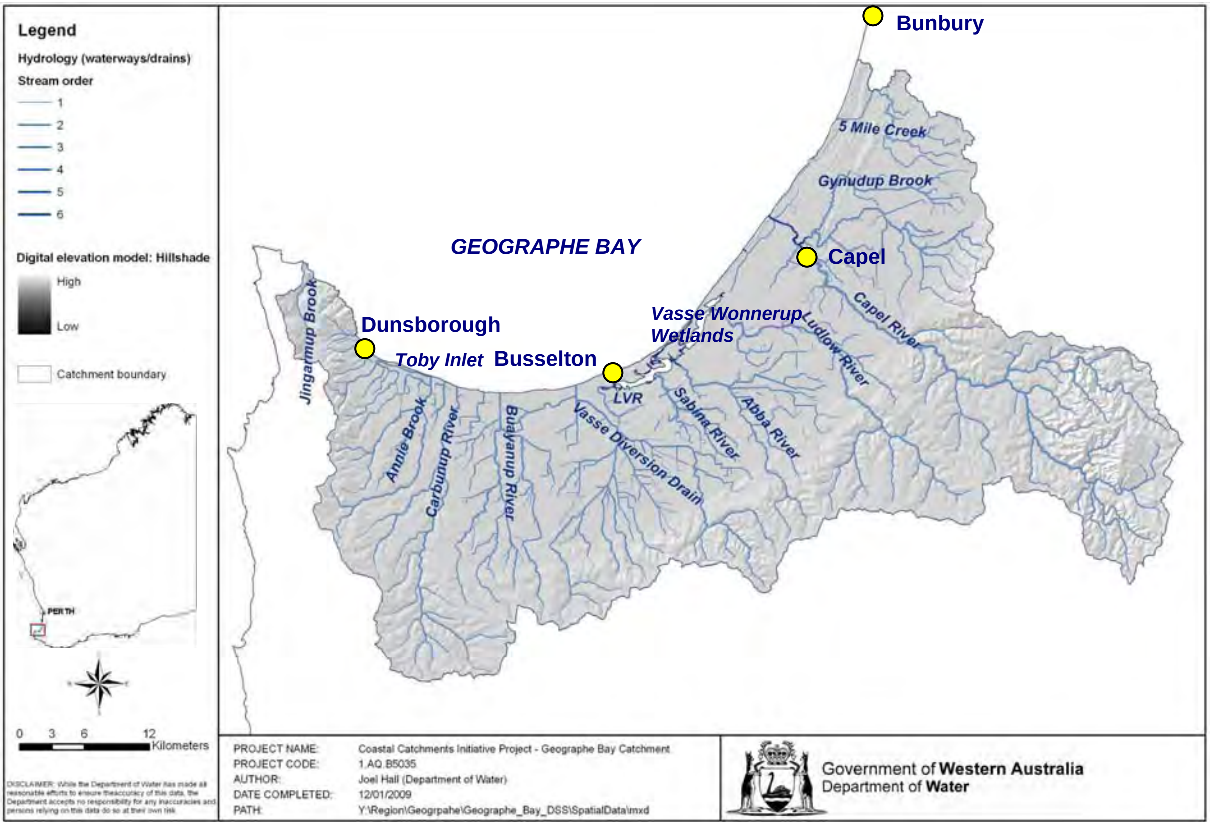


Figure 3.1. Hydrology and digital elevation model

The catchment has two major receiving water bodies: Geographe Bay and the Vasse Wonnerup Wetlands (Figure 3.2). The Lower Sabina River, the Lower Vasse River, the Abba River and the Ludlow River drain to the Vasse Wonnerup Wetlands. The Vasse Wonnerup Wetlands have local and international significance for waterbirds and are recognised through the Ramsar Convention on Wetlands as one of the most important waterbird habitats in Western Australia (WAPC 2005). Between 20 000 and 30 000 birds make use of the wetlands annually, with numbers being swelled by migratory species using the wetlands as a major stopover. Seventy-eight species have been observed on the wetlands and 12 species are known to breed there. Despite the importance of the estuary as a wildlife habitat, it is threatened by eutrophication and development pressures (Weaving 1998).

Geographe Bay supports extensive seagrass meadows that serve important ecological functions and hosts a diverse array of marine life. The bay is sheltered from prevailing swells and winds for most of the year, with the seagrass colonising the sandy base of its shallow intercontinental shelf. The influence of the Leeuwin current enables both tropical and temperate species to occur in the bay. It is also highly valued and used extensively for recreation and tourism.

Figure 3.2. Aerial photograph of the Vasse Wonnerup Wetlands and Geographe Bay.

3.2 Climate

The Geographe catchment has a Mediterranean-type climate with dry warm summers and cool wet winters. The mean annual rainfall ranges from approximately 1000 mm in the west to 700 mm on the catchment's eastern border. About 80 per cent of the rain falls from May to October. The average annual potential evaporation (Class A pan evaporation) ranges from 1100 mm to 1300 mm and follows a west to east gradient. The monthly-average maximum daily temperature varies between 18^{o}C in winter (June) to 28^{o}C in summer (January).

3.3 Hydrogeology

The hydrogeology of the Geographe catchment forms a subset of the southern Perth basin. There are three aquifers containing low-salinity groundwater within the southern Perth basin: the Superficial Aquifer, the Leederville Aquifer and the Yarragadee Aquifer. Below the Yarragadee Aquifer are deeper confined aquifers that contain brackish to saline groundwater within early Jurassic to Permian age sediments. The Bunbury Basalt and Parmelia Formation comprise discontinuous confining beds between the Leederville and Yarragadee aquifers.

The Superficial Aquifer is unconfined and relatively thin, with saturated thickness generally less than 10 m. The depth of the watertable varies seasonally between about 0.5 and three metres below ground level. The Superficial Aquifer is recharged directly from rainfall and some upward leakage from the Leederville Aquifer near the Geographe coastline. Groundwater discharges from the aquifer into streams, drains and wetlands and by downward leakage into underlying aquifers. The Superficial Aquifer can contain high levels of nutrients, particularly in regions with intense land uses and poor drainage: the majority of the nutrient load is contained within the top one to two metres of the aquifer. On the sandy coastal plain of the Geographe catchment, the Superficial Aquifer regularly rises to the land surface during the winter months, and the land becomes waterlogged. Various drainage works are used to convey water from paddocks to prevent excessive waterlogging.

The Leederville Aquifer is a multi-layered confined aquifer located in the Warnbro Group. It is typically 150 m thick and occurs over most of the southern Perth basin. The Leederville Aquifer is recharged by direct infiltration of rainfall on the Blackwood Plateau and by downward leakage from the Superficial Aquifer on the Swan and Scott coastal plains. Upward leakage from underlying aquifers occurs near the Geographe coastline. Most of the groundwater recharge to the aquifer discharges by downward leakage into the Yarragadee Aquifer. However, groundwater from the aquifer also discharges to the Blackwood River, Capel River and the coast. Many farmers in the Geographe catchment use the Leederville Aquifer as a source of water for paddock irrigation in the summer and autumn months and, as a result, the aquifer’s levels have dropped by up to two metres in some regions of the catchment. The aquifer contains very low concentrations of nitrogen and phosphorus.

The Yarragadee is a major confined aquifer present throughout most of the southern Perth basin. The Yarragadee Aquifer is recharged directly by rainfall on outcrop areas at the southern end of the Blackwood Plateau and by downward leakage from the Superficial Aquifer near Bunbury on the Swan coastal plain, as well as the eastern Scott coastal plain. It is also recharged by downward leakage from the Leederville Aquifer, principally beneath the Blackwood Plateau. Groundwater flow from the Yarragadee Aquifer is southwards to the South Coast and northwards to Geographe Bay from the main recharge areas. There is significant groundwater discharge from the Yarragadee Aquifer into the Blackwood River south of the

Geographe catchment. However, greater quantities of groundwater discharge to Geographe Bay and the South Coast.

3.4 Waterways and catchments

The Busselton region was settled in about 1840, but drainage works were not required until 1907 when a scheme to alleviate flooding at Busselton and Wonnerup began (English 1994). These works included floodgates on the Vasse and Wonnerup estuaries to limit sea-water inflow on high tides and protect the estuarine flats from flooding. During the 1920s major drainage work to facilitate the Group Settlement Scheme in the Busselton–Margaret River area was carried out. The resulting floodgates prevent summer salt-water intrusion and maintain fresh water in the estuary all year to assist farming. However, the floodgates act as a barrier to upstream/downstream movement of fish and reduce flushing flows that may otherwise help ameliorate high nutrient concentrations from catchment runoff. Excessive algal blooms, anoxia and fish deaths are not uncommon. On several documented occasions, sudden mass fish deaths have occurred between the sand bar and the floodgates (Lane et al. 1997).

Most rivers of the Geographe catchment have been modified as a result of the extensive clearing and drainage of the Swan coastal plain. Clearing in the catchment and the artificial drainage system has resulted in large increases in river flows. This increased flow, combined with clearing of fringing native vegetation, has in many cases led to erosion problems. Many sections of the natural watercourses have been modified through diversion, channel straightening, de-snagging, enlargement of the channel and creation of levee banks with the excavated soil. As a result of the artificial drainage measures, many of the catchment's wetlands have been subsumed by agricultural and urban land uses. The remaining wetlands are generally in poor condition due to the impacts of the surrounding land uses and most are located on private land.

Many of the waterways and receiving water bodies 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. 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. Catchment regions that have experienced the worst problems include the Lower Vasse River (Figure 3.3), which flows through the Busselton town site and is prone to regular summer blue-green algal blooms; upstream of the Vasse and Wonnerup floodgates (Figure 3.4); and Toby Inlet (Figure 3.5), which has been subject to regular blooms of phytoplankton and macroalgae during summer in recent years.

Figure 3.3. Toxic blue-green algal bloom in the Lower Vasse River, 2006.

Figure 3.4. Blue-green algal bloom upstream of the Vasse floodgates, 2007.

Figure 3.5. Algal bloom in Toby Inlet, 2006.

3.5 Soils

The Geographe catchment is bounded by the Whicher Range to the south and south-east, the Leeuwin-Naturaliste ridge to the west and the Darling Range to the east. Most of the catchment is on the Swan coastal plain, which consists of low-lying seasonally wet flats with alluvial soils, which characterise a sub-unit of the coastal plain known as the Pinjarra plain. Bassendean dunes with grey quartzite soils are dispersed about the plain, especially in the north-east. Bassendean sands have a particularly poor ability to adsorb phosphorus, and generally the soluble phosphorus concentration in waterways containing Bassendean sands is very high. The Quindalup and Spearwood dunal systems form narrow belts parallel to the coast. The Spearwood dunes, which consist of yellow sands over limestone, back onto the coastal and active Quindalup dunes. Between the Quindalup and Spearwood dunes are the elongated estuarine lagoons and swampy flats of the Vasse Wonnerup and Broadwater wetlands. This low-lying land is apparent in the topography displayed in Figure 3.1.

The coastal plain rises to about 60 metres above sea level at the foot of the Whicher scarp. The Whicher scarp is characterised by an increased topographic gradient with deeply incised stream channels. It was formed by marine erosion along an ancient coastline and separates the coastal plain from the Blackwood plateau to the south (Weaving, 1998). The Blackwood Plateau is a gently undulating area of moderately raised land which consists of laterite, lateritic gravels and sand overlaying Mesozoic rocks. It has an elevation of approximately 120 to 180 metres above sea level.

The Department of Agriculture and Food has adopted a hierarchy of soil-landscape mapping. A map of the soil-landscape systems is given in Figure 3.6 and descriptions of the soils and associated native vegetation (Weaving 1998) are included in Table 3.1.

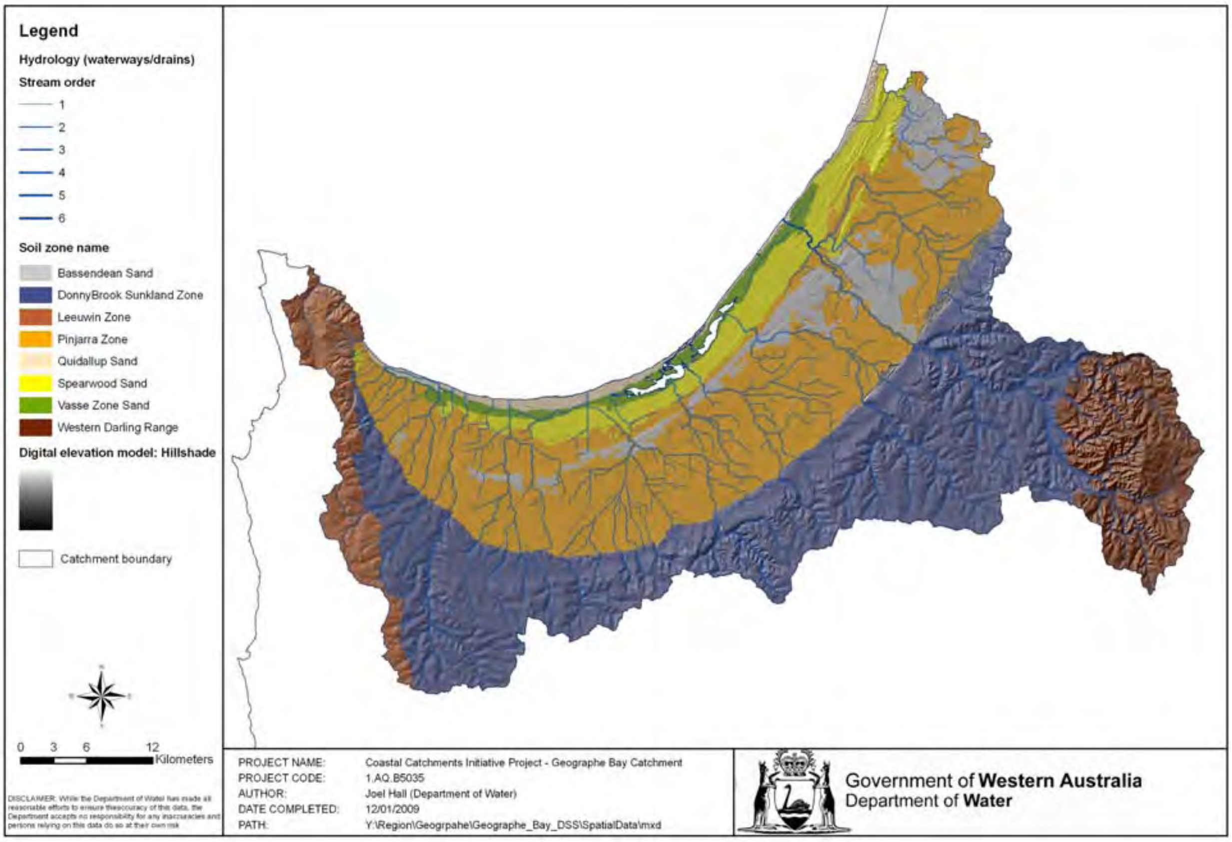


Figure 3.6. Soil zones in the Geographe catchment.

Table 3.1. Soil zones in the Geographe catchment.

Soil-landscape system	Description
Bassendean Sands	Dunes, flats and swampy depressions of the Swan coastal plain with pale deep sand. The main vegetation types are Banksia woodlands and heath on dunes and paperbark woodlands on the falts.
Donnybrook Sunkland Zone	The Blackwook plateau is a lateritic plateau of the Donnybrook Sunkland Zone consisting of sandy gravel, loamy gravel and deep sand. Valleys have soils of sandy gravel, loamy gravel and deep sand. The Treeton Hills consist of rises and low hills of the western Donnybrook Sunkland, and main soils include sandy gravels and grey deep sandy duplexes. The Whicher Scarp is the low scarp and raised platform on the northern edge of the zone. Main soils include sandy gravel, pale deep sand, loamy gravel and non-saline wet soils. Principal vegetation consists of jarrah-marri forest.
Leeuwin Zone	Cowaramup uplands are the lateritic plateau in the Leeuwin Zone with sandy gravel, loamy gravel and grey sandy duplex soils. Wilyabrup Valleys are granitic valleys in the Leeuwin Zone with loamy gravel, sandy gravel and loamy earth. Jarrah-marri forest predominates.
Pinjarra Zone	Poorly drained flats on the central coastal plain with grey deep sandy duplex soils, yellow loamy earth and cracking clays. The vegetation consists of jarrah, marri, wandoo and paperbark forest and woodland.
Quindalup Sand	Coastal dunes of the Swan coastal plain with calcareous deep sands and yellow sands. Coastal scrub is the principal vegetation.
Spearwood Sand	Dunes and flats overlying limestone on the Swan coastal plain with deep yellow sand, pale deep sand and yellow/brown shallow sand. The predominant vegetation is Tuart forest and woodland.
Vasse Zone Sand	Poorly drained estuarine flats of the Swan coastal plain. Soils include tidal-flat soils, saline wet soils and pale deep sands. The main vegetation tyupes include samphire, sedges and paperbark woodland.
Western Darling Range	The Darling Plateu is a lateritic plateau in the Western Darling Range with sandy gravel, loamy gravel, deep sand and wet soil. Vegetation is mainly jarrah-marri forest and woodland. Lowden Valleys consist of deep gneissic valleys in the south of the Western Darling Range. Principal soils are loamy earths, loamy duplex, gravel and stony soil.

3.6 Land use

The Geographe catchment is an important productive agricultural area. Thirty per cent of Western Australia's milk and potatoes are produced in this catchment (Shire of Busselton 2005). The main agricultural industries are dairy and beef cattle, forestry, horticulture and viticulture. Other significant industries are pasture cut for hay, sheep, vegetables, fruit and some grains (oats and barley). There has been increasing diversification of farming practices in the region with the appearance of alternative produce such as wines, fruit, vegetables, nuts and the farming of exotic animals.

The Geographe region has one of the highest rates of urban expansion in Australia. The desirable lifestyle and holiday opportunities available in the region have created a large rate of growth and development during the past 10 years. The high urban growth rate is likely to continue during the next 20 to 30 years. According to the Shire of Busselton, the population is projected to increase from approximately 28 000 residents in 2006 to approximately 46 000 residents by 2021 (Shire of Busselton 2005). District structure plans outlining future developments are displayed in Appendix E.

The largest urban developments in the Geographe catchment include the Vasse-Newtown, Provence and Ambergate developments (Figure 3.7). Vasse-Newtown, a new land development 11 km south-west of Busselton, will be a self-sustainable community that will extend over 400 ha and include 1750 home sites, four schools, provision for a university, a health-care and hospital precinct, parks, sporting and recreational grounds, and a village-style town centre.

Provence is a new land development located at the eastern gateway to Busselton. The developer, Satterley Real Estate, estimates that $1 billion will be invested in capital infrastructure over the life of the development. Due for completion in 2015, the total landholding of 230 ha will be divided into three villages, with a combined total of 2000 homes and an estimated population of 6000.

Ambergate is located approximately 10 km inland from Busselton adjacent to the Vasse Diversion Drain, and is expected to comprise 4300 residential home sites. Port Geographe is a major 10-year project that will result in the development of 1000 residential lots, of which approximately half have already been released. The 300 ha site also includes a marina as well as a shopping complex and tourist facilities.

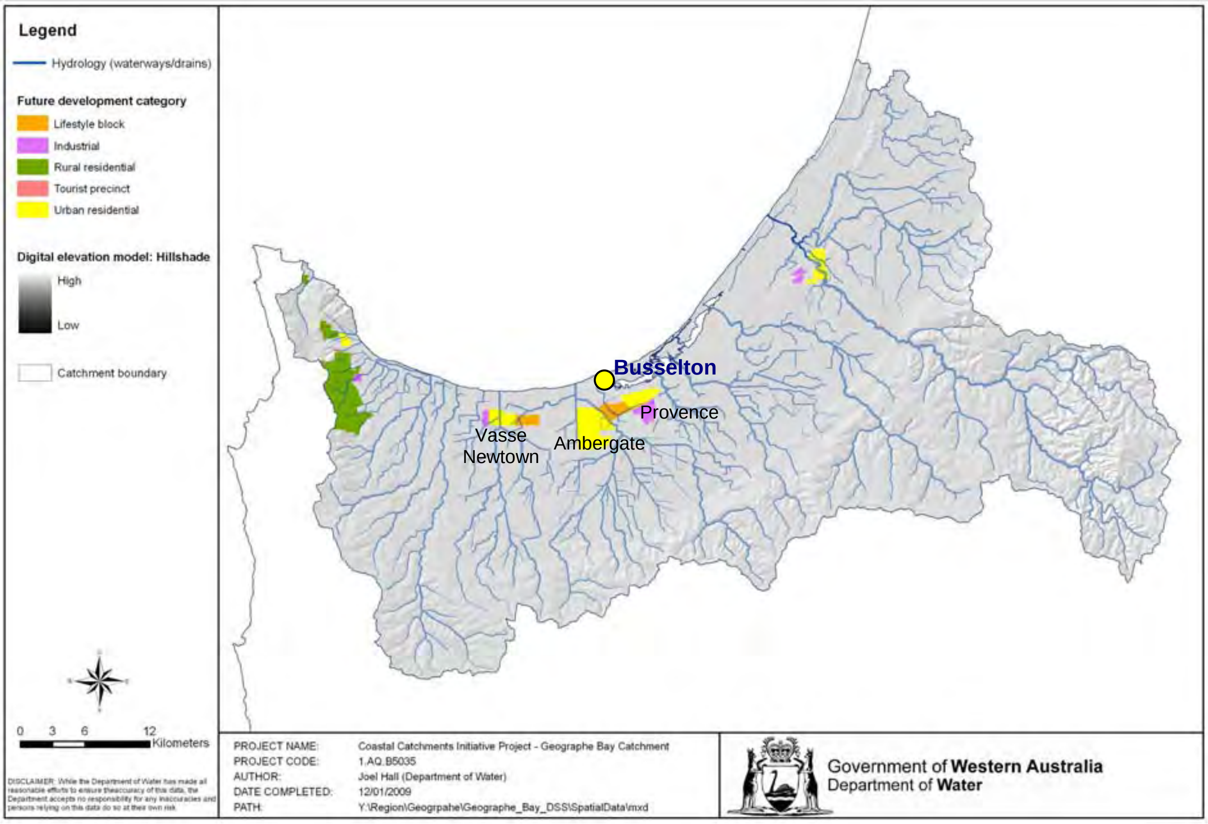


Figure 3.7. Future urban development regions (from district structure plans).

3.6.1 Diffuse land uses

As part of the CCI project, the Department of Agriculture and Food and the Department of Water embarked on a joint land-use mapping exercise. The exercise made use of geographic information systems (GIS), aerial photographs, local council historical datasets, and various other land-use datasets. Members of the Geographe Catchment Council (GeoCatch) – who are landholders in the catchment – helped to ground-truth the data. The Department of Water used the 2005 land-use dataset (Figure 3.8) for the SQUARE modelling exercise, while the Department of Agriculture and Food used it for the SSPND model (Ecotones & Associates 2008). In addition, historical land-use datasets were determined for the catchment, using historical aerial photography, structure plans, local council historical maps and expert stakeholder advice. Future land use was also determined using the *Busselton Structure Plan, Dunsborough Structure Plan,* and *Capel Shire Land Use Strategy*. Land-use coverages for the years 1983, 2002, 2003, 2005, 2010, 2015, 2020 and 2025 were developed for the catchment.

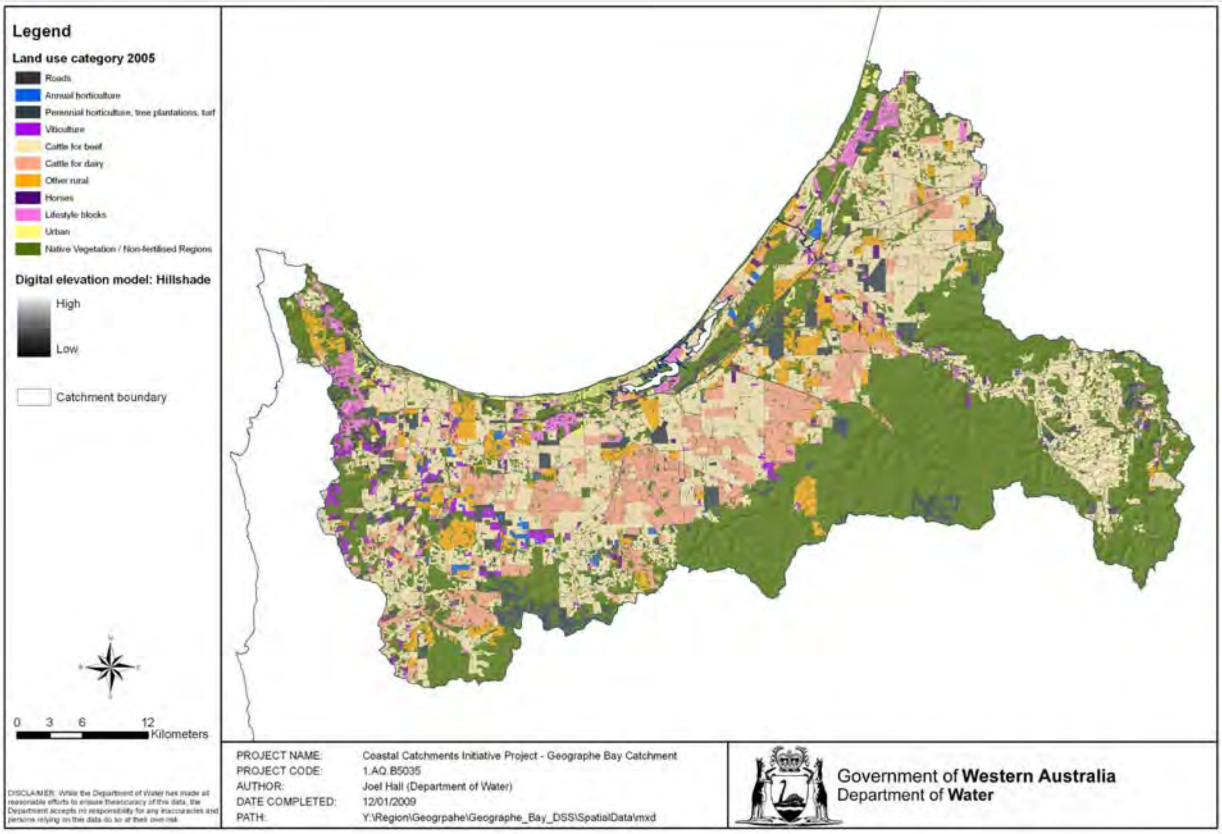


Figure 3.8. Land use by cadastre for the Geographe catchment (2005 land-use layer).

3.6.2 Point sources of nutrient pollution

Nutrient pollution can be delivered from diffuse sources – such as fertiliser application, animal waste or nitrogen fixation – or from point sources. Various datasets were analysed to extract nutrient point-source information for the Geographe catchment, including the National Pollutant Inventory (NPI), the Dairy Catch dairies, the Environmental Protection Authority's licensed premises and contaminated sites datasets, and the Hirschberg historic nutrient point-source dataset (Hirschberg 1991).

In the Geographe catchment seven categories of point sources that contributed significant nutrients were identified: dairy milking sheds, cattle feedlots, landfills, wastewater treatment plants, industrial point sources, unsewered campgrounds and unsewered caravan parks. These were mapped on the catchment (Figure 3.9) and annual nutrient inputs were determined. Point source nutrient input calculations are outlined in detail in Appendix B. Annual point-source nutrient loads are displayed in Table 3.2.

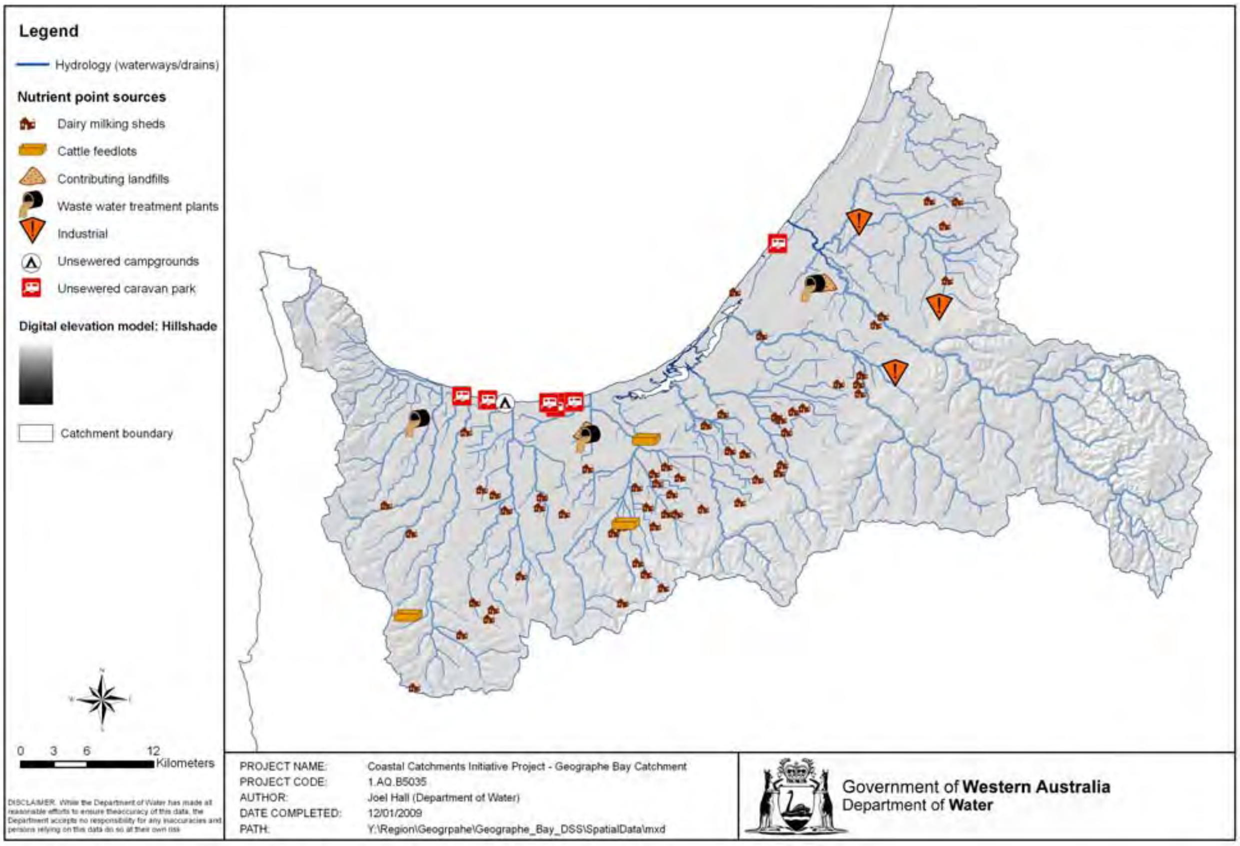


Figure 3.9. Nutrient point sources in the Geographe catchment.

Table 3.2. Point-source average annual nutrient inputs.

Point source	Total nitrogen input (t/yr)	Total phosphorus input (t/yr)
Dairy effluent from milk sheds	45.9	7.98
Contributing landfills	0.3	0.07
Industrial point sources	7.3	0.00
Unsewered caravan parks	4.3	0.87
Cattle feedlots	12.0	0.94
Wastewater treatment plants	3.5	1.80
Coastal campgrounds	1.8	0.35
Septic tanks	33.7	6.73
Total	**108.8**	**18.70**

3.6.3 Septic tanks

Septic tanks were identified in a previous nutrient report to the National Pollutant Inventory (Kelsey 2003) as a likely major contributor to the nutrient loads in the waterways and receiving water bodies of the Geographe catchment. It was therefore necessary to map the septic tanks to estimate the total nutrient export. The Water Corporation provided a spatial coverage to highlight areas connected to deep sewerage and the year they were connected to the infill sewerage program. The infill sewerage program began on 1 July 1994 with the aim to provide a sewerage service to 100 000 properties state-wide (comprising 80 000 properties within metropolitan Perth and 20 000 properties in country towns) over a 10-year period, at an estimated cost of $800 million. Properties targeted by the program to have septic systems replaced with a reticulated sewerage service were conventionally-sized existing residential and town-centre properties in medium and large country towns and cities not serviced by other organisations.

The septic-tank spatial coverage was developed by extracting all residential, industrial and commercial land parcels from the land-use spatial coverage, and assigning each parcel a septic tank if it did not fall within the Water Corporation infill or deep sewerage coverage (Figure 3.10). Rates of occupancy were taken from the Australian Bureau of Statistics for Busselton Shire and export loads for septic tanks of 2.2 kg phosphorus per person per year and 5.5 kg nitrogen per person per year were taken from a Western Australian study by Whelan and Barrow (1984a, 1984b). The septic tank inputs are displayed in Table 3.1.

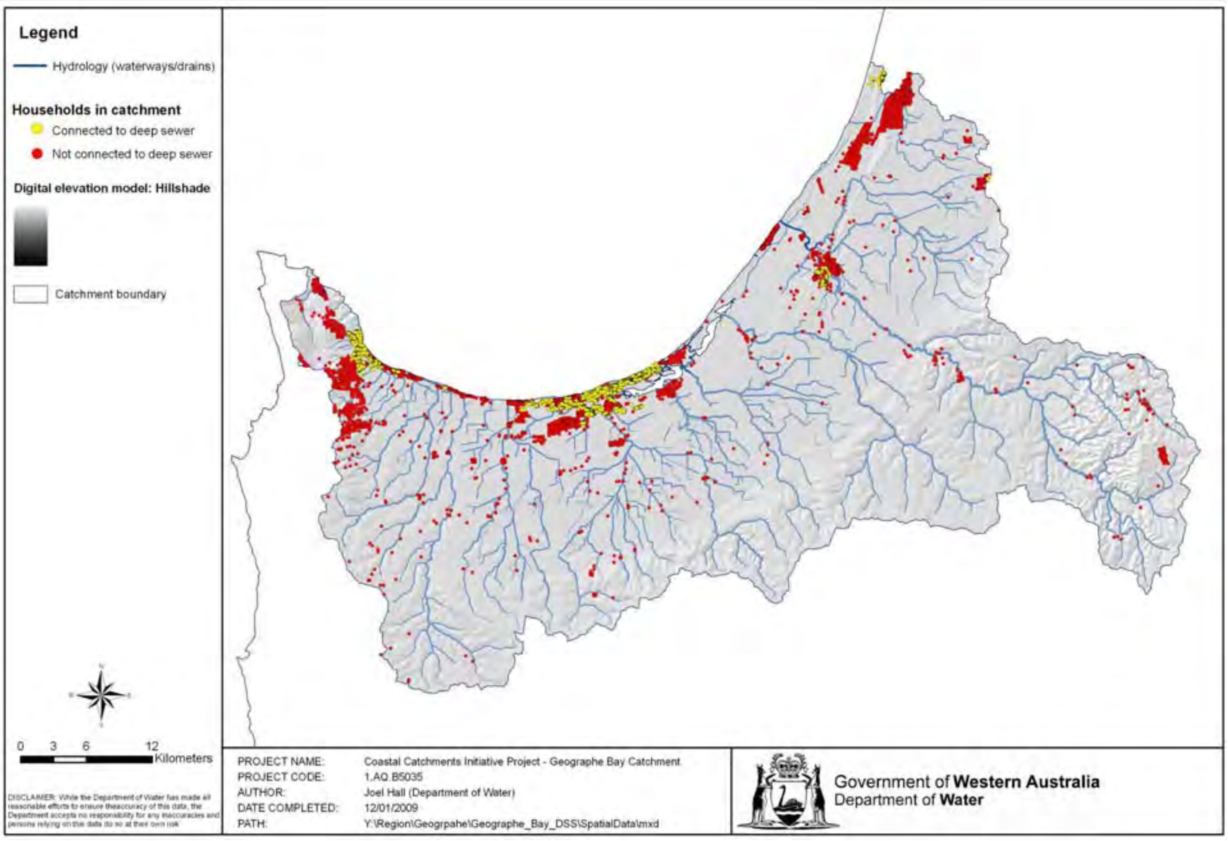


Figure 3.10. Infill sewerage and septic-tank locations (2005).

4 Monitoring program

SQUARE requires flow, nutrient and sediment data for parameter calibration. At the start of the CCI project a review of all historic catchment-monitoring data was necessary, since the water quality sampling data for the Geographe catchment was sourced from a variety of projects with varying levels of sample quality. The summary of the analysis and the nutrient status of the waterways is presented in the *Geographe Bay nutrient status and trends report* (Hall et al. 2005). All projects involving data collection, and any gaps associated with nutrient data collection, are summarised in the *Monitoring report* (DOW 2008c).

As a result of this review process, a nutrient-sampling regime was undertaken for the Geographe catchment using funds allocated to catchment monitoring from the CCI project. In addition, it was agreed that the Greener Pastures project (Department of Agriculture and Food) would provide fortnightly samples at sites along the Vasse River and its tributaries. The locations of the monitoring sites are displayed in Figure 4.1, and examples of monitoring sites and flow-gauging stations are displayed in figures 4.2 and 4.3. Department of Water monitoring occurred fortnightly when the waterways were flowing (generally from May to December although the Capel River waterways are perennial) and samples were analysed for total nitrogen, total phosphorus, total suspended solids, free reactive phosphorus, nitrate/nitrite, ammonia/ammonium, dissolved organic nitrogen, temperature, conductivity and dissolved oxygen. Department of Agriculture and Food samples were analysed for total phosphorus, total nitrogen, free reactive phosphorus, nitrate/nitrite, ammonia/ammonium and total suspended solids, and were sampled from June to November.

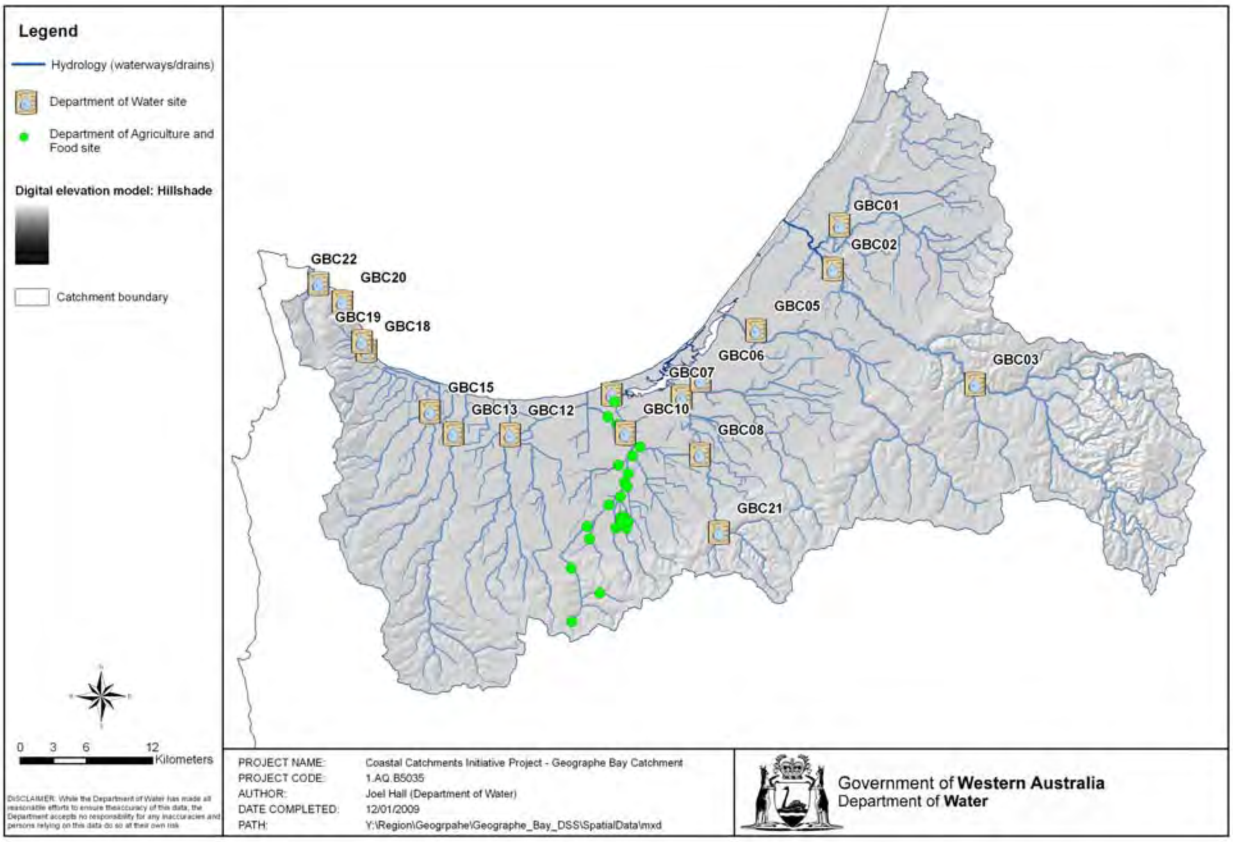
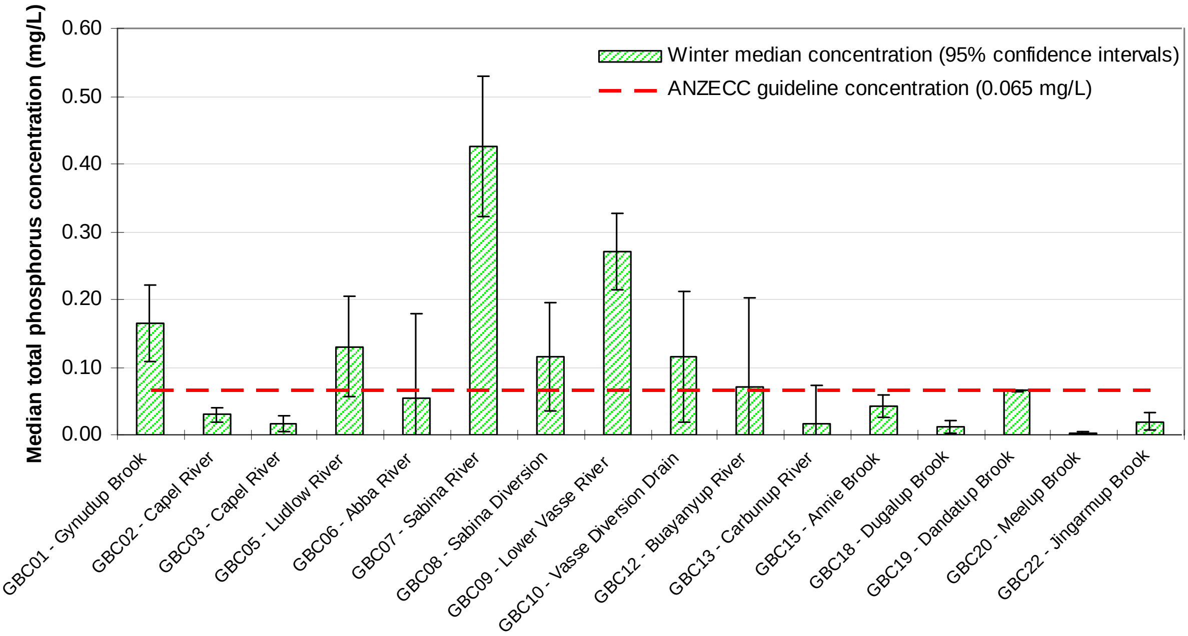


Figure 4.1. Nutrient-sampling locations for the 2007 monitoring program.

Figure 4.2. Water quality sampling at the flow-gauging station in the upper Capel River (610219, GBC03).

Figure 4.3. Flow-gauging station and sampling location on the lower Ludlow River (610009).

Samples at each of the Department of Water locations were analysed, and the medians for total nitrogen and total phosphorus for the sampling period are displayed in Figure 4.4. Confidence intervals are included, and the red line denotes the Australian and New Zealand Environment Conservation Council (ANZECC) guideline concentrations for winter median concentrations (ANZECC & ARMCANZ 2000).



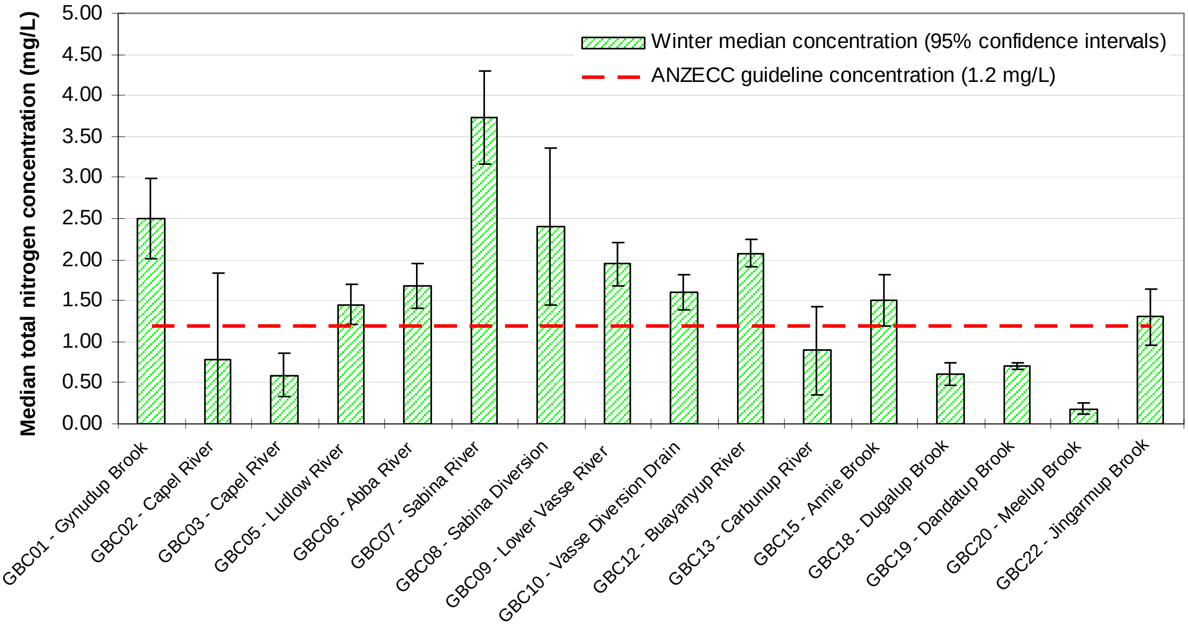


Figure 4.4. Sample median concentrations for total phosphorus and total nitrogen in waterways of the Geographe catchment.

5 Water quality objectives

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 CCI program is:

> 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.

5.1 Defining water quality targets

After discussions with the CCI technical advisory committee about the water quality objectives and modelling requirements, the region was divided into 14 reporting subcatchments. These subcatchments embodied the major watersheds of the catchment (Figure 5.1). Loads, load-reduction targets, maximum acceptable loads, and relative contributions from individual land uses were reported with respect to these subcatchments.

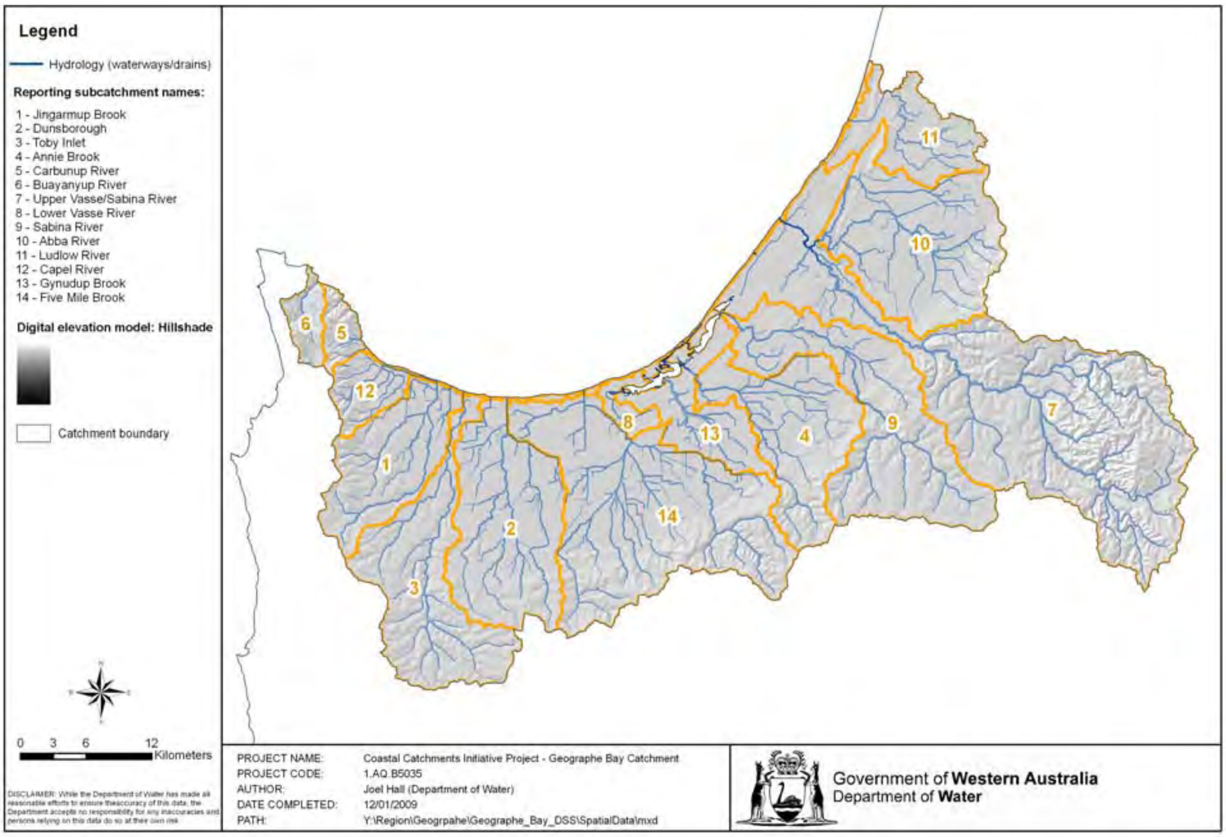


Figure 5.1. Water quality improvement plan reporting subcatchments.

Water quality sampling results were analysed for each of the reporting subcatchments. The technical advisory committee agreed to adopt winter median concentration targets of 0.1 mg/L for total phosphorus and 1.0 mg/L for total nitrogen as the water quality objectives for the waterways of the Vasse Geographe catchments. These concentration targets are based on a study that linked nutrient concentration to waterway health across Western Australia's South West. In this study, waterways that achieved these targets generally exhibited good health.

The choice to use concentration targets instead of load targets is further supported by the absence of load measuring units (LMUs) in the catchment. Without LMUs, determining compliance with the targets is extremely difficult and estimation techniques are subject to large errors. Furthermore, loads in ephemeral waterways (the majority of the Geographe catchment's waterways) are highly dependent on rainfall – a low rainfall year will yield a load that differs from a high rainfall year by up to one order of magnitude. Therefore, if load targets are used, compliance with the target will be more dependent on the annual rainfall than on any remedial work undertaken in the catchment. Nutrient concentrations vary with the annual rainfall, but not by as much as the load, and trends in nutrient concentration are more likely to arise from catchment land-use change or remedial activities, rather than variation in rainfall.

5.2 Monitoring for compliance

Compliance with the targets is assessed using a binomial-type compliance regime. To achieve compliance using this regime, the nutrient concentration is allowed to 'fail' a certain number of times, where 'fail' implies that the sample concentration is above the target concentration. The number of allowable 'fails' is based on the number of samples taken in the waterway. If the waterway has too many 'fails' compared with the number of samples, then it does not comply.

Furthermore, the amount of allowable 'fails' depends on the prior assumption of compliance. If the prior assumption is non-compliance, 'fail-safe' compliance rules are enforced. If the prior assumption is compliance, 'benefit-of-doubt' compliance rules are adopted. The difference between 'benefit-of-doubt' and 'fail-safe' compliance is the number of allowable 'fails' from a sampling record. To explain this more simply, assume that there are two catchments: Catchment A and Catchment B. Catchment A has a waterway that is known to be above a certain guideline concentration, and we are aiming to reduce the concentration in the catchment. In this case our prior assumption is 'non-compliance', and 'fail-safe' compliance is adopted. Catchment B has low nutrient concentrations and already meets compliance targets, and we wish to maintain this level. Now the prior assumption is 'compliance', and 'benefit-of-doubt' compliance is adopted for this catchment. Compliance is usually tested annually, using the previous two years of data as well as the current year. If Catchment A 'passes' – in that it meets 'fail-safe' compliance for a given year – then the following year 'benefit-of-doubt' compliance rules are adopted, as the prior assumption will now be 'compliance'. Conversely, if Catchment B fails to meet the 'benefit-of-doubt' compliance rules, then the waterway fails compliance, and the following year 'fail-safe' compliance rules are adopted. For various numbers of samples, the number of ‘fails’ allowed for ‘benefit-of-doubt’ or ‘fail-safe’ compliance is presented in Table 5.1.

Table 5.1. Number of samples and allowable ‘fails’ for ‘fail-safe’ and ‘benefit-of-doubt’ compliance.

Number of samples	Allowable 'fails' for each type of compliance	
n	Fail safe	Benefit of doubt
18	12	6
19	13	6
20	14	6
21	14	7
22	15	7
23	15	8
24	16	8
25	17	8
26	17	9
27	18	9
28	18	10
29	19	10
30	19	11
31	20	11
32	21	11
33	21	12
34	22	12
35	22	13
36	23	13
37	23	14
38	24	14
39	25	14
40	25	15

5.3 Water quality objective categories

A number of waterways in the Geographe catchment had median concentration values significantly below the target values. Therefore, if the target values of 0.1 mg/L for total phosphorus and 1.0 mg/L for total nitrogen were adopted for these catchments, then a relatively large amount of waterway degradation would have been allowable before failure of compliance was observed. The technical advisory committee decided this was not acceptable, and for catchments that had median values below the target values, the median value was adopted as the target value. This infers that the target for these waterways is ‘no further deterioration of the water quality within the catchment’.

Reporting subcatchments that were below the target median winter concentrations for phosphorus and nitrogen, and would undergo ‘benefit-of-doubt’ compliance rules, were assigned the category ‘protection’ for their water quality objectives. Reporting subcatchments that were meeting target median winter concentrations for phosphorus but not for nitrogen, and would thus adopt 'benefit-of-doubt' compliance rules for phosphorus and 'fail-safe' compliance rules for nitrogen, were assigned the category 'intervention'. Reporting subcatchments with both the phosphorus and nitrogen concentrations exceeding the winter median targets, and therefore adopting 'fail-safe' compliance rules, were assigned the category 'recovery' for their water quality objectives. The details of the water quality objectives for each of these categories are displayed in Table 5.2, and the categories for each of the reporting subcatchments are displayed in Figure 5.2.

Table 5.2. Water quality objective categories for the Geographe catchment

	Protection	Intervention	Recovery
Objective	Maintin current good water quality	Stop phosphorus levels rising and reduce nitrogen to target levels	Reduce both nitrogen and phosphorus to target levels
Waterways: flowing to the Vasse Wonnerup wetlands		Abba River	Lower Vasse River, Sabina River, Ludlow River
Waterways: flowing to the Geographe Bay	Dunsborough, Carbunup River, Capel River	Jingarmup Brook, Toby Inlet, Annie Brook, Buayanyup River	Vasse Diversion Drain, Gynudup, Five Mile Brook
Assessment against water quality targets	Meet both nitrogen and phosphorus targets	Fails nitrogen target, meets phosphorus target	Fails both nitrogen and phosphorus targets
Water quality objective: Nitrogen	Prevent further increases from current winter median concentrations.	Decrease median winter concentrations to 1.0 mg/L	Decrease median winter concentrations to 1.0 mg/L
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

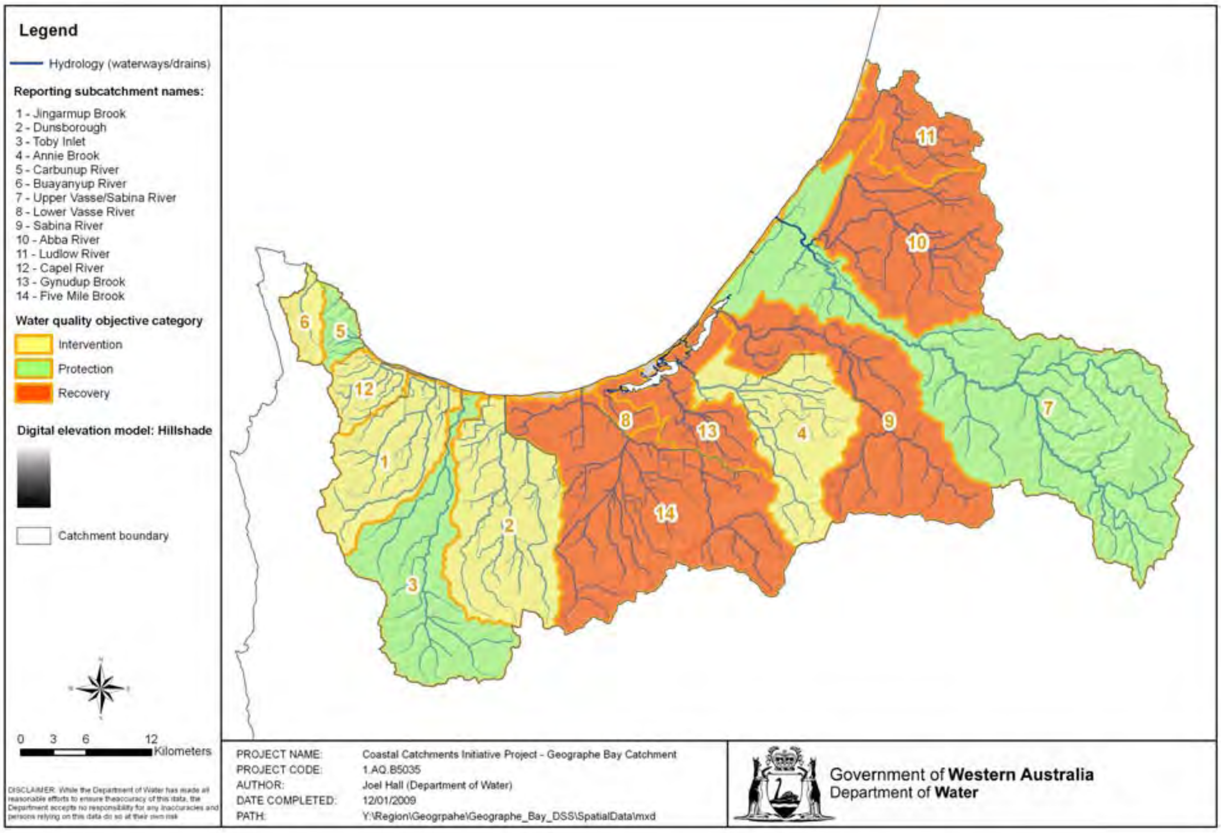


Figure 5.2. Water quality objective categories for the reporting subcatchments.

5.4 Rainfall time-series for future prediction

Annual nutrient loads obtained from waterways in the Geographe catchment are highly dependent on the quantity and timing of rainfall. An important component of the modelling project was to predict future nutrient loads for the reporting catchments to compare with the current nutrient loads. Therefore, the selection of an appropriate future rainfall time-series was essential.

The future rainfall time-series is the rainfall the model uses for all years post-2006. The rainfall can either be observed data or simulated data. For the purpose of the water quality improvement plan, and for a more accurate means of comparison, it was decided to use observed rainfall data (i.e. the future rainfall will be equal to a repetition of a series of past, observed rainfall years). To select an appropriate rainfall sequence to use in the future scenarios, an analysis of the past 36 years of rainfall was completed. Annual catchment rainfall was calculated by taking an average of the annual rainfall generated for each of the modelling subcatchments (outlined in section 6.1.1). Figure 5.3 shows the catchment's average annual rainfall for the years 1970–2006 and the flow-gauging stations that contain data for given years are displayed on the blue horizontal lines. The technical advisory committee decided that the past 12 years' rainfall (1995–2006) was to be used for future rainfall generations for the following reasons:

- The mean rainfall for the period 1995–2006 is very close to the mean for the period 1975–2006. The rainfall period 1975–current is believed to represent the latest ‘step down’ in climate change, therefore this period represents the generally accepted rainfall level for the current climate scenario.
- The period 1995–2006 contains both the highest rainfall year (1999) and the lowest rainfall year (2006) in the 36-year range, and hence gives a good representation of the variation in rainfall.
- All gauging stations have data for part of the period 1995–2006, so the rainfall-runoff relationship is known for this period in most catchments.

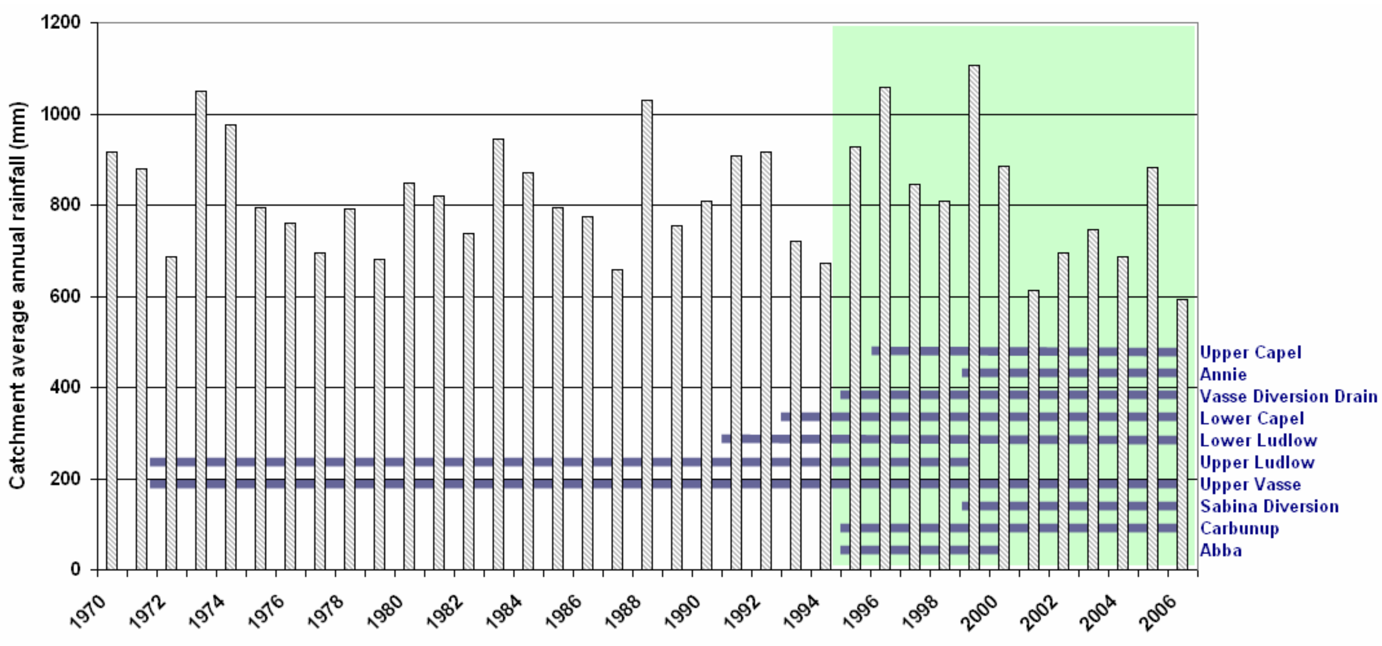


Figure 5.3. Average annual rainfall series for the Geographe catchment. The horizontal lines represent the years that the associated flow-gauging stations contain data.

When catchment loads were forecast taking into account future land use, the time periods 2007–2018, 2019–2030, 2031–2042, 2043–2054 and 2055–2066 were given the equivalent daily rainfall values to the time period 1995–2006 (with the exception of the climate change scenarios outlined in Section 7). The time period 2055–2066 was generally when the loads had stabilised after land-use changes (which cease in 2025), and hence was used as the representative future modelling time-series to be compared with the current time-series (1995–2006). When a current load is presented for a subcatchment in the water quality improvement plan, it is the average annual load for the time-series 1995–2006, unless otherwise stated. Likewise, when a future load is presented in the following sections or in the water quality improvement plan, it is the average annual load for the time series 2055–2066 unless otherwise stated. The annual load can vary by up to one order of magnitude within the 12-year series, especially when comparing the 1999 load with the 2006 load, and this is important to take note of when reviewing the modelling results.

6 Catchment modelling

6.1 Input data preparation

The SQUARE model requires meteorological inputs, spatial inputs and observed data for calibration. Meteorological inputs describe the rainfall and evaporation. The spatial inputs describe the soil and land-use attributes (impervious areas, deep-rooted vegetation, leaf-area index and fertilisation rates). The observed data includes daily stream flow and nutrient-sampling data, which is used in the model for calibration and validation.

As mentioned in Chapter 2, SQUARE is a semi-distributed model and all information is ‘lumped’ at a subcatchment level. The Geographe catchment was divided hydrologically into 797 subcatchments which are displayed in Figure 6.1.

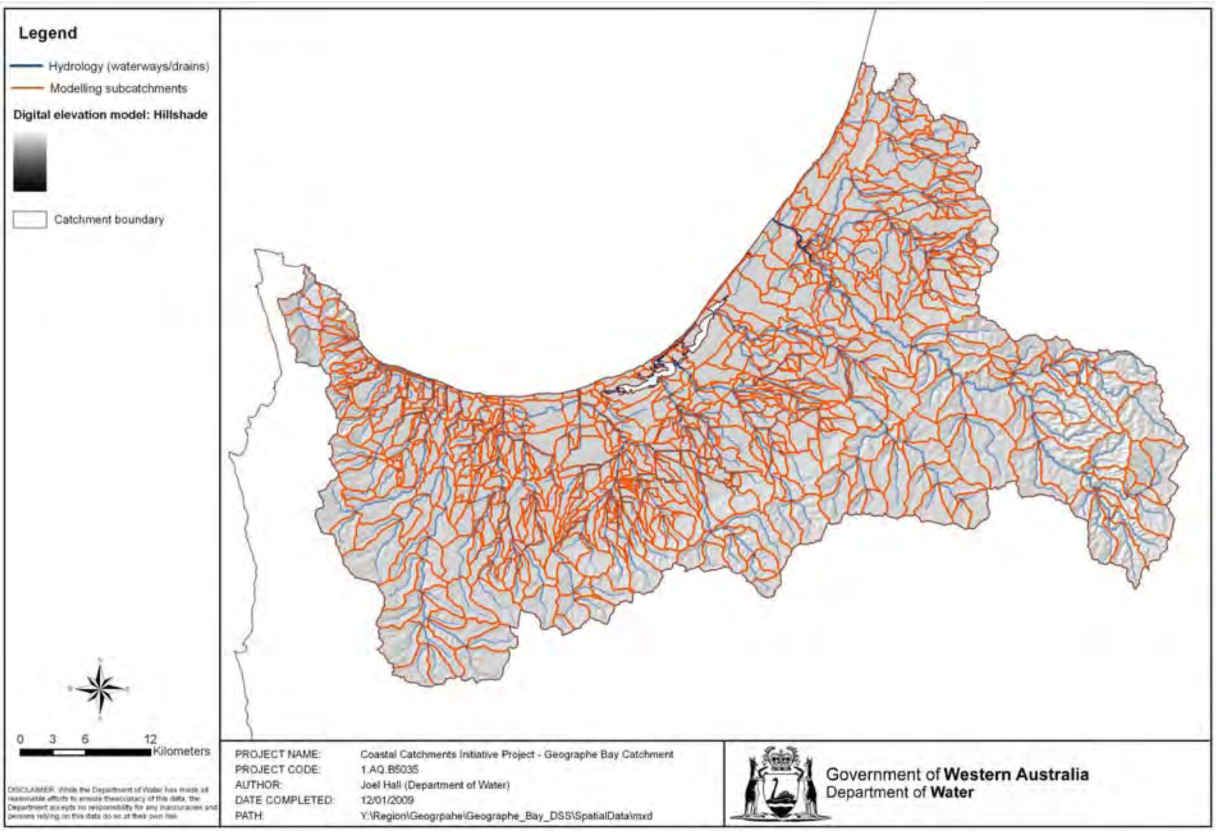


Figure 6.1. SQUARE modelling subcatchments.

The process of ‘lumping’ involves the area-weighting of land-coverage component values within each subcatchment, so that each subcatchment is given a single, unique value for a particular input. This information is pre-processed to the required data format, and comprises the catchment-modelling-input dataset.

Sites that contained observed data are displayed in Section 2 (Figure 2.5 for the gauging stations that contain daily flow data, and Figure 2.6 for sites that contain nutrient-sampling locations). A more detailed analysis of the observed data is given in the calibration report in Appendix A.

6.1.1 Meteorological data

Distributed daily rainfall

Rainfall is the fundamental driver of the SQUARE model, and rainfall data is required as a daily time-step. Rainfall data from 1970–2006 was extracted from the Bureau of Meteorology and Department of Water rainfall gauges, displayed in Figure 6.2.

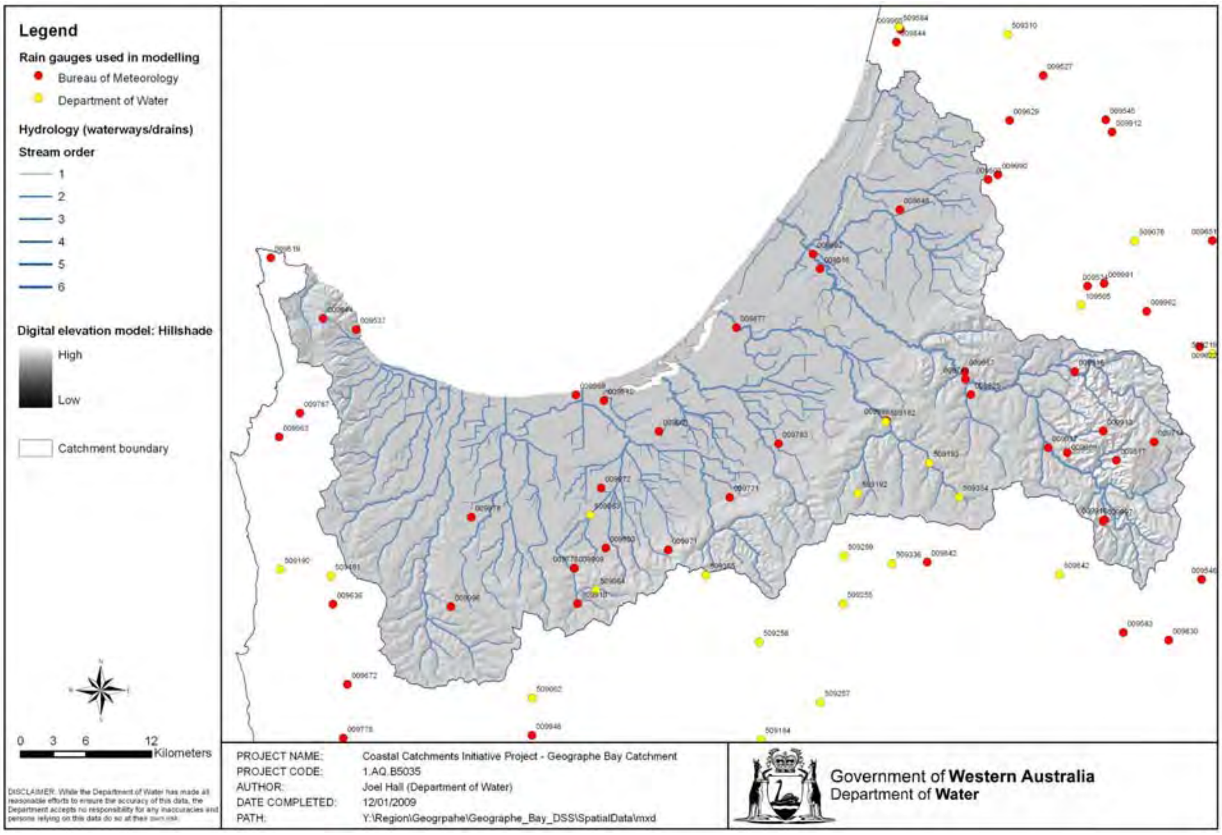


Figure 6.2. Rainfall gauge locations.

Each subcatchment is given a daily rainfall value for each day of the simulation using the ‘makerainf.exe’ program, which is one of the suite of SQUARE pre-processing programs. The program ‘makerainf.exe’ assigns a daily rainfall value to the centroid of each subcatchment based on the ‘inverse distance weighted’ method, taking into account the nearest five rain gauges that contain high-quality data for each day of the modelling time period.

Daily potential evaporation

SQUARE avoids the need to have continuous daily pan evaporation or potential evaporation measurements (these are inaccurate and sparse in the Geographe catchment). Instead, it assumes that the daily potential evaporation values follow a sinusoidal trend in time according to a predetermined harmonic distribution. The sinusoidal trend is calculated using a mean potential evapotranspiration value for each subcatchment, and a parameter relating to the amplitude and phase of the curve. Daily evapotranspiration is calculated based on the potential daily evaporation, leaf-area index, deep-rooted vegetation, and the availability of water in the subsequent stores.

Mean annual potential evaporation and rainfall

Mean annual rainfall (mm) for each subcatchment is used to adjust initial storage values to some approximate equilibrium value. Mean annual potential evaporation (mm) is used as a scalar for the daily evaporation calculation from each store in each subcatchment. The accuracy of their absolute values is not critical: only reasonable representations of their spatial variability are required.

6.1.2 Spatial data

The spatial coverages that make up the set of SQUARE input data files include:

- leaf-area index
- deep-rooted vegetation
- impervious area
- phosphorus retention index (PRI)
- nutrient input rates.

Leaf-area index, deep-rooted vegetation and impervious area

Values for the leaf-area index, deep-rooted vegetation fraction, and impervious area fraction are assigned to each of the land-use parcels, based on literature and satellite imagery studies. The land-use dataset was used to assign these values rather than Landsat imagery and Land Monitor datasets, because satellite imagery is at a 25 m pixel grid (which is too coarse for some subcatchments) and historic Landsat imagery and Land Monitor datasets were not available as far back as the land-use mapping exercise requires.

The values for leaf-area index, deep-rooted vegetation and impervious area assigned to each land-use type are displayed in Table 6.1. The leaf-area index and deep-rooted vegetation coverages are displayed in figures 6.3 and 6.4 (for the 2005 dataset).

Leaf-area indices vary seasonally, and SQUARE adjusts the annual LAI values monthly, according to the values obtained by the CSIRO (McVicar et al, 1996).

Table 6.1. Leaf-area indices, impervious area and deep-rooted vegetation values for land-use categories in the Geographe catchment.

Landuse category	Leaf-area index	Impervious area	Deep-rooted vegetation
Airport	0.200	20%	0%
Annual horticulture	0.700	0%	0%
Aquaculture	0.000	0%	0%
Beef feedlot	0.500	0%	0%
Camping grounds	1.300	10%	40%
Canals	0.000	0%	0%
Cattle for beef	0.500	0%	5%
Cattle for dairy	0.500	0%	5%
Cemetery	0.500	0%	5%
Cleared land - unused	1.000	0%	0%
Commercial	0.100	60%	5%
Dam	0.000	0%	0%
Drain reserve	1.200	0%	5%
Effluent treatment	0.000	0%	0%
Estuary fringe	1.200	0%	10%
Floriculture	1.100	0%	5%
Foreshore reserve	0.800	0%	15%
Golf course	1.000	5%	20%
Government facility	0.100	5%	60%
Heavy industry	0.100	90%	2%
Horses	0.400	0%	5%
Horticulture	0.700	0%	0%
Lifestyle block	0.800	0%	10%
Light industrial	0.100	90%	2%
Mixed cattle and sheep	0.900	0%	10%
Mixed grazing	0.900	0%	10%
Native forest	1.800	0%	90%
Other rural activities	1.200	0%	5%
Pasture for hay	1.200	0%	5%
Perennial horticulture	0.700	0%	0%
Perennial horticulture - trees	1.400	0%	80%
Poultry	0.100	10%	5%
Private institution	0.800	40%	5%
Public access way	0.000	0%	0%
Quarry	0.000	0%	0%
Railway reserve	1.800	0%	90%
Recreation reserve	1.000	0%	10%
River or stream reserve	1.080	0%	0%
Road reserve	0.622	0%	20%
Rural residential	1.440	5%	80%
Sand mine	0.000	0%	0%
Sheep	0.500	0%	5%
Tourist precinct	0.050	40%	5%
Tree plantation	1.600	0%	80%
Turf farm	1.100	0%	5%
Uncleared land - unused	1.800	0%	90%
Urban residential	0.500	20%	10%
Utility	0.000	40%	0%
Viticulture	1.100	0%	10%
Water	0.000	0%	0%
Wetland	1.500	0%	60%

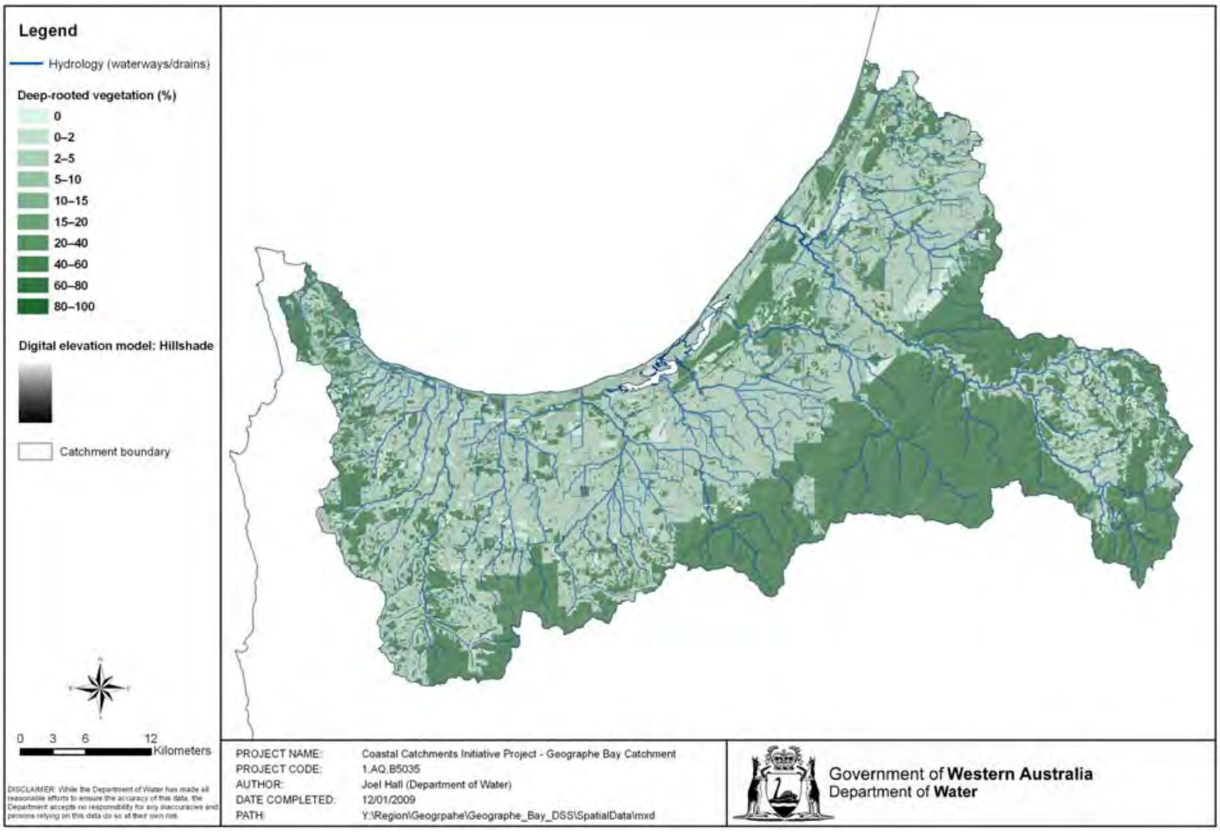


Figure 6.3. Deep-rooted vegetation coverage for the Geographe catchment(2005).

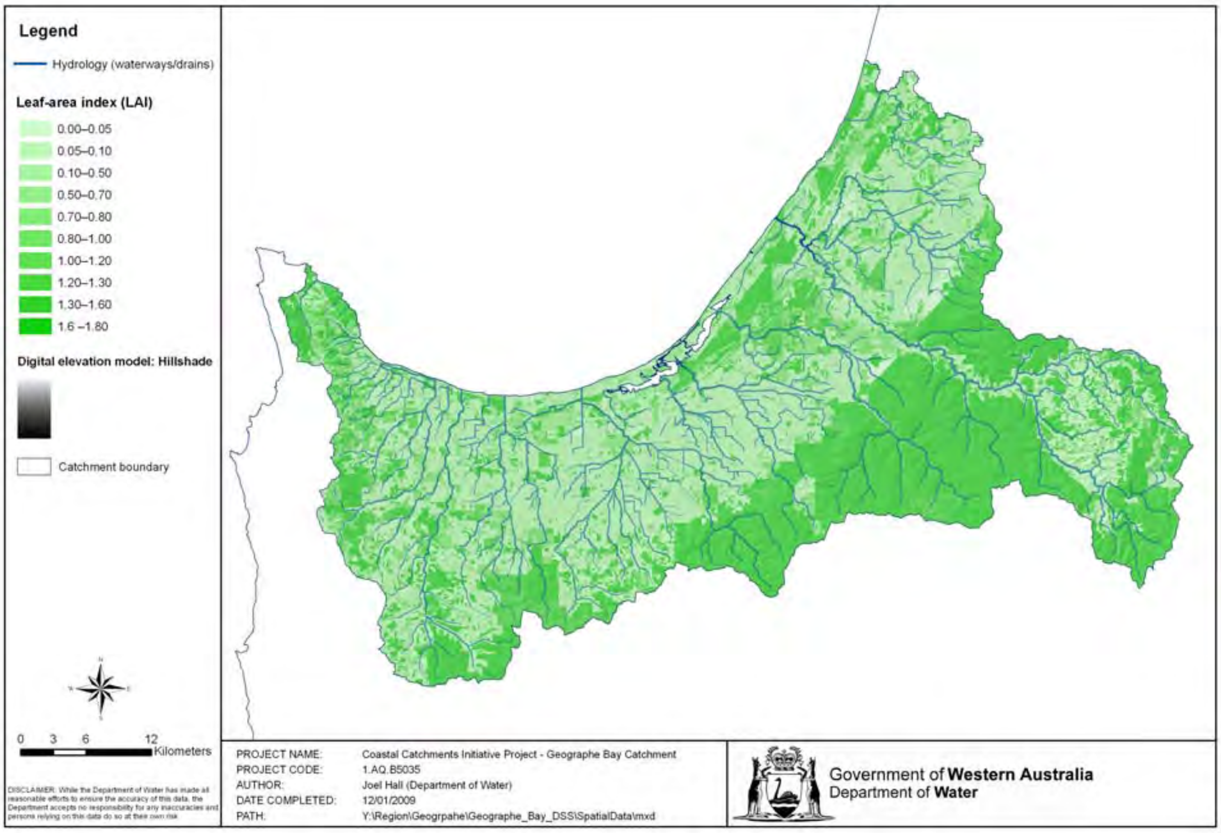


Figure 6.4. Leaf-area index (LAI) coverage for the Geographe catchment (2005).

Phosphorus retention index (PRI)

In SQUARE, the soil is characterised by its phosphorus retention Index (PRI) – a measure of the soil's ability to retain phosphorus through adsorption to soil particles. Many of the sandy soils on the Swan coastal plain have a low PRI, and hence a low capacity to adsorb phosphorus. The soil PRI is determined from Department of Agriculture and Food mapping units, and is displayed in Figure 6.5.

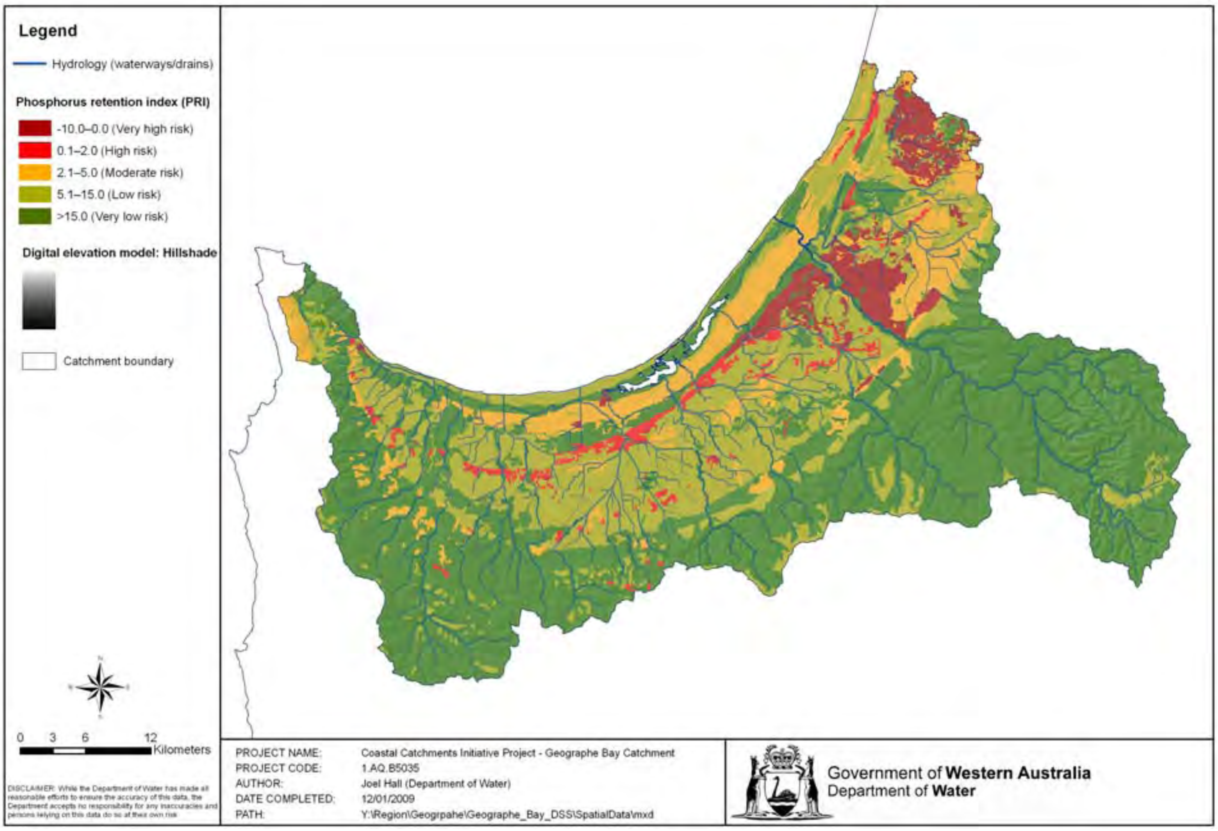


Figure 6.5. Phosphorus retention index coverage.

Nutrient fertiliser rates

Each land use is assigned a nutrient fertiliser rate (in kg/ha) and a temporal breakdown of fertiliser application (monthly). Data was gathered from the Department of Agriculture and Food's fertiliser surveys of rural properties and the Department of Water's 2006 urban nutrient survey (Kitsios & Kelsey 2007). The fertiliser surveys covered rural or semi-rural properties in the Ellenbrook, Geographe Bay and Peel Harvey catchments. For the Geographe catchment, most rural landholders completed the surveys: 152 in total (Figure 6.6). Land parcels that had a fertiliser survey undertaken were assigned the actual fertiliser rate that was calculated from the survey. Land parcels that did not complete a fertiliser survey were assigned the median fertiliser rate of the particular land-use category. Median fertiliser rates were taken from the Geographe Bay survey dataset where there were sufficient samples to obtain a plausible result, otherwise the medians were taken from the entire fertiliser dataset of the Department of Agriculture and Food's surveys.

The median nutrient-input rates for the diffuse land uses are displayed in Table 6.2.

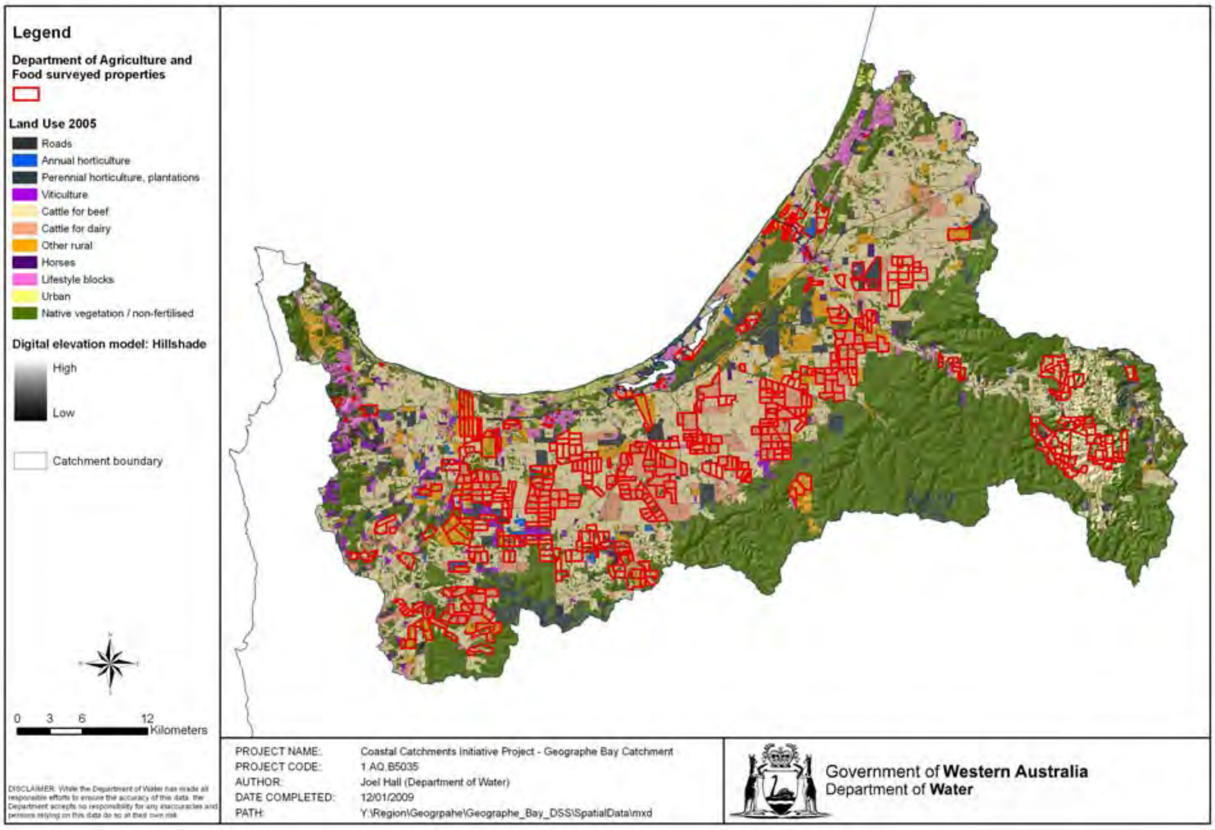


Figure 6.6. Department of Agriculture and Food surveyed properties

The urban nutrient study's aim was to determine the amount of nitrogen and phosphorus being applied in residential urban areas of the Swan coastal plain. Approximately 7000 questionnaires were sent to 17 suburbs in the Perth, Peel Harvey and Geographe areas, which were chosen based on the following differences: location (Perth metropolitan and regional), dwelling type (house, unit, villa and canal), dwelling age (new: 0–2 years, recent: 3–5 years, established: 6–10 years and old: >11 years) and lot size.

Twelve-hundred people responded with information including lot size, areas of lawn, garden, pavement and roof, number and type of pets, plant types, water usage, fertiliser regimes and disposal of garden and pet waste. Fertiliser regimes were specified by fertiliser type, application amount, frequency and seasonality. The data from the surveys was analysed and fertiliser types were researched for phosphorus and nitrogen content, and a fertiliser rate in kg/ha for each urban residence was calculated.

There was no statistically significant difference between fertiliser application rates for different urban lot sizes, which ranged from 100 to 2124 m^2. Thus the urban fertilisation rates for nitrogen and phosphorus used in the modelling project were the median of the rates calculated for all residences within the Geographe catchment. Median fertilisation rates assigned to each land-use type are displayed in Table 6.2, and the monthly breakdown of the application is displayed in Table 6.3.

Table 6.2. Fertiliser rates for non-surveyed diffuse land uses in the Geographe catchment.

Landuse category	Nitrogen application rate (kg/ha/yr)	Phosphorus application rate (kg/ha/yr)
Airport	0.00	0.00
Annual horticulture	176.20	220.00
Aquaculture	1.92	0.18
Beef feedlot	13.39	12.01
Camping grounds	0.00	0.00
Canals	0.00	0.00
Cattle for beef	13.39	12.01
Cattle for dairy	86.49	25.04
Cemetery	0.00	0.00
Cleared land - unused	0.00	0.00
Commercial	0.00	0.00
Dam	0.00	0.00
Drain reserve	0.00	0.00
Effluent treatment	0.00	0.00
Estuary fringe	0.00	0.00
Floriculture	176.20	220.00
Foreshore reserve	0.00	0.00
Golf course	103.43	0.00
Government facility	103.43	29.20
Heavy industry	0.00	0.00
Horses	5.87	13.20
Horticulture	176.20	220.00
Lifestyle block	10.15	4.84
Light industrial	0.00	0.00
Mixed cattle and sheep	13.53	16.11
Mixed grazing	13.53	16.11
Native forest	0.00	0.00
Other rural activities	13.53	16.11
Pasture for hay	13.53	16.11
Perennial horticulture	27.00	18.00
Perennial horticulture - trees	23.11	5.40
Poultry	0.00	0.00
Private institution	125.00	29.20
Public access way	0.00	0.00
Quarry	0.00	0.00
Railway reserve	0.00	0.00
Recreation reserve	125.00	35.00
River or stream reserve	0.00	0.00
Road reserve	0.00	0.00
Rural residential (bush block)	0.00	0.00
Sand mine	0.00	0.00
Sheep	2.03	0.24
Tourist precinct	125.00	29.20
Tree plantation	16.14	9.61
Turf farm	176.20	220.00
Uncleared land - unused	0.00	0.00
Urban residential	125.00	29.20
Utility	0.00	0.00
Viticulture	4.40	15.18
Water	0.00	0.00
Wetland	0.00	0.00

Table 6.3. Fertiliser timing for land-use categories that have non-zero fertiliser application

	January	February	March	April	May	June	July	August	September	October	November	December
Annual horticulture	18%	4%	3%	0%	24%	12%	19%	0%	9%	3%	4%	4%
Floriculture	18%	4%	3%	0%	24%	12%	19%	0%	9%	3%	4%	4%
Horticulture	18%	4%	3%	0%	24%	12%	19%	0%	9%	3%	4%	4%
Turf farm	18%	4%	3%	0%	24%	12%	19%	0%	9%	3%	4%	4%
Aquaculture	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%
Cattle for beef	3%	9%	14%	17%	16%	12%	6%	7%	9%	3%	4%	0%
Beef feedlot	3%	9%	14%	17%	16%	12%	6%	7%	9%	3%	4%	0%
Cattle for dairy	6%	0%	22%	17%	13%	5%	6%	8%	12%	6%	4%	0%
Horses	0%	0%	0%	50%	0%	0%	0%	50%	0%	0%	0%	0%
Lifestyle block	5%	4%	4%	11%	12%	10%	10%	5%	18%	11%	7%	4%
Mixed cattle and sheep	17%	10%	3%	10%	12%	11%	0%	16%	9%	11%	0%	0%
Mixed grazing	17%	10%	3%	10%	12%	11%	0%	16%	9%	11%	0%	0%
Other rural activities	17%	10%	3%	10%	12%	11%	0%	16%	9%	11%	0%	0%
Pasture for hay	17%	10%	3%	10%	12%	11%	0%	16%	9%	11%	0%	0%
Perennial horticulture	40%	10%	0%	0%	0%	0%	40%	10%	0%	0%	0%	0%
Perennial horticulture - tees	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%
Tree plantation	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	0%
Sheep	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Sheep feedlot	0%	0%	70%	0%	0%	0%	0%	30%	0%	0%	0%	0%
Viticulture	0%	0%	0%	0%	0%	0%	0%	0%	36%	36%	14%	14%
Government facility	23%	0%	18%	0%	0%	13%	0%	0%	46%	0%	0%	0%
Private institution	23%	0%	18%	0%	0%	13%	0%	0%	46%	0%	0%	0%
Tourist precinct	23%	0%	18%	0%	0%	13%	0%	0%	46%	0%	0%	0%
Urban residential	23%	0%	18%	0%	0%	13%	0%	0%	46%	0%	0%	0%
Recreation reserve	23%	0%	18%	0%	0%	13%	0%	0%	46%	0%	0%	0%

The spatial representation of phosphorus fertiliser-input rates are displayed in Figure 6.7 and the nitrogen fertiliser-input rates are displayed in Figure 6.8. Fertiliser nutrient input is one of three nutrient-input datasets required by the SQUARE model. Other nutrient datasets include point sources and septic tanks, which were described in Section 3.

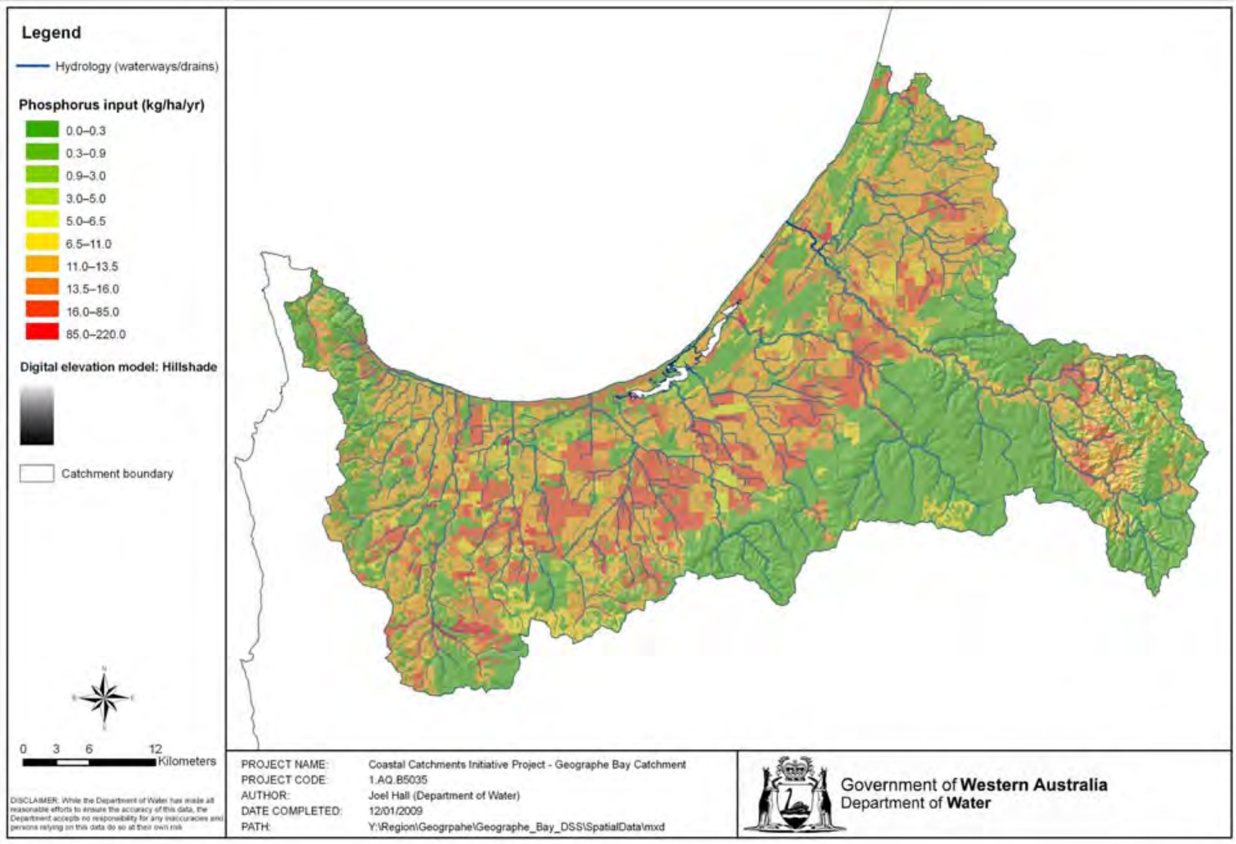


Figure 6.7. Phosphorus input coverage for the Geographe catchment (2005).

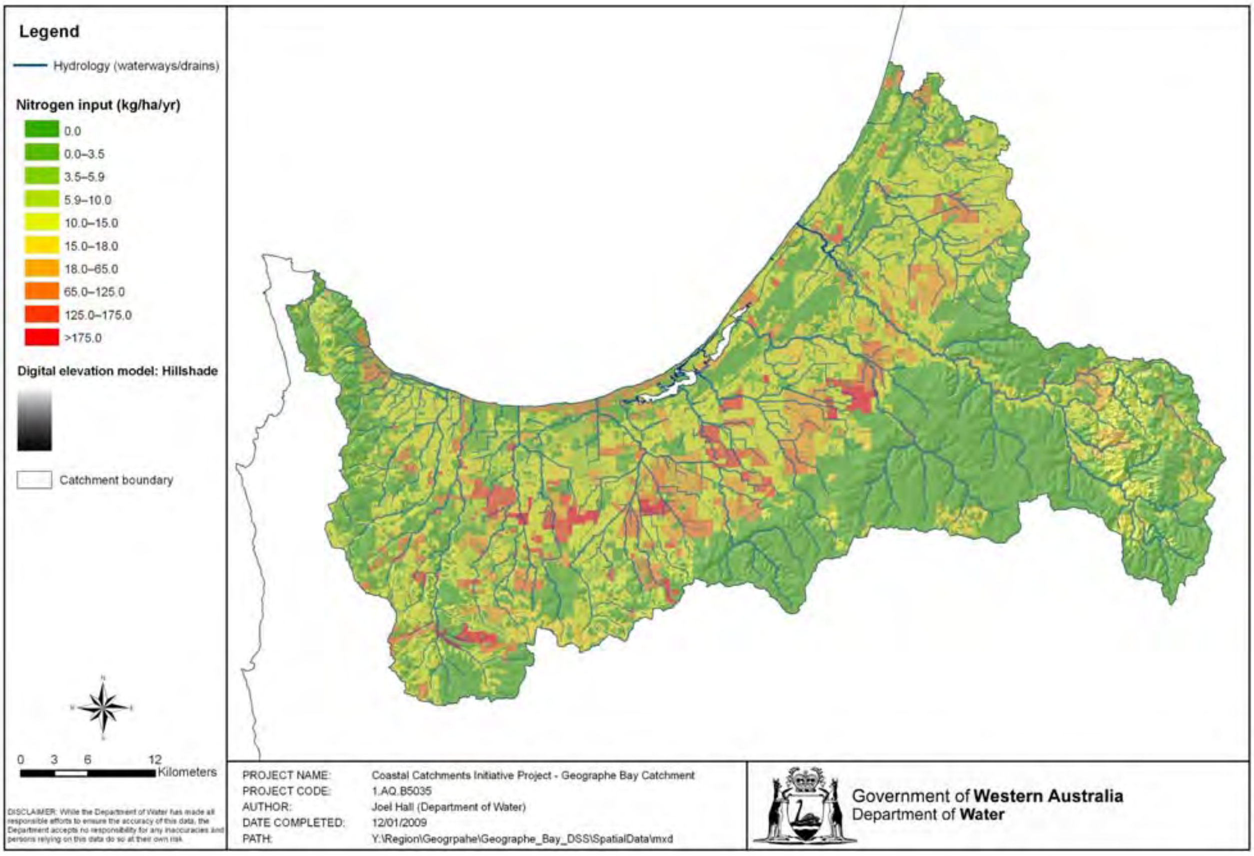


Figure 6.8. Nitrogen input coverage for the Geographe catchment (2005).

6.2 Model outputs

Loads and load-reduction targets are calculated when the calibration process is complete. The calibration process involves the adjustment of model parameters so that modelling outputs reproduce the measured values as closely as possible. This process was described in Section 2, and the calibration report is presented in Appendix A. As mentioned previously, the Nash-Sutcliffe efficiency was maximised during calibration – based on the comparison of modelled versus observed daily loads for nutrient and sediment species. It was also important for median nutrient concentrations obtained from the calibration to reflect the median concentrations in the waterways, which added another level of complexity to the calibration. The calibration for each reporting subcatchment was complete when a set of parameters was obtained that satisfied the median nutrient concentration in the waterways, while maximising the efficiency and satisfying store and flux verifications.

When the calibration was complete, the following outputs were calculated for each reporting subcatchment:

- current load
- predicted load
- load-reduction target
- maximum acceptable load.

It is important to note that SQUARE models future urban developments as traditional-style urban developments with no water sensitive urban design (WSUD). This is because the changes in nutrient yields due to WSUD have not yet been quantified for Western Australian conditions. If it is assumed that WSUD reduces nutrient yields and that urban developments in the Geographe catchment incorporate WSUD, then the SQUARE predicted loads may be slightly overestimated.

6.2.1 Current and predicted loads

As mentioned previously, SQUARE calculates modelled daily flows, sediment loads and nutrient loads. Daily loads are aggregated to produce monthly, seasonal or annual loads. The current load, which is reported for each of the subcatchments, is the average annual load for the time period 1995–2006. It is important to represent the current annual load as an average annual load over a time period of a number of years, because large variations in annual loads occur due to climatic variability. Loads are extremely dependent on the rainfall quantity, timing and intensity of any given year. The predicted load is the average annual nutrient load for the time period 2055–2066. This is the future average annual load that is predicted once all of the future proposed urban developments occur on the catchment (and has the same rainfall as the period 1995–2006).

6.2.2 Maximum acceptable load

The maximum acceptable load is the average annual load required for the waterway to achieve the water quality objective (i.e. the concentration target described in Section 5). The calculation of the maximum acceptable load was an iterative process described below:

- A decrease in nutrient input was applied to the reporting subcatchment and the model run from 1970–2066.
- The winter median concentration was then calculated for the period 2055–2066. This period was selected because soil-nutrient stores and output loads had generally reached equilibrium by this time.
- The post-2006 nutrient input was then adjusted, depending on whether the winter median concentration was below or above the target concentration and the model re-run. This process was repeated until the winter median concentration was equal to the concentration target. The average annual modelled load (from the period 2055–2066) was thus the maximum acceptable load.

For catchments that did not require a load reduction (i.e. the current observed winter median concentration was below the target concentration), the maximum acceptable load was equal to the current load. This implies that no increase in load was desired for catchments that were already performing well.

6.2.3 Load-reduction target

The load-reduction target (LRT) is the reduction in output load required for the waterway to meet the water quality objective. The LRT is thus the difference between the current load and the maximum acceptable load. For catchments that are already meeting their water quality objectives, the LRT is zero.

The current, predicted and maximum acceptable loads and load-reduction targets for the reporting subcatchments are 1 – 1 displayed in Table 6.4 and in Figure 6.9. The output for each subcatchment is included in Appendix C.

Table 6.4. Current loads, predicted loads, LRTs, maximum acceptable loads and winter median concentrations for reporting subcatchments.

Phosphorus - modelled data

	Current load (1995–2006) tonnes/year	Predicted load (2055–2066) tonnes/year	Load reduction target tonnes/year	Maximum acceptable load tonnes/year	Current winter median conc mg/L	Predicted winter median conc mg/L
Five Mile Brook	3.47	3.47	2.63	0.84	0.415	0.437
Gynudup Brook	2.85	2.24	1.40	1.45	0.204	0.237
Capel River	6.72	8.41	0.00	6.72	0.051	0.061
Ludlow River	2.94	3.38	0.63	2.31	0.138	0.147
Abba River	4.35	5.18	0.00	4.35	0.051	0.051
Sabina River	3.57	3.61	2.63	0.94	0.387	0.381
Vasse River	14.08	25.11	9.24	4.84	0.266	0.530
Lower Vasse River	4.72	6.66	3.17	1.55	0.251	0.438
Buayanyup River	6.46	10.66	0.00	6.46	0.069	0.101
Carbunup River	1.81	1.90	0.00	1.90	0.021	0.022
Annie Brook	1.76	1.72	0.00	1.76	0.039	0.039
Toby Inlet	0.42	0.65	0.00	0.42	0.031	0.045
Dunsborough region	0.13	0.17	0.00	0.13	-	-
Jingarmup Brook	0.09	0.09	0.00	0.09	0.008	0.007
TOTAL	**53.37**	**73.25**	**19.70**	**33.76**		

Nitrogen - modelled data

	Current load (1995–2006) tonnes/year	Predicted load (2055–2066) tonnes/year	Load reduction target tonnes/year	Maximum acceptable load tonnes/year	Current winter median conc mg/L	Predicted winter median conc mg/L
Five Mile Brook	32.1	32.7	24.2	7.9	4.09	4.27
Gynudup Brook	21.4	21.3	9.2	12.2	2.55	2.86
Capel River	42.2	51.6	0.0	42.2	0.87	1.03
Ludlow River	22.9	30.9	12.7	10.2	2.16	2.90
Abba River	37.5	55.4	9.4	28.1	2.09	3.12
Sabina River	39.5	39.1	28.2	11.3	3.62	3.50
Vasse River	75.6	89.3	42.4	33.2	2.14	2.46
Lower Vasse River	21.4	28.8	11.1	10.3	1.51	2.44
Buayanyup River	33.2	36.9	16.9	16.3	2.11	2.36
Carbunup River	21.1	23.1	0.0	21.1	0.67	0.73
Annie Brook	30.4	31.7	7.1	23.3	1.36	1.41
Toby Inlet	13.7	20.3	5.0	8.7	1.74	2.48
Dunsborough region	1.3	1.7	0.0	1.3	-	-
Jingarmup Brook	4.5	4.9	0.8	3.7	1.31	1.37
TOTAL	**396.8**	**467.7**	**167.0**	**229.8**		

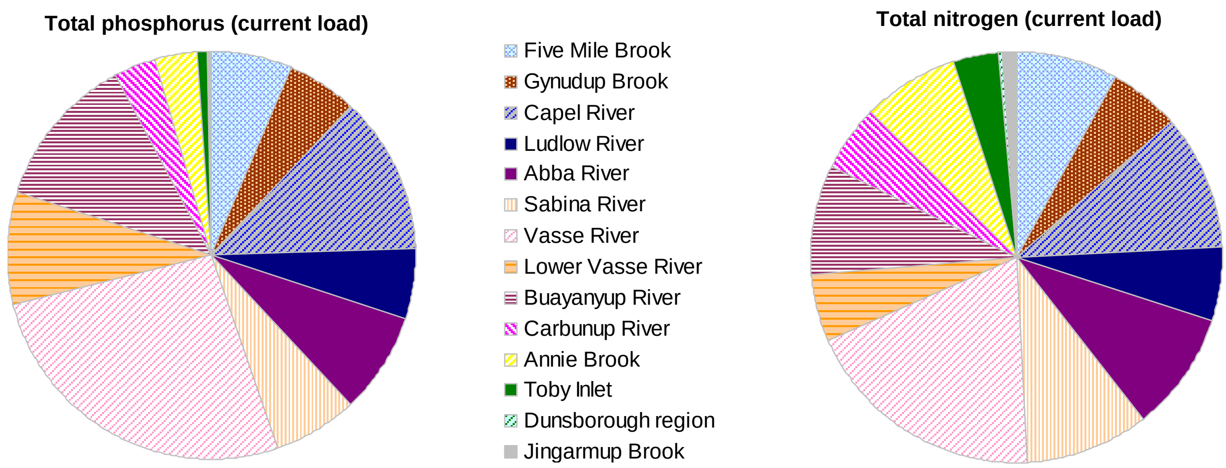


Figure 6.9. Relative current phosphorus and nitrogen loads for reporting subcatchments in the Geographe catchment.

6.3 Source separation

Source separation involves the separation of the output load into various land-use components. This feature allows managers to target specific land uses that contribute most strongly to the total load output. There were 27 land-use types that contributed to the nutrient load, and these were grouped to form nine categories for the source separation. The purpose of grouping was for ease of analysis and presentation, and the various source land-use groupings are presented in Table 6.5.

The results of the source separation are presented in Table 6.6 and in Figure 6.10. Note that nitrogen fixation is modelled by SQUARE and the estimated nitrogen outputs from fixation have also been included. For both phosphorus and nitrogen, the majority of the nutrient loads delivered to the receiving water body were from cattle grazing (beef and dairy). The fixation term in the nitrogen results is likely to be due largely to beef grazing, where nitrogen-fixing pastures are commonly used as a nitrogen source in place of fertilisers. The nitrogen fixed in cattle paddocks becomes more readily transportable to waterways than nitrogen fixed by native vegetation (such as *Acacia* species) because cattle graze on it and then reprocess it back to the catchment in high concentrations as urine, which is highly soluble and transported readily to waterways.

Table 6.5. Land-use category groupings for source separation.

Landuse category	Category for source separation
Annual horticulture	Horticulture
Floriculture	
Horticulture	
Turf farm	
Perennial horticulture	Perennial horticulture/plantation
Perennial horticulture - trees	
Tree plantation	
Viticulture	Viticulture
Cattle for beef	Cattle for beef
Cattle for dairy	Cattle for dairy
Aquaculture	Other rural
Mixed cattle and sheep	
Mixed grazing	
Other rural activities	
Pasture for hay	
Sheep	
Sheep feedlot	
Horses	Horses
Lifestyle block	Lifestyle
Government facility	Urban residential
Private institution	
Tourist precinct	
Urban residential	
Recreation reserve	
Wastewater treatment plants	Point sources
Landfills	
Feedlots	
Caravan parks	
Dairy sheds	
Industrial discharges	
Septic tanks	Septic tanks
Nitrogen fixation	Nitrogen fixation

Table 6.6. Source separation for all reporting subcatchments of the Geographe catchment for the time period 1995–2006.

Phosphorus	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
Five Mile Brook	3.47	0.00	0.21	0.02	0.00	0.01	1.91	0.04	0.06	0.06	0.07	1.10
Gynudup Brook	2.85	0.01	0.00	0.01	0.03	0.01	1.68	0.95	0.10	0.03	0.03	0.00
Capel River	6.72	0.89	0.15	0.59	0.07	0.05	2.98	0.61	1.02	0.14	0.04	0.19
Ludlow River	2.94	0.19	0.00	0.08	0.09	0.00	0.48	1.13	0.93	0.02	0.00	0.00
Abba River	4.35	1.03	0.00	0.09	0.01	0.00	0.93	1.69	0.59	0.00	0.00	0.00
Sabina River	3.57	0.27	0.00	0.00	0.00	0.00	1.04	2.19	0.07	0.00	0.00	0.00
Vasse River	14.08	3.29	0.68	0.36	0.05	0.01	4.32	3.28	0.91	0.06	0.32	2.12
Lower Vasse River	4.72	1.72	0.45	0.07	0.01	0.00	0.75	0.61	0.46	0.00	0.02	0.65
Buayanyup River	6.46	0.72	0.02	1.30	0.10	0.06	1.38	2.49	0.32	0.00	0.00	0.06
Carbunup River	1.81	0.37	0.00	0.11	0.01	0.02	0.59	0.58	0.12	0.00	0.00	0.00
Annie Brook	1.76	0.01	0.00	0.21	0.06	0.05	1.08	0.25	0.06	0.03	0.01	0.00
Toby Inlet	0.42	0.00	0.03	0.00	0.00	0.00	0.26	0.00	0.01	0.01	0.01	0.10
Dunsborough region	0.13	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.10
Jingarmup Brook	0.09	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.00
TOTAL	**53.4**	**8.5**	**1.5**	**2.8**	**0.4**	**0.2**	**17.4**	**13.8**	**4.7**	**0.4**	**0.5**	**4.3**
%TOTAL	**100.0%**	**15.5%**	**2.8%**	**5.2%**	**0.8%**	**0.4%**	**31.9%**	**25.3%**	**8.6%**	**0.7%**	**0.9%**	**7.9%**

Nitrogen	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
Five Mile Brook	32.1	0.0	2.2	0.1	0.0	0.0	10.1	2.5	0.5	0.1	1.0	6.2	9.4
Gynudup Brook	21.4	1.4	0.1	0.1	0.2	0.0	8.9	5.9	0.4	0.0	0.2	0.1	4.2
Capel River	42.2	4.4	4.6	0.6	0.0	0.0	11.3	8.3	0.9	0.2	0.0	1.8	10.0
Ludlow River	22.9	1.5	0.0	0.2	0.2	0.0	1.2	14.4	2.0	0.0	0.0	0.0	3.5
Abba River	37.5	6.3	0.1	0.2	0.3	0.0	3.1	16.4	3.6	0.0	0.0	0.0	7.5
Sabina River	39.5	1.4	0.0	0.0	0.0	0.0	4.6	31.9	0.2	0.0	0.0	0.0	1.3
Vasse River	75.6	8.9	3.0	0.0	0.3	0.0	10.0	45.8	0.5	0.0	0.3	3.2	4.9
Lower Vasse River	33.8	3.6	1.3	0.0	0.1	0.0	4.3	20.3	1.0	0.0	0.0	1.2	2.2
Buayanyup River	33.2	3.9	0.0	4.5	0.2	0.0	2.7	16.2	0.1	0.0	0.0	0.1	5.5
Carbunup River	21.1	2.3	0.0	1.3	0.0	0.0	2.4	13.1	1.0	0.0	0.0	0.0	0.8
Annie Brook	30.4	0.5	0.0	2.6	0.6	0.0	12.7	5.5	0.3	0.1	0.0	0.0	7.9
Toby Inlet	13.7	0.0	1.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.2	4.2	3.8
Dunsborough region	1.3	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.5	0.2
Jingarmup Brook	4.5	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.0	0.5	2.7
TOTAL	**409.2**	**34.1**	**13.2**	**9.5**	**2.0**	**0.1**	**76.2**	**180.5**	**11.0**	**0.5**	**1.9**	**17.7**	**64.0**
%TOTAL	**100.0%**	**8.3%**	**3.2%**	**2.3%**	**0.5%**	**0.0%**	**18.6%**	**43.9%**	**2.7%**	**0.1%**	**0.5%**	**4.3%**	**15.6%**

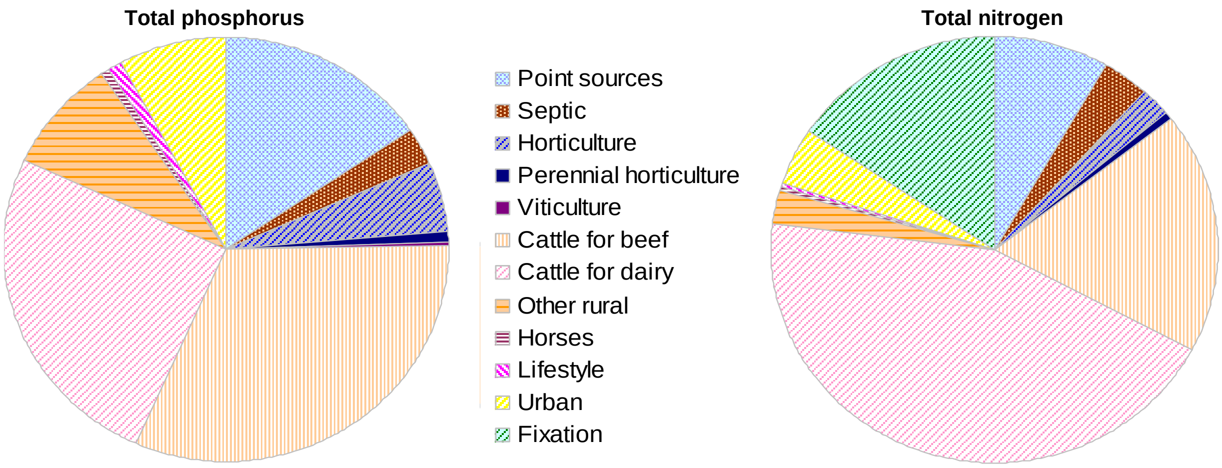


Figure 6.10. Source separation for current phosphorus and nitrogen loads for the Geographe catchment.

6.4 Confidence assessment for modelling outputs

Modelled results for loads and flows by themselves are not sufficient for a modelling project: the well-known contemporary aphorism ‘garbage in, garbage out’ applies to the fact that mathematical models can perpetuate any errors in data. The accuracy of modelling outputs is only as good as the available data that is used to drive the models. Good modelling practice requires that the modeller provides an evaluation of confidence in the model, assessing the uncertainties associated with the modelling process and with the outcome of the model itself.

One method to test the robustness of a model is to perform a sensitivity analysis on the model parameters and/or inputs. Sensitivity analysis is the study of how the variation in the model’s output can be apportioned to the different sources of variation in the model’s inputs. The SQUARE model has 82 parameters and approximately 25 input datasets (depending on the subcatchment). As such, the sensitivity analysis process for a model with this many parameters is extremely large and not possible to pursue within the scope of this project.

Table 6.7. Risk scoring based on the available data for flow and nutrient sampling in each of the reporting subcatchments of the Geographe catchment.

	Five Mile Brook	Gynudup Brook	Capel River	Ludlow River	Abba River	Sabina River	Lower Vasse River	Vasse Diversion Drain	Buayanyup River	Carbunup River	Annie Brook	Toby Inlet	Dunsborough region	Jingarmup Brook
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**

A more qualitative approach has been adopted for the Geographe modelling project, whereby factors affecting the quality of the calibration data (flow and nutrients) are scored for each of the reporting subcatchments. The scores are then added to provide a total score for the flow, nitrogen and phosphorus components of the model (Table 6.7). The scores are then interpreted to give an assessment of the confidence in the modelled results, based on the input data (Table 6.8).

Table 6.8. Risk rating outlining the confidence in the modelled results based on the score obtained from the risk-scoring table.

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. If a value of 6 is obtained then also confident that upstream and intermediate points have modelled flows that are very accurate.
3/4	Modelled flows are likely to represent acutal 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. Less confidence for daily and monthly flows.
1/2	Annual flows will be likely to have some error associated with them (plus or minus 20%), which will be reflected in annual nutrient load quantities. Cross-checks with other flow data is essential, and priority actions in these catchments should be to improve the understanding of the flow. Daily and monthly flow quantities are likely to be associated with larger errors.
0	Flow quantities are likely to be associated with large errors (plus or minus 50%), and priority in these catchments will be to improve the estimation and understanding of the flow, and to re-assess 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 levels 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. Priority in these catchments to capture sampling fortnightly for 3 years, and then re-assess the required load reductions and targets.
1/2	Annual loads will be likely to have some error associated with them (plus or minus 30%), even if there is good flow quality. Error in loads will deteriorate to >50% if flow quality is also poor. Cross-checks with other data and budget modelling techniques (such as Catchment Management Support System) is essential, and priority actions in these catchments should be to extend the sampling regime and re-assess the load targets.
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%). Priority is to begin a sampling regime in these catchments before any remedial activities commence.

Depending on the reporting subcatchment, there is a large variation in confidence in the modelling results. Many reporting subcatchments have a very poor sampling history in the Geographe catchment, and eight of the 14 reporting subcatchments are ungauged. Two reporting subcatchments (Five Mile Brook and Toby Inlet) have no current or historical surface-water sampling data. A priority for these two catchments should be that they undergo regular surface-water sampling to validate modelling results, as well as to re-assess the modelling loads and load-reduction targets based on the sampling results.

The Capel River, Carbunup River, Ludlow River and Vasse Diversion Drain all achieved high scores, so there is a high level of confidence that both flow and nutrient loads from these catchments are accurate, and errors associated with the total loads entering the bay and estuary will be small.

The Buayanyup River, Abba River, Sabina River, Annie Brook and Lower Vasse River have mid-range scores, so errors are expected to be associated with the loads and flows in these catchments. These errors are not likely to be large, especially at an annual scale, but these catchments should be re-assessed when more sampling data becomes available.

The Gynudup, Dunsborough and Jingarmup Brook subcatchments all achieved low scores, and large errors are expected to be associated with the modelled values for these catchments. It should be a priority to gain a better understanding of the flow in these catchments, and to continue regular surface-water sampling. For these subcatchments it is important to re-assess the modelling loads and load-reduction targets based on the updated sampling results.

Although there are several streams that have low scores, it should be noted that if SQUARE is, for instance, over-predicting for a particular catchment, then both the current and maximum acceptable loads will be over-predicted. Thus the error in the load-reduction target given as a percentage of the modelled current load will be much less than the errors in the absolute loads. In this case, confidence in the required percentage decrease in load to achieve the desired water quality is high, although confidence in the absolute loads (tonnes) is not.

7 Management questions and scenario modelling

A major component of the Coastal Catchments Initiative (CCI) project involved a series of management questions posed by stakeholders from catchment groups, community groups, landholders and various state government departments. The questions were to be addressed by the modelling components of the CCI project. A list of the management questions is provided in Table 7.1.

As discussed in Section 1, two models were used in the CCI project: the Department of Water's SQUARE model and the Department of Agriculture and Food's SSPND model. SQUARE was used to provide results at large scales – generally catchments or subcatchments. Because it is a rainfall-driven process-based model, SQUARE can also be used to predict changes in flow regimes (and associated nutrient loads) due to climate change or hydrological manipulations.

Table 7.1. Management questions for the Coastal Catchments Initiative project posed by Vasse Geographe stakeholders

	Vasse Geographe management questions	Model
Impacts of current and future land uses		
1	To what degree will the infill sewerage program reduce nutrient loads to receiving water bodies, giving consideration to the number of people currently connected and seasonal use of non-sewered dwellings in summer?	***SQUARE***
2	What is the contribution of the light industrial areas in Busselton, Dunsborough and Capel?	***SQUARE***
3	Based on current land use, what is the component contribution of specific agricultural and non-agricultural uses in the catchment to the overall nutrient load (i.e. dairy, beef, horticulture, viticulture, etc.)? Consideration of the overall contribution of these land uses versus the area of land occupied by specific land uses is needed.	***SQUARE***
4	How will the various forms of land-use change predicted to occur over the next five or more years influence nutrient loads?	***SQUARE***
5	What is the nutrient contribution of the various point-source components?	***SQUARE***
6	What are the nutrient contributions from small subcatchments/areas of the catchment?	***SQUARE***
7	Does existing stock grazing on the Vasse Wonnerup Wetlands contribute a significant load of nutrients? How does this contribution weigh up against the benefit provided by grazing for the creation of waterbirds' feeding habitat?	***SQUARE***
8	What is the timing of peaks/loads to receiving waters?	***SQUARE***
9	How will changing land use associated with implementation of the Busselton Urban Growth Strategy affect nutrient loads in the next five and 10 years?	***SQUARE***
Climate change / extreme weather events		
10	What will be the impact of climate change on water quality and ecosystem response of key assets, particularly with regard to an increase in summer rainfall?	***SQUARE***
Hydrological manipulations		
11	What is the water quality impact of making hydrological changes to the Vasse Wonnerup and Lower Vasse River systems through the Vasse Diversion Drain?	***SQUARE***
Management scenarios to investigate		
12	What is the net water quality benefit of fencing / revegetation of streams and rivers and how does this compare to fencing drains and other restoration options?	*SSPND*
13	Where in the catchment are specific management practices predicted to have the best outcome?	*SSPND*
14	What are the most cost efficient management practices to achieve the greatest degree of nutrient reduction?	*SSPND*

SSPND operates at a farm scale, and includes detailed best-management practice implementation and pricing modules. SSPND was used for detailed cost-benefit analysis and scenario modelling of a range of nutrient management practices, and was used as a guide to select the nutrient management practices recommended in the water quality implementation plan.

For the CCI project, SSPND and SQUARE used common datasets (land use, soils, point sources etc.). SSPND was calibrated using the annual loads, source separation and load reductions that were calculated using SQUARE. Using this modelling approach, concentration targets were used by SQUARE to calculate loads, load targets and load-reduction targets. These were in turn used by SSPND to estimate the best-management practices to achieve the required reductions, which also provided the cost-benefit information associated with these scenarios.

As illustrated in Table 7.1, the management questions were addressed by either the SQUARE modelling scenarios (the large-scale questions, and those requiring hydrological, rainfall, or climate manipulation) or by the SSPND modelling scenarios (those requiring cost-benefit analysis or farm-scale management scenarios). This section outlines the management questions that were addressed by SQUARE, and discusses the subsequent analysis and results of the scenarios.

7.1 Impacts of current and future land uses

7.1.1 Infill sewerage program

Management question #1: *To what degree will the infill sewerage program reduce nutrient loads to receiving water bodies, giving consideration to the number of people currently connected and seasonal use of non-sewered dwellings in summer?*

Waste from septic tanks accounts for a predicted average of 1.5 tonnes of phosphorus and 13.2 tonnes of nitrogen annually, which is 2.8 per cent of the annual total phosphorus load, and 3.2 per cent of the annual total nitrogen load that is delivered to the bay and estuary. However, septic-tank exports account for less than one per cent of the total nutrient input. The high level of output compared with the level of input is due to the low levels of nutrient assimilation from septic tanks. The majority of the septic-tank export is from seven of the reporting catchments, listed in Table 7.2.

The major portion of the septic-tank contribution to the Lower Vasse River is the Busselton light industrial area, accounting for over 90 per cent of the septic-tank contribution for the catchment. In the Vasse subcatchment the major component of the septic-tank contribution is from the urban residential and lifestyle blocks at the northern, downstream end of the Vasse Diversion Drain, close to the outlet to Geographe Bay. For Jingarmup Brook, the load-reduction target for nitrogen is 1.2 tonnes. Connection to infill sewerage in the Eagle Bay region will meet one third of the required nitrogen load reduction. Phosphorus in the Jingarmup Brook catchment does not require reduction, but connection to deep sewers in this region would improve the water quality.

Table 7.2. Septic-tank exports for reporting subcatchments where septic has a significant load contribution.

	Total phosphorus		Total nitrogen	
Reporting subcatchment	**Septic export (t/yr)**	**Subcatchment load (%)**	**Septic export (t/yr)**	**Subcatchment load (%)**
Five Mile Brook	0.21	5.9%	2.2	7.0%
Capel River	0.15	2.2%	4.6	11.0%
Vasse Diversion Drain	0.68	4.8%	3.0	4.0%
Lower Vasse River	0.45	9.4%	1.3	3.7%
Toby Inlet	0.03	6.0%	1.0	7.5%
Dunsborough	0.01	9.6%	0.3	23.7%
Jingarmup Brook	0.00	3.4%	0.4	9.6%
TOTAL	**1.54**	**2.8%**	**13.2**	**3.2%**

Septic-tank contribution to the Toby Inlet catchment is primarily due to approximately 250 beach houses lining the bank of the inlet that do not have deep-sewer connections. Export from the septic tanks to the Toby Inlet is particularly significant during the summer months, when the inlet experiences significant algal blooms. During this period there are negligible inputs from other areas of the catchment (the catchment waterways are ephemeral). However, input from septic tanks in the beach houses is likely because they have higher occupancy rates in summer. The effect of the septic tanks on the nutrient loads during this period requires further investigation.

In Dunsborough, septic tanks are the second-highest contributor of nitrogen and phosphorus load after urban sources. The townships of Capel and Peppermint Grove make large septic-tank contributions in the Capel catchment.

Septic tanks are a major contributor to nutrient load in the Five Mile Brook catchment, with 5.9 per cent of phosphorus (0.21 tonnes) and 7.0 per cent (2.2 tonnes) of nitrogen. The septic load in the Five Mile Brook catchment is due to the expansion of urban lifestyle blocks south of Bunbury. Infilling would reduce the load reduction target by 10 per cent for both nitrogen and phosphorus.

7.1.2 Light industrial areas

Management question #2: *What is the contribution of the light industrial areas in Busselton, Dunsborough and Capel?*

The nutrient load from the Busselton light industrial area is comprised entirely of septic-tank outputs. For the purposes of the model, industrial regions were assigned a fertilisation rate of zero kg/ha, and no point sources were identified in these regions. This does not necessarily imply that no industrial discharges of nutrients to the waterways exist in these regions, rather a search of the point-source databases (National Pollutant Inventory, EPA contaminated sites and licensed sites datasets and Hirschberg) did not identify any premises in these regions as a high-level nutrient polluter. The scope of the CCI project did not include detailed analysis of minor nutrient discharges from industrial regions that were not listed in the above databases. It is possible that some levels of nutrient discharge are omitted from these regions and are thus not taken into account by the modelling exercise. If project managers are dubious about the assumption of zero point-source discharge from light industrial areas within the catchment, further analysis of the industrial discharge is recommended.

The Busselton light industrial area was responsible for over 90 per cent of the septic-tank nutrient contribution to the Lower Vasse River, and was predicted to deliver 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) annually. The load delivered to the Lower Vasse River by septic tanks in the Busselton light industrial area is a significant contributor to the total nutrient load.

The Capel light industrial area is much smaller than the Busselton light industrial area, and the contribution to the Capel River is estimated to be 0.013 tonnes of phosphorus (0.2 per cent of the total phosphorus load) and 0.2 tonnes of nitrogen (0.5 per cent of the total nitrogen load) annually. The contribution from the Capel light industrial area is not significant when compared with the total load in the waterway.

The Dunsborough light industrial area did not contribute significantly to the total nutrient load in its reporting subcatchment.

7.1.3 Source separation and component analysis

Management question #3: *Based on current land use, what is the component contribution of specific agricultural and non-agricultural uses in the catchment to the overall nutrient load (i.e. dairy, beef, horticulture, viticulture, etc.)? Consideration of the overall contribution of these land uses versus the area of land occupied by specific land uses is needed.*

Source separation involves separating the land uses that contribute to the output load, as outlined in Section 6.3. The source separation for the whole catchment and each of the reporting subcatchments is given in Table 6.6. The source separation for the entire Geographe catchment is displayed in Figure 7.1a, and the breakdown of load per unit area is displayed in Figure 7.1b. The proportional areas of land that each fertilised diffuse source occupies is displayed in Figure 7.1c.

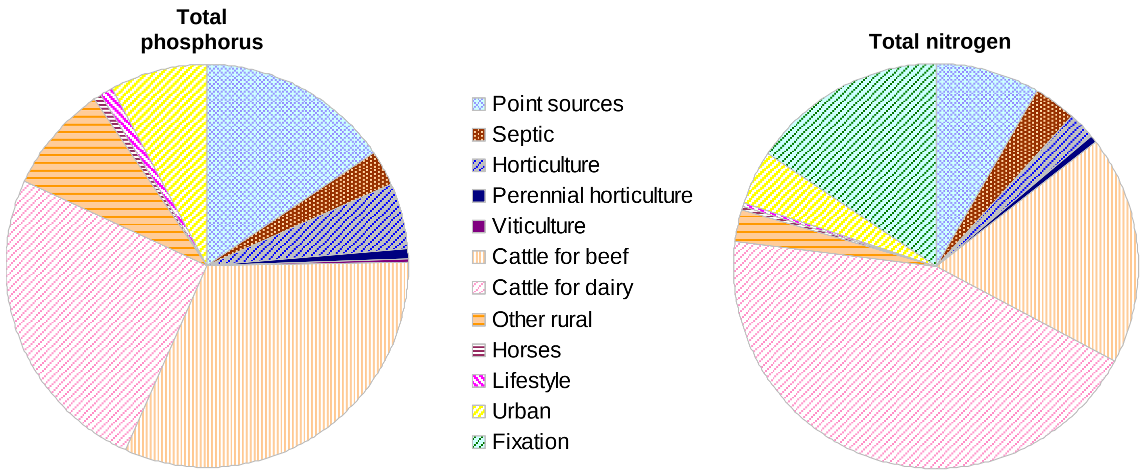


Figure 7.1a. Proportion of total load contributions for various nutrient land-use source components.

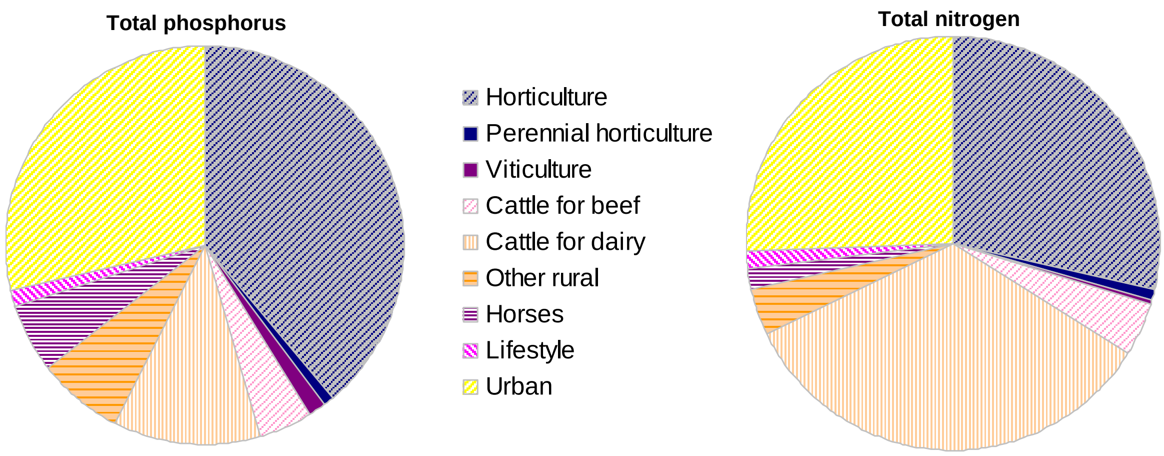


Figure 7.1b. Proportional load per unit area for land uses.

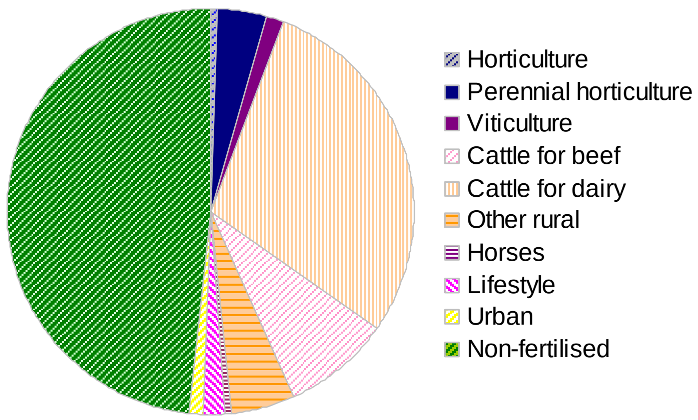


Figure 7.1c. Proportional land area for land uses.

The major contributor of total load for both nitrogen and phosphorus is cattle grazing for beef and dairy. This is largely because these farms occupy the majority of the fertilised land area in the Geographe catchment.

A major contributor of total nitrogen load is fixation, which is the third-largest nitrogen source after cattle for dairy and cattle for beef. This fixation load is likely to be due mostly to beef grazing, where nitrogen-fixing pastures are commonly used to limit the use of chemical fertilisers. The nitrogen fixed in cattle paddocks is more readily transportable to waterways than nitrogen fixed by native vegetation (such as *Acacia* species) because cattle graze on it and reprocess it back to the catchment in high concentrations as animal waste (urine and manure), which is readily transported to waterways. Lifestyle blocks, horses, native vegetation and some dairy paddocks are also likely to contribute to the fixation quantity, but the current version of the SQUARE model does not discriminate fixation between different land-use types. For this reason, the fixation component is not present in the load per unit area (Figure 7.1b).

Point sources contribute a significant proportion of the total output load, especially when compared with the relative input load. Most of the point sources are discharged directly to the waterways, and as such the nutrients have little opportunity to be assimilated compared with fertiliser that is applied directly to the land. The breakdown of the point-source contributions is discussed in Section 7.1.5.

The land uses with the greatest nutrient load per unit area are urban and horticulture, due to fertilisation intensity. In the case of urban land uses, this is also due to proximity to the outlet of the catchments, which gives the nutrients little time to be assimilated in-stream. Targeting these land uses for remediation is likely to achieve the greatest load reductions per unit area.

7.1.4 Future land-use predictions and Busselton urban growth

Management question #4: *How will the various forms of land-use change predicted to occur over the next five or more years influence nutrient loads?*

Management question #9: *How will changing land use associated with implementation of the* Busselton Urban Growth Strategy *affect nutrient loads in the next five and 10 years?*

Information for future land-use modelling scenarios was extracted from the *Busselton Urban Growth Strategy*, the *Capel Shire Land Use Strategy* and the *Dunsborough Structure Plan*. Various phases of the plans are to be implemented in 2010, 2015, 2020 and 2025. Total estimated catchment-input loads for phosphorus and nitrogen are displayed in Table 7.3, and copies of the structure plans are presented in Appendix E. The urban expansion scenario predicts that the phosphorus and nitrogen loads are expected to increase over the next 25 years. The cause of the increase is primarily due to land-use change – which is generally from beef grazing to urban land uses – and a corresponding increase in the fertiliser input rate. In addition, urban expansion will result in a higher catchment water yield, due to increased impervious areas and decreased deep-rooted vegetation that evapotranspires water out of the system (scenario does not include water sensitive urban design).

Table 7.3. Total catchment nutrient imports for the years of changing land-use coverages.

Year	Phosphorus input (tonnes/year)	Nitrogen input (tonnes/year)
2005	1872	3611
2010	1884	3702
2015	1899	3785
2020	1901	3780
2025	1904	3821

Many of these changes will be a result of the *Busselton Urban Growth Strategy*, which includes the developments of Provence, Ambergate and Vasse Newtown. The shire's population is projected to increase from approximately 28 000 residents in 2006, to approximately 46 000 residents by 2021 (Shire of Busselton 2005). These developments will affect the Sabina, Lower Vasse River, Vasse Diversion Drain and Buayanyup subcatchments. The *Capel Shire Land Use Strategy* affects only the Capel subcatchment, and is restricted to the region immediately surrounding the Capel town site. The *Dunsborough Structure Plan* will affect the Dunsborough, Toby Inlet and very marginally the Annie Brook and Jingarmup Brook catchments. Subcatchments unaffected by the land-use changes include Abba, Ludlow, Carbunup, Gynudup and Five Mile Brook (Figure 7.2). The predicted changes in nutrient load due to urban growth strategies being put in place are displayed in Table 7.4.

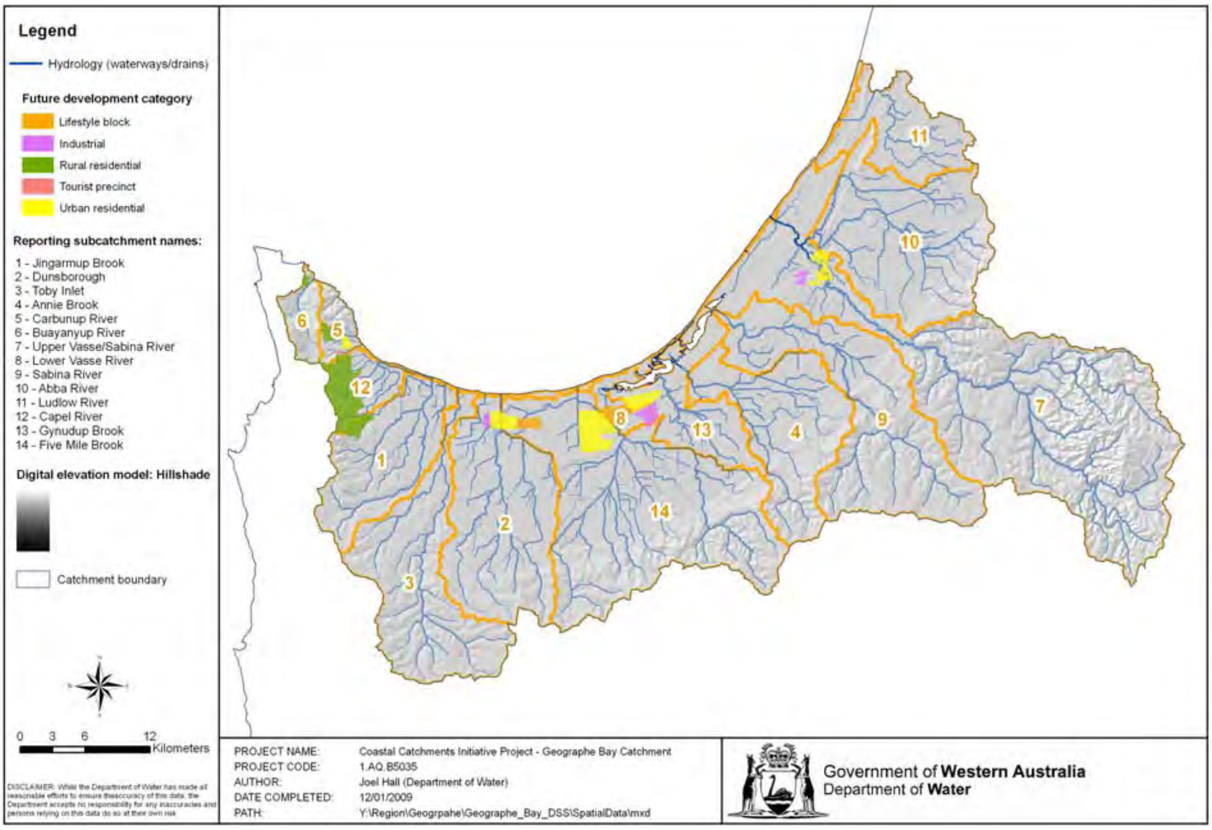


Figure 7.2. Future land-use developments and reporting subcatchments.

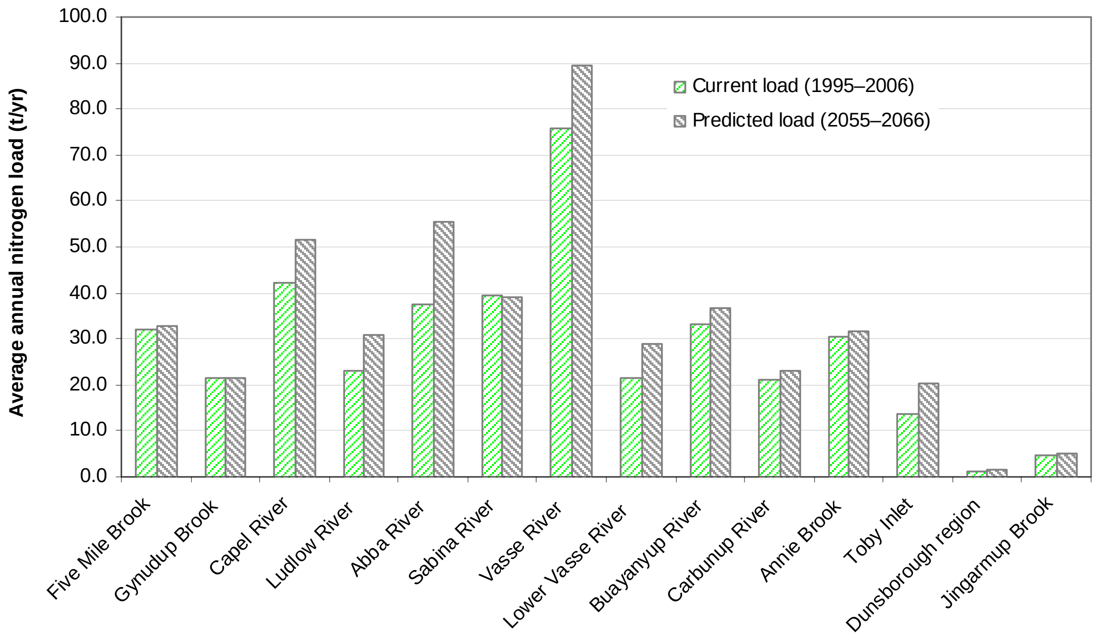
The *Dunsborough Urban Growth Strategy* is predicted to result in a small increase in output load. Only a small region is set aside for high-density residential development, while the main focus for the strategy is lifestyle and rural residential blocks, which have minimal nutrient export. It should be noted that a large portion of the area highlighted for rural residential development in Figure 7.2 is already developed, and changes in the next 20 years are restricted to regions that are currently undeveloped. The predicted load increase in the Dunsborough catchment is required to be offset by a load reduction, since the water quality objective in this subcatchment is ‘protection‘ and there is a requirement for no future increases in load to the waterways.

Table 7.4. The predicted effects of urban growth on the nutrient load due to the implementation of urban growth strategies.

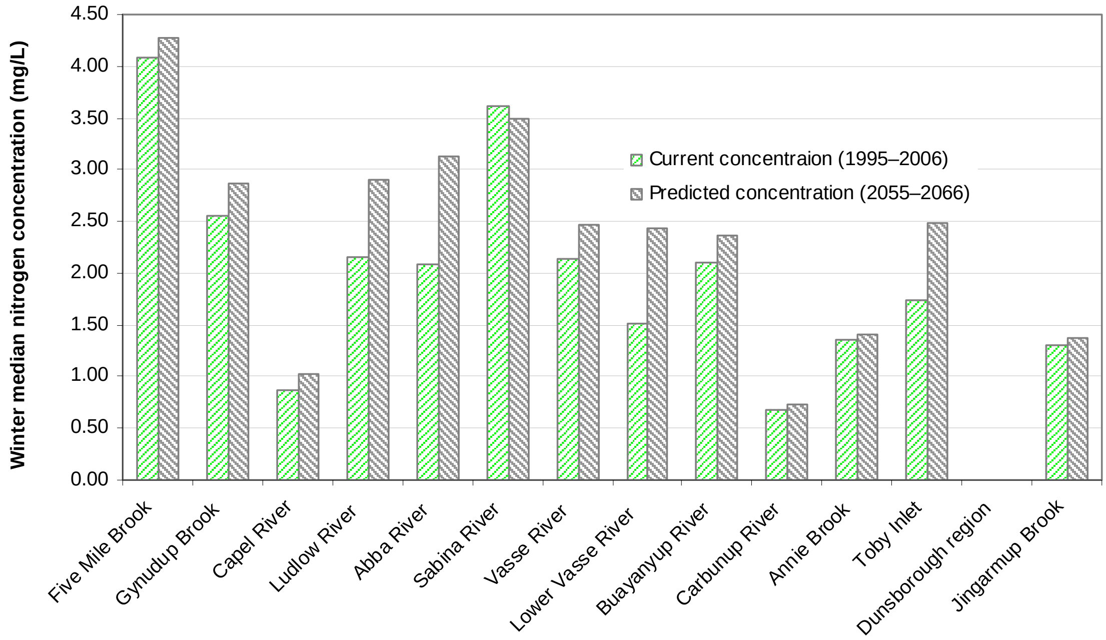
Phosphorus - modelled data				
	Current load (1995–2006) tonnes/year	Predicted load (2055–2066) tonnes/year	Current winter median conc mg/L	Predicted winter median conc mg/L
Capel River	6.72	8.41	0.051	0.061
Sabina River	3.57	3.61	0.387	0.381
Vasse River	14.08	25.11	0.266	0.531
Lower Vasse River	4.72	6.66	0.251	0.438
Buayanyup River	6.46	10.66	0.069	0.101
Toby Inlet	0.42	0.65	0.031	0.045
Dunsborough region	0.13	0.17	-	-
Jingarmup Brook	0.09	0.09	0.008	0.007
Capel urban growth	**1.69**			
Busselton urban growth	**17.21**			
Dunsborough urban growth	**0.27**			
Total increase in load	**19.17**			
Nitrogen - modelled data				
	Current load (1995–2006) tonnes/year	Predicted load (2055–2066) tonnes/year	Current winter median conc mg/L	Predicted winter median conc mg/L
Capel River	42.2	51.6	0.9	1.0
Sabina River	39.5	39.1	3.6	3.5
Vasse River	75.6	89.3	2.1	2.5
Lower Vasse River	33.8	41.6	2.7	4.0
Buayanyup River	33.2	36.9	2.1	2.4
Toby Inlet	13.7	20.3	1.7	2.5
Dunsborough region	1.3	1.7	-	-
Jingarmup Brook	4.5	4.9	1.3	1.4
Capel urban growth	**9.4**			
Busselton urban growth	**24.8**			
Dunsborough urban growth	**7.4**			
Total increase in load	**41.6**			

The *Busselton Urban Growth Strategy* results in the largest load increase of any of the urban strategies, due to the ~20 000 people expected to be housed in this region. The land-use changes are predicted to alter the average annual nutrient load in most of the catchments (the predicted change in nutrient load and concentration for all catchments are presented in figures 7.3 and 7.4).

It should be noted that some catchments (such as the Ludlow and Abba) predict an increase in load even though no future land-use change is occurring within the catchment. This is due to the land-use change that has already occurred in the catchment between the years 1995–2006, and the fact that catchment nutrient yields have not reached equilibrium with respect to these changes.

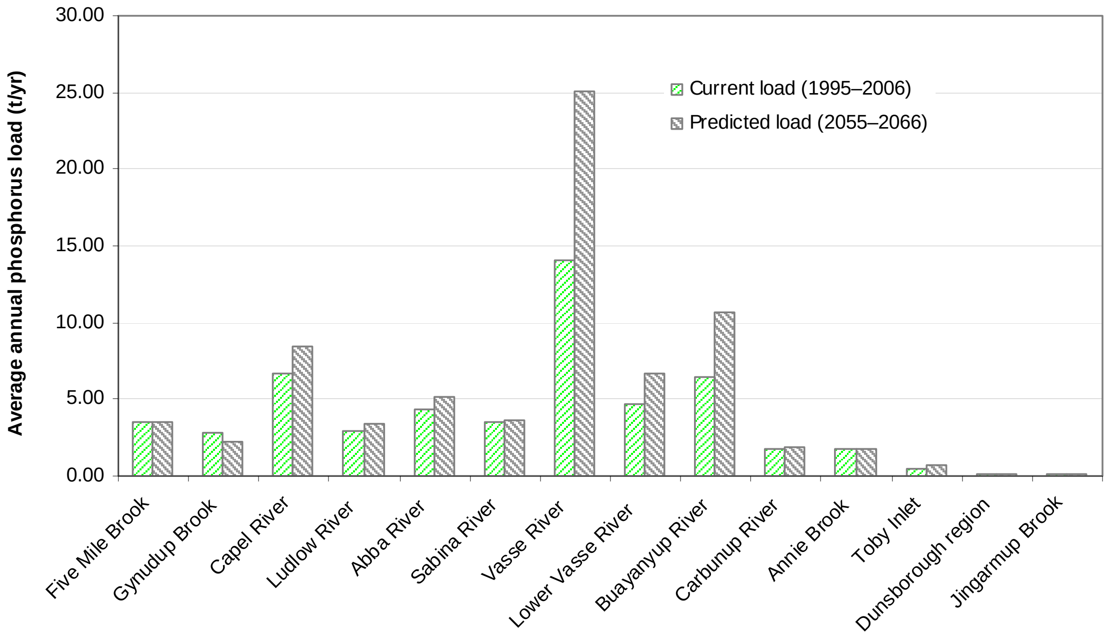


A

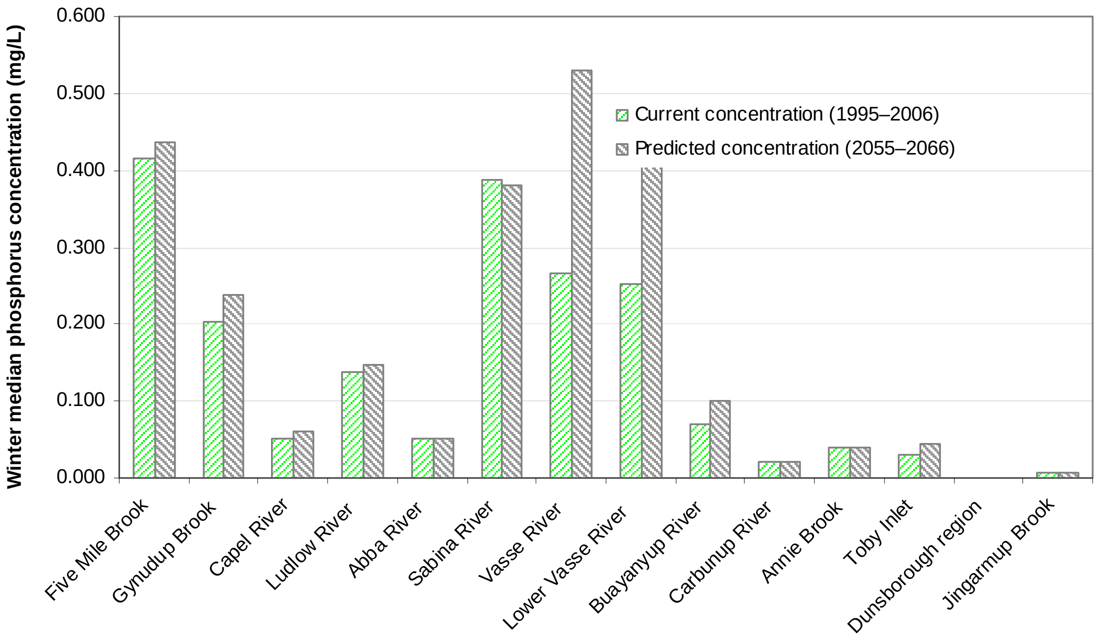


B

Figure 7.3. Current and predicted average annual nitrogen loads (A) and concentrations (B) for reporting subcatchments of the Geographe catchment.



A



B

Figure 7.4. Current and predicted average annual phosphorus loads (A) and concentrations (B) for reporting subcatchments of the Geographe catchment.

7.1.5 Point-source contributions

Management question #5: *What is the nutrient contribution of the various point-source components?*

As discussed in Section 3.6.2, a range of point-source data was used to model this management scenario. Point sources comprise a significant proportion of the total load – 15.5 per cent of the total phosphorus load and 8.3 per cent of the total nitrogen load. Most point sources are delivered directly to drains and waterways through effluent runoff or by direct discharge, and have less opportunity to assimilate than fertiliser applications of nutrients. According to the model, the ratio of point-source input to point-source export at the bottom of the catchment is approximately 50 per cent compared with a 3–10 per cent reduction for diffuse fertiliser sources. The contributions of the various point sources to the total phosphorus and nitrogen point-source loads are displayed in Table 7.5 and in Figure 7.5.

Most point-source contributions are from dairy-shed effluent, with an estimated 5.1 tonnes of phosphorus and 23.0 tonnes of nitrogen being discharged into the receiving waterways each year. Wastewater treatment plants contribute significantly to the point-source loads, and are expected to double in capacity in the next 20 years. However, export loads are expected to remain constant due to improved treatment technologies.

Table 7.5. Point-source load contributions from catchment point sources.

Point source	Reporting subcatchment	Phosphrous export (t/yr)	Nitrogen export (t/yr)
Camping	Buayanyup	0.32	1.71
Caravan park	Capel	0.10	0.53
Caravan park	Annie	0.26	1.46
Caravan park	Buayanyup	0.04	0.23
Caravan park	Vasse	0.69	2.68
Total caravan park		**1.41**	**6.61**
Dairy	Vasse	0.84	3.73
Dairy	Sabina	0.27	1.40
Dairy	Carbunup	0.37	2.30
Dairy	Buayanyup	0.72	3.90
Dairy	Abba	1.03	6.30
Dairy	Gynudup	0.01	0.03
Dairy	Capel	0.21	2.00
Dairy	Ludlow	0.19	1.20
Dairy	Annie	0.01	0.10
Dairy	Lower Vasse	1.49	2.00
Total dairy		**5.14**	**22.95**
Feedlot	Lower Vasse	0.23	1.60
Feedlot	Vasse	0.66	1.04
Total feedlot		**0.89**	**2.64**
Industrial	Gynudup	0.00	1.28
Industrial	Ludlow	0.00	0.30
Total industrial		**0.00**	**1.58**
Landfill	Capel	0.01	0.03
Landfill	Vasse	0.14	0.08
Total landfill		**0.15**	**0.11**
WWTP	Capel	0.57	1.80
WWTP	Annie	0.00	0.40
WWTP	Vasse	1.31	1.33
Total WWTP		**1.88**	**3.53**

The significant dairy nutrient-load contribution highlights the need to review dairy-shed effluent practices in the catchment. The Geographe Catchment Council is currently researching this issue. Landfill data was obtained from the *Post Closure Management Plan* for the Busselton wastewater treatment plant (Lundstrum 2001). Linear interpolation was then used to predict load quantities for the Capel and Dunsborough landfills. Landfills are not likely to be a major contributor to total nutrient load in the catchment – although they may contribute other pollutants. Groundwater analysis of the new landfill located in the Naturaliste Ranges in the Jingarmup Brook catchment revealed it was not likely to be significantly contributing to nutrient load.

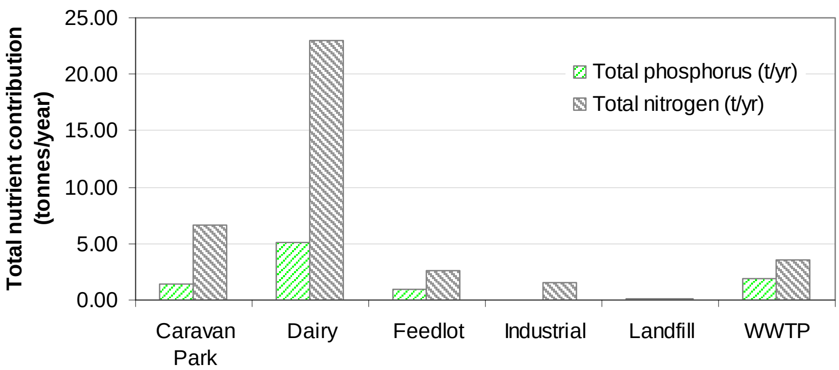


Figure 7.5. Nutrient-load contributions from various point-source components.

7.1.6 Catchment nutrient hotspots

Management question #6: *What are the nutrient contributions from small subcatchments/areas of the catchment?*

The modelled subcatchment outputs for the entire Geographe catchment were used to derive relative export rates of nitrogen and phosphorus (in grams per square metre). The output was used to display hotspots in the catchment, that is, the regions where nutrient exports are highest. This is a useful scenario for targeting catchment remediation. The nutrient hotspots are displayed in figures 7.6 and 7.7 for phosphorus and for nitrogen respectively. Values presented are for the average annual export load per unit area for the time period 1995–2006.

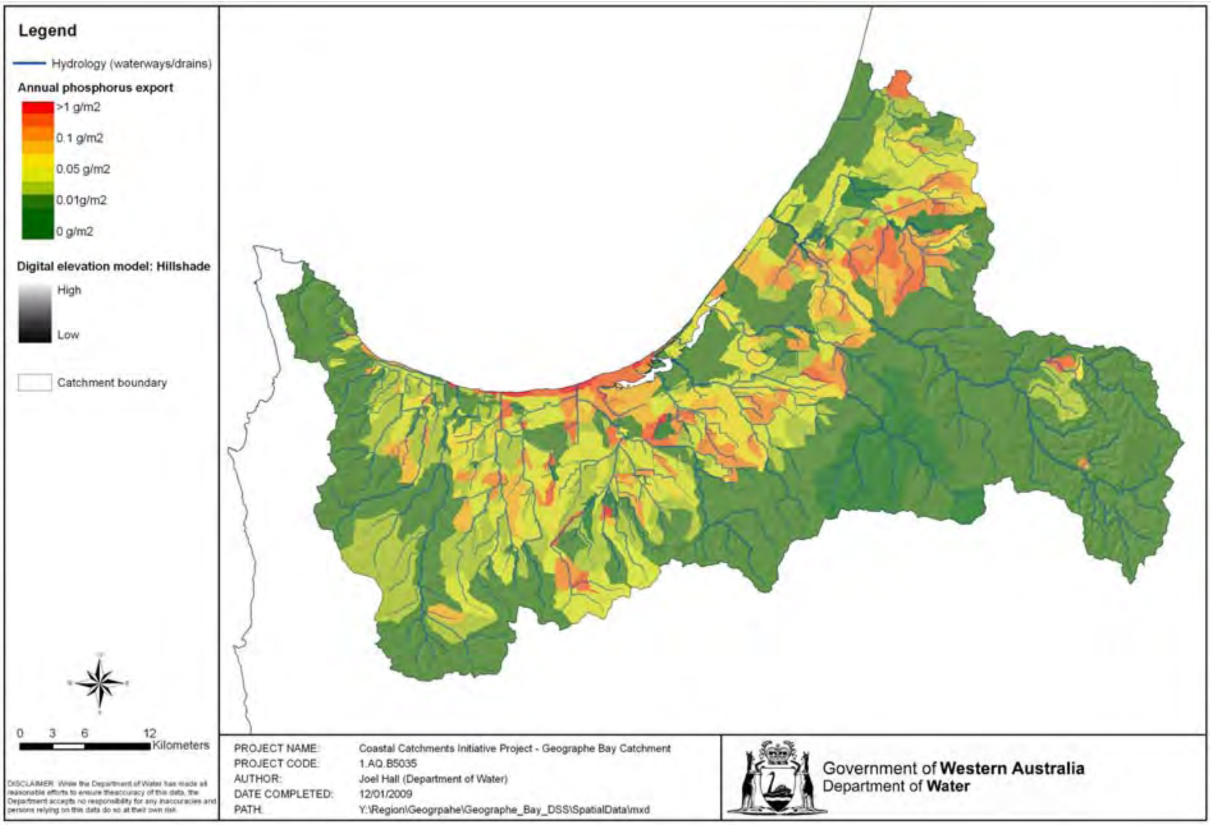


Figure 7.6. Catchment hotspots: phosphorus

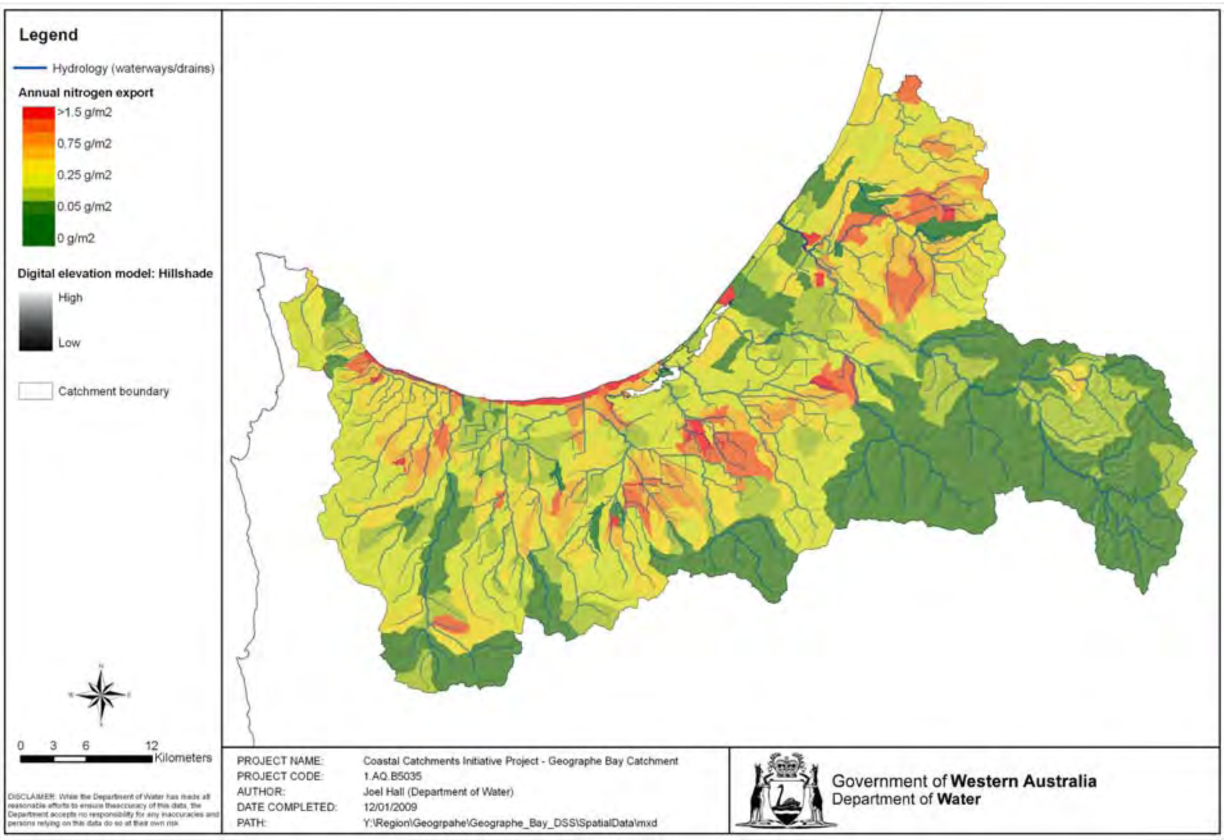


Figure 7.7. Catchment hotspots: nitrogen.

The highest nutrient-export rates are located in the centre of the Geographe Bay catchment, in the regions surrounding the Sabina River, the Vasse Diversion Drain, and the Buayanyup River. High exports also occur in the Gynudup Brook catchment, and are evident on the coastline in the urban regions.

Some subcatchments exhibited a net assimilation of nutrients (usually subcatchments that are highly vegetated or contain wetlands) and the nutrient-export values were negative. For the purpose of the above diagrams, these subcatchments were assigned a value of zero for nutrient export.

7.1.7 Grazing on the Vasse Wonnerup Wetlands

Management question #7: *Does existing stock grazing on the Vasse Wonnerup Wetlands contribute a significant load of nutrients? How does this contribution weigh up against the benefit provided by grazing for the creation of waterbirds' feeding habitat?*

The Vasse Wonnerup Wetlands are Ramsar–listed wetlands of international importance due to their significance as habitat for waterbirds (Government of Western Australia 2000). The wetlands now regularly support 20 000 to 30,000 waterbirds and provide one of the state's most significant breeding habitats for the black swan (*Cygnus atratus*).

As part of the CCI project, Wetland Research and Management Pty Ltd prepared an Ecological Character Description for the Vasse Wonnerup Wetlands on behalf of the Department of Environment and Conservation (DEC 2007). This describes in detail the wetlands' ecology and formulates planning to promote their conservation and sustainable use.

The report outlines the wetlands' importance to promote waterbird habitat, and highlights the ecological threats associated with increased nutrient loading. Much of the estuary's fringes are grazed by cattle, predominantly for beef, but with some dairy cattle on the eastern fringes (Figure 7.8). It is believed that cattle grazing in the wetlands provides a benefit to the waterbirds through the trampling of excessive vegetation, and providing feeding and roosting habitats for the waterbirds (Lane et al 1997). However, grazing has a negative affect on the estuary in terms of increased nutrient export to the Vasse Wonnerup system, which can result in the occurrence of algal blooms and fish deaths. There is some debate as to whether cattle on the wetland fringes provide a benefit or detrimental effect to the values of the Ramsar wetland.

Figure 7.8. Beef grazing on the Vasse Wonnerup Wetlands.

In response, the nitrogen- and phosphorus-load components of the estuary were separated into the loads provided by the rivers (Lower Vasse, Sabina, Abba and Ludlow) and the load delivered directly to the estuary due to grazing on the wetland fringes. The results of the analysis are displayed in Table 7.6 and in Figure 7.9. Beef grazing on the wetland fringes is responsible for 10 per cent of the total phosphorus and five per cent of the total nitrogen load, with the majority of the nutrient load being delivered through the rivers that drain into the Vasse Wonnerup Wetlands.

Table 7.6. Breakdown of the nutrient load entering the Vasse Wonnerup Wetlands

Phosphorus						
Year	Ludlow River	Lower Vasse River	Abba River	Sabina River	Estuary fringes	TOTAL ESTUARY
1995	2.60	4.32	2.25	4.35	1.77	15.29
1996	3.00	4.22	2.59	4.65	1.82	16.27
1997	3.23	4.25	2.99	4.14	1.79	16.39
1998	1.65	4.32	1.45	3.13	1.41	11.95
1999	9.03	4.50	19.31	7.20	3.57	43.62
2000	3.69	4.07	4.65	3.79	2.11	18.31
2001	1.23	5.21	1.78	1.46	1.12	10.80
2002	1.22	5.31	1.25	2.32	1.16	11.26
2003	1.51	4.88	1.40	2.95	1.29	12.03
2004	1.50	5.05	1.62	2.93	1.29	12.39
2005	6.09	5.62	11.83	4.71	2.79	31.03
2006	0.57	4.93	1.05	1.20	0.96	8.70
Average load (t/yr)	**2.94**	**4.72**	**4.35**	**3.57**	**1.76**	**17.34**
Percentage load	**17%**	**27%**	**25%**	**21%**	**10%**	**100%**

Nitrogen						
Year	Ludlow River	Lower Vasse River	Abba River	Sabina River	Estuary fringes	TOTAL ESTUARY
1995	30.4	33.0	34.0	51.9	11.1	160.4
1996	36.6	32.6	45.5	60.3	12.5	187.4
1997	26.0	32.3	43.1	41.1	8.3	150.8
1998	15.9	34.8	16.3	35.9	6.5	109.4
1999	50.0	36.5	113.8	72.0	18.2	290.5
2000	25.4	29.3	32.7	40.8	8.7	137.0
2001	4.8	36.4	8.5	14.6	1.9	66.3
2002	12.0	33.4	13.0	27.9	2.9	89.1
2003	17.8	34.1	23.8	35.5	4.5	115.7
2004	16.4	34.0	25.2	33.1	4.6	113.3
2005	33.7	47.8	86.0	48.5	8.1	224.1
2006	5.3	22.0	8.5	13.0	1.6	50.5
Average load (t/yr)	**22.9**	**33.8**	**37.5**	**39.5**	**7.4**	**141.2**
Percentage load	**16%**	**24%**	**27%**	**28%**	**5%**	**100%**

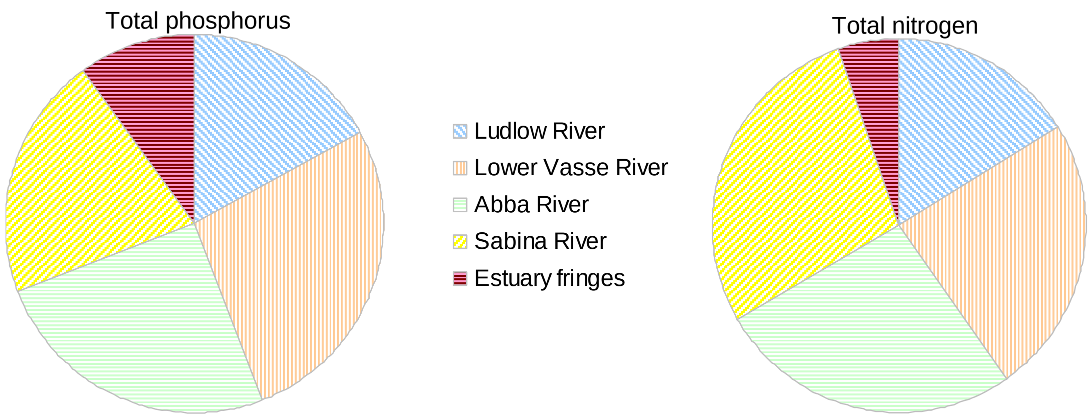


Figure 7.9. Relative load contributions for rivers and estuary fringes for the Vasse Wonnerup Wetlands.

7.1.8 Timing of peak loads

Management question #8: *What is the timing of peaks/loads to receiving waters?*

Nutrient-load timing was analysed by aggregating the daily loads to provide monthly, annual and cumulative load components. Table 7.7 and Figure 7.10 display the monthly distribution of phosphorus and nitrogen loads. The median monthly load is displayed for the years 1980–2006, and the average monthly rainfall is displayed on the same chart. The 25th and 75th percentiles of the monthly loads are displayed as error bars on the charts. It is evident that the majority of the nutrient load is delivered between May and October, with only a small fraction of the load delivered in the summer months. For phosphorus, the two months that deliver the greatest load are generally June and July; for nitrogen the peak months are July and August.

The timing of the loads is consistent with the timing of the flows in the catchment. In almost all cases, flows in the catchment are ephemeral, which result in low summer loads. The exception is the Capel River, which intersects the Leederville Aquifer and has summer dam releases from the catchment's upper reaches. However, the summer nutrient concentrations are generally low, and summer loads are almost insignificant in this catchment. The variation around the summer loads is small, and cyclonic events are not likely to be large contributors to annual loads in this part of Western Australia (at least for the period 1980–2006).

There are large variations in the timing of loads, and again, this is because of the variation in monthly rainfall and hence monthly flow. The months May to August consistently have larger load delivery than the summer months, but the load produced within each month is extremely variable.

Table 7.7. Analysis of the monthly distribution of flow and loads.

	Median			75th percentile			25th percentile			
	TP load (t)	TN load (t)	Flow (GL)	TP load (t)	TN load (t)	Flow (GL)	TP load (t)	TN load (t)	Flow (GL)	Rainfall (mm)
January	0.08	0.6	0.8	0.15	0.8	0.9	0.03	0.5	0.7	8
February	0.07	0.3	0.7	0.23	0.7	0.7	0.01	0.2	0.6	12
March	0.15	0.4	0.8	0.37	0.9	0.9	0.08	0.3	0.6	17
April	0.44	1.0	0.9	0.79	1.8	1.1	0.25	0.5	0.8	37
May	1.85	5.0	2.3	2.64	7.9	4.0	1.11	2.6	1.6	109
June	5.61	31.5	21.5	8.15	45.6	33.7	4.21	18.3	12.9	156
July	6.53	65.0	47.8	8.84	90.3	84.5	4.85	50.1	38.2	162
August	5.17	66.5	57.9	5.62	70.5	75.4	4.20	54.1	42.9	124
September	2.71	39.8	33.9	3.95	49.8	50.3	2.41	30.7	23.1	82
October	1.39	16.7	10.2	1.67	21.5	12.1	1.05	12.9	9.2	41
November	0.54	4.6	3.2	0.79	6.7	4.1	0.37	3.2	2.4	32
December	0.15	1.4	1.3	0.23	1.8	1.6	0.07	1.1	1.0	12

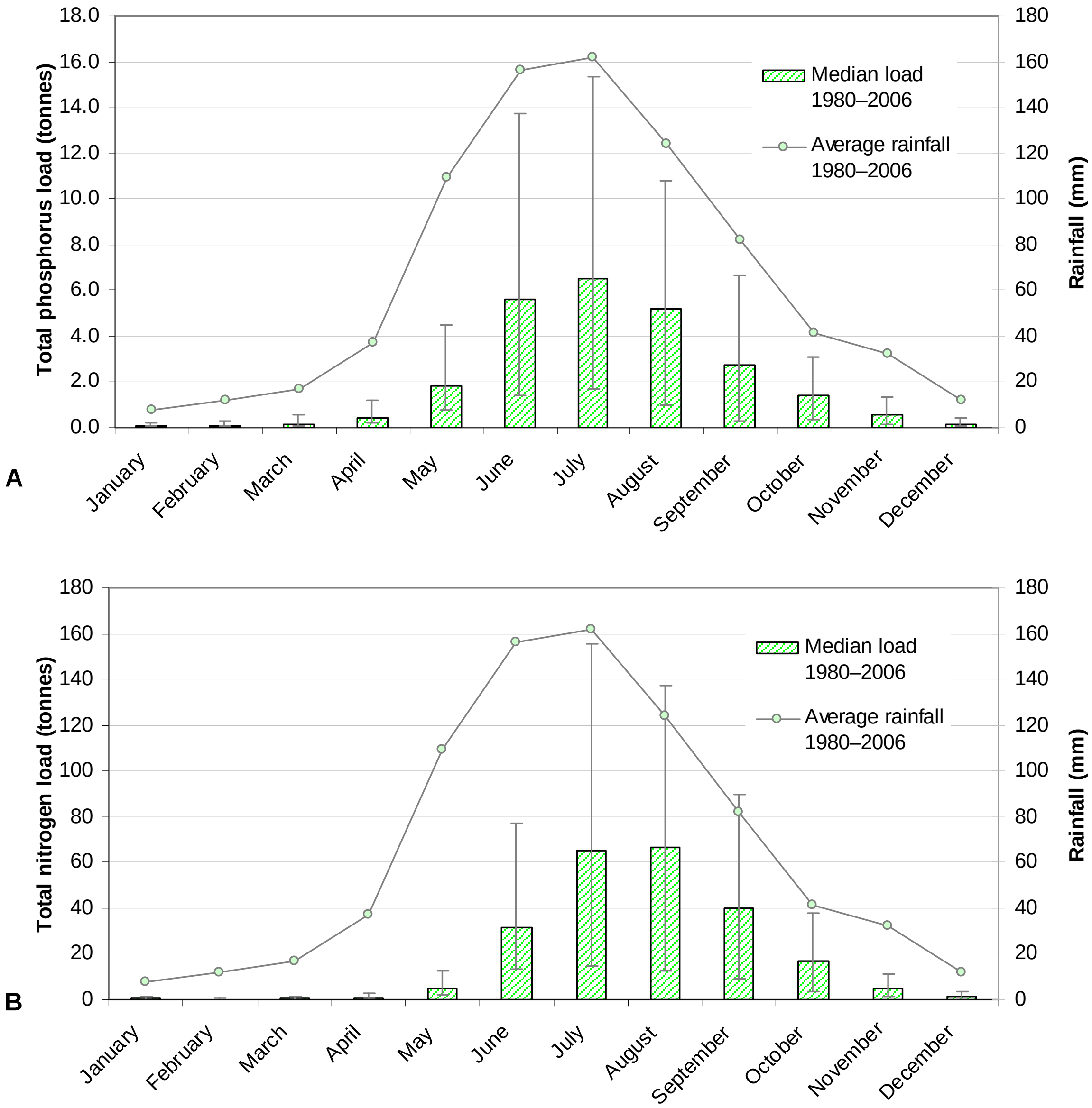


Figure 7.10. The breakdown of modelled monthly phosphorus loads (A) and monthly nitrogen loads (b) for the period 1980—2006. The error bars denote 25th and 75th percentiles, and average monthly rainfall is for the Geographe catchment.

Figure 7.11 displays the annual load delivery from all catchments, with the annual rainfall also displayed on the chart. The catchment load is highly dependent on the rainfall, and high rainfall years (such as 1999) will generally deliver a load over five times the magnitude of low rainfall years (such as 1987 or 2006). This is an important attribute that needs to be taken into account from a management perspective, as any given year could meet a load-reduction target, simply by producing less rainfall. Load-reduction targets need to be conceptualised as an average annual load over a period of years that will account for the variation in annual rainfall.

Both nitrogen and phosphorus annual loads are highly rainfall-dependent, but nitrogen is generally more highly correlated to the annual rainfall than phosphorus. One reason for this is because large rainfall events that cause erosion can release very large quantities of particulate phosphorus, and a year does not necessarily have a large total annual rainfall for this to occur. Phosphorus load is dependent not only on the quantity of the rainfall, but also on the intensity of the rainfall (as is the correlation with sediment release and delivery).

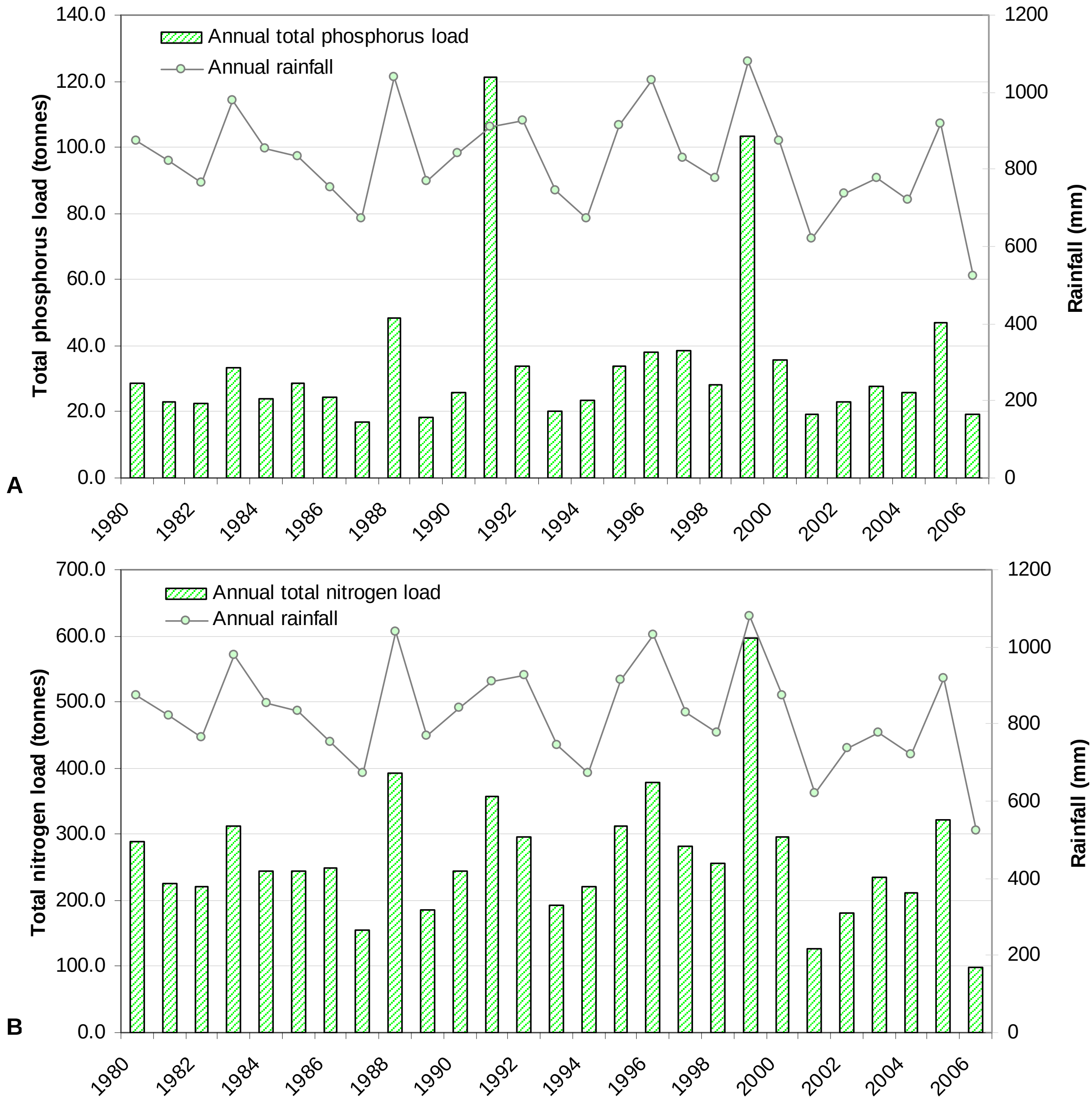


Figure 7.11. Modelled annual load time-series for the Vasse Wonnerup Estuary for phosphorus (A) and nitrogen (B).

The cumulative flow and load for total phosphorus and total nitrogen delivered for various durations are displayed in Table 7.8 and in Figure 7.12. These figures demonstrate that the majority of the flow is delivered over a very small percentage of the time, with 50 per cent of the flow and associated nutrient load being delivered five per cent of the time, and almost the entire load and flow occurring only 50 per cent of the time. This is not uncommon for ephemeral waterways in a Mediterranean-style climate.

Table 7.8. Modelled nutrient load quantities and percentages for various flow durations.

	Load 1980–2006 (tonnes)			Load 1980–2006 (% total load)		
Flow duration	**Flow (GL)**	**Total phosphorus (tonnes)**	**Total nitrogen (tonnes)**	**Flow (%)**	**Total phosphorus (%)**	**Total nitrogen (%)**
0.5%	482	145	415	8.3%	15.6%	5.8%
1.0%	806	199	708	13.9%	21.3%	9.9%
2.0%	1303	284	1149	22.4%	30.4%	16.1%
5.0%	2337	397	2108	40.2%	42.6%	29.6%
10.0%	3421	551	3350	58.8%	59.0%	47.0%
20.0%	4660	697	5119	80.1%	74.7%	71.8%
50.0%	5662	897	6976	97.3%	96.2%	97.9%
Total	5818	933	7126	100.0%	100.0%	100.0%

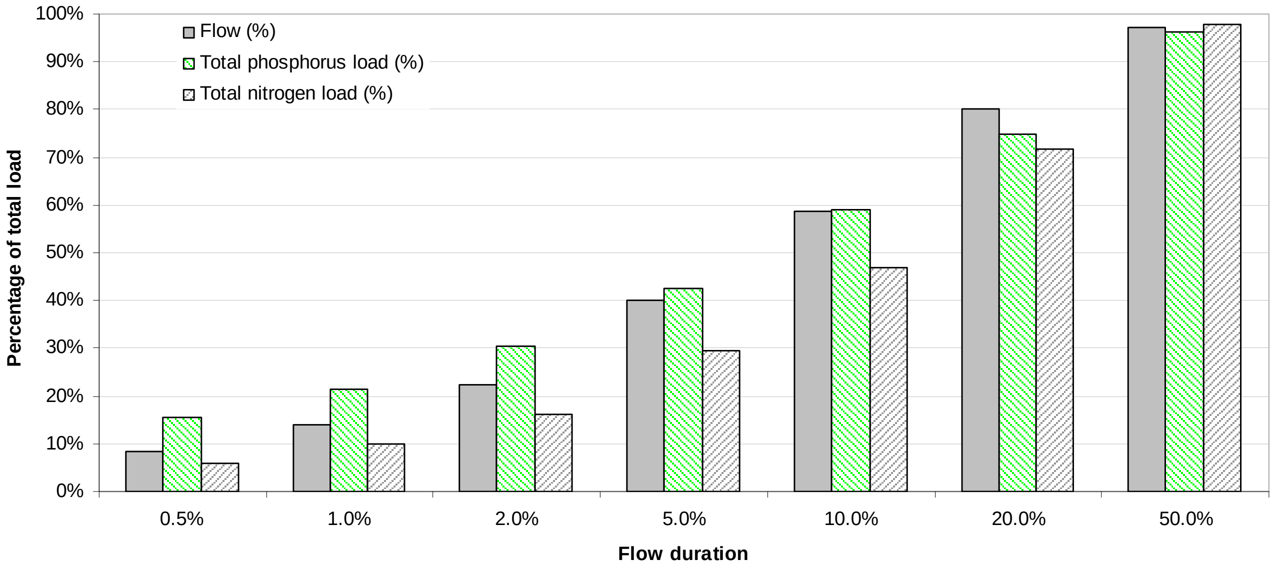


Figure 7.12. Modelled cumulative flow and nutrient-load percentages for various duration periods.

7.1.9 Load contributions and predictions for the Busselton wastewater treatment plant

The Busselton wastewater treatment plant is located on Queen Elizabeth Avenue, approximately seven kilometres from the Busselton town centre. The treatment plant produces tertiary-treated wastewater through an Intermittently Decanted Extended Aeration (IDEA) process. The plant has influent and screening works, two concrete rectangular treatment tanks, filters, UV disinfection, on-site bio-solids drying beds, wetlands and a re-use lagoon and pumping facility. Treated wastewater is filtered and disinfected. The majority of the summer flow is pumped to the nearby Busselton Golf Course; however most of the annual wastewater quantity is discharged to a tributary of the Vasse Diversion Drain, where it discharges to Geographe Bay.

The treated wastewater is discharged into a northern or a southern wetland, where it overflows to the adjacent drain. Flow and water quality are measured at the outlet of each of the wetlands in accordance with Environmental Protection Authority (EPA) licensing conditions. Daily flows and sample concentrations were used to determine a daily load of phosphorus and nitrogen for each of the wetlands, as well as the breakdown of nutrients into their corresponding sub-species. Daily loads were calculated by multiplying the daily flow by the most recently collected nutrient-concentration value. Median nutrient-concentration values in the effluent exported to the drain are approximately 1.7 mg/L for total nitrogen and 1.0 mg/L for total phosphorus from the southern wetland, and 4.2 mg/L for total nitrogen and 2.5 mg/L for total phosphorus from the northern wetland.

Kelsey (2003) did a similar analysis on the Busselton wastewater treatment plant for the National Pollutant Inventory report, using only the 2002 data, where an annual value of 1.1 tonnes per year was reported for phosphorus and 1.7 tonnes per year for nitrogen. For the years 2001–2005 (the only full years with available data), an average discharge of 1.7 tonnes per year of phosphorus and 2.3 tonnes per year of nitrogen were calculated for the CCI modelling project (Table 7.9 and Figure 7.13).

Table 7.9. Annual load discharges from the Busselton wastewater treatment plant

Year	TP (kg)	TN (kg)	Nox (kg)	NH3 (kg)
2000 (2nd half)	121	1282	208	763
2001	1053	2588	719	687
2002	1092	1765	432	408
2003	1571	2487	146	1245
2004	503	1586	378	322
2005	4460	3310	155	675
2006 (1st half)	1353	2074	57	567
Average (2001-2005)	1736	2347	366	667

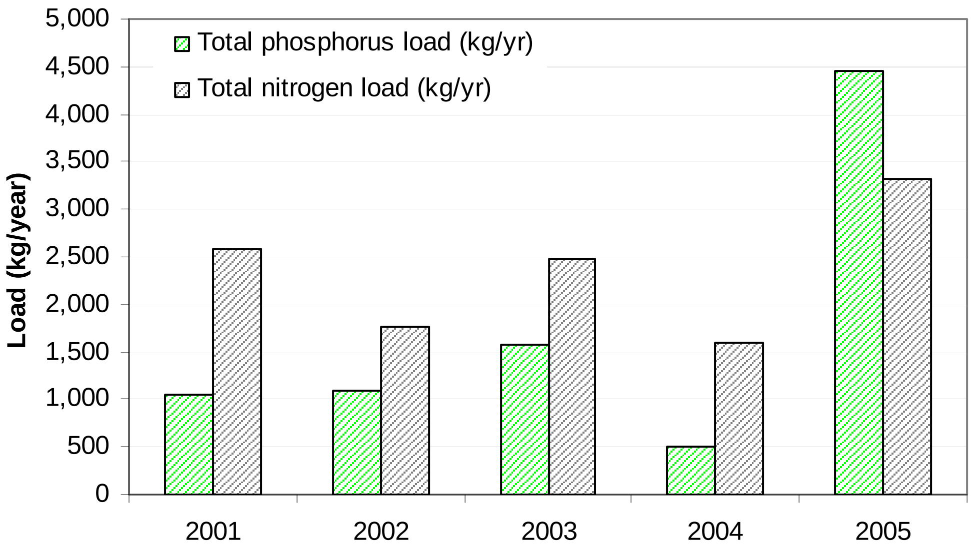


Figure 7.13. Total nitrogen and total phosphorus annual exports from the Busselton wastewater treatment plant

The model predicts an average annual discharge of 1.31 tonnes of total phosphorus and 1.33 tonnes of total nitrogen to the bay from the wastewater treatment plant. The amount of assimilation of the nutrient export is relatively small when compared with nutrients applied by fertiliser, due to the direct discharge of the wastewater to the drain, and the relatively close proximity of the wastewater treatment plant to the catchment outlet. Without change to the treatment technologies, this figure is expected to rise to approximately 2.6 tonnes of total phosphorus and 2.7 tonnes of total nitrogen per year. This would be a result of Busselton Shire's urban expansion, whereby the capacity of the wastewater treatment plant, and hence the export, would double. However, the Water Corporation plans to upgrade the treatment facility in 2009, and the improved facility is expected to halve the nutrient concentration of the wastewater outflow.

The wastewater treatment plant is a significant contributor of phosphorus load in the Vasse Diversion Drain catchment. Nitrogen is not so significant, as nitrogen is removed more efficiently in the wastewater treatment process. Figure 7.14 shows the source separation of the Vasse Diversion Drain subcatchment, and includes the Busselton wastewater treatment plant.

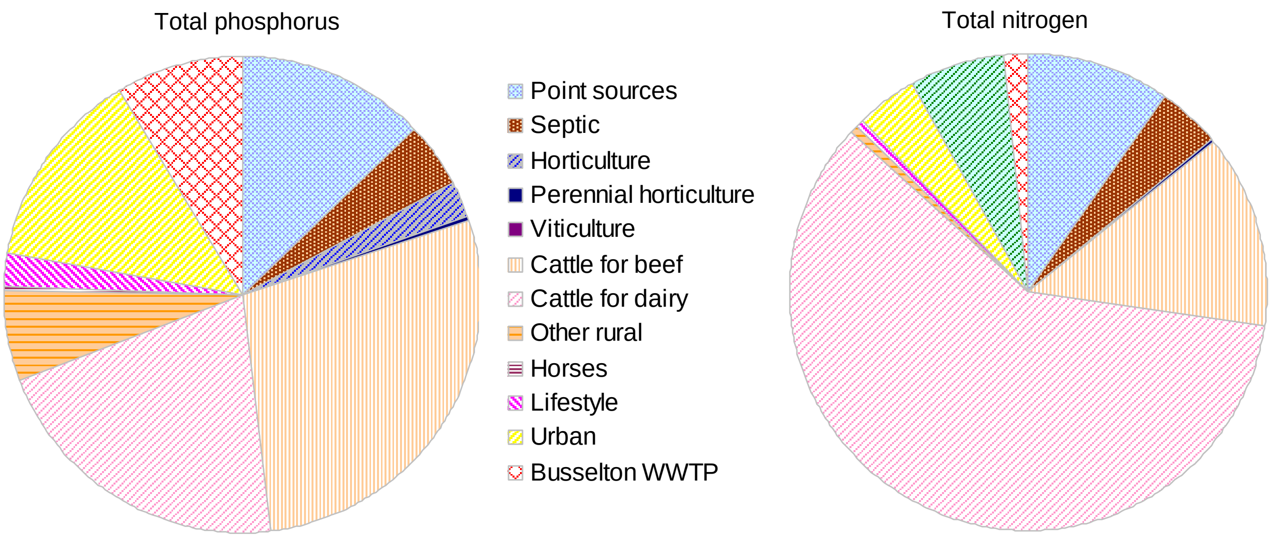


Figure 7.14. Source separation of the load from the Vasse Diversion Drain catchment (average over the years 1995–2006).

The wastewater treatment plant is responsible for 10 per cent of the current phosphorus load in the Vasse Diversion Drain catchment. Without further treatment, the figure would to rise to approximately 20 per cent over the next 20 years, and the load to the bay would reach approximately 4.7 per cent of the total phosphorus contribution (2.6 out of 57 tonnes) by 2050. For nitrogen, the contribution is not as high. Without further treatment nitrogen loads to the bay are predicted to reach 0.8 per cent (2.7 out of 316 tonnes) by 2050.

There is a large load-reduction target for both phosphorus and nitrogen in the Vasse Diversion Drain subcatchment. A critical step in achieving this will be the introduction of a more effective treatment technology to limit the export of nutrients from the Busselton wastewater treatment plant, as proposed by the Water Corporation.

7.2 Climate modelling scenarios

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 (Houghton et al. 1997). For this project two of the emission scenarios are analysed:

- **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 (pessimistic scenario).

- **B1 scenario:** a scenario describing a convergent world with a population that peaks around 2050 and declines thereafter. There is an emphasis on global solutions to economic, social and environmental sustainability, including the introduction of clean, efficient technologies (optimistic scenario).

General Circulation Models (GCMs) have been used world-wide to project future temperature and rainfall variations in response to climate change. The Department of Water and the CSIRO undertook a project in 2005 in which the general circulation rainfall model Mk3 and Mk3.5 were run for climate change scenarios A2 and B1 for the South Coast of Western Australia, and for scenario B1 for the South West of Western Australia (Cleary 2008). Statistical down-scaling allows the GCM outputs to be locally defined. Analysis of the down-scaled rainfall values was used to determine the amount by which the future rainfall regime was to be altered to reflect the A2 and B1 scenarios.

It is important to note that only two rainfall points in the Geographe catchment were used for the CSIRO's Mk3.5 B1 down-scaling project. For the Mk3 A2 project the points used for the analysis were in South Coast catchments, as none of the gauging stations in the Geographe catchment were used by the CSIRO for the A2 analysis. Therefore, two different GCMs have been used for the B1 and A2 scenarios (Mk3 for A2 and Mk3.5 for B1) and there are issues with spatial heterogeneity within the catchment.

It is desirable to have the GCM models run specifically for the project catchment. Ideally a series of points in the Geographe catchment would have been analysed using the same GCM for both climate scenarios. However, costs and timeframes required to achieve this were outside the scope of the CCI project. Nonetheless, the reduction rates calculated for the modelling were consistent with past studies and literature (DEC 2004).

7.2.1 Effects of climate change

Management question #10: *What will be the impact of climate change on water quality and ecosystem response of key assets, particularly with regard to an increase in summer rainfall?*

Results of statistical analysis on the down-scaled GCM data for the climate change scenarios A2 and B1 are displayed in Table 7.10. Both models predict reduced rainfall in summer, autumn and winter, but only the A2 model predicts a decrease in spring rainfall. In both cases, the largest magnitude of change is in the decrease in autumn rainfall.

Table 7.10. Statistical analysis of rainfall stations 9519, 9534, 9573 and 9615 in the South West of Western Australia and the effects of the B1 and A2 climate scenarios on the rainfall patterns.

Mk3 Model for 30 year period in the South West–A2 climate model

	Current rainfall (mm)			Future rainfall (mm)			Percentage change		
Station	**9519**	**9534**	**Average**	**9519**	**9534**	**Average**	**9519**	**9534**	**Average**
Summer	43	55	49	41	50	45	-6.2%	-8.9%	-7.7%
Autumn	134	150	142	103	110	106	-23.2%	-27.0%	-25.2%
Winter	447	510	478	403	452	428	-9.8%	-11.2%	-10.5%
Spring	209	227	218	192	211	202	-8.0%	-6.8%	-7.4%
Annual	**833**	**941**	**887**	**739**	**823**	**781**	**-11.3%**	**-12.5%**	**-11.9%**

Mk3.5 Model for 30 year period in the South Coast–B1 climate model

	Current rainfall (mm)			Future rainfall (mm)			Percentage change		
Station	**9573**	**9615**	**Average**	**9573**	**9615**	**Average**	**9573**	**9615**	**Average**
Summer	61	47	54	56	43	49	-9.1%	-7.8%	-8.5%
Autumn	175	144	159	165	134	149	-6.0%	-6.8%	-6.3%
Winter	408	332	370	409	329	369	0.2%	-1.0%	-0.3%
Spring	230	186	208	233	187	210	1.4%	0.4%	0.9%
Annual	**874**	**709**	**791**	**862**	**693**	**777**	**-1.4%**	**-2.3%**	**-1.8%**

Figure 7.15 displays the overall decrease in load predicted in the Geographe catchment as a result of the predicted climate scenarios. The A2 scenario is predicted to result in approximately 30 per cent load reductions for both nitrogen and phosphorus, whereas the B1 scenario is predicted to result in five per cent load reductions. Results of the change in rainfall regimes for individual subcatchments are displayed in Table 7.11.

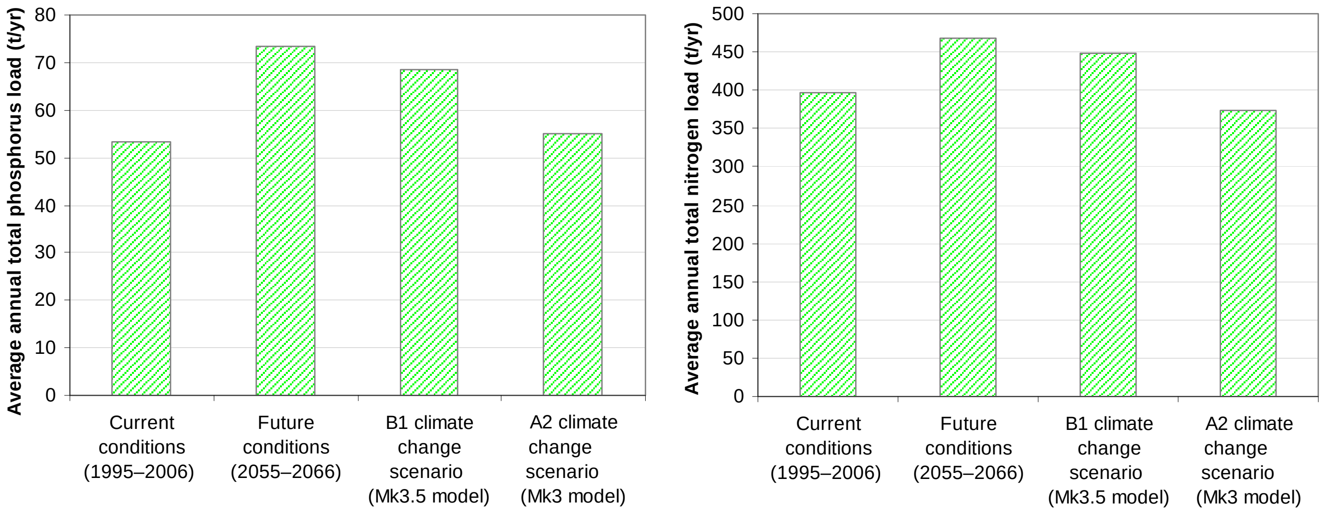


Figure 7.15. Load predictions for A1 and B2 climate modelling scenarios for phosphorus and nitrogen.

Although loads are expected to decrease for climate change scenarios, flows will also decrease, resulting in lower groundwater levels that would not replenish wetlands, dry permanent pools in waterways, and a string of detrimental ecological effects. The negative effects associated with a reduced rainfall regime would far outweigh the positive effects of the reduced load delivery to the bay and wetlands from the catchment.

Table 7.11. Load predictions for A1 and B2 climate modelling scenarios for phosphorus and nitrogen in individual reporting subcatchments.

Phosphorus						
	Current load (1995–2006) (tonnes/year)	Predicted load (2055–2066) (tonnes/year)	Mk3 A2 climate change scenario (tonnes/year)		Mk3.5 B1 climate change scenario (tonnes/year)	
Five Mile Brook	3.47	3.55	2.65	-24%	3.40	-2%
Gynudup Brook	2.85	2.24	0.56	-80%	0.80	-72%
Capel River	6.72	8.41	5.26	-22%	8.01	19%
Ludlow River	2.94	3.38	1.87	-36%	3.08	5%
Abba River	4.35	5.18	2.37	-46%	4.53	4%
Sabina River	3.57	3.61	2.76	-23%	3.50	-2%
Vasse River	14.08	25.11	23.24	65%	25.09	78%
Lower Vasse River	4.72	6.66	6.50	38%	6.65	41%
Buayanyup River	6.46	10.66	6.90	7%	9.21	43%
Carbunup River	1.81	1.90	1.22	-33%	1.77	-2%
Annie Brook	1.76	1.72	1.03	-41%	1.65	-6%
Toby Inlet	0.42	0.65	0.43	2%	0.61	45%
Dunsborough region	0.13	0.17	0.14	11%	0.17	28%
Jingarmup Brook	0.09	0.09	0.03	-67%	0.07	-22%
TOTAL	**53.37**	**73.33**	**54.96**	**-23%**	**68.54**	**4%**
Nitrogen						
	Current load (1995–2006) (tonnes/year)	Predicted load (2055–2066) (tonnes/year)	Mk3 A2 climate change scenario (tonnes/year)		Mk3.5 B1 climate change scenario (tonnes/year)	
Five Mile Brook	32.1	32.7	30.1	-0.06	32.5	1%
Gynudup Brook	21.4	21.3	7.2	-0.66	7.9	-63%
Capel River	42.2	51.6	44.9	0.06	51.1	21%
Ludlow River	22.9	30.9	21.6	-0.06	29.7	30%
Abba River	37.5	55.4	37.6	0.00	52.5	40%
Sabina River	39.5	39.1	32.9	-0.17	38.5	-3%
Vasse River	75.6	89.3	73.8	-0.02	87.9	16%
Lower Vasse River	21.4	28.8	28.2	0.32	41.6	94%
Buayanyup River	33.2	36.9	25.5	-0.23	27.3	-18%
Carbunup River	21.1	23.1	16.4	-0.22	21.9	4%
Annie Brook	30.4	31.7	30.5	0.00	31.6	4%
Toby Inlet	13.7	20.3	19.8	0.45	20.2	47%
Dunsborough region	1.3	1.7	1.3	0.02	1.7	28%
Jingarmup Brook	4.5	4.9	4.6	0.02	4.8	7%
TOTAL	**396.8**	**467.7**	**374.4**	**-1%**	**449.2**	**11%**

7.3 Hydrological manipulations

7.3.1 Diversions to Lower Vasse River and Vasse Wonnerup Wetlands

Management question #11: *What is the water quality impact of making hydrological changes to the Vasse Wonnerup and Lower Vasse River systems through the Vasse Diversion Drain?*

Flowing directly through the Busselton town site, the Lower Vasse River has important social and recreational values. Each year it experiences toxic blue-green algal blooms during the summer months, and is closed for recreation and fishing. The Lower Vasse River receives flow from local stormwater and groundwater, and from a small culvert that releases flow from the Vasse Diversion Drain. The upper reaches of the Vasse River was disconnected from the Lower Vasse River in the early 1900s during the construction of the Vasse Diversion Drain, primarily to alleviate flooding of the Busselton township in winter. Community groups claim that increasing the flow in the Lower Vasse River would mitigate the summer algal blooms – by flushing the nutrient-rich water that is present in the Lower Vasse River in summer and by scouring the nutrient-laden sediment from the river bed. Increased flows can be only be achieved by increasing the size of the culvert in the upstream end of the Lower Vasse River, thereby increasing the proportion of flow from the Vasse Diversion Drain.

The inlet for the culvert is 900 mm in diameter, and is located at the bottom of a local basin within the drain. In low flows all water will flow to the Lower Vasse River (Figure 7.16), but in larger flows, water will flow past the drain and will discharge to the Vasse Diversion Drain outlet in Geographe Bay. The culvert is closed during summer (as water in the Vasse Diversion Drain is generally very nutrient rich during this period), and although opening periods vary from year to year, it is assumed that the culvert is open from the start of June to the end of October for the purpose of this modelling exercise (as there are no records of the exact opening and closing dates).

The effect on the water quality and quantity being delivered to the Lower Vasse River was investigated for this scenario. Five diameter sizes of culvert (including the size currently being used) were analysed. For each culvert diameter size, a function relating the height of the water in the Vasse Diversion Drain at the culvert (the stage) to the flow was determined. Figure C1 in Appendix D (from *Hydraulics of Precast Concrete Conduits*, Concrete Pipe Association of Australasia, 1991) was used to derive the diameter versus head-discharge quantities. Assuming the head in the Vasse Diversion Drain was proportional to the discharge in the same drain, the formula used to determine the flow to the Lower Vasse River, based on the flow in the Vasse Diversion Drain was:

$$Flow\_LVR = a*\ln(Flow\_VDD) + b.$$

Coefficients *a* and *b* were determined by plotting the head/discharge relationship derived in Figure C1, Appendix D. The relationship between flow and water level, and the equations relating each of these relationships, are displayed in Appendix D. For the current diameter (900 mm), the equation coefficients *a* and *b* were calibrated so that the daily flow at the gauging station 610016 was consistent for modelled and measured data. On an annual basis, an average of approximately 20 per cent of the flow in the Vasse Diversion Drain enters the Lower Vasse River.

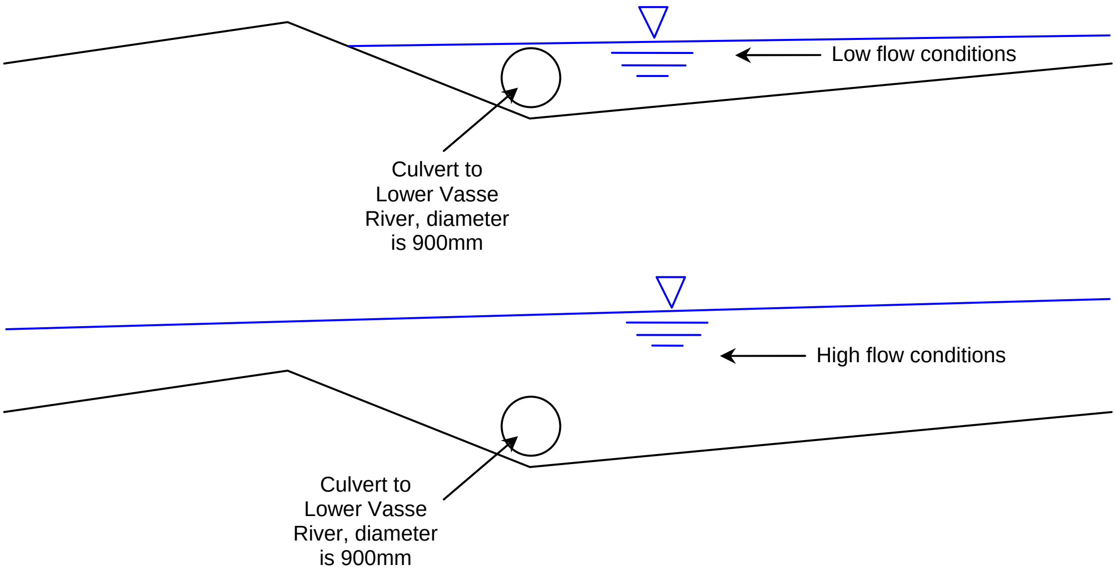


Figure 7.16. Conceptual cross-section of the Vasse Diversion Drain displaying the position of the culvert to the Lower Vasse River.

For the time period 1995–2006, average annual flows for the various diameter sizes were calculated: 525 mm, 700 mm, 900 mm (the current diameter), 1050 mm and 1200 mm. Daily input loads were calculated for the Lower Vasse River assuming the nutrient load was proportional to the flow (the stream was fully mixed).

The results of the analysis are displayed on Table 7.12 and Figure 7.17. It is evident that the load will increase and the concentration will decrease when the diameter size is increased, resulting in higher flows to the Lower Vasse River. With current land uses in the Vasse Diversion Drain subcatchment, the concentration will never decrease to a level with a winter median concentration of 0.1 mg/L for phosphorus or of 1.0 mg/L for nitrogen, as the concentration will level out at about 0.13 mg/L for total phosphorus and 1.4 mg/L for total nitrogen (which are the winter median concentrations in the Vasse Diversion Drain). Therefore, even if high levels of flushing were occurring (e.g. with a culvert diameter of 1200 mm) from the Vasse Diversion Drain, algal problems would be likely to continue, as current nutrient concentrations from the inflow would be high enough to trigger algal blooms. If nutrients are retained within the Lower Vasse River water body, the increase in load as a result of the increase in culvert diameter size could possibly make the algal problems worse, due to storage and release of nutrients in the sediment. In the higher flows that were modelled (D = 1200 mm) it is unlikely that the flow would be of high-enough velocity to scour the nutrient-rich sediment from the Lower Vasse River, as the river is wide in this region and the slope is very small. If flows in the Lower Vasse River increase by too much, flooding could occur in urban regions close to the river banks. However, SQUARE can only provide the likely changes in flow and nutrient load entering the Lower Vasse River. Detailed effects of sediment scouring and bank flooding require a hydraulic model for further investigation.

Table 7.12. The effects of changing culvert diameter sizes on the load and winter median concentration of the outflow from the Lower Vasse River.

Phosphorus					
	At outlet to Vasse Estuary				
Year	**Culvert diameter = 0.525m**	**Culvert diameter = 0.7m**	**Current conditions (diameter = 0.9m)**	**Culvert diameter = 1.0m**	**Culvert diameter = 1.2m**
1995	3.20	3.74	4.32	4.63	5.16
1996	3.19	3.67	4.22	4.53	5.13
1997	3.06	3.64	4.25	4.68	5.32
1998	3.15	3.65	4.32	4.67	5.30
1999	3.38	3.90	4.50	4.99	5.80
2000	2.98	3.48	4.07	4.40	5.07
2001	3.14	4.22	5.21	5.69	6.34
2002	3.55	4.45	5.31	5.62	6.23
2003	3.45	4.17	4.88	5.22	5.87
2004	3.53	4.24	5.05	5.40	6.00
2005	3.79	4.60	5.62	6.28	7.26
2006	3.77	4.34	4.93	5.17	5.52
Average load (t/yr)	**3.35**	**4.01**	**4.72**	**5.11**	**5.75**
Median winter concentration (mg/L)	**0.390**	**0.270**	**0.232**	**0.199**	**0.179**

Nitrogen					
	At outlet to Vasse Estuary				
Year	**Culvert diameter = 0.525m**	**Culvert diameter = 0.7m**	**Current conditions (diameter = 0.9m)**	**Culvert diameter = 1.0m**	**Culvert diameter = 1.2m**
1995	11.1	16.6	21.4	26.4	33.1
1996	10.9	16.1	21.4	27.6	36.0
1997	9.5	14.9	20.4	26.3	33.6
1998	10.1	15.7	21.7	27.9	35.0
1999	12.0	17.8	24.1	31.3	41.2
2000	9.5	14.3	19.3	24.7	31.8
2001	10.5	18.0	22.9	26.2	29.2
2002	9.5	15.4	20.3	24.9	29.6
2003	10.0	15.5	20.7	25.8	31.8
2004	9.7	15.3	20.7	25.7	30.9
2005	12.3	20.4	28.6	36.4	44.6
2006	7.6	11.5	15.0	18.1	21.1
Average load (t/yr)	**10.2**	**16.0**	**21.4**	**26.8**	**33.2**
Median winter concentration (mg/L)	**2.07**	**1.56**	**1.51**	**1.49**	**1.46**

Water					
	At outlet to Vasse Estuary				
Year	**Culvert diameter = 0.525m**	**Culvert diameter = 0.7m**	**Current conditions (diameter = 0.9m)**	**Culvert diameter = 1.0m**	**Culvert diameter = 1.2m**
1995	6.0	9.7	13.1	16.9	22.1
1996	7.1	11.3	15.7	20.9	28.1
1997	5.7	9.8	14.0	18.8	24.8
1998	5.3	9.3	13.5	18.0	23.6
1999	8.9	13.8	19.3	25.6	34.3
2000	6.2	9.9	13.9	18.3	24.3
2001	3.2	6.1	8.3	9.9	11.4
2002	3.8	7.1	10.0	13.0	16.3
2003	4.4	7.8	11.1	14.6	19.0
2004	4.4	7.9	11.2	14.5	18.3
2005	5.3	9.8	14.5	19.3	24.8
2006	2.5	4.5	6.4	8.1	10.0
Average flow (GL)	**5.2**	**8.9**	**12.6**	**16.5**	**21.4**

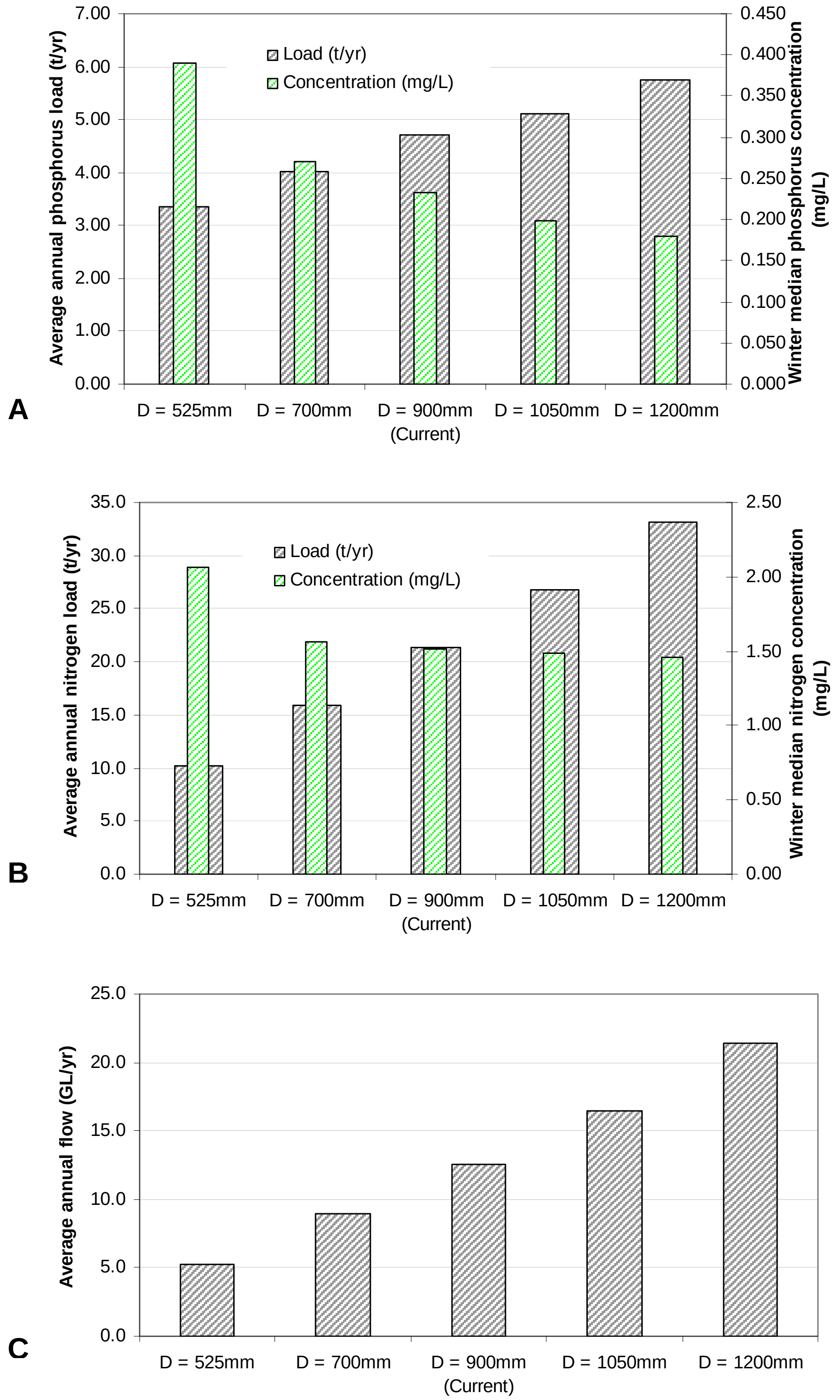


Figure 7.17. The effects of changing culvert diameter sizes on the load and winter median concentration for phosphorus (A), nitrogen (B) of the outflow (C) from the Lower Vasse River.

8 Future modelling recommendations

As mentioned in Section 6, the accuracy of modelling outputs is only as good as the data available to drive the models. For the Geographe catchment a large variation in confidence in the modelling results exists, depending on the reporting subcatchment. Many reporting subcatchments have a very poor sampling history, the majority of subcatchments are not flow-gauged, and two reporting subcatchments (Five Mile Brook and Toby Inlet) have no current or historical surface water sampling or flow data. The majority of the water quality data (particularly the total suspended solids and total phosphorus data) has only been collected since 2006, and few sites have a consistent, high-quality nutrient sampling record.

The modelling achieved in this project was based on best-available data, but in many cases where the data record is short or poor, it will be necessary to re-visit the modelling after data has been collected for a few more years. Loads, load-reduction targets and specific management recommendations should be reviewed in three to five years’ time when more input data are available.

To validate the modelling results, it is important to retain a regular fortnightly sampling regime at all subcatchments currently being sampled, and to begin sampling in the Five Mile Brook and Toby Inlet subcatchments. In three to five years there will be sufficient data to obtain much higher confidence in modelling results. In addition, is important to record any projects that involve remediation of the catchment so that they can be included in future modelling exercises. This would allow trends and status of nutrient samples to be re-visited in locations downstream of remediation activities, thus measuring the effectiveness of the management options.

Most nutrients delivered to the receiving water bodies and the bay are from surface-water flows. However, there is likely to be a small portion of groundwater being discharged to the receiving water bodies (probably less than five per cent of the total nutrient load) which is not being captured in this project. Groundwater analysis would complete the total budget for nutrient export from the Geographe catchment. The Department of Water is currently drilling a series of bores in the vicinity of the Geographe coastline to characterise the flow in the Superficial Aquifer. Sampling of these bores for nutrients and analysis of the flow and nutrient concentrations would provide a good estimate of groundwater load delivery, and is recommended if an estimation of the total nutrient delivery to the bay and/or wetlands is desired.

As mentioned in Section 7.2, the analysis used two different General Circulation Models (GCMs), and there were issues with spatial heterogeneity within the catchment. It is desirable to have the GCM models run specifically for the project catchment, and ideally a series of points in the Geographe catchment would have been analysed using the same GCM for both climate scenarios. If a more detailed investigation of the effects of climate change is desired, then this approach is recommended.

9 Summary of findings

In 2006 the Geographe catchment – including the Vasse Wonnerup Wetlands and Geographe Bay – was recognised through the Australian Government's Coastal Catchments Initiative (CCI) as a priority water quality 'hotspot'. This was due to the high levels of nitrogen and phosphorus entering the coastal environment from land-based sources. The Australian and Western Australian governments initiated a series of projects that contributed to the preparation of a *Water quality improvement plan for the Vasse Wonnerup Wetlands and Geographe Bay* (DOW 2009) and a framework for its implementation. A dynamic hydrologic and nutrient model was used to determine current nutrient loads, load targets, load-reduction targets, nutrient sources and priority subcatchments for remediation.

The model predicted that on average, 53 tonnes of phosphorus and 397 tonnes of nitrogen enter Geographe Bay and the Vasse Wonnerup Wetlands annually. A load reduction target of 20 tonnes per year of phosphorus and 167 tonnes per year of nitrogen are required to meet the water quality objectives established as part of this project (winter median concentrations of 0.1 mg/L for phosphorus and 1.0 mg/L for nitrogen). If these water quality objectives are met, a maximum of 34 tonnes of phosphorus and 232 tonnes of nitrogen per year would be delivered to the receiving water bodies.

The main sources of the nutrients are cattle grazing for beef and dairy, which together contribute approximately 60 per cent of the phosphorus and nitrogen loads. However, horticulture, septic tanks, and urban and point sources (wastewater treatment plants, dairy sheds, feedlots, landfills etc.) also make up significant proportions of the load. Priority regions identified for remediation included the Sabina River, Vasse Diversion Drain, Lower Vasse River, Ludlow River, Gynudup Brook and Five Mile Brook subcatchments. The model was used to predict the effect of various management scenarios on nutrient loads and concentrations, which included climate change, various land-use changes (including urban expansion), regional hydrological manipulations, and the implementation of best-management practices.

Waste from septic tanks accounts for a predicted average of 1.5 tonnes of phosphorus and 13.2 tonnes of nitrogen annually, which is 2.8 per cent of the total annual phosphorus load, and 3.2 per cent of the total annual nitrogen load that is delivered to the bay and estuary. The Busselton light industrial area was responsible for over 90 per cent of the septic tank nutrient contribution to the Lower Vasse River, and was predicted to deliver approximately 0.45 tonnes of phosphorus and 1.3 tonnes of nitrogen annually. The load delivered to the Lower Vasse River by septic tanks in the Busselton light industrial area is a significant contributor to the total nutrient load.

The major contributor of total load for both nitrogen and phosphorus is cattle grazing for beef and dairy. This is largely because these farms occupy the majority of the fertilised land area in the Geographe catchment. Point sources contribute a significant proportion of the total output load, especially when compared with the relative input load. Most point sources are discharged directly to the waterways, and as such the nutrients have little opportunity to be assimilated compared with fertiliser that is applied directly to the land. The land uses with the greatest nutrient load per unit area are urban and horticulture, due to fertilisation intensity.

Most point-source contributions are from dairy-shed effluent. An estimated 5.1 tonnes of phosphorus and 23.0 tonnes of nitrogen are discharged into the receiving water bodies each year. Wastewater treatment plants contribute significantly to the point-source loads, and are expected to double in capacity in the next 20 years. The model predicts an average annual discharge of 1.31 tonnes of total phosphorus and 1.33 tonnes of total nitrogen to the bay from the Busselton wastewater treatment plant. The Water Corporation plans to upgrade the treatment facility in 2009: the improved facility is expected to halve the nutrient concentration of the wastewater outflow.

The urban expansion scenario predicts that the phosphorus and nitrogen loads will increase during the next 25 years. The cause of the increase will primarily be land-use change – moving from beef grazing to urban land uses – which corresponds to an increase in fertiliser input rate. Water sensitive urban design measures will be required to minimise the load increase.

Nutrient-hotspot analysis revealed that the highest rates of nutrient export were located in the centre of the Geographe catchment – in the regions surrounding the Sabina River, the Vasse Diversion Drain, and the Buayanyup River. High exports also occur in the Gynudup Brook catchment, and are evident on the coastline in urban regions.

Beef grazing on the wetland fringes is responsible for 10 per cent of the total phosphorus and five per cent of the total nitrogen loads to the Vasse Wonnerup Wetlands, with the majority of the nutrient load being delivered through the rivers that discharge into the wetlands.

Analysis of the timing of loads revealed that much of the nutrient load is delivered between May and October, with only a small fraction of the load delivered in the summer months. There are large variations in the timing of loads, and this is due to the variation in the monthly rainfall, and hence monthly flow. The annual catchment load is highly dependent on the rainfall, and high rainfall years (such as 1999) will generally deliver a load over five times the magnitude of low rainfall years (such as 1987 or 2006). The majority of the flow is delivered over a very small percentage of the time, with 50 per cent of the flow and associated nutrient load being delivered five per cent of the time.

Two emission scenarios from the Intergovernmental Panel on Climate Change (IPCC) were investigated. The A2 (pessimistic) and B1 (optimistic) scenarios were modelled as part of the climate change scenario analysis. The A2 scenario is predicted to result in approximately 30 per cent reductions in load for both nitrogen and phosphorus, whereas the B1 scenario is predicted to result in five per cent reductions in load. Although nutrient loads are expected to decrease for climate change scenarios, flows will also decrease, resulting in lower groundwater levels, decreased flows to wetlands, and drying of permanent pools and waterways. The negative effects associated with a reduced rainfall regime would outweigh the positive effects of the reduced load delivery to the bay and wetlands from the catchment.

Increased flushing of the Lower Vasse River was analysed by modelling increased water releases from the Vasse Diversion Drain. With current land uses in the Vasse Diversion Drain subcatchment, the modelled concentration did not decrease to a level with a winter median concentration of below 0.1 mg/L for phosphorus or of 1.0 mg/L for nitrogen. Even if high levels of flushing were occurring from the Vasse Diversion Drain, algal problems would be likely to continue as current nutrient concentrations from the inflow would be sufficient to trigger algal blooms. If nutrients are retained within the Lower Vasse River water body, the increase in load as a result of the increase in culvert diameter size could possibly make the algal problems worse, due to storage and release of nutrients in the sediment.

To validate the modelling results, it is important to retain a regular fortnightly sampling regime at all subcatchments currently being sampled, and to begin sampling in the Five Mile Brook and Toby Inlet subcatchments. In addition, is important to record any projects that involve remediation of the catchment so that they can be included in future modelling exercises. This would allow trends and status of nutrient samples to be re-visited in locations downstream of remediation activities, thus measuring the effectiveness of the management options.

The modelling achieved in this project was based on best-available data, but in many cases where the data record is short or poor, it will be necessary to re-visit the modelling after data has been collected for a few more years. Loads, load-reduction targets and specific management recommendations should be reviewed in three to five years' time when more input data are available.

References

ANZECC & ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water quality*, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.

Cleary, SL 2008, 'Project rainfall in the South West of Western Australia: Analysis of down-scaled rainfall from the Mk3 and Mk3.5 General Circulation Models (GCMs)', unpublished report for the Department of Water.

Concrete Pipe Association of Australasia 1991, 'Hydraulics of precast concrete conduits: pipe and box culverts', *Hydraulics Manual edition 2*

Department of Agriculture 2000, 'Guidelines for Managing Dairy Effluent in Western Australia', *Bulletin 4336 Department of Ag., W.A.*

Department of Environment 2004, 'Aggregated emissions of total nitrogen and total phosphorus to the Vasse Wonnerup catchment, Western Australia', a submission to the National Pollutant Inventory.

Department of Environment and Conservation 2007, *Ecological Character of the Vasse Wonnerup Wetlands Ramsar Site in South-West Western Australia*, technical report produced by Wetland Research and Management for the Department of Environment and Conservation and Geographe Catchment Council.

Department of Environment 2003, South West Info: Lower Vasse River Phoslock™ trials, March 2003.

Department of Environment and Berti, ML, Bari, MA, Charles SP and Hauck EJ 2004, *Climate change, catchment runoff and risks to water supply in the South West of Western Australia.*

Department of Water 2008a, 'Sustainable diversion limits: Recommendations for sustainable diversion limits over winterfill periods in unregulated South West Western Australian catchments', unpublished report.

Department of Water 2008b, *Capel River hydrology summary*, technical report produced by the Surface Water Hydrology section of the Department of Water.

Department of Water 2008c, *Water quality modelling and monitoring program for the Vasse Geographe catchment*, unpublished report from the Water Science Branch, Department of Water, WA.

Donohue, R and van Looij, E 2001, *The derivation of percentile quality criteria for the Swan-Canning Estuary: A binomial approach*, Swan River Trust, Swan-Canning Clean-up Program Report SCCP24.

Duan, QY, Gupta, VK and Sorooshian, S 1993, ‘Shuffled complex evolution approach for effective and efficient global minimisation’, *Journal of Optimisation Theory and Applications,* 76(3), pp. 501-521.

Ecotones and Associates 2008, ‘SSPND: the support system for phosphorus and nitrogen decisions – BMP scenarios for the Vasse Geographe catchment’, consulting report to the Department of Agriculture and Food: Vasse Geographe CCI project.

English, LB 1994, Country Drainage – Busselton Drainage District, Water Authority of Western Australia, Pub. No. RS0042.

Esterby, SR 1996, ‘Review of methods for the detection and estimation of trends with emphasis on water quality applications’, *Hydrological Processes* 10 (2): 127-149.

Fahrner, S 2002, ‘Groundwater nitrate removal using a bioremediation trench’, *Honours Thesis, University of Western Australia.* Department of Environmental Engineering.

Gerritse, R 2002, ‘Movement of nutrients from onsite wastewater systems in soils’ *Department of Health, W.A.*

Gilbert, RO, 1987, *Statistical methods for environmental pollution monitoring*, Van Nostrand Reinhold, New York, 250 pp.

Government of Western Australia 2000, ‘Wetlands nominated by the Government of Western Australia for inclusion on the list of Wetlands of International Importance, Ramsar Convention’, nominating document prepared by the WA Department of Conservation and Land Management.

Hall, J, 2006, *Nutrient Status and Trends Report for the Vasse Geographe catchment*, unpublished report from the Water Science Branch, Department of Water, WA.

Helshel, DR, and Hirsch, RM, 1992, *Statistical methods in water resources*, Elsevier, Amsterdam, 522 pp.

Hipel, K W and McLeod, AI 1994, *Time series modelling of environmental and water resources systems*, Elsevier, Amsterdam.

Hirschberg, KJ 1991, ‘Nutrient export in surface and groundwater under various land uses’, in *Land Development in Areas of High Water Table Forum Proceedings*, Institution of Engineers Australia in association with Urban Development Institute of Australia.

Houghton, JT, Filho, LGM, Griggs, DJ, Maskell, K, 1997, 'An Introduction to Simple Climate Models used in the IPCC Second Assessment Report', nominating document prepared by the Intergovernmental Panel on Climate Change.

Humphries R, Oma, R and O'Grady, B 2001, 'Busselton Environmental Improvement Initiative', conference paper – LandCare Conference, 2001.

Kitsios, A and Kelsey, P 2008, *Nutrient survey of urban areas in coastal catchments of Western Australia*, Water Science Branch, Department of Water, Western Australia.

Lane, JAK, Hardcastle, KA, Tregonning, RJ, Holfreter, GJ, 1997, 'Management of the Vasse Wonnerup Wetland system in relation to sudden mass fish deaths', unpublished report prepared on behalf of the Vasse Estuary Technical Working Group, Busselton, Western Australia

Lettenmaier, DP 1976, 'Detection of trends in water quality from records with independent observations', *Water Resources Research* 12 (5): 1037-1046

Loftis, JC, McBride, GB, and Ellis, JC.1991, 'Considerations of scale in water quality monitoring and data analysis', *Water Resources Research*, 12 (5): 1037-1046.

Lundstrom, MJ 2001, *Busselton Waste Facility Rendezvous Road, Post Closure Management Plan,* Shire of Busselton.

McVicar, T, Jupp, D, Reece, P, Williams, N, 1996, *Relating LANDSA TM vegetation indicies to In Situ leaf area index measurement',* Technical Memorandum 96.14, Division of Water Resources, CSIRO Australia.

Nakicenovic, N, Ogunlade, D, Davis, D, Grubler, A, Kram, T, Lebre La Rovere, E, Metz, B, Morita, M, Pepper, W, Pitcher, H, Sankovski, A, Shukla, P, Swart, R, Watson, R, Dadi, Z 2000, *Special report on emission scenarios, a special report of Working Group III of the Intergovernmental Panel on Climate Change.*

Robson, AJ, and Neal, C 1996, ,Water quality trends at an upland site in Wales,, *Hydrological Processes* 10 (2): 183-203.

Shire of Busselton 2007, 'Demography and Planning 2007', unpublished report prepared by the Shire of Busselton.

Viney, NR and Sivapalan, M 1996, 'The hydrological response of catchments to simulated changes in climate', *Ecological Modelling*, 86, pp. 189-193

Viney, NR, Sivapalan, M and Deeley, D 2000, 'A conceptual model of nutrient mobilisation and transport applicable at large catchment scales', *Journal of Hydrology,* 240, pp. 23-44.

Viney, NR and Sivapalan, M 2001, ‘Modelling catchment processes in the Swan-Avon River Basin’, *Hydrological Process*, 15, 2671-2685

Ward, R, Loftis, J, and McBride, G 1990, *Design of water quality monitoring systems*, Van Nostrand Reinhold, New York.

Weaving, S 1998, *Geographe Bay Catchment Natural Resource Atlas*, Department of Agriculture, Western Australia.

Westera, M, Barnes, P, Kendrick, G and Cambridge, M 2007, *Establishing benchmarks of seagrass communities and water quality in Geographe Bay, Western Australia,* School of Plant Biology, University of Western Australia, Perth.

Whelan, B 1988, ‘Disposal of septic tank effluent in calcareous sands’, *Journal of Environmental Quality 17: 217–277*

Whelan, B and Barrow, N 1984a, ‘The movement of septic tank effluent through sandy soils near Perth 1: Movement of nitrogen’, *Australian Journal of Soil Research* 22: 283-292.

Whelan, B and Barrow, N 1984b, ‘The movement of septic tank effluent through sandy soils near Perth 1: Movement of phosphorus’, *Australian Journal of Soil Research* 22: 293-302.

Whelan, B, Barrow, N, Carbon, B 1981 ‘Movement of phosphate and nitrogen from septic tank effluent in sandy soils near Perth, Western Australia. In: Lawreence, C, and Hughes, R, (eds) *Proceedings of “The groundwater pollution conference”, Perth, Western Australia, 19-23 Feb 1979. Aust Govt. Publishing Service, Canberra, pp391–401*

Zammit, C, Sivapalan, M, Kelsey, P, Viney, N 2005, ‘Modelling the effects of land-use modifications to control nutrient loads from an agricultural catchment in Western Australia’, *Ecological Modelling*, 187, pp. 60-70.

Appendix A: Calibration report

Part 1: Flow Calibration Results

Table A1. Gauging stations used for calibration of reporting subcatchments

Gauging station reference	Station location	Reporting subcatchment	Ungauged reporting subcatchment/s adopting flow parameters
610010	Lower Capel	Capel River	Gynudup Brook, Five Mile Brook*
610219	Upper Capel	Capel River	-
610009	Lower Ludlow	Ludlow River	-
610005	Upper Ludlow	Ludlow River	-
610016	Abba River	Abba River	-
610014	Vasse Diversion Drain	Vasse Diversion Drain	Sabina River, Buayanyup River, Lower Vasse River
610025	Sabina Diversion Drain	Vasse Diversion Drain	-
610012	Vasse Research Station	Vasse Diversion Drain	-
610003	Upper Vasse River	Vasse Diversion Drain	-
610015	Carbunup River	Carbunup River	-
800236	Station Gully Drain	Annie Brook	Dunsborough, Toby Inlet, Jingarmup Brook

* Alteration to the flow parameters was required to remove the influence of the intersection with the Leederville aquifer that was observed in the Capel River.

Table A2. Daily, monthly and annual efficiencies for gauging station calibrations

	Daily	Monthly	Annual
610010	0.898	0.950	0.987
610219	0.876	0.932	0.926
610009	0.819	0.898	0.935
610005	0.867	0.947	0.957
610016	0.833	0.968	0.961
610014	0.747	0.945	0.916
610025	0.360	0.688	0.863
610012**	0.427	0.661	0.892
610003	0.905	0.960	0.795
610015	0.920	0.965	0.969
800236	0.871	0.957	0.922

* Not sufficient sampling data for analysis of efficiency

**Only for years 2005 and 2006, since there was a drainage change between 1995 and 2005

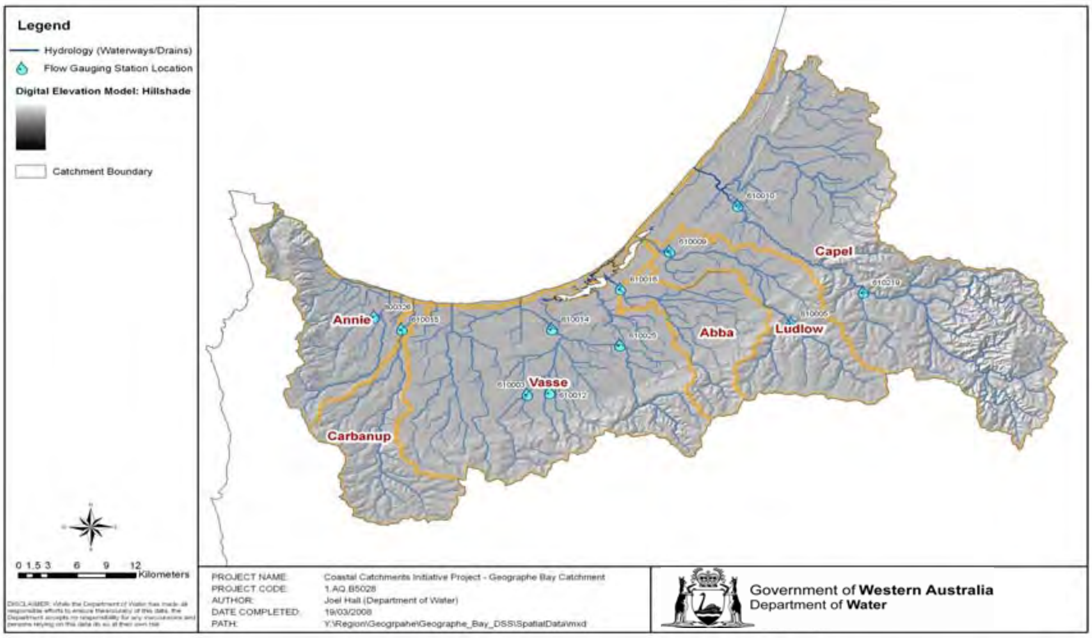


FIgure A1. Gauging station locations and regions of equivalent hydrological paramatisation.

Lower Capel

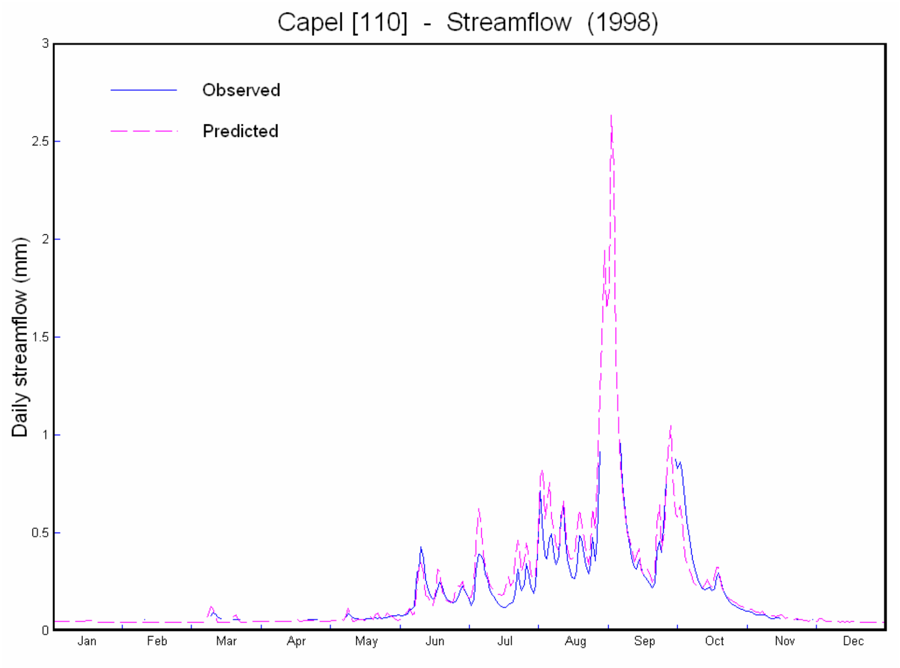
610010 (Capel Railway Bridge)

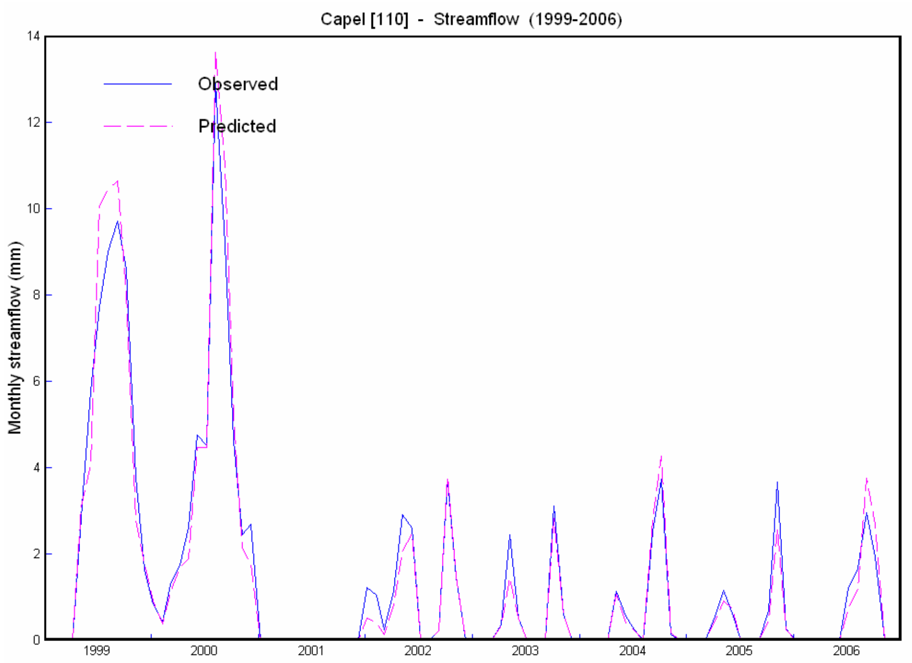
Efficiency:

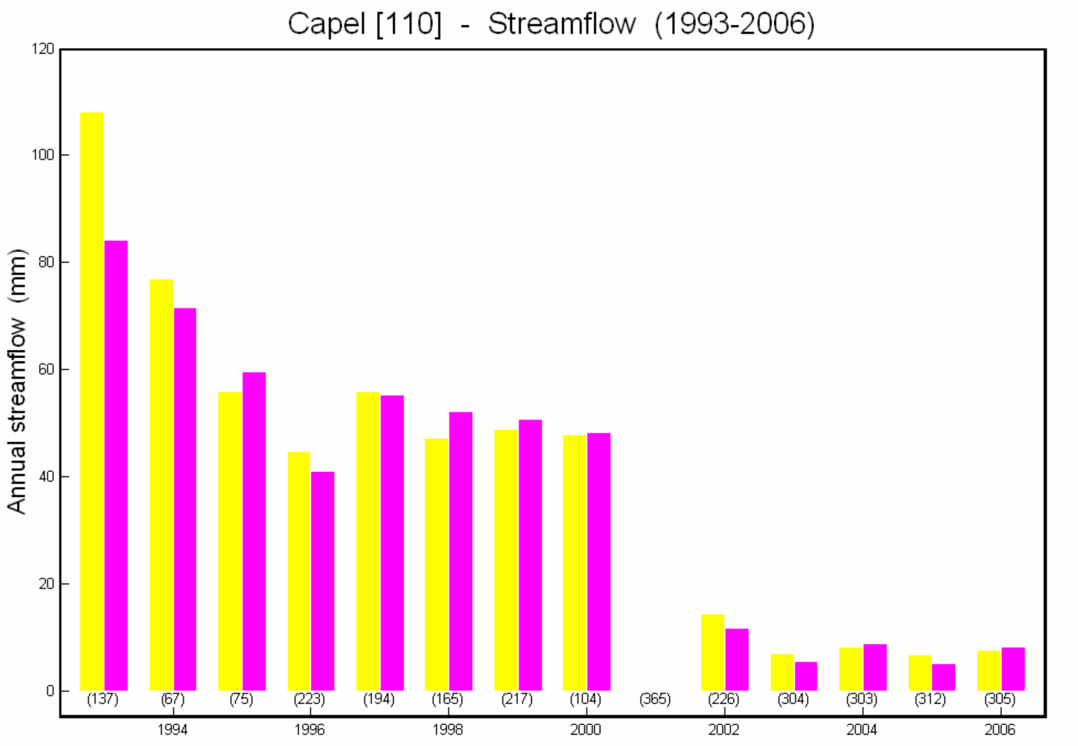
Daily = 0.898

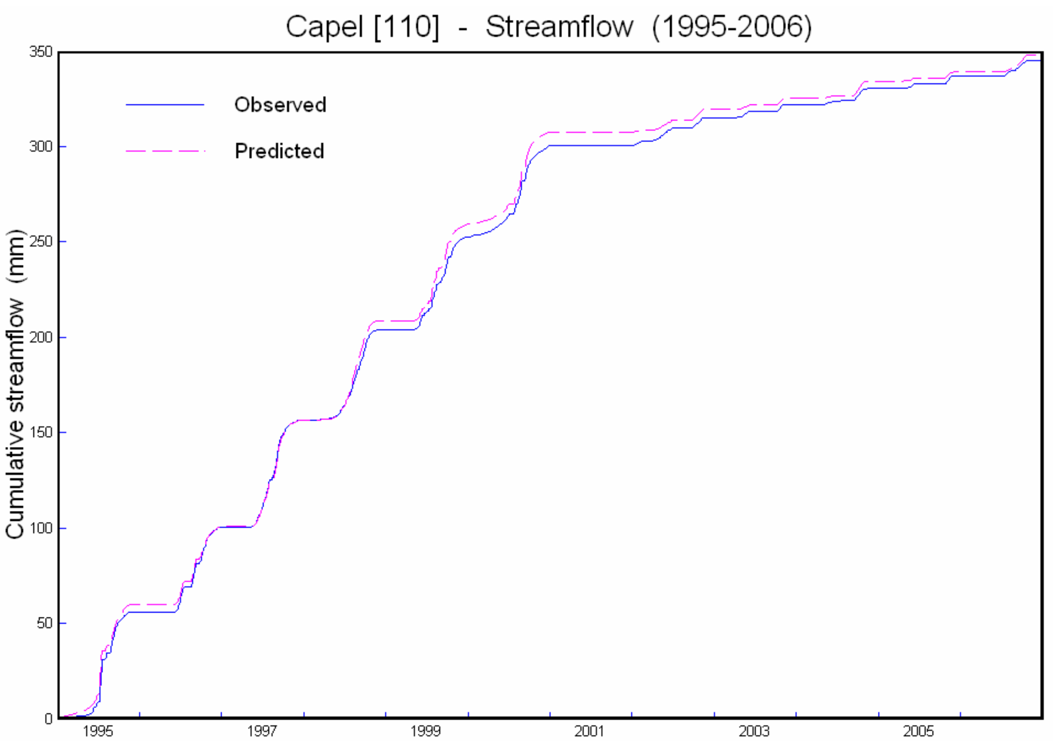
Monthly = 0.950

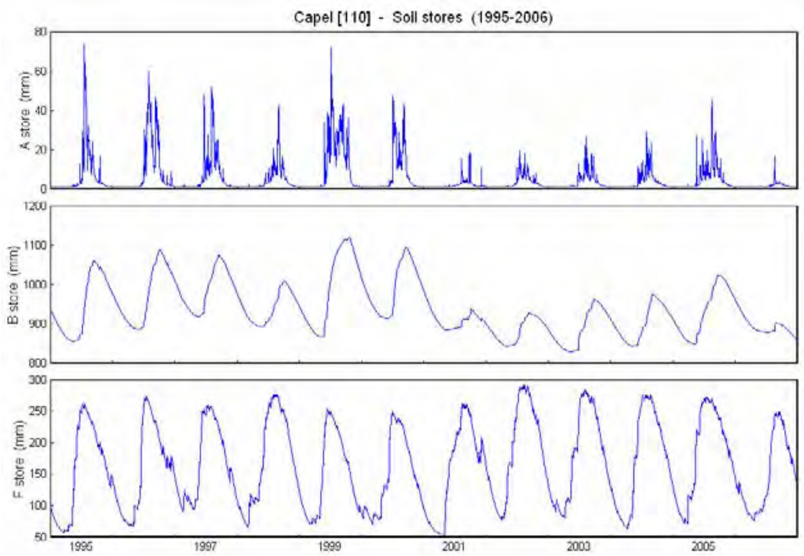
Annual = 0.987






Capel [110] - Streamflow (1993-2006)
Annual streamflow (mm)
120
100
80
60
40
20
0
(137)
(67)
(75)
(223)
(194)
(165)
(217)
(104)
(365)
(226)
(304)
(303)
(312)
(305)
1994
1996
1998
2000
2002
2004
2006


Capel [110] - Streamflow (1995-2006)
Observed
Predicted
Cumulative streamflow (mm)
350
300
250
200
150
100
50
0
1995
1997
1999
2001
2003
2005



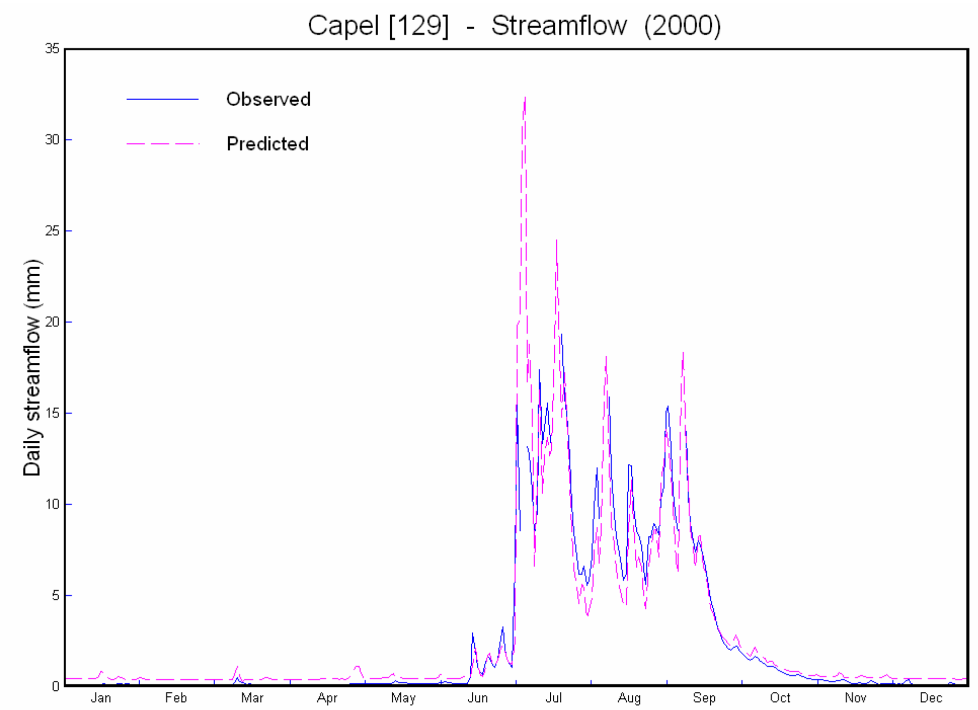
Cumulative precipitation :29161mm, representing 100 % of the rain
Cumulative precipitation after inteception :26683mm, representing 92 % of the rain
Cumulative interception :2478mm, representing 8 % of the rain
Cumulative evaporation :19967mm, representing 68 % of the rain and 75 % of the rain after interceptaion
Cumulative streamflow :6063mm, representing 21 % of the rain and 23 % of the rain after interceptaion
Cumulative Water Balance : in 29161mm, representing100 % of the rain
: out 28507mm, representing98 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :3231mm, representing 11 % of the rain and 16 % of the total evaporation
Cumulative evaporation form the F store :11216mm, representing 38 % of the rain and 56 % of the total evaporation
Cumulative evaporation form the B store :5519mm, representing 19 % of the rain and 28 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :3683mm, representing 13 % of the rain and 61 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):1330mm, representing 5 % of the rain and 22 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):1049mm, representing 4 % of the rain and 17 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :9160mm, representing 31 % of the rain and 151 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):7063mm, representing 24 % of the rain and 77 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):2097mm, representing 4 % of the rain and 23 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :46 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :3 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :409 mm
Average yearly Unsaturated zone discharge :103 mm
Average yearly Unsaturated zone evaporation :303 mm
...
Groundwater
Average yearly Groundwater recharge :647 mm
Average yearly Groundwater discharge :483 mm
Average yearly Groundwater evaporation :149 mm

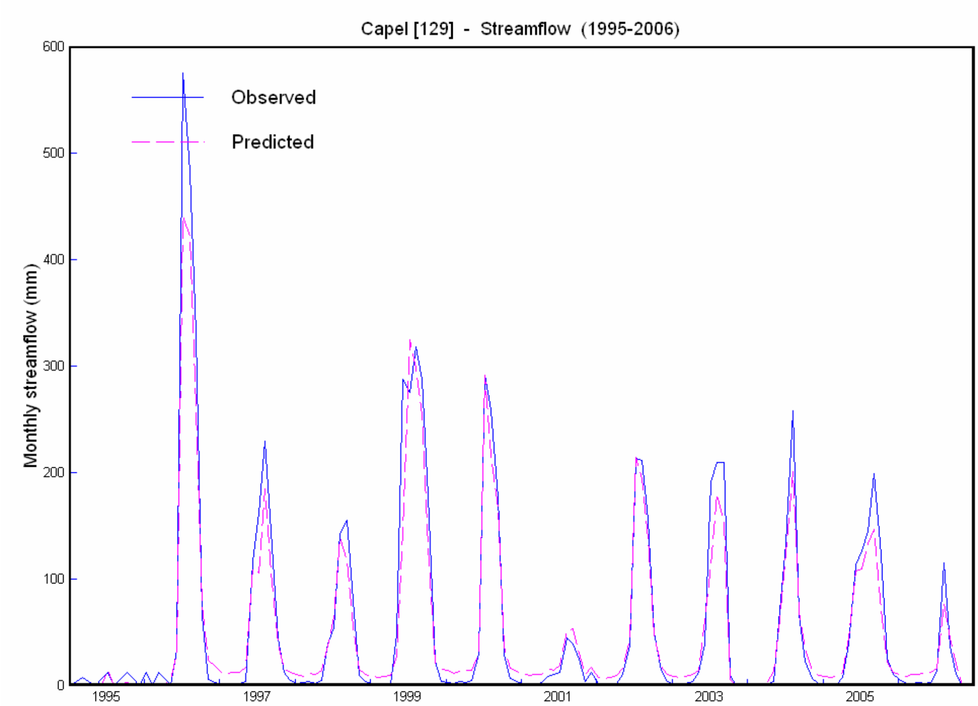
Upper Capel

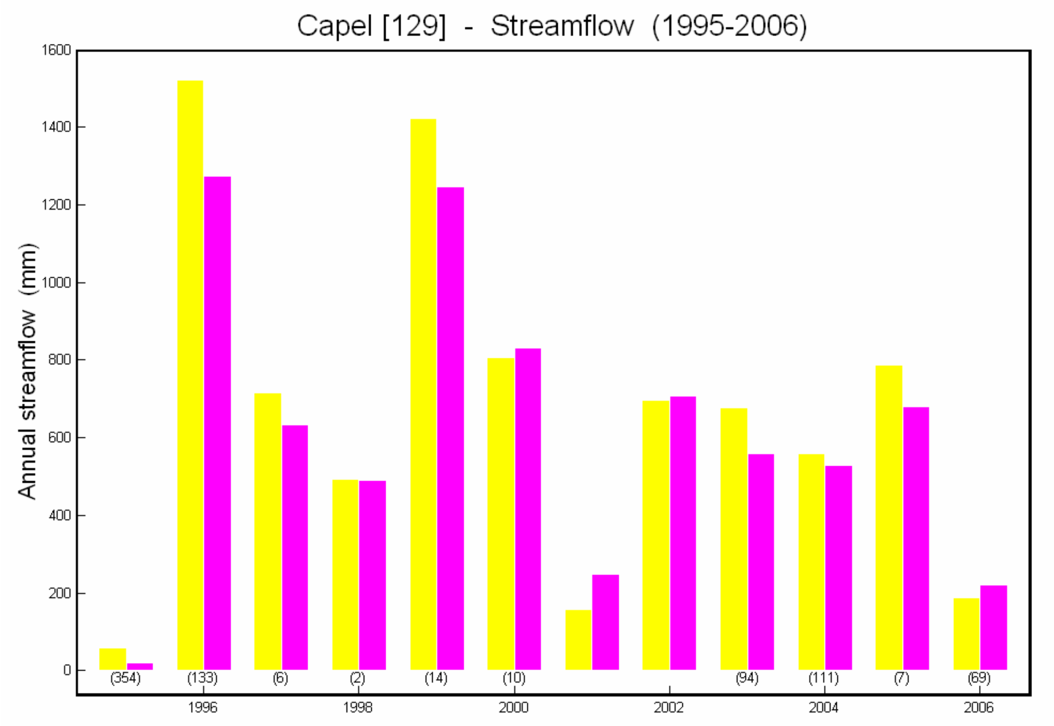
610219 (Capel Railway Bridge)

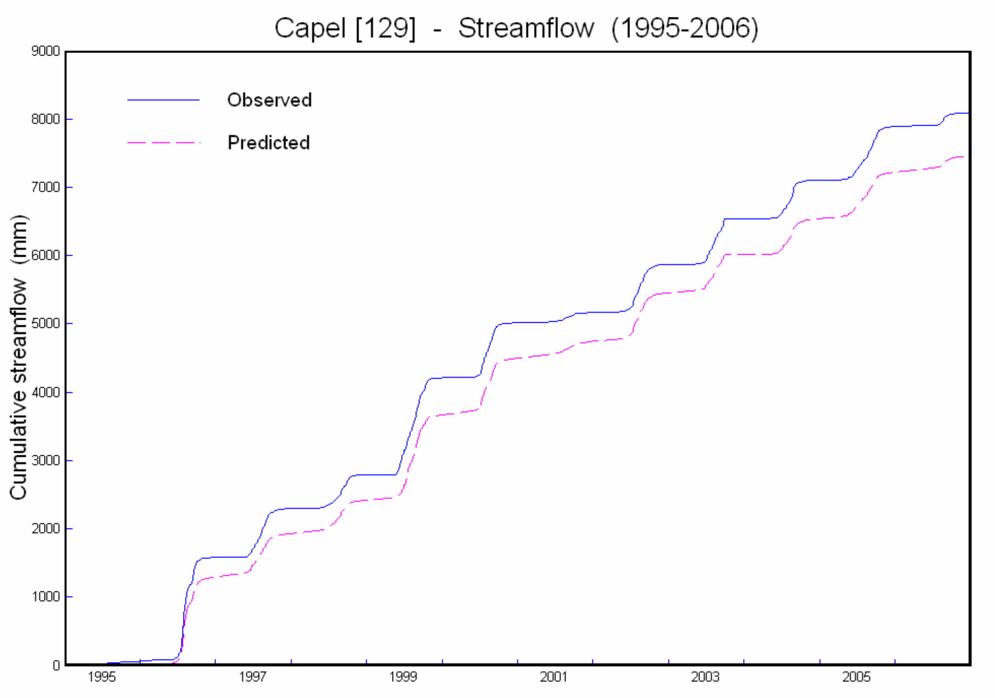
Efficiency:

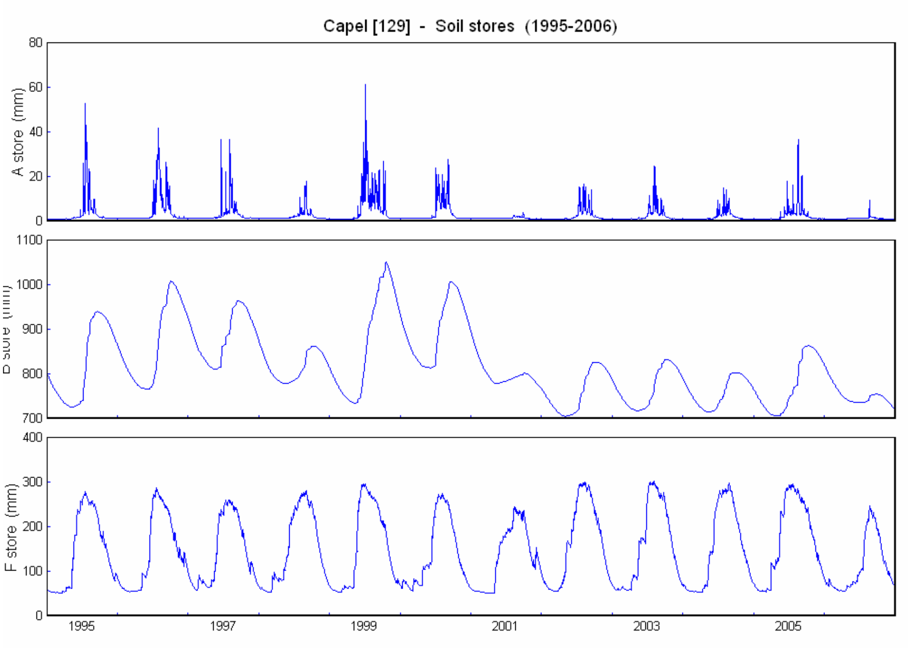
Daily = 0.876
Monthly = 0.932
Annual = 0.926






Capel [129] - Streamflow (1995-2006)
Annual streamflow (mm)
1600
1400
1200
1000
800
600
400
200
0
(354)
(133)
(6)
(2)
(14)
(10)
(94)
(111)
(7)
(69)
1996
1998
2000
2002
2004
2006


Capel [129] - Streamflow (1995-2006)
Observed
Predicted
Cumulative streamflow (mm)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1995
1997
1999
2001
2003
2005



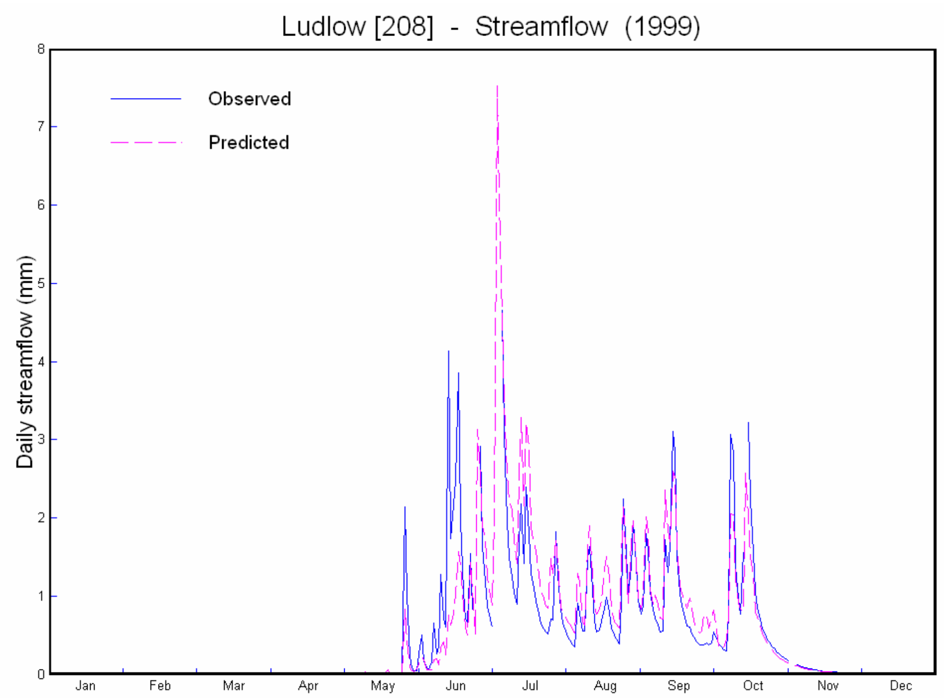
Cumulative precipitation :9992mm, representing 100 % of the rain
Cumulative precipitation after inteception :8374mm, representing 84 % of the rain
Cumulative interception :1617mm, representing 16 % of the rain
Cumulative evaporation :7591mm, representing 76 % of the rain and 91 % of the rain after interceptaion
Cumulative streamflow :864mm, representing 9 % of the rain and 10 % of the rain after interceptaion
Cumulative Water Balance : in 9992mm, representing100 % of the rain
: out 10072mm, representing101 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :945mm, representing 9 % of the rain and 12 % of the total evaporation
Cumulative evaporation form the F store :5072mm, representing 51 % of the rain and 67 % of the total evaporation
Cumulative evaporation form the B store :1574mm, representing 16 % of the rain and 21 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :648mm, representing 6 % of the rain and 75 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):216mm, representing 2 % of the rain and 25 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):0mm, representing 0 % of the rain and 0 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :2046mm, representing 20 % of the rain and 237 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):1382mm, representing 14 % of the rain and 68 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):664mm, representing 0 % of the rain and 32 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :44 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :1 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :530 mm
Average yearly Unsaturated zone discharge :90 mm
Average yearly Unsaturated zone evaporation :439 mm
...
Groundwater
Average yearly Groundwater recharge :549 mm
Average yearly Groundwater discharge :409 mm
Average yearly Groundwater evaporation :128 mm

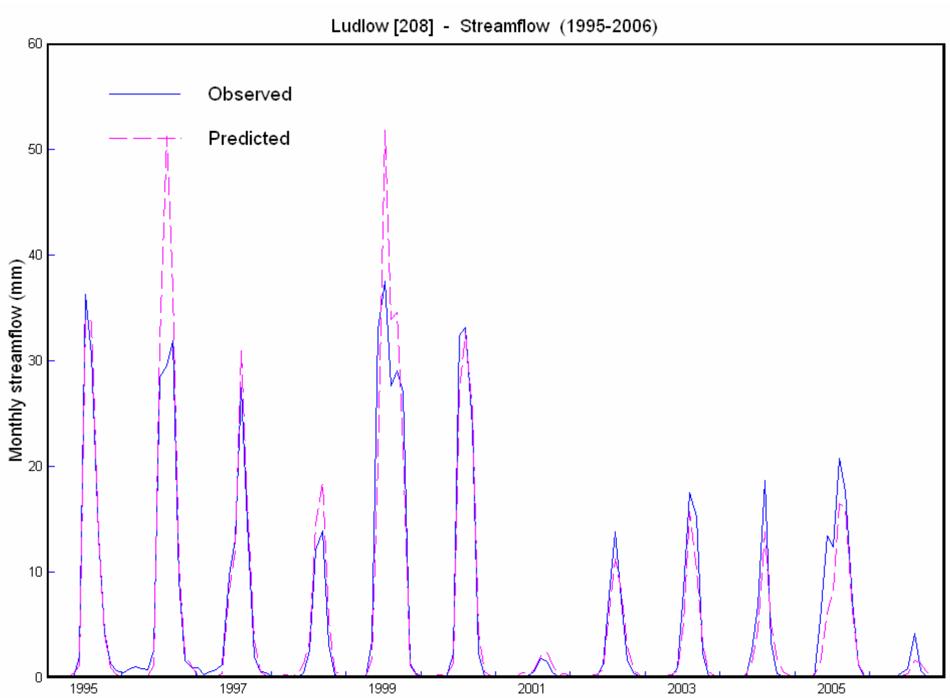
Lower Ludlow

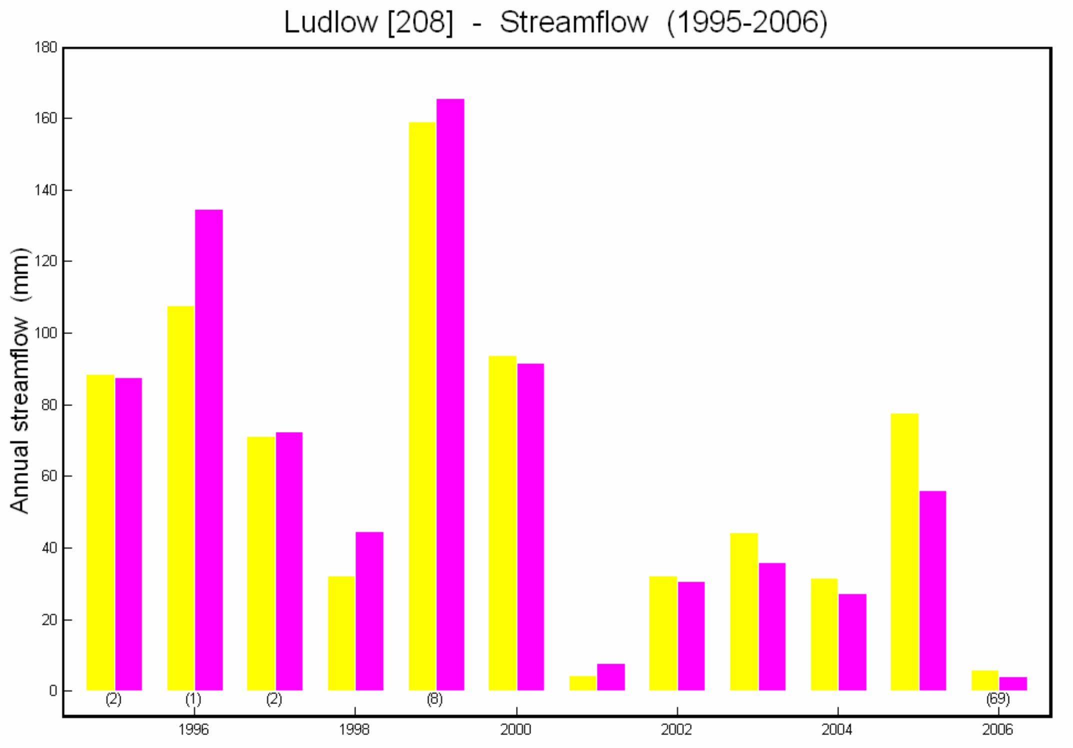
610009 (Ludlow)

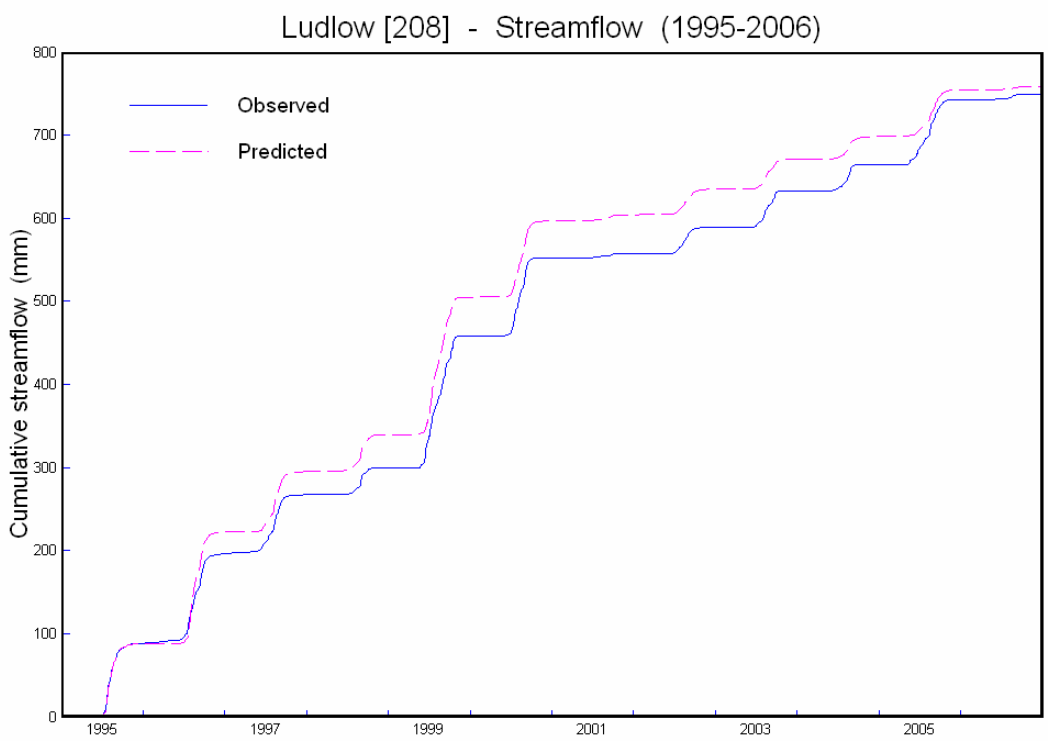
Efficiency:

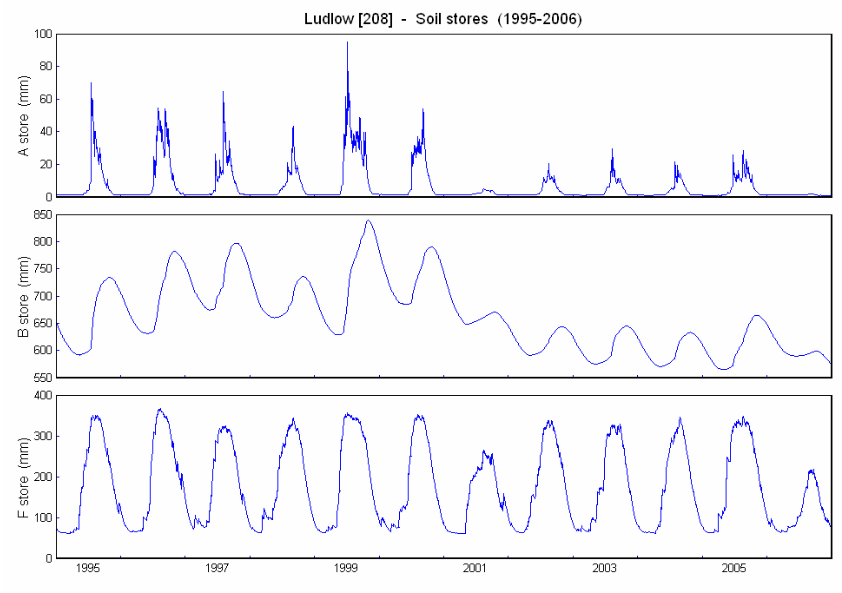
Daily = 0.819
Monthly = 0.898
Annual = 0.935






Ludlow [208] - Streamflow (1995-2006)
Annual streamflow (mm)
180
160
140
120
100
80
60
40
20
0
(2)
(1)
(2)
(8)
(69)
1996
1998
2000
2002
2004
2006


Ludlow [208] - Streamflow (1995-2006)
Observed
Predicted
Cumulative streamflow (mm)
800
700
600
500
400
300
200
100
0
1995
1997
1999
2001
2003
2005



Cumulative precipitation :9650mm, representing 100 % of the rain
Cumulative precipitation after inteception :8464mm, representing 88 % of the rain
Cumulative interception :1186mm, representing 12 % of the rain
Cumulative evaporation :7819mm, representing 81 % of the rain and 92 % of the rain after interceptaion
Cumulative streamflow :724mm, representing 8 % of the rain and 9 % of the rain after interceptaion
Cumulative Water Balance : in 9650mm, representing100 % of the rain
: out 9729mm, representing101 % of the rain

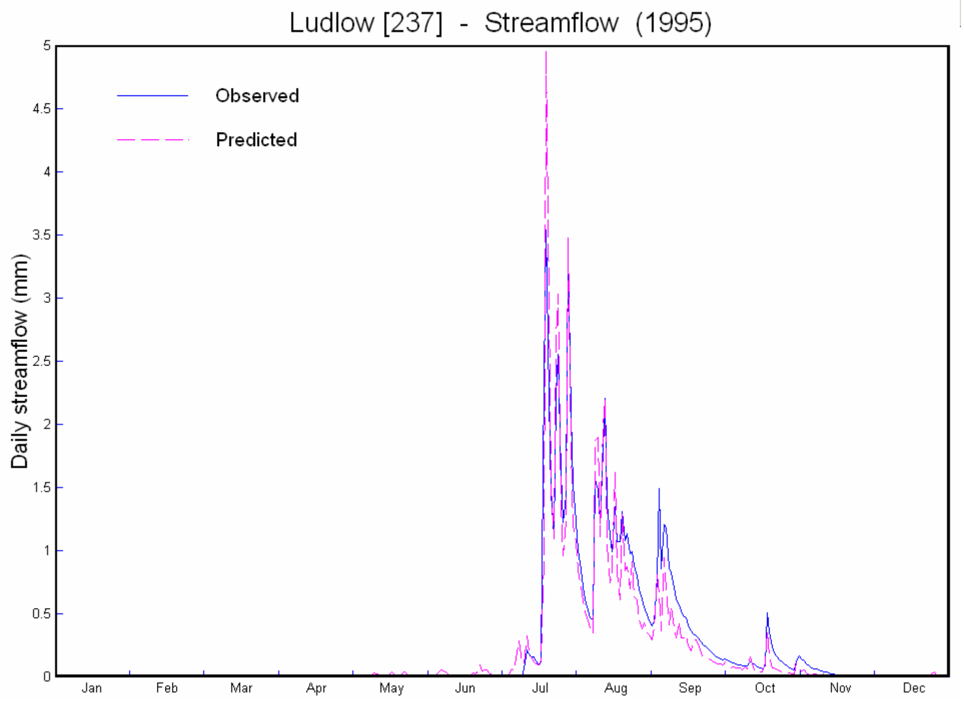
...
Cumulative evaporation
Cumulative evaporation form the A store :979mm, representing 10 % of the rain and 13 % of the total evaporation
Cumulative evaporation form the F store :5674mm, representing 59 % of the rain and 73 % of the total evaporation
Cumulative evaporation form the B store :1166mm, representing 12 % of the rain and 15 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :448mm, representing 5 % of the rain and 62 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):276mm, representing 3 % of the rain and 38 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):0mm, representing 0 % of the rain and 0 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :1605mm, representing 17 % of the rain and 222 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):1073mm, representing 11 % of the rain and 67 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):532mm, representing 0 % of the rain and 33 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :29 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :2 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :570 mm
Average yearly Unsaturated zone discharge :78 mm
Average yearly Unsaturated zone evaporation :491 mm
...
Groundwater
Average yearly Groundwater recharge :581 mm
Average yearly Groundwater discharge :493 mm
Average yearly Groundwater evaporation :80 mm

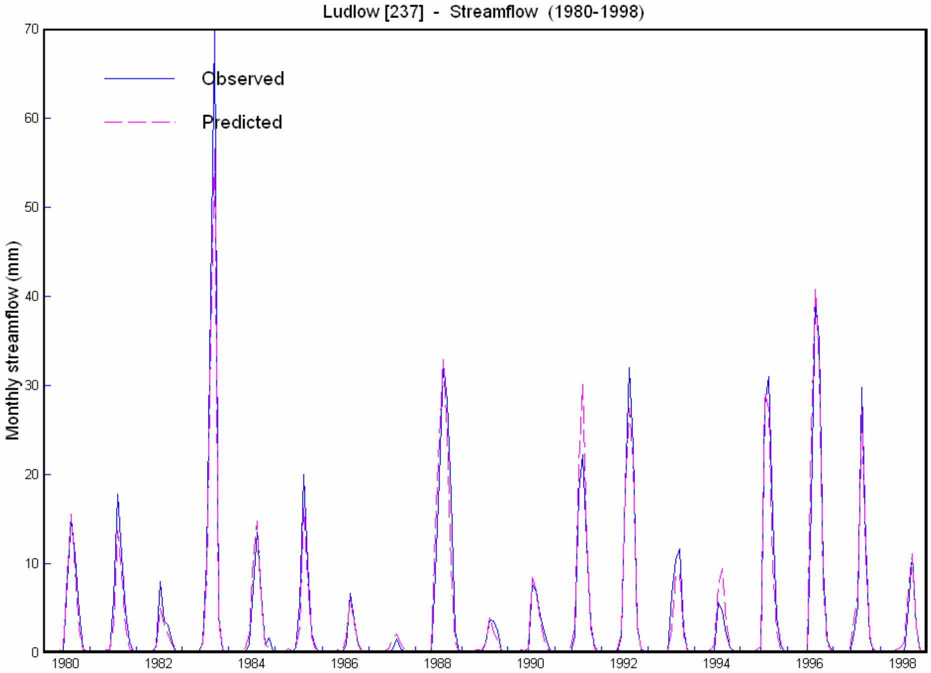
Upper Ludlow

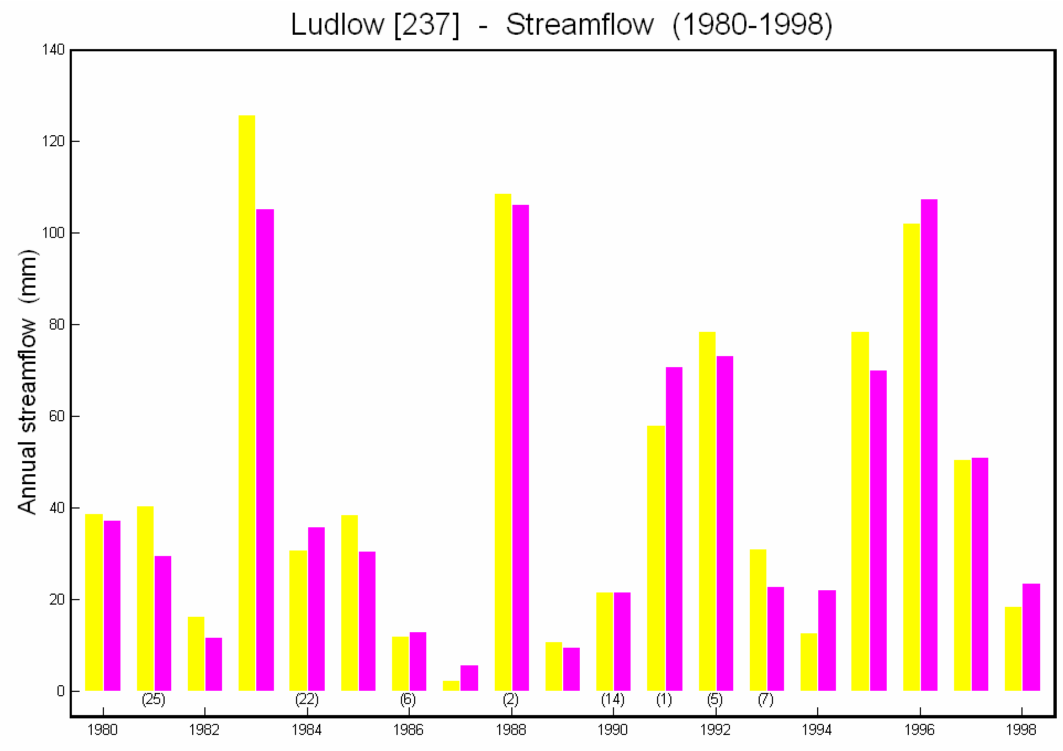
610005 (Happy Valley)

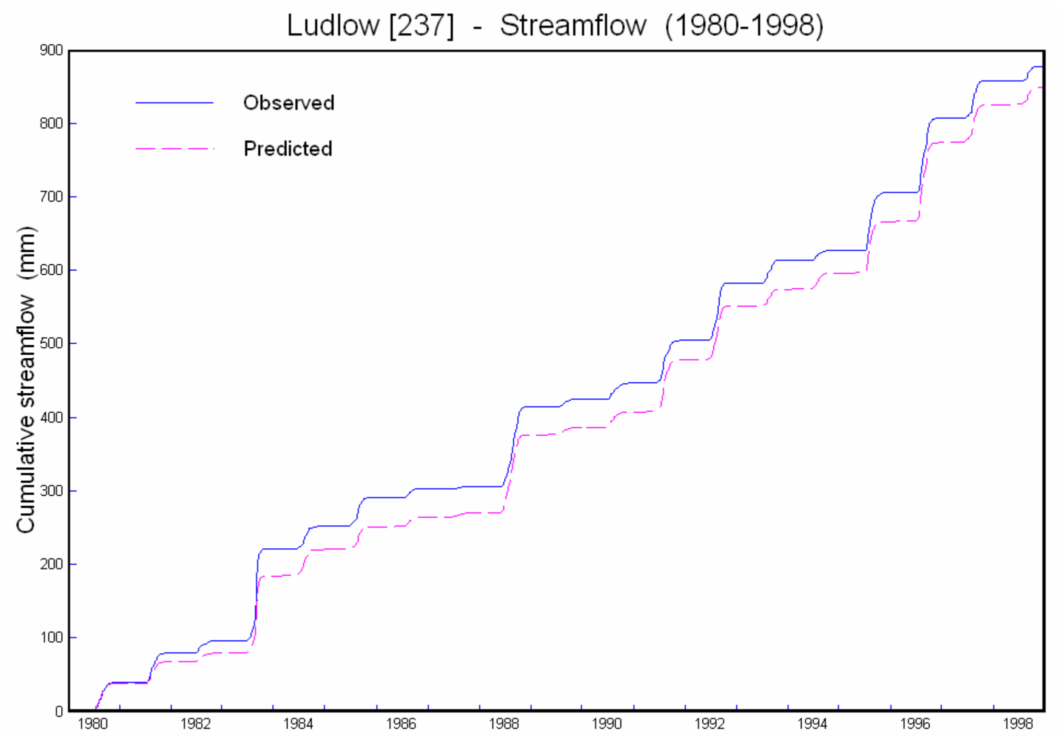
Efficiency:

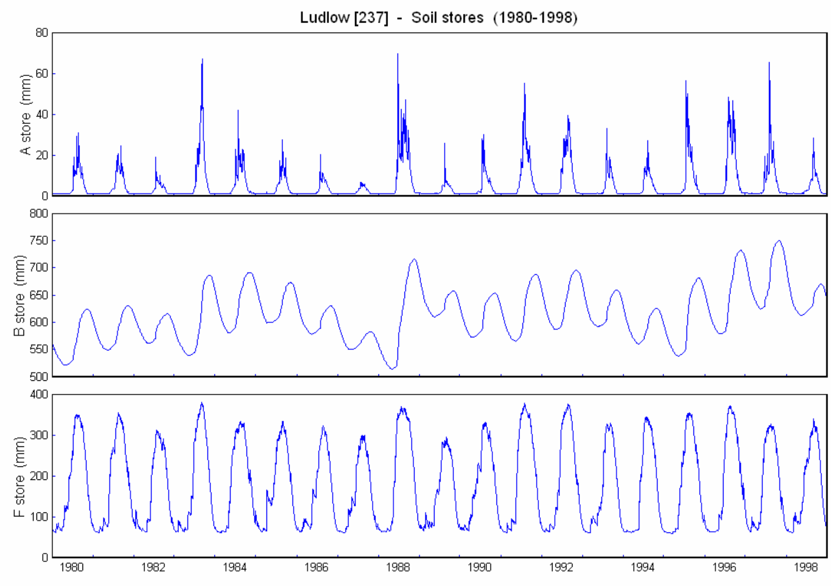
Daily = 0.867
Monthly = 0.947
Annual = 0.957






Ludlow [237] - Streamflow (1980-1998)
Annual streamflow (mm)
0
20
40
60
80
100
120
140
(25)
(22)
(6)
(2)
(14)
(1)
(5)
(7)
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998


Ludlow [237] - Streamflow (1980-1998)
Cumulative streamflow (mm)
Observed
Predicted
0
100
200
300
400
500
600
700
800
900
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998



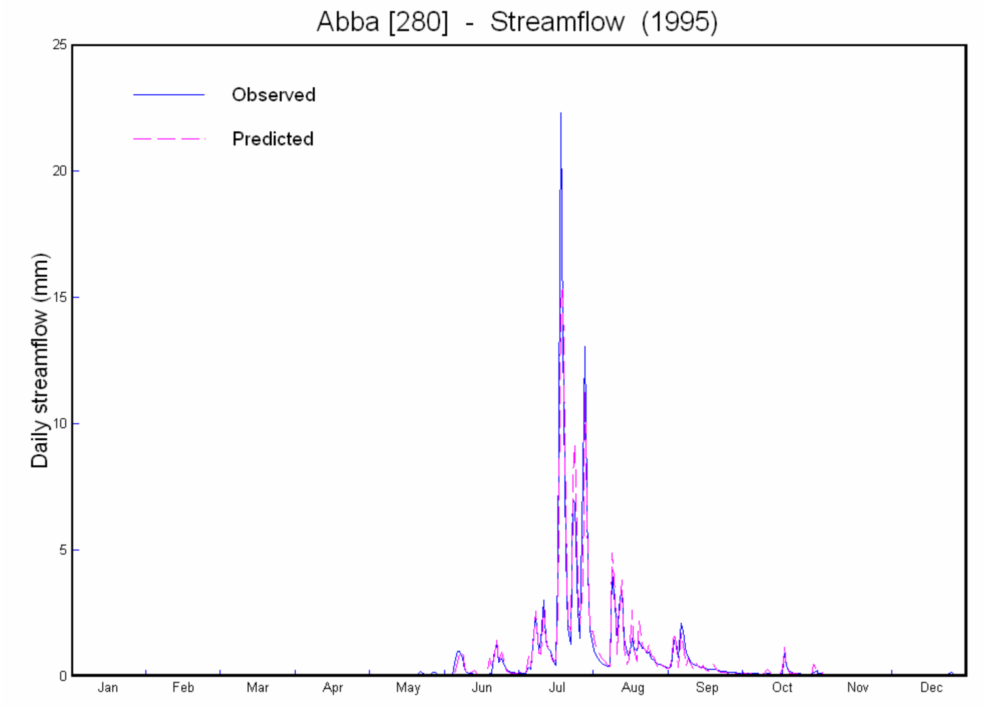
Cumulative precipitation :10197mm, representing 100 % of the rain
Cumulative precipitation after inteception :8473mm, representing 83 % of the rain
Cumulative interception :1725mm, representing 17 % of the rain
Cumulative evaporation :8002mm, representing 78 % of the rain and 94 % of the rain after interceptaion
Cumulative streamflow :534mm, representing 5 % of the rain and 6 % of the rain after interceptaion
Cumulative Water Balance : in 10197mm, representing100 % of the rain
: out 10261mm, representing101 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :945mm, representing 9 % of the rain and 12 % of the total evaporation
Cumulative evaporation form the F store :6025mm, representing 59 % of the rain and 75 % of the total evaporation
Cumulative evaporation form the B store :1032mm, representing 10 % of the rain and 13 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :323mm, representing 3 % of the rain and 61 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):211mm, representing 2 % of the rain and 39 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):0mm, representing 0 % of the rain and 0 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :1355mm, representing 13 % of the rain and 254 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):821mm, representing 8 % of the rain and 61 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):533mm, representing 0 % of the rain and 39 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :25 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :1 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :599 mm
Average yearly Unsaturated zone discharge :76 mm
Average yearly Unsaturated zone evaporation :522 mm
...
Groundwater
Average yearly Groundwater recharge :524 mm
Average yearly Groundwater discharge :446 mm
Average yearly Groundwater evaporation :72 mm

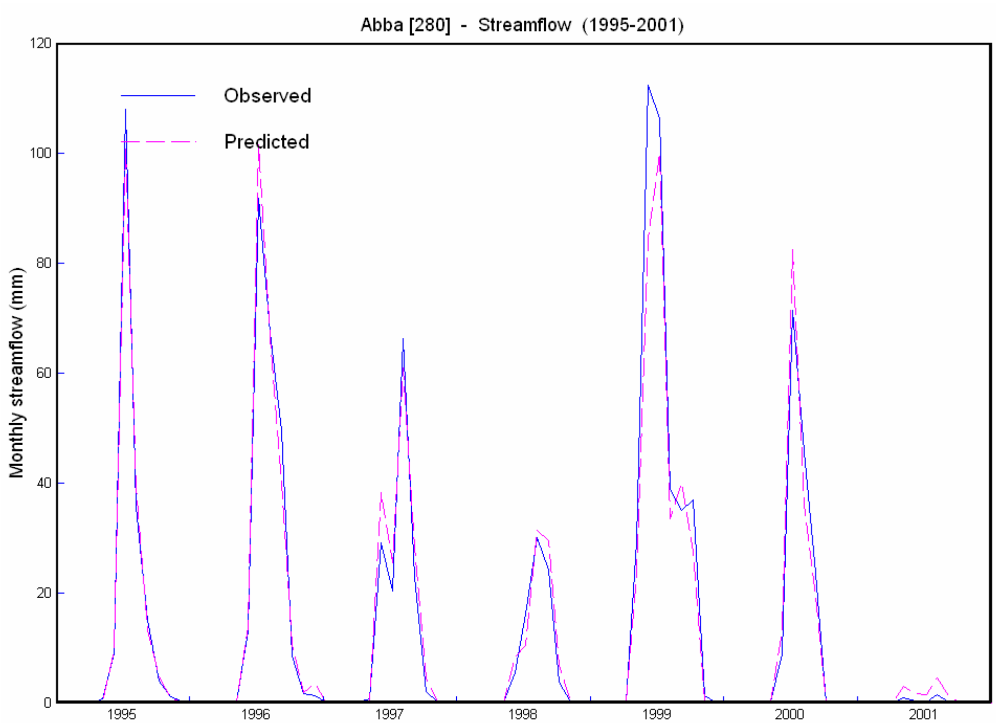
Abba River

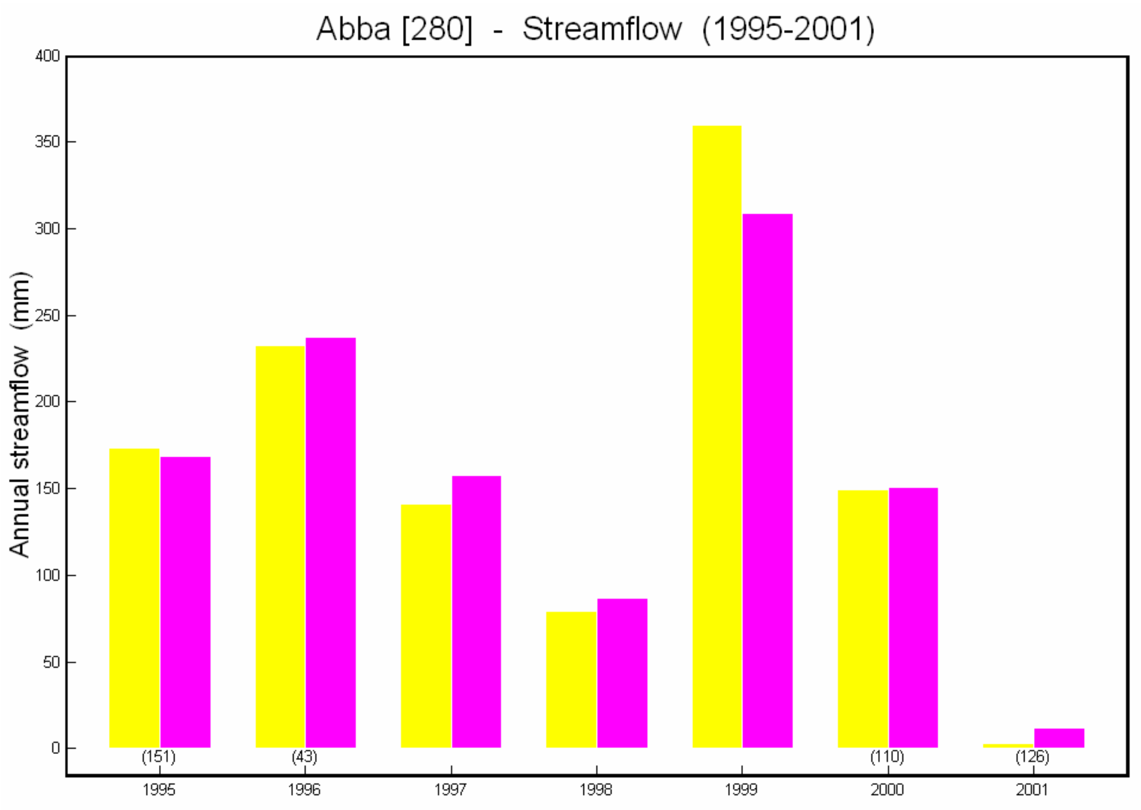
610016 (Wonnerup Siding)

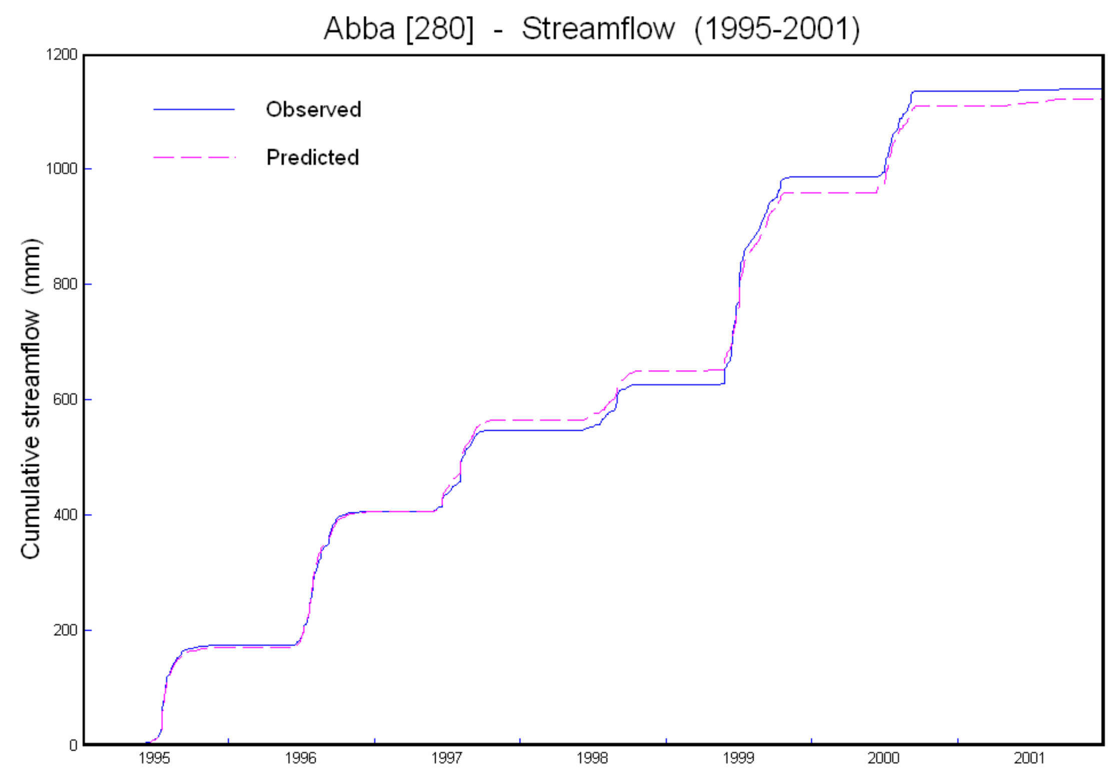
Efficiency:

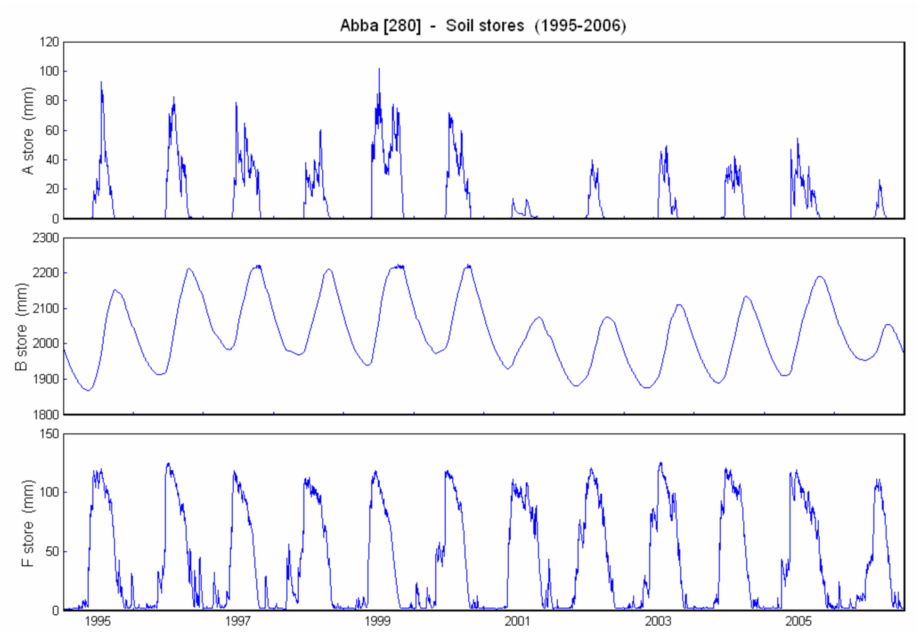
Daily = 0.833
Monthly = 0.968
Annual = 0.961






Abba [280] - Streamflow (1995-2001)
Annual streamflow (mm)
400
350
300
250
200
150
100
50
0
(151)
(43)
(110)
(126)
1995
1996
1997
1998
1999
2000
2001


Abba [280] - Streamflow (1995-2001)
Cumulative streamflow (mm)
Observed
Predicted
1200
1000
800
600
400
200
0
1995
1996
1997
1998
1999
2000
2001



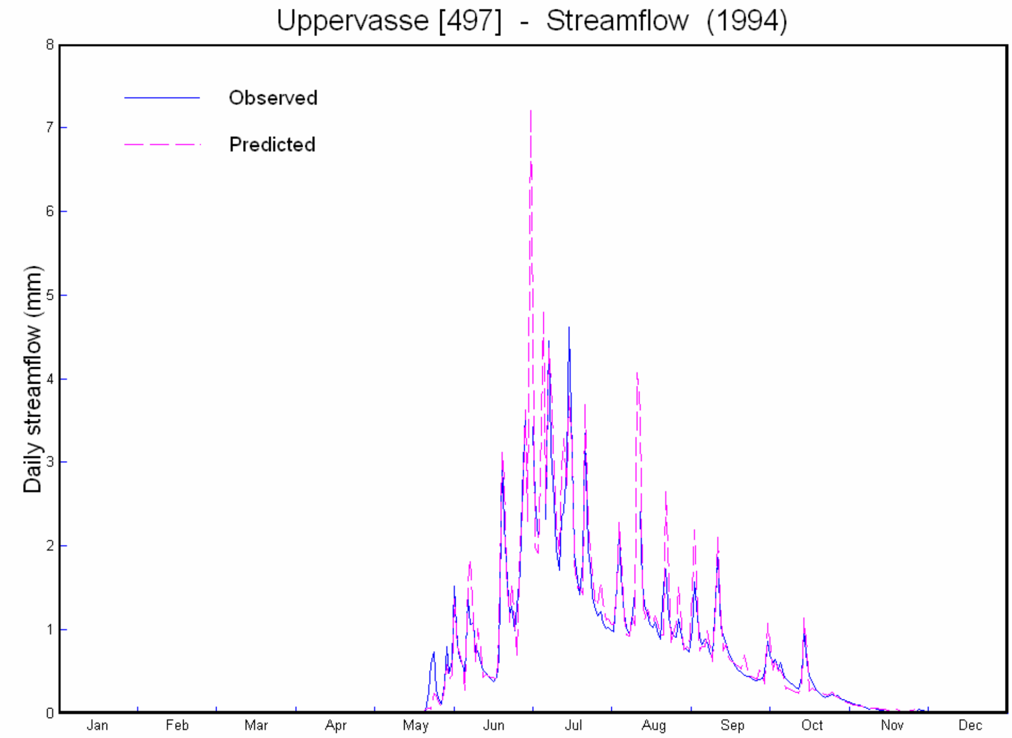
Cumulative precipitation :9668mm, representing 100 % of the rain
Cumulative precipitation after inteception :8807mm, representing 91 % of the rain
Cumulative interception :860mm, representing 9 % of the rain
Cumulative evaporation :7549mm, representing 78 % of the rain and 86 % of the rain after interceptaion
Cumulative streamflow :1281mm, representing 13 % of the rain and 15 % of the rain after interceptaion
Cumulative Water Balance : in 9668mm, representing100 % of the rain
: out 9690mm, representing100 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :561mm, representing 6 % of the rain and 7 % of the total evaporation
Cumulative evaporation form the F store :3604mm, representing 37 % of the rain and 48 % of the total evaporation
Cumulative evaporation form the B store :3384mm, representing 35 % of the rain and 45 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :343mm, representing 4 % of the rain and 27 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):877mm, representing 9 % of the rain and 68 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):62mm, representing 1 % of the rain and 5 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :2424mm, representing 25 % of the rain and 189 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):1157mm, representing 12 % of the rain and 48 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):1267mm, representing 1 % of the rain and 52 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :50 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :4 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :492 mm
Average yearly Unsaturated zone discharge :166 mm
Average yearly Unsaturated zone evaporation :326 mm
...
Groundwater
Average yearly Groundwater recharge :394 mm
Average yearly Groundwater discharge :110 mm
Average yearly Groundwater evaporation :239 mm

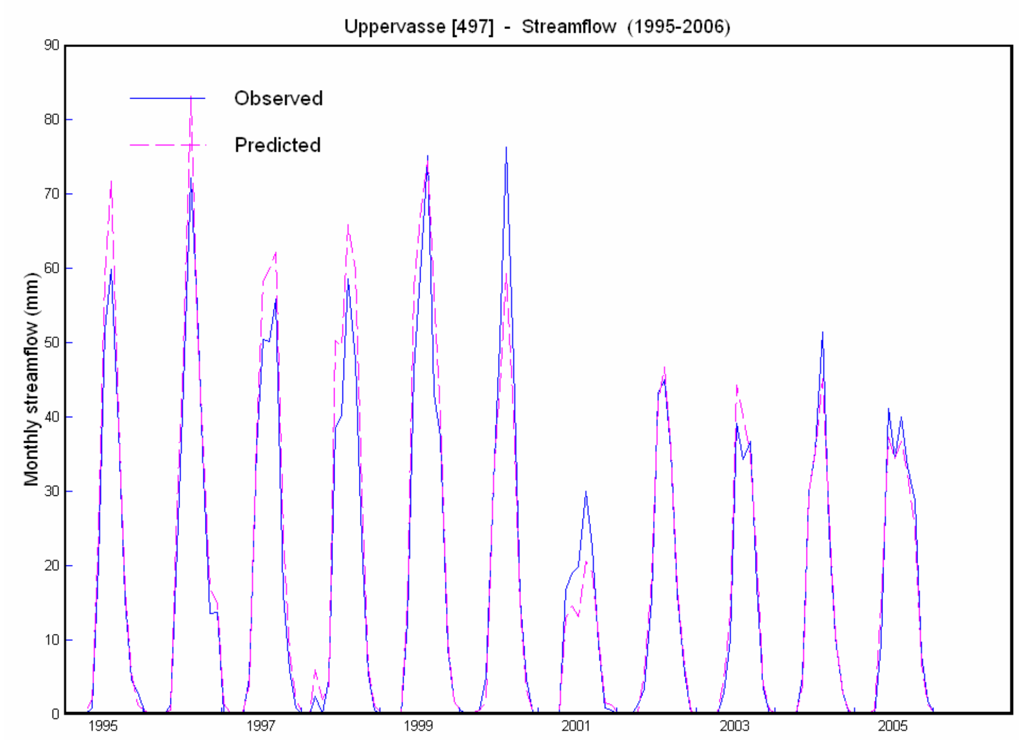
Upper Vasse River

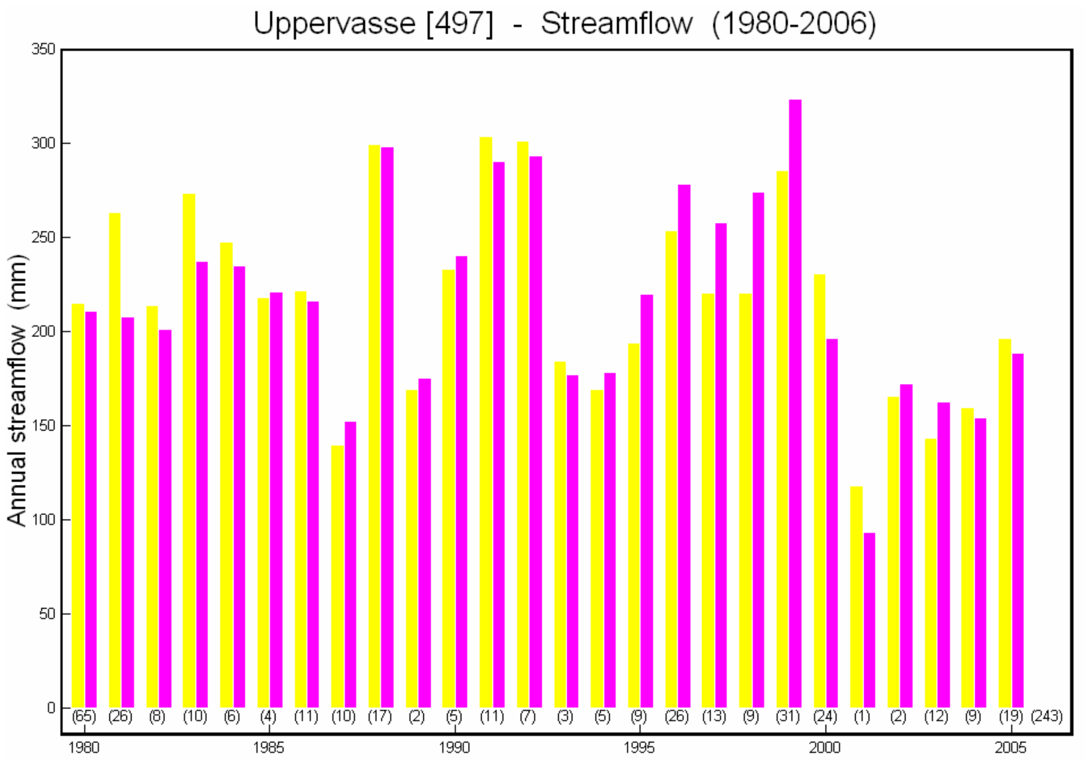
610003 (Chapman Hill)

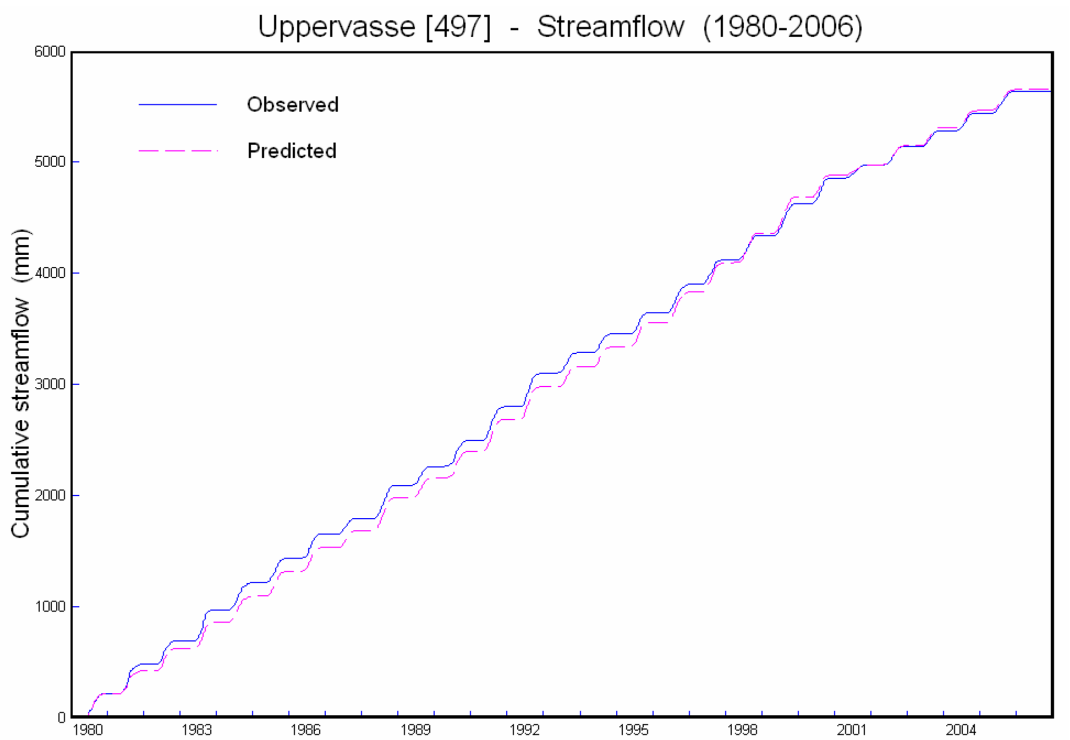
Efficiency:

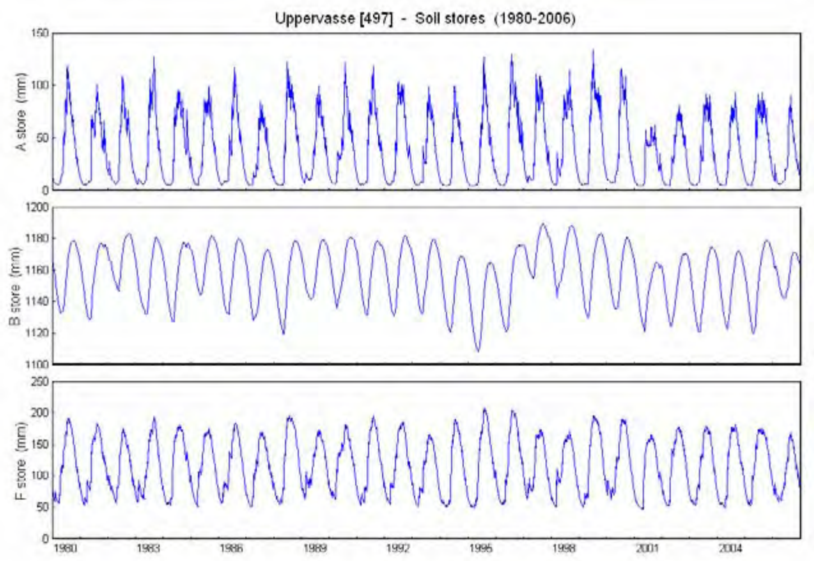
Daily = 0.905
Monthly = 0.960
Annual = 0.795






Uppervasse [497] - Streamflow (1980-2006)
Annual streamflow (mm)
350
300
250
200
150
100
50
0
(65) (26) (8) (10) (6) (4) (11) (10) (17) (2) (5) (11) (7) (3) (5) (9) (26) (13) (9) (31) (24) (1) (2) (12) (9) (19) (243)
1980
1985
1990
1995
2000
2005


Uppervasse [497] - Streamflow (1980-2006)
Observed
Predicted
Cumulative streamflow (mm)
6000
5000
4000
3000
2000
1000
0
1980
1983
1986
1989
1992
1995
1998
2001
2004



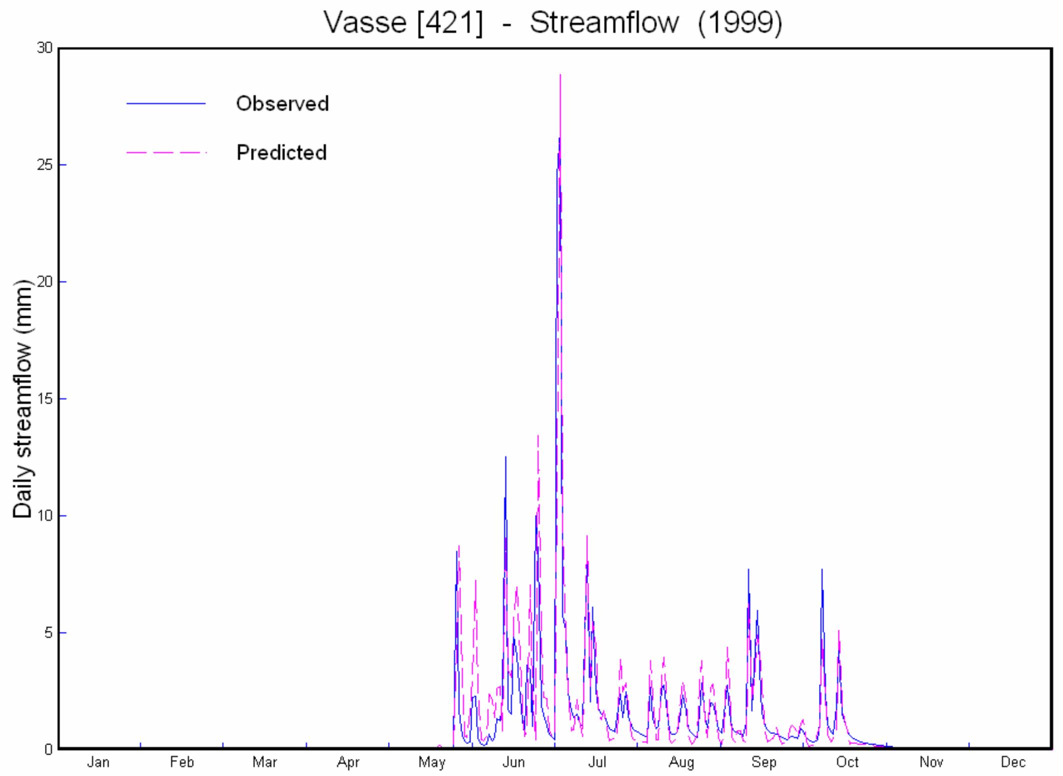
Cumulative precipitation :9692mm, representing 100 % of the rain
Cumulative precipitation after inteception :9112mm, representing 94 % of the rain
Cumulative interception :580mm, representing 6 % of the rain
Cumulative evaporation :4937mm, representing 51 % of the rain and 54 % of the rain after interceptaion
Cumulative streamflow :4158mm, representing 43 % of the rain and 46 % of the rain after interceptaion
Cumulative Water Balance : in 9692mm, representing100 % of the rain
: out 9675mm, representing100 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :1768mm, representing 18 % of the rain and 36 % of the total evaporation
Cumulative evaporation form the F store :2098mm, representing 22 % of the rain and 43 % of the total evaporation
Cumulative evaporation form the B store :1071mm, representing 11 % of the rain and 22 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :2494mm, representing 26 % of the rain and 60 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):1521mm, representing 16 % of the rain and 37 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):142mm, representing 1 % of the rain and 3 % of the total streamflow
Cumulative Groundwater discharge :2658mm, representing 27 % of the rain and 107 % of the interflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :3797mm, representing 39 % of the rain and 91 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):1305mm, representing 13 % of the rain and 34 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):2492mm, representing 1 % of the rain and 66 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :40 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :10 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :329 mm
Average yearly Unsaturated zone discharge :138 mm
Average yearly Unsaturated zone evaporation :190 mm
...
Groundwater
Average yearly Groundwater recharge :319 mm
Average yearly Groundwater discharge :211 mm
Average yearly Groundwater evaporation :85 mm

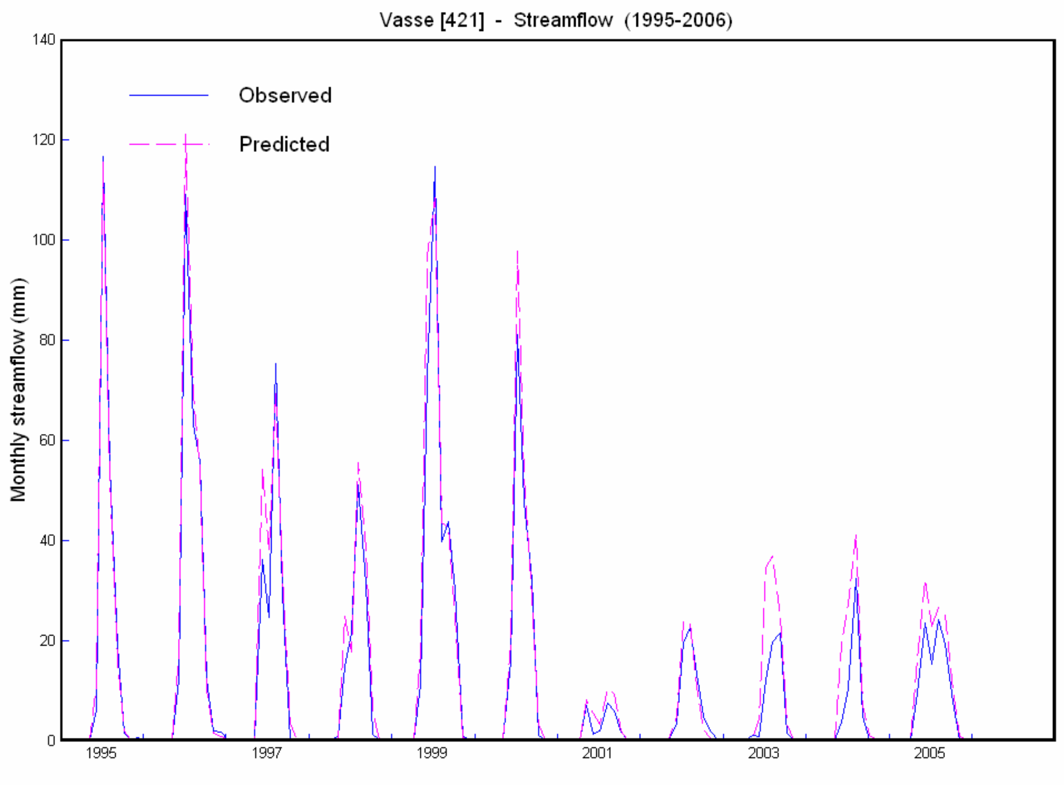
Vasse Diversion Drain

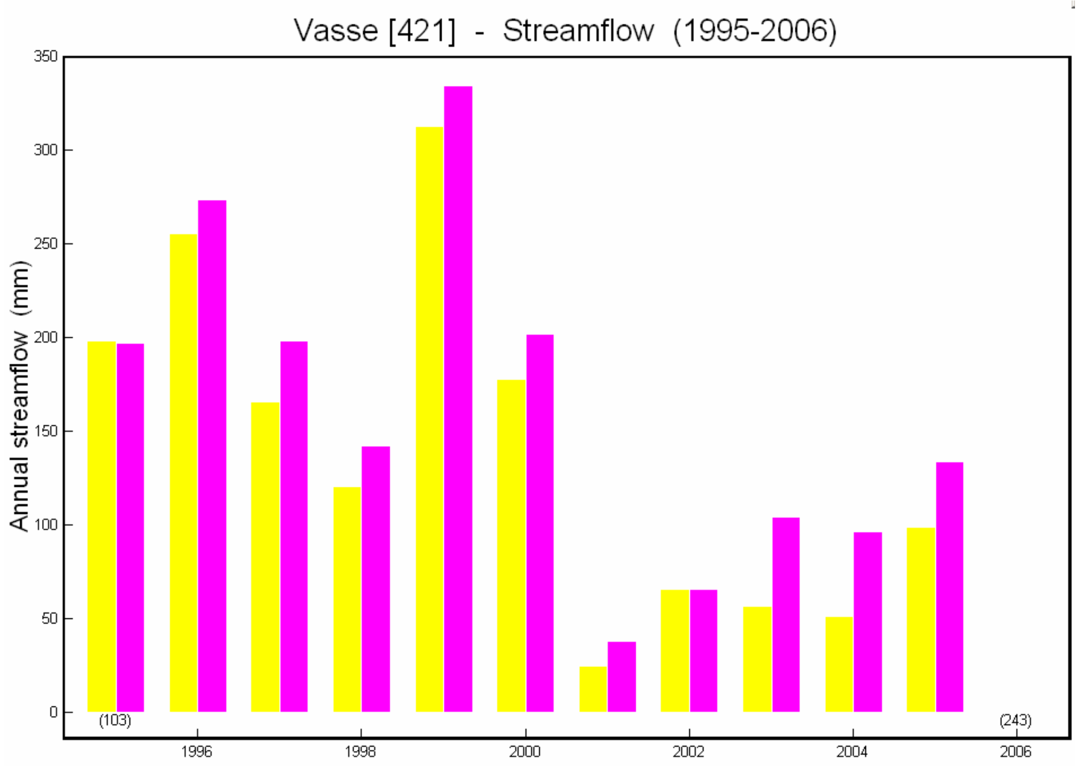
610014 (D-S Hill Road)

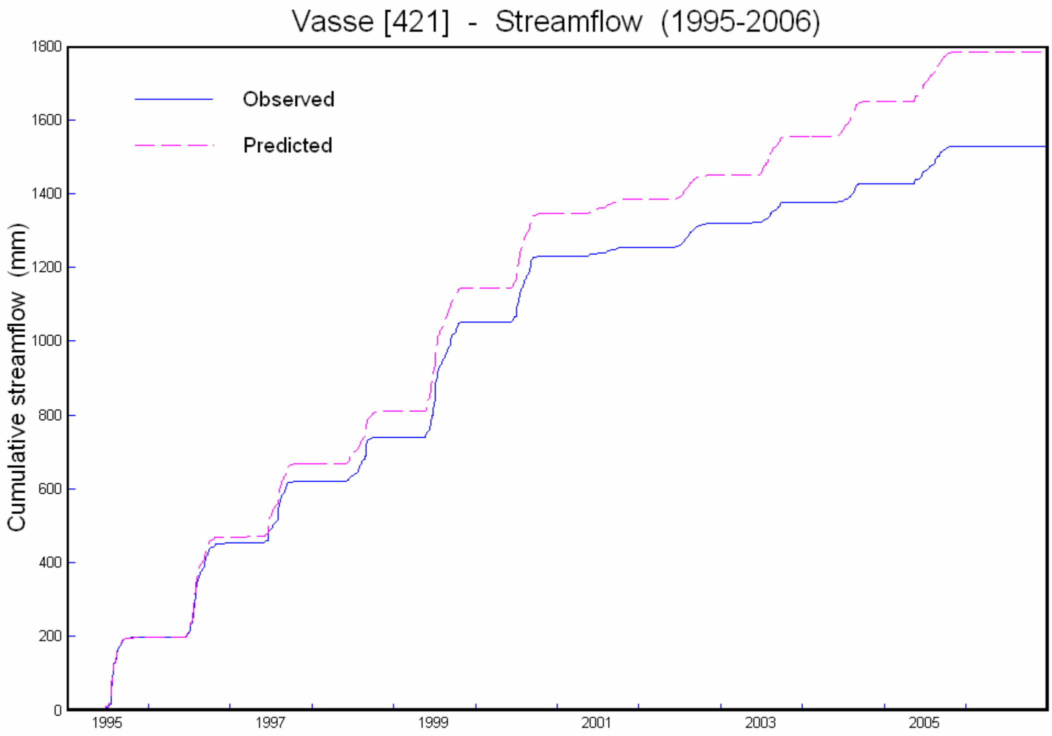
Efficiency:

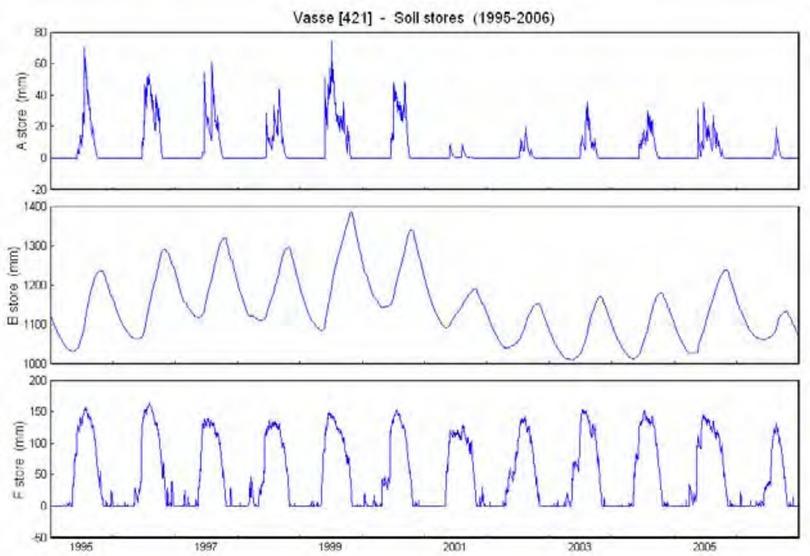
Daily = 0.747
Monthly = 0.945
Annual = 0.916






Vasse [421] - Streamflow (1995-2006)
Annual streamflow (mm)
350
300
250
200
150
100
50
0
(103)
(243)
1996
1998
2000
2002
2004
2006


Vasse [421] - Streamflow (1995-2006)
Cumulative streamflow (mm)
Observed
Predicted
1800
1600
1400
1200
1000
800
600
400
200
0
1995
1997
1999
2001
2003
2005

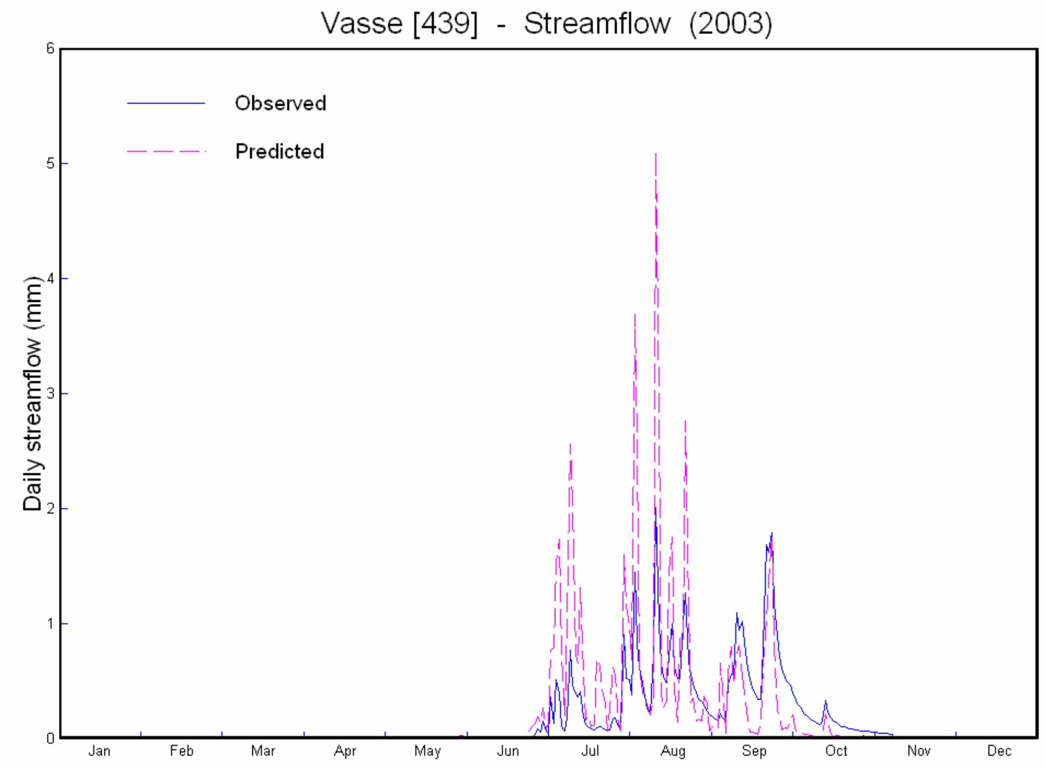


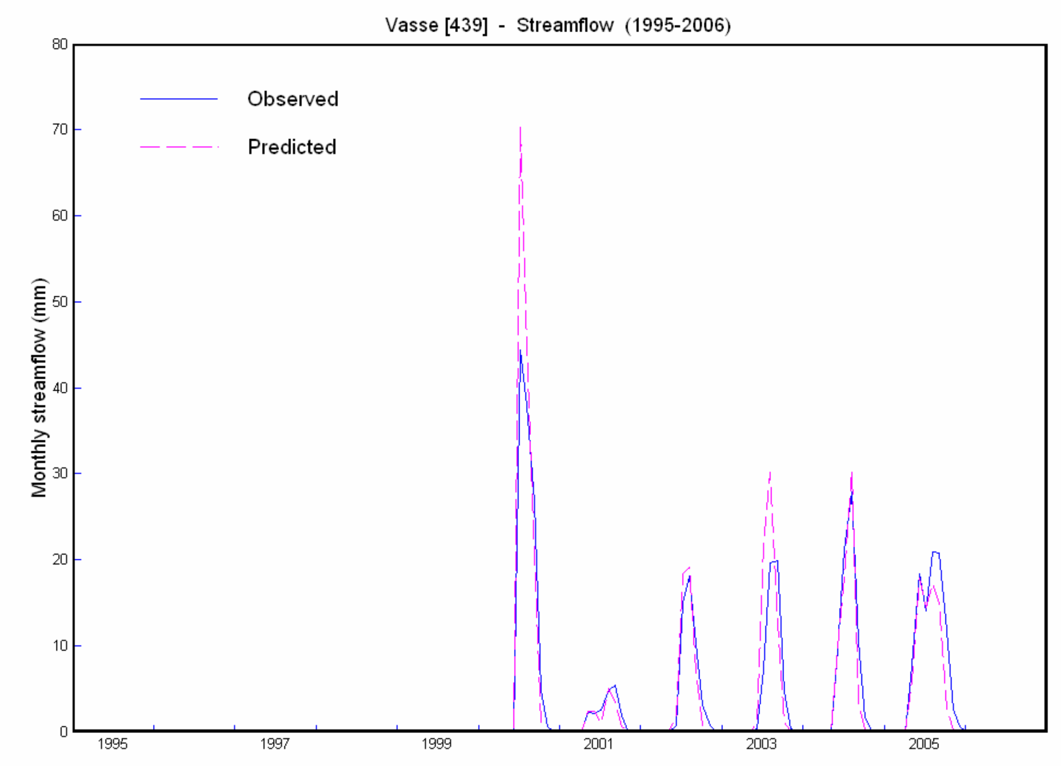
Cumulative precipitation :29898mm, representing 100 % of the rain
Cumulative precipitation after inteception :26308mm, representing 88 % of the rain
Cumulative interception :3591mm, representing 12 % of the rain
Cumulative evaporation :22246mm, representing 74 % of the rain and 85 % of the rain after interceptaion
Cumulative streamflow :3420mm, representing 11 % of the rain and 13 % of the rain after interceptaion
Cumulative Water Balance : in 29898mm, representing100 % of the rain
: out 29257mm, representing98 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :425mm, representing 1 % of the rain and 2 % of the total evaporation
Cumulative evaporation form the F store :15722mm, representing 53 % of the rain and 71 % of the total evaporation
Cumulative evaporation form the B store :6100mm, representing 20 % of the rain and 27 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :580mm, representing 2 % of the rain and 17 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):2821mm, representing 9 % of the rain and 82 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):20mm, representing 0 % of the rain and 1 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :4364mm, representing 15 % of the rain and 128 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):0mm, representing 0 % of the rain and 0 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):4364mm, representing 0 % of the rain and 100 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :74 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :5 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :516 mm
Average yearly Unsaturated zone discharge :92 mm
Average yearly Unsaturated zone evaporation :425 mm
...
Groundwater
Average yearly Groundwater recharge :187 mm
Average yearly Groundwater discharge :2 mm
Average yearly Groundwater evaporation :165 mm

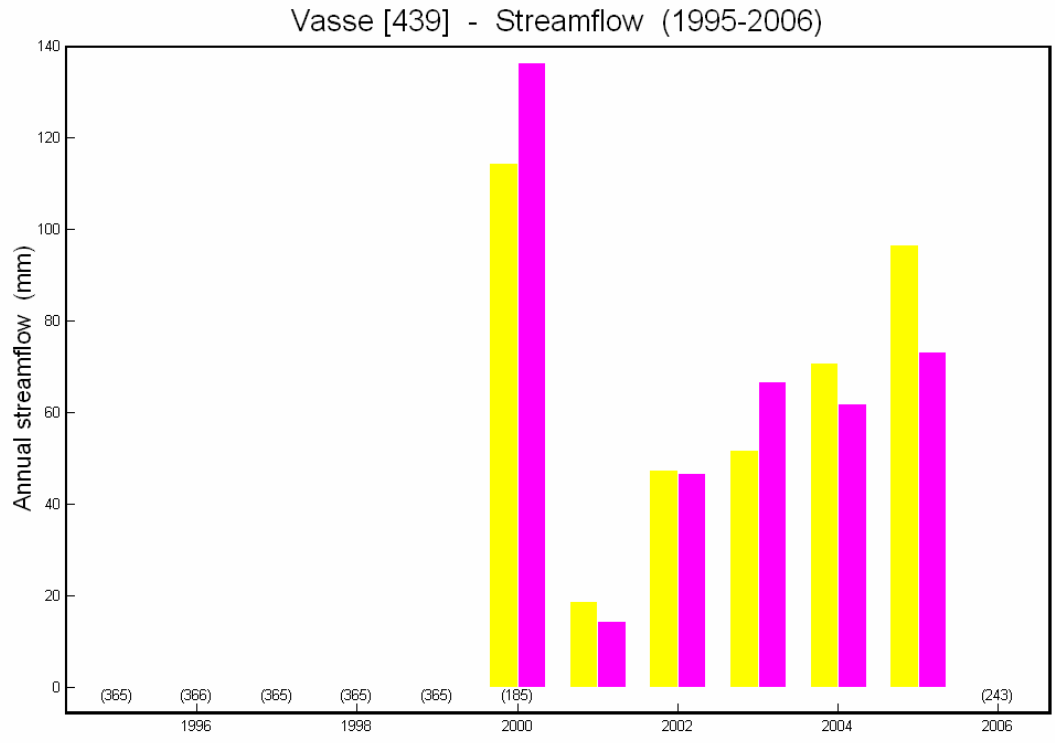
Sabina Diversion Drain
610025 (Wonnerup East Road)

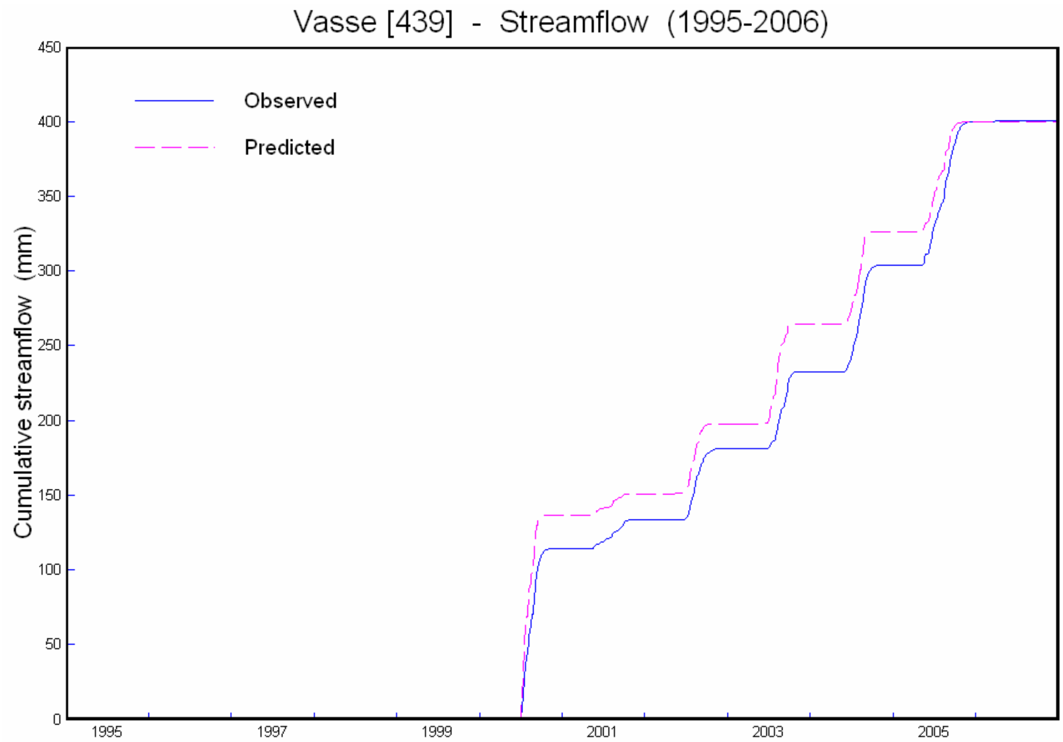
Efficiency:

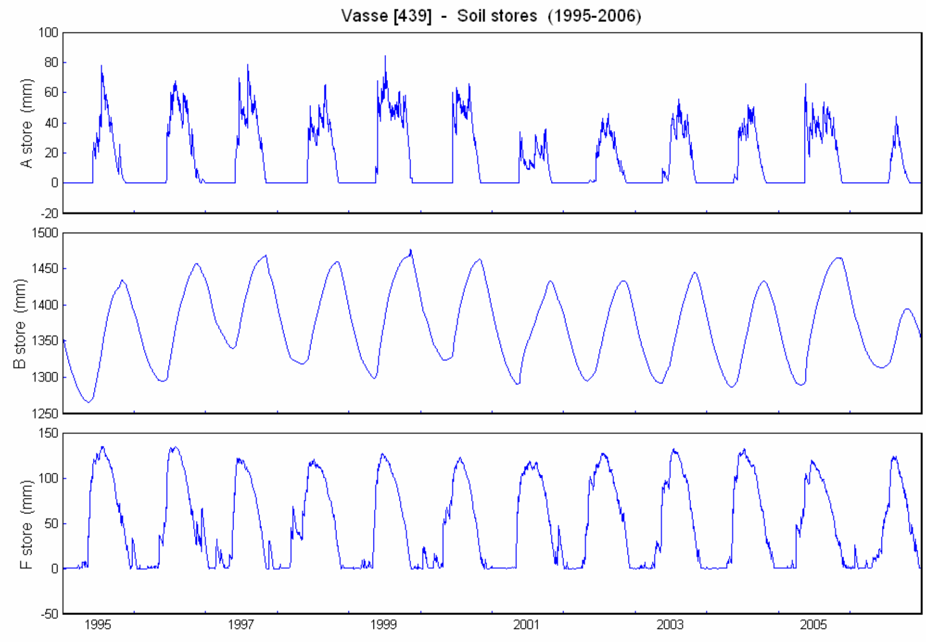
Daily = 0.360
Monthly = 0.688
Annual = 0.863






Vasse [439] - Streamflow (1995-2006)
Annual streamflow (mm)
0
20
40
60
80
100
120
140
(365)
(366)
(365)
(365)
(365)
(185)
(243)
1996
1998
2000
2002
2004
2006


Vasse [439] - Streamflow (1995-2006)
Observed
Predicted
Cumulative streamflow (mm)
0
50
100
150
200
250
300
350
400
450
1995
1997
1999
2001
2003
2005



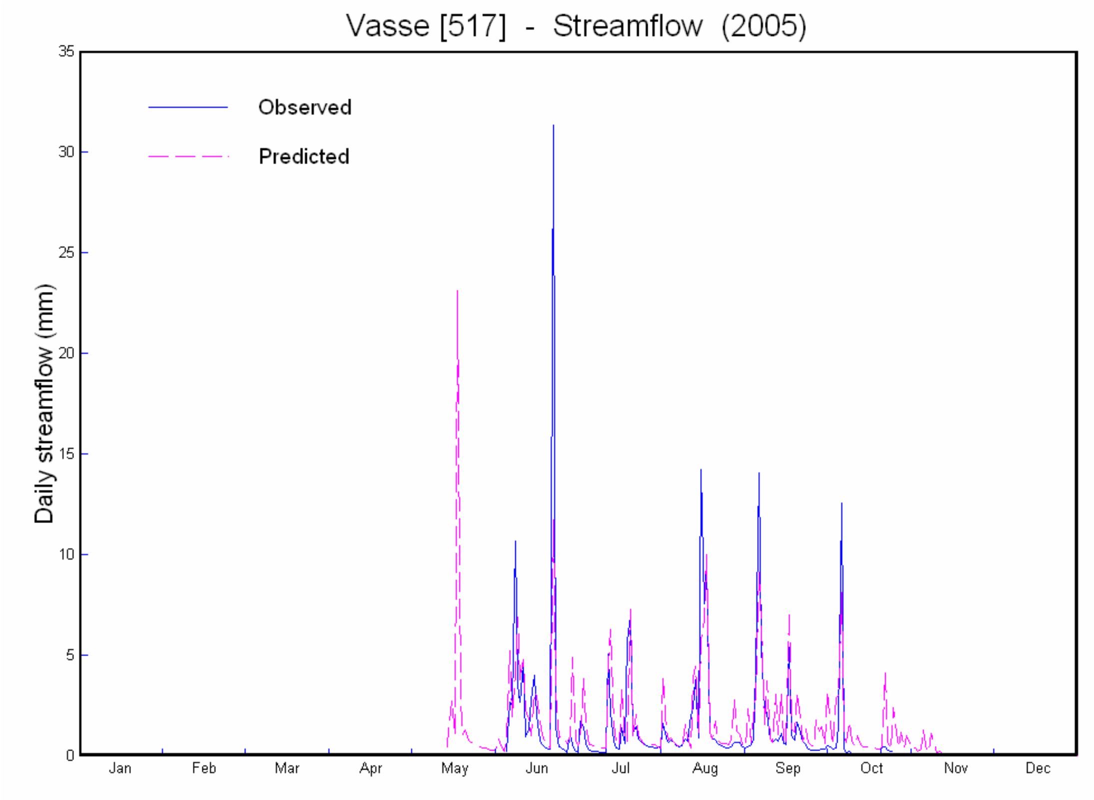
Cumulative precipitation :9902mm, representing 100 % of the rain
Cumulative precipitation after inteception :9389mm, representing 95 % of the rain
Cumulative interception :513mm, representing 5 % of the rain
Cumulative evaporation :6245mm, representing 63 % of the rain and 67 % of the rain after interceptaion
Cumulative streamflow :3154mm, representing 32 % of the rain and 34 % of the rain after interceptaion
Cumulative Water Balance : in 9902mm, representing100 % of the rain
: out 9912mm, representing100 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :443mm, representing 4 % of the rain and 7 % of the total evaporation
Cumulative evaporation form the F store :3260mm, representing 33 % of the rain and 52 % of the total evaporation
Cumulative evaporation form the B store :2541mm, representing 26 % of the rain and 41 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :673mm, representing 7 % of the rain and 21 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):2465mm, representing 25 % of the rain and 78 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):16mm, representing 0 % of the rain and 1 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :2578mm, representing 26 % of the rain and 82 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):0mm, representing 0 % of the rain and 0 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):2578mm, representing 0 % of the rain and 100 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :84 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :13 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :389 mm
Average yearly Unsaturated zone discharge :100 mm
Average yearly Unsaturated zone evaporation :290 mm
...
Groundwater
Average yearly Groundwater recharge :222 mm
Average yearly Groundwater discharge :2 mm
Average yearly Groundwater evaporation :191 mm

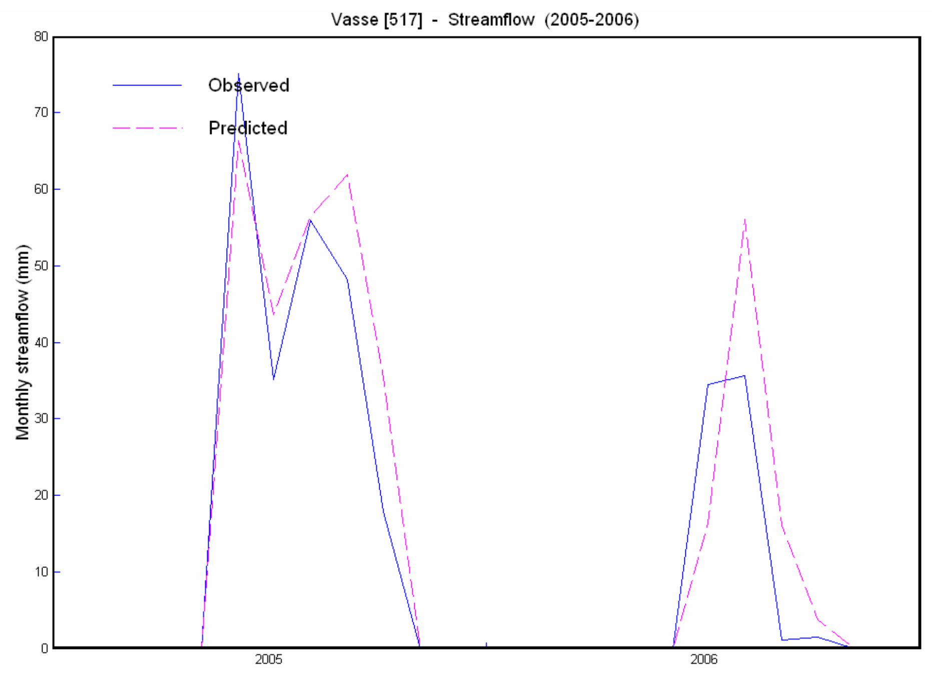
Vasse Research Station

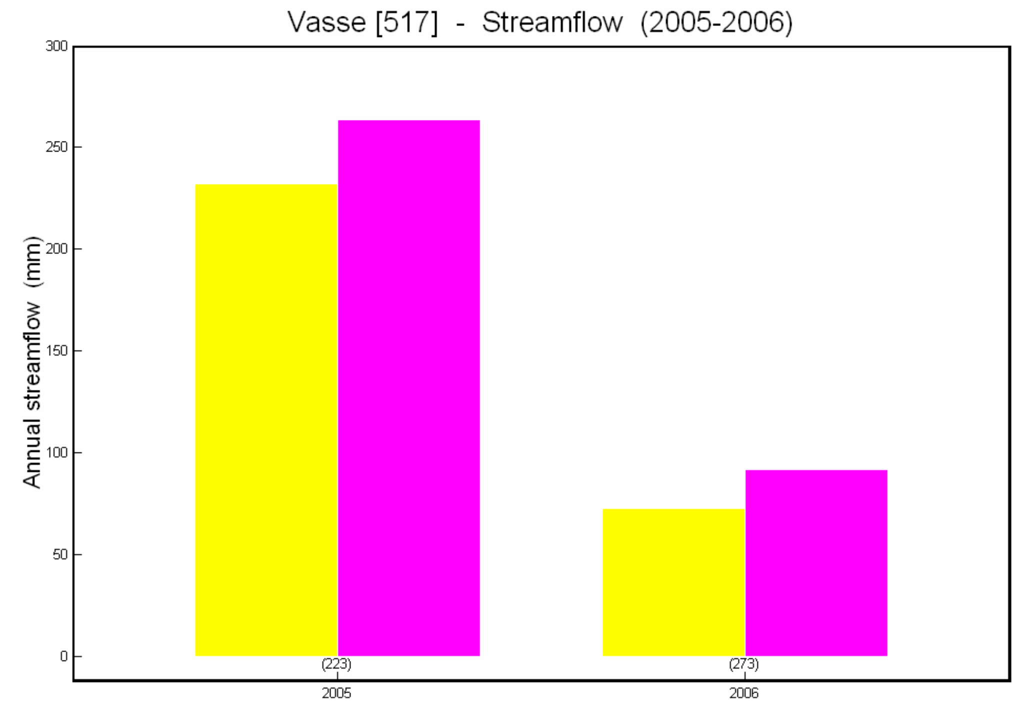
610012 (Vasse Research Station)

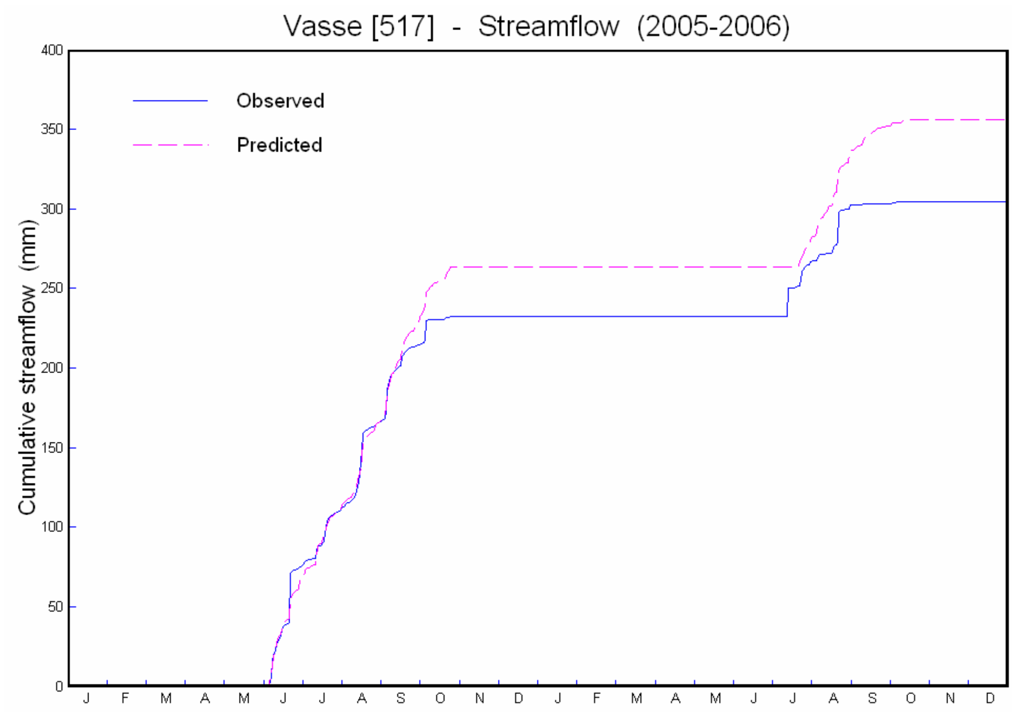
Efficiency:

Daily = 0.427
Monthly = 0.661
Annual = 0.982

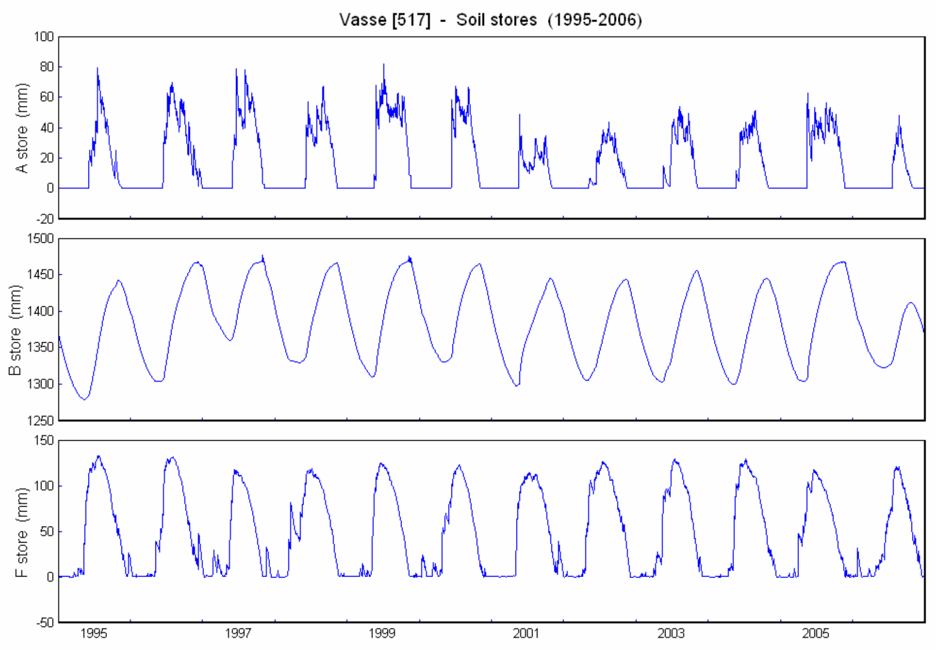








* Large errors are likely to exist in 1996 because the drainage pattern changed between 1995 and 2005, this is reflected in the poor calibration, as *SQUARE* cannot change drainage patterns mid-calibration

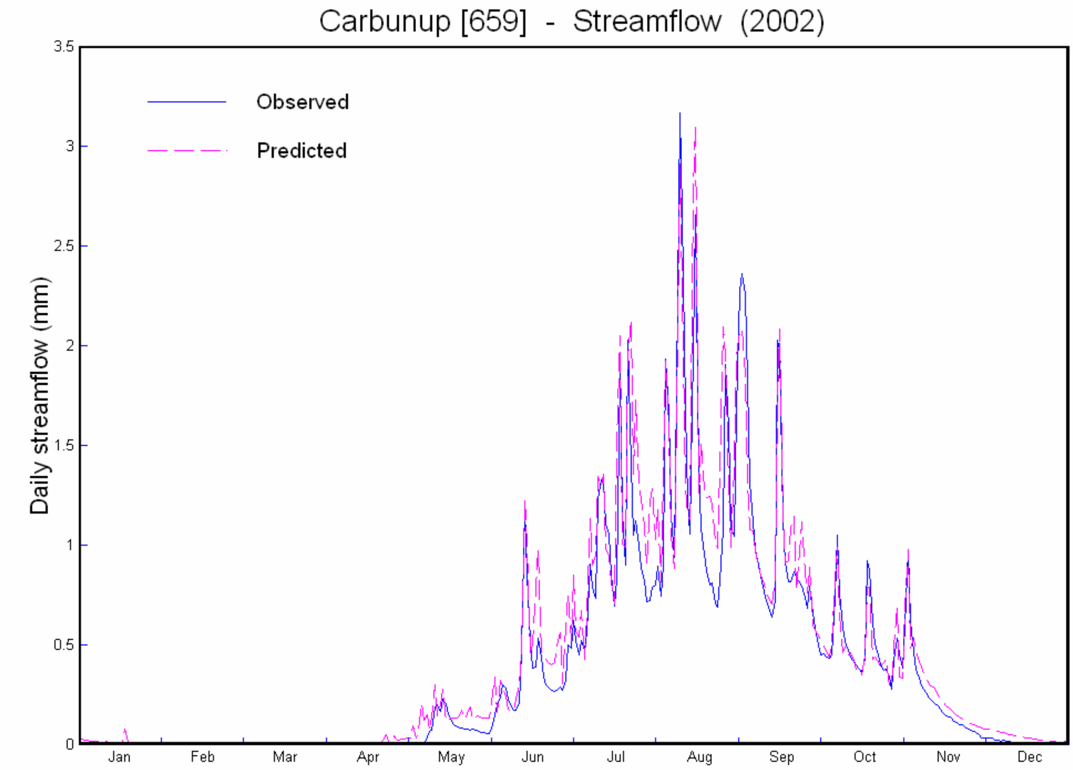


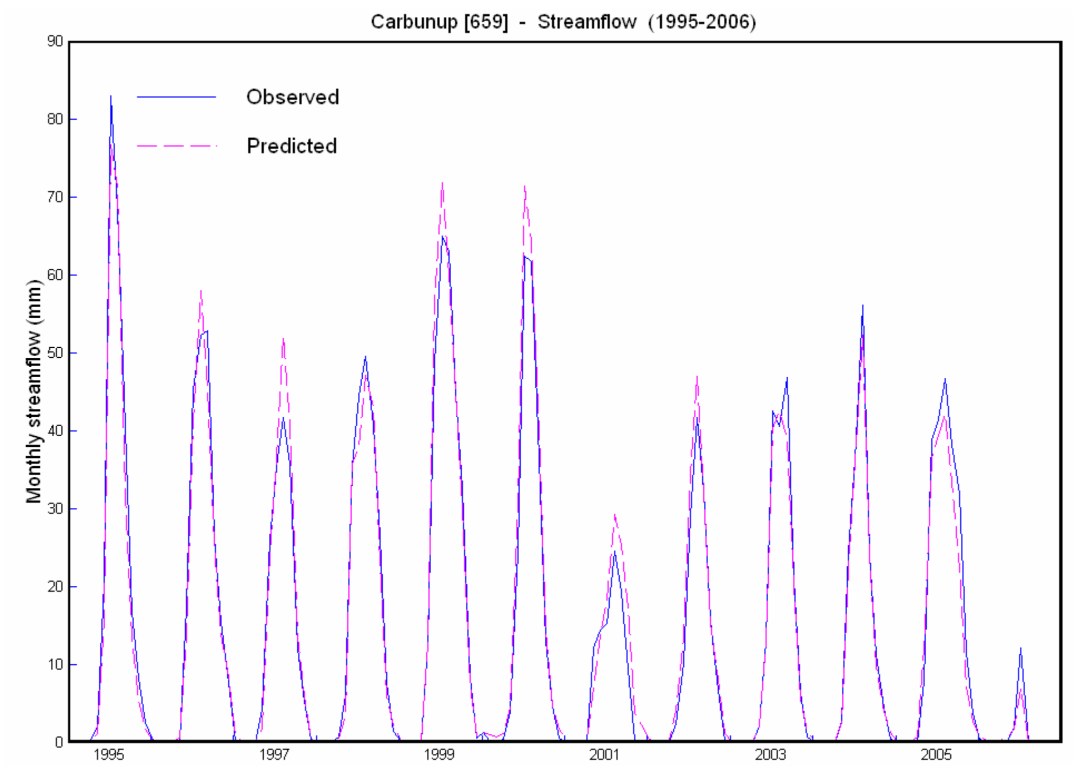
Cumulative precipitation :9874mm, representing 100 % of the rain
Cumulative precipitation after inteception :9348mm, representing 95 % of the rain
Cumulative interception :526mm, representing 5 % of the rain
Cumulative evaporation :6056mm, representing 61 % of the rain and 65 % of the rain after interceptaion
Cumulative streamflow :3300mm, representing 33 % of the rain and 35 % of the rain after interceptaion
Cumulative Water Balance : in 9874mm, representing100 % of the rain
: out 9881mm, representing100 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :467mm, representing 5 % of the rain and 8 % of the total evaporation
Cumulative evaporation form the F store :3088mm, representing 31 % of the rain and 51 % of the total evaporation
Cumulative evaporation form the B store :2500mm, representing 25 % of the rain and 41 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :729mm, representing 7 % of the rain and 22 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):2554mm, representing 26 % of the rain and 77 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):17mm, representing 0 % of the rain and 1 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :2648mm, representing 27 % of the rain and 80 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):0mm, representing 0 % of the rain and 0 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):2648mm, representing 0 % of the rain and 100 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :82 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :14 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :372 mm
Average yearly Unsaturated zone discharge :97 mm
Average yearly Unsaturated zone evaporation :275 mm
...
Groundwater
Average yearly Groundwater recharge :220 mm
Average yearly Groundwater discharge :2 mm
Average yearly Groundwater evaporation :189 mm

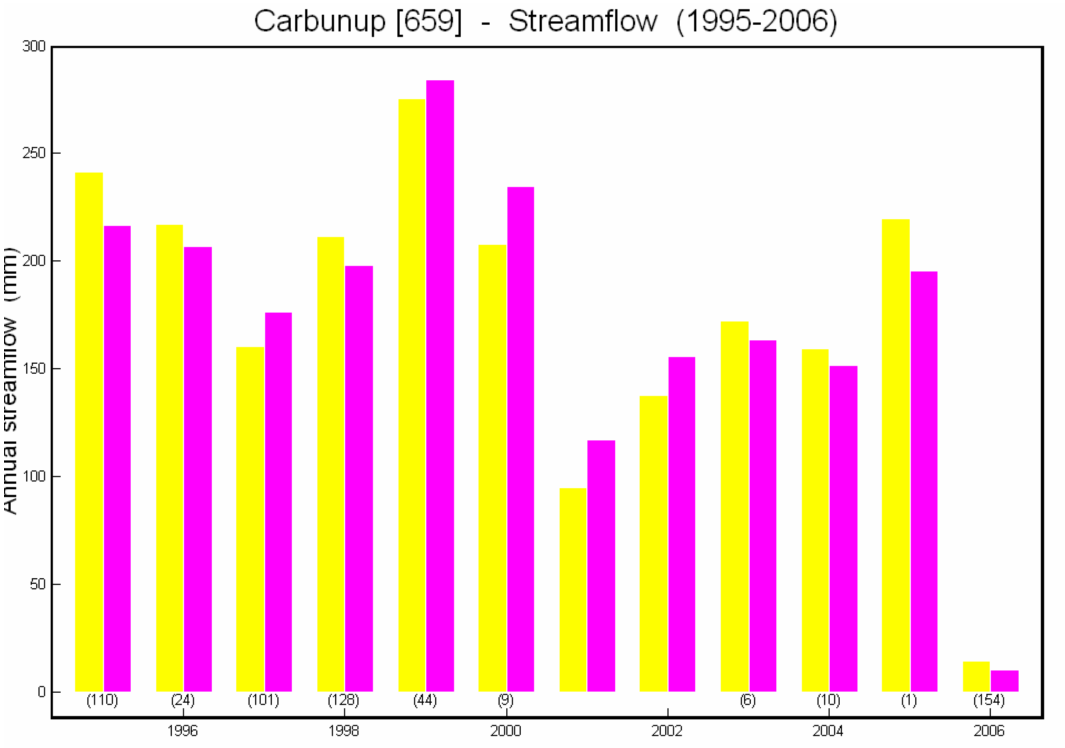
Carbunup River
610015 (Lennox Vineyard)

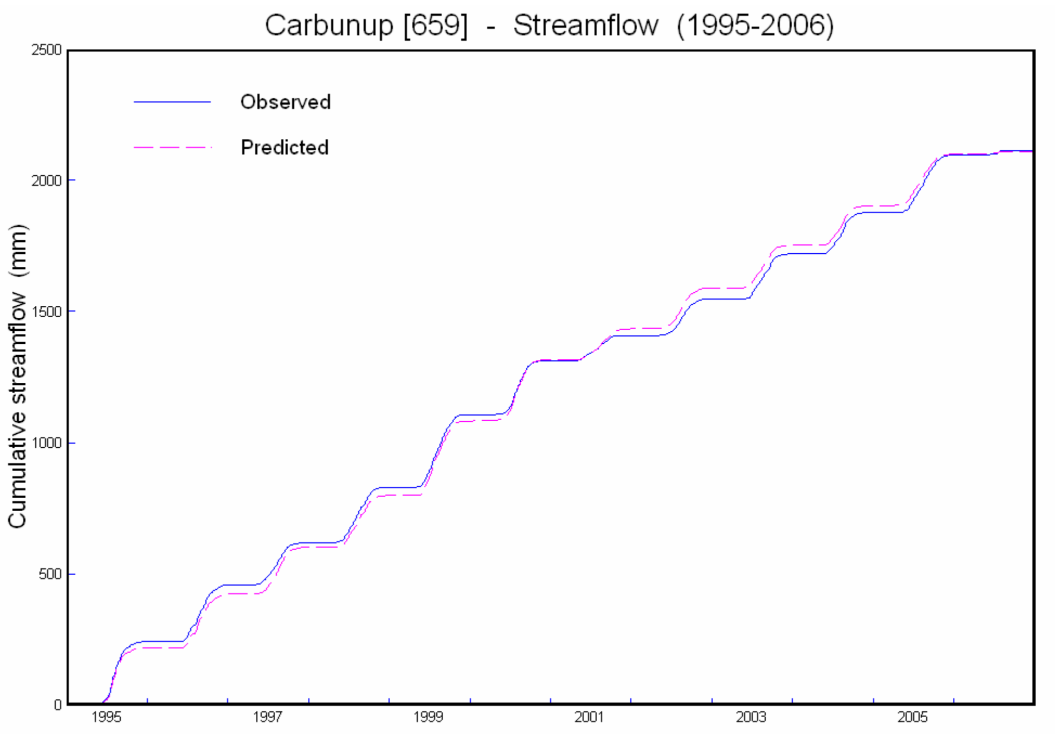
Efficiency:

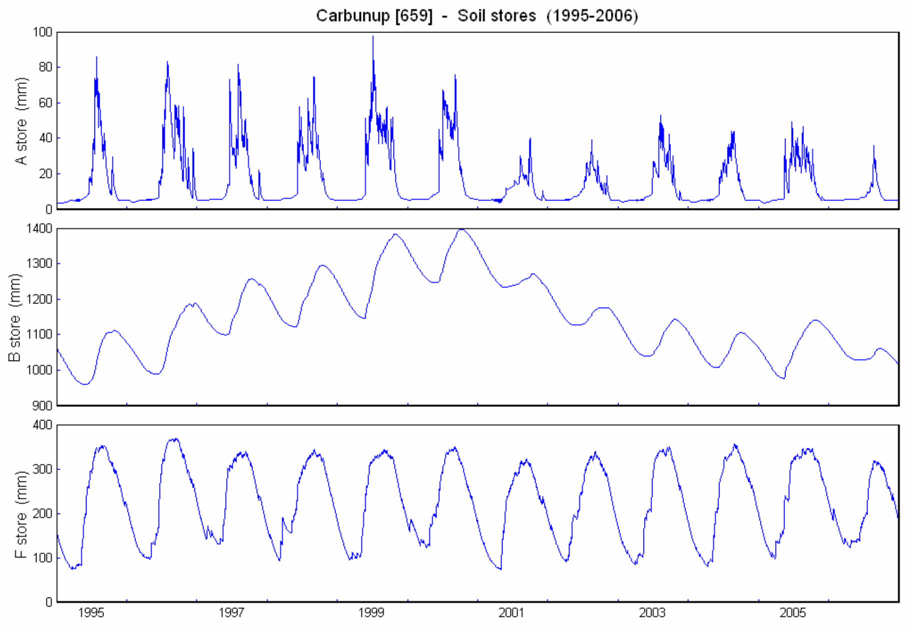
Daily = 0.920
Monthly = 0.965
Annual = 0.969






Carbunup [659] - Streamflow (1995-2006)
Annual streamflow (mm)
300
250
200
150
100
50
0
(110)
(24)
(101)
(128)
(44)
(9)
(6)
(10)
(1)
(154)
1996
1998
2000
2002
2004
2006


Carbunup [659] - Streamflow (1995-2006)
Cumulative streamflow (mm)
Observed
Predicted
2500
2000
1500
1000
500
0
1995
1997
1999
2001
2003
2005

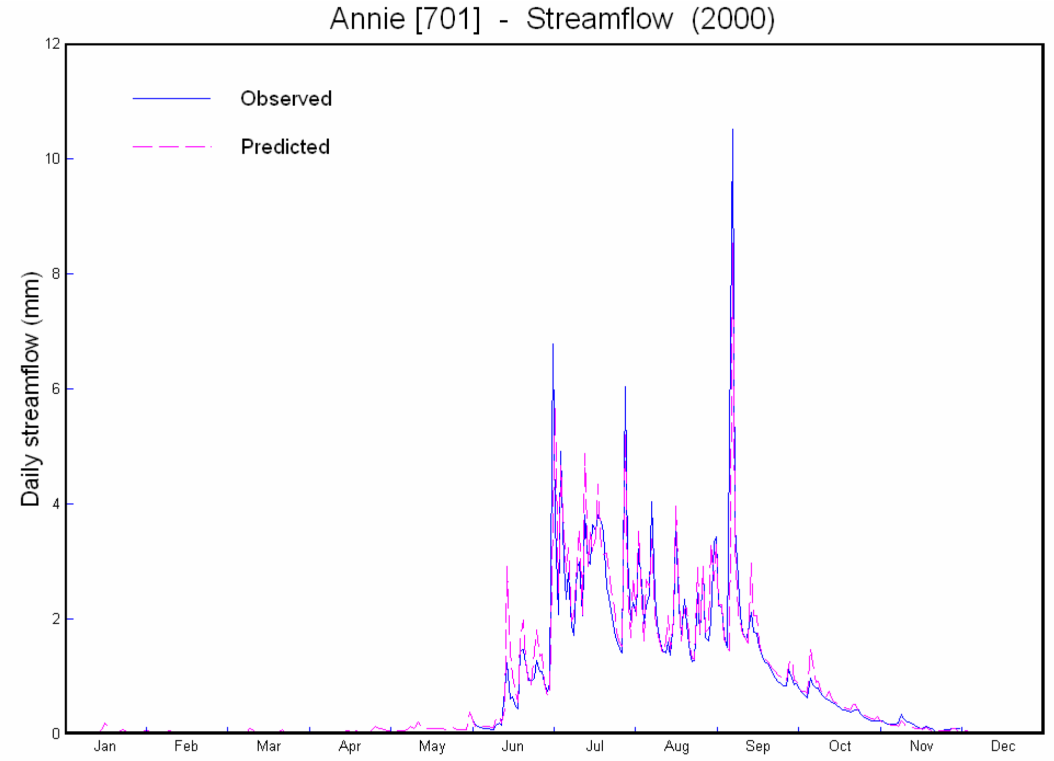


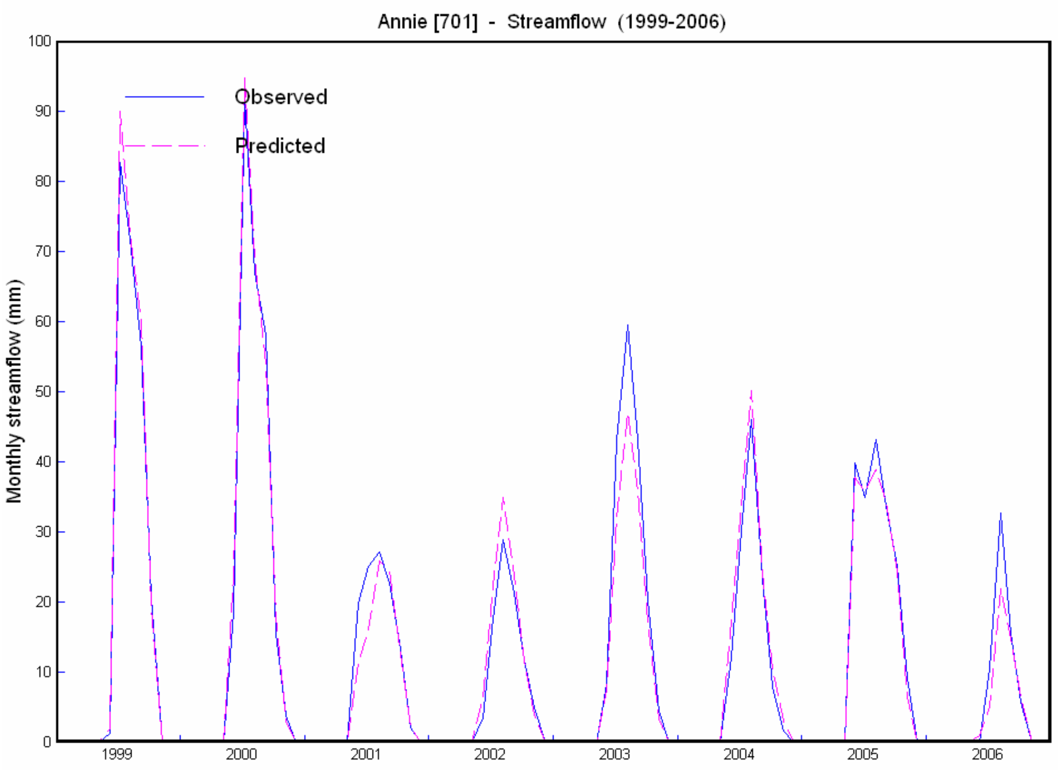
Cumulative precipitation :10513mm, representing 100 % of the rain
Cumulative precipitation after inteception :9629mm, representing 92 % of the rain
Cumulative interception :884mm, representing 8 % of the rain
Cumulative evaporation :7984mm, representing 76 % of the rain and 83 % of the rain after interceptaion
Cumulative streamflow :1730mm, representing 16 % of the rain and 18 % of the rain after interceptaion
Cumulative Water Balance : in 10513mm, representing100 % of the rain
: out 10598mm, representing101 % of the rain
...
Cumulative evaporation
Cumulative evaporation form the A store :3256mm, representing 31 % of the rain and 41 % of the total evaporation
Cumulative evaporation form the F store :4015mm, representing 38 % of the rain and 50 % of the total evaporation
Cumulative evaporation form the B store :713mm, representing 7 % of the rain and 9 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :1157mm, representing 11 % of the rain and 67 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):573mm, representing 5 % of the rain and 33 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):0mm, representing 0 % of the rain and 0 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :2920mm, representing 28 % of the rain and 169 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):1235mm, representing 12 % of the rain and 42 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):1685mm, representing 0 % of the rain and 58 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :29 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :3 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :533 mm
Average yearly Unsaturated zone discharge :182 mm
Average yearly Unsaturated zone evaporation :347 mm
...
Groundwater
Average yearly Groundwater recharge :371 mm
Average yearly Groundwater discharge :296 mm
Average yearly Groundwater evaporation :55 mm

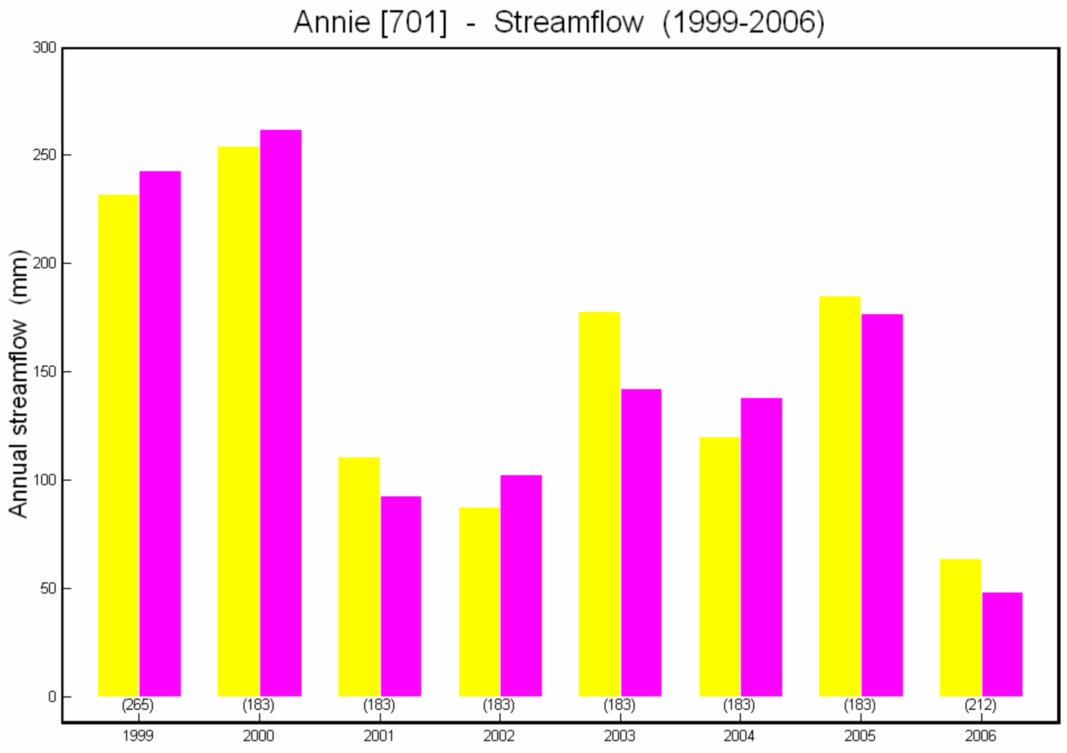
Station Gully Drain
800236 (Water Corporation station)

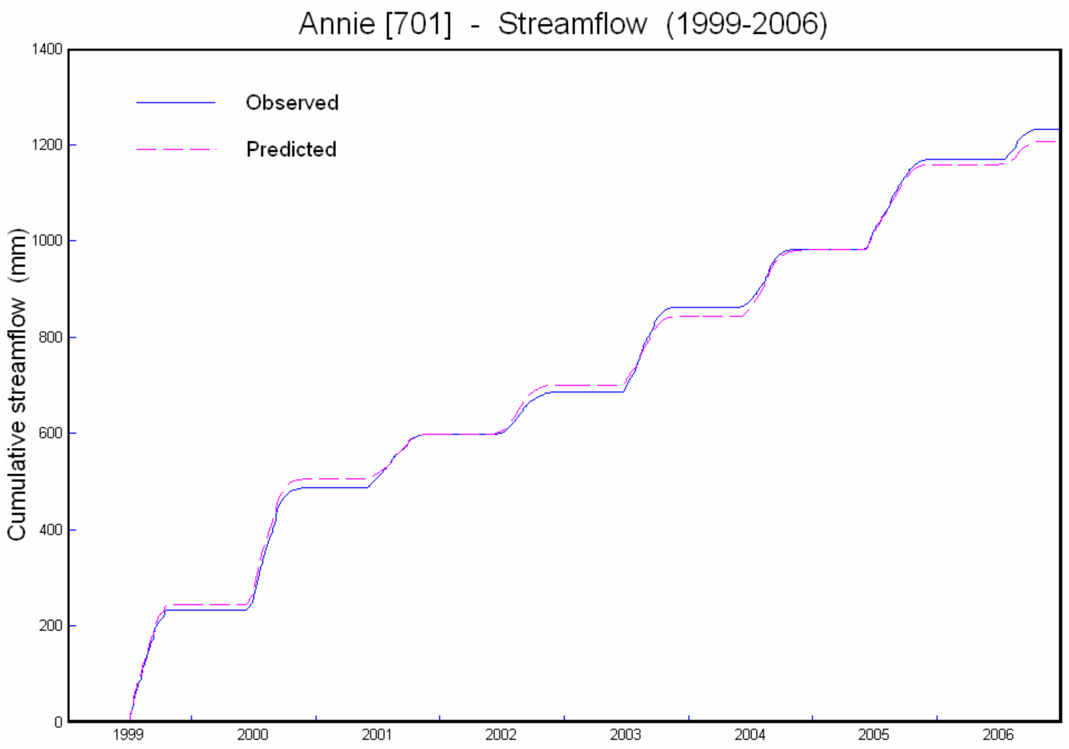
Efficiency:

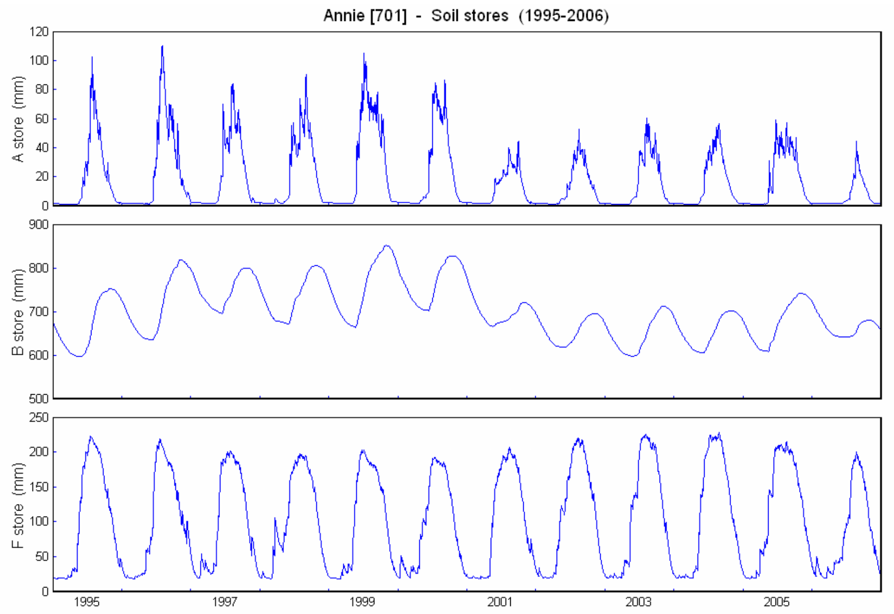
Daily = 0.871
Monthly = 0.957
Annual = 0.922






Annie [701] - Streamflow (1999-2006)
Annual streamflow (mm)
300
250
200
150
100
50
0
(265)
(183)
(183)
(183)
(183)
(183)
(183)
(212)
1999
2000
2001
2002
2003
2004
2005
2006


Annie [701] - Streamflow (1999-2006)
Observed
Predicted
Cumulative streamflow (mm)
1400
1200
1000
800
600
400
200
0
1999
2000
2001
2002
2003
2004
2005
2006



Cumulative precipitation :10570mm, representing 100 % of the rain
Cumulative precipitation after inteception :9589mm, representing 91 % of the rain
Cumulative interception :982mm, representing 9 % of the rain
Cumulative evaporation :6976mm, representing 66 % of the rain and 73 % of the rain after interceptaion
Cumulative streamflow :2631mm, representing 25 % of the rain and 27 % of the rain after interceptaion
Cumulative Water Balance : in 10570mm, representing100 % of the rain
: out 10589mm, representing100 % of the rain

...
Cumulative evaporation
Cumulative evaporation form the A store :872mm, representing 8 % of the rain and 12 % of the total evaporation
Cumulative evaporation form the F store :4411mm, representing 42 % of the rain and 63 % of the total evaporation
Cumulative evaporation form the B store :1693mm, representing 16 % of the rain and 24 % of the total evaporation
...
Cumulative streamflow
Cumulative interflow :1653mm, representing 16 % of the rain and 63 % of the total streamflow
Cumulative Saturation Excess runoff (Dune):883mm, representing 8 % of the rain and 34 % of the total streamflow
Cumulative Infiltration Excess runoff (Horton):95mm, representing 1 % of the rain and 4 % of the total streamflow
...
Cumulative subsurfaceflow
Cumulative Subsurface runoff :3339mm, representing 32 % of the rain and 127 % of the total streamflow
Cumulative Subsurface Saturation Excess runoff (Dune):2459mm, representing 23 % of the rain and 74 % of the total subsurface flow
Cumulative Subsurface Infiltration Excess runoff (Horton):879mm, representing 1 % of the rain and 26 % of the total subsurface flow
...
Saturated area
Maximum Top soil Saturated Area value :39 %
Minimum Top soil Saturated Area value :0 %
Average Top soil Saturated Area value :5 %
...
Unsaturated zone
Average yearly Unsaturated zone recharge :455 mm
Average yearly Unsaturated zone discharge :74 mm
Average yearly Unsaturated zone evaporation :381 mm
...
Groundwater
Average yearly Groundwater recharge :724 mm
Average yearly Groundwater discharge :585 mm
Average yearly Groundwater evaporation :129 mm

Part 2: Nutrient calibration results

Table A3. Sampling locations used for calibration of reporting subcatchments

Sampling location	Site name	Reporting subcatchment	Unsampled reporting subcatchment/s adopting nutrient parameters
GBC01	Gynudup - Bussel Highway	Gynudup Brook	Five Mile Brook
GBC02	Capel Railway Bridge	Capel River	-
GBC03	Capel Yates Bridge	Capel River	-
GBC05	Ludlow	Ludlow River	-
GBC06	Wonnerup Siding	Abba River	-
GBC07	Sabina - Bussel Hwy Crossing	Sabina River	-
GBC08	Wonnerup East Road	Vasse Diversion Drain	-
GBC09	Old Butter Factory	Lower Vasse River	-
GBC10	Chapman Hill Road	Vasse Diversion Drain	-
GBC12	Florence Road Bridge	Buayanyup River	-
GBC13	Lennox Vinyard	Carbunup River	-
GBC15	Annie Brook Drain	Annie Brook	Toby Inlet
GBC18	Dugalup Brook	Dunsborough region	-
GBC19	Dantanup Brook	Dunsborough region	-
GBC20	Meelup Brook	Dunsborough region	-
GBC21	Upper Sabina	Sabina River	-
GBC22	Jingarmup Brook	Jingarmup Brook	-

Table A4. Comparison of annual monthly and daily efficiencies at nutrient sampling and flow gauging locations

	Total phosphorus			Total nitrogen		
	Daily	Monthly	Annual	Daily	Monthly	Annual
610010	0.669	0.709	0.898	0.306	0.468	-0.180
610219	0.778	0.746	*	0.182	0.205	*
610009	0.205	0.170	-0.261	0.492	0.552	0.590
610005	*	*	*	*	*	*
610016	0.214	0.181	0.001	0.690	0.729	0.700
610014	0.404	0.385	0.211	0.388	0.415	0.450
610025	0.247	0.180	*	0.494	0.427	*
610012**	*	*	*	*	*	*
610003	0.543	0.448	*	0.873	0.868	*
610015	0.616	0.693	*	0.527	0.596	0.413
800236	*	*	*	*	*	*

* Not sufficient sampling data for analysis of efficiency

**Only for years 2005 and 2006, since there was a drainage change between 1995 and 2005

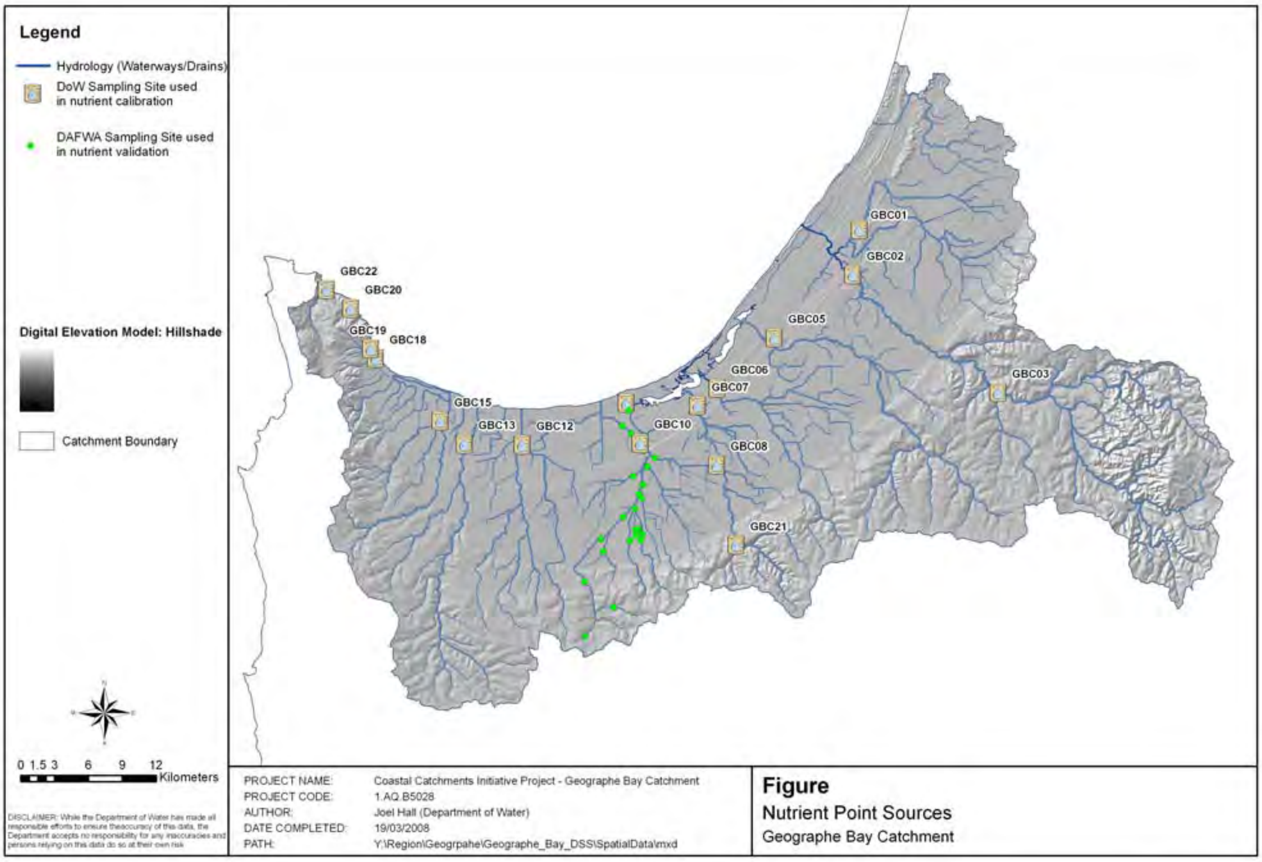


Figure A2. Gauging station locations and regions of equivalent hydrological paramatisation.

Table A5. Comparison of modelled and measured winter median concentrations at nutrient sampling locations

		Total phosphorus			Total nitrogen		
Sampling location	**Reporting subcatchment**	**No. samples**	**Measured winter median concentration (mg/L)**	**Modelled winter median concentration**	**No. samples**	**Measured winter median concentration (mg/L)**	**Modelled winter median concentration**
GBC01	Gynudup Brook	14	0.165	0.204	14	2.50	2.55
GBC02	Capel River	59	0.030	0.051	101	0.79	0.87
GBC03	Capel River	24	0.017	0.030	23	0.59	0.66
GBC05	Ludlow River	27	0.130	0.143	64	1.45	2.18
GBC06	Abba River	24	0.054	0.051	68	1.68	2.21
GBC07	Sabina River	14	0.426	0.410	28	3.73	3.69
GBC08	Sabina Diversion	20	0.115	0.167	17	2.40	1.54
GBC09	Lower Vasse River	16	0.270	0.300	16	1.95	2.51
GBC10	Vasse Diversion Drain	48	0.115	0.135	83	1.60	2.06
GBC12	Buayanyup River	21	0.071	0.068	61	2.08	2.13
GBC13	Carbunup River	24	0.017	0.020	67	0.89	0.64
GBC15	Annie Brook	15	0.042	0.038	15	1.50	1.41
GBC18	Dugalup Brook	14	0.011	0.007	17	0.60	0.37
GBC19	Dantanup Brook	22	0.065	0.034	22	0.71	0.74
GBC20	Meelup Brook	8	0.003	0.008	8	0.18	0.33
GBC22	Jingarmup Brook	9	0.020	0.010	9	1.30	1.37

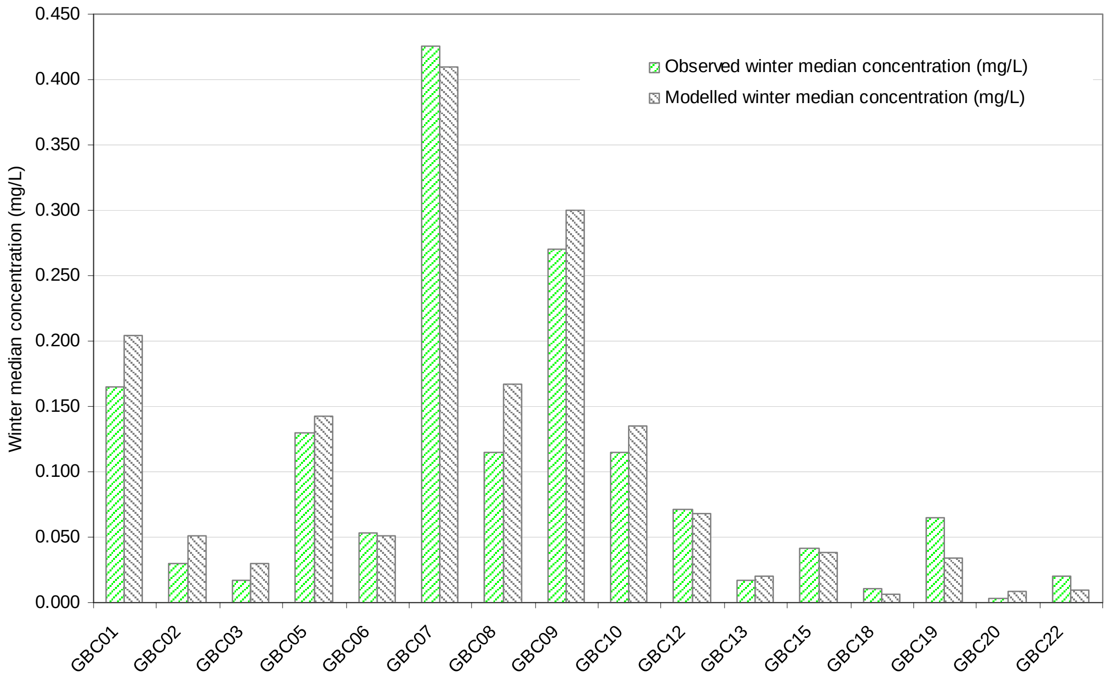


Figure A3. Winter median phosphorus concentrations: Modelled and observed values

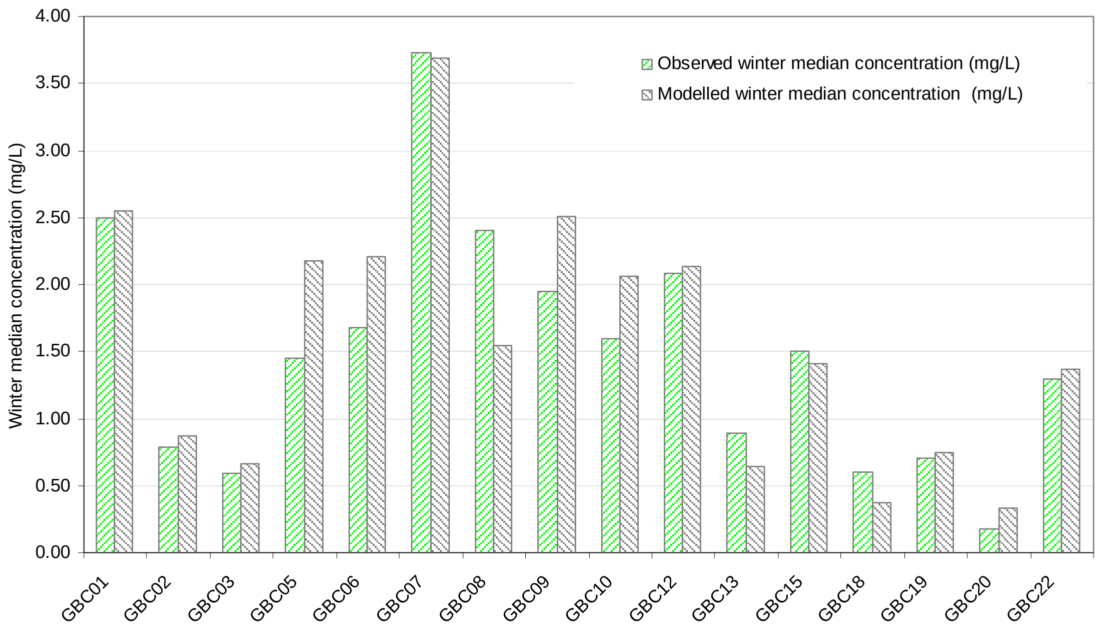
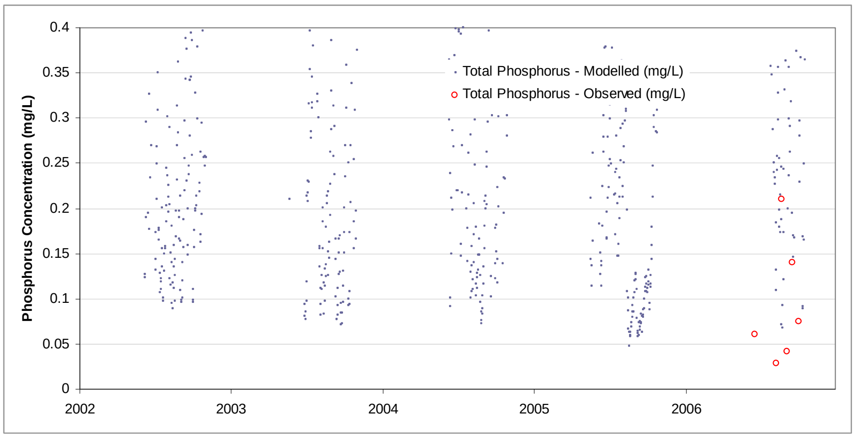
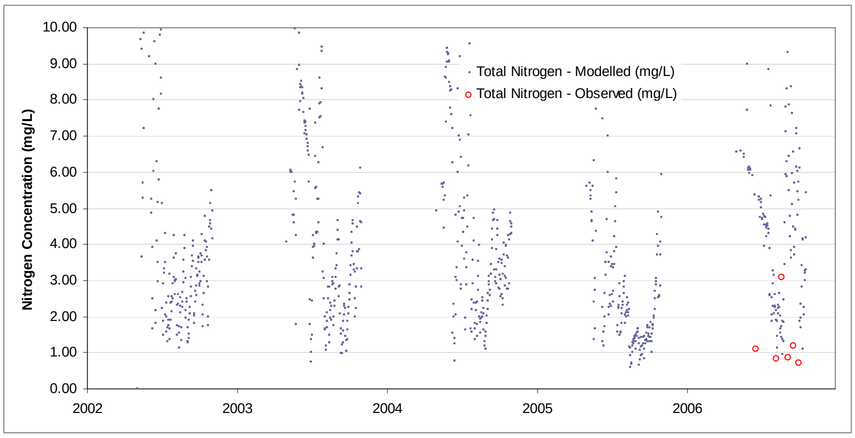


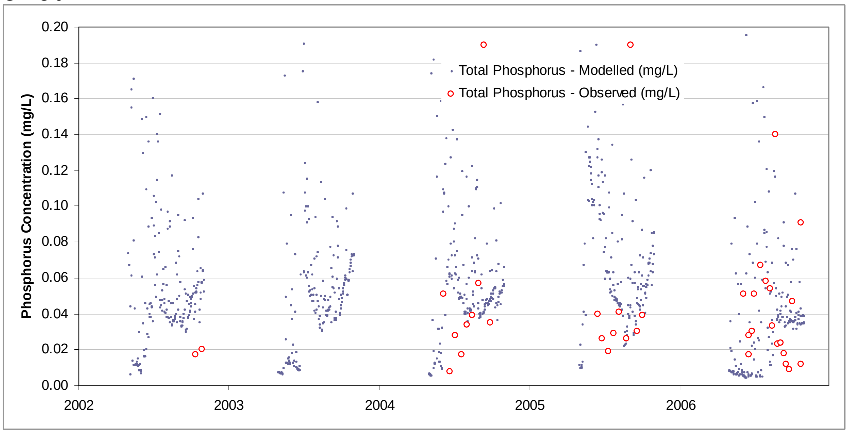
Figure A4. Winter median nitrogen concentrations: Modelled and observed values

GBC01


Phosphorus Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2002
2003
2004
2005
2006
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)

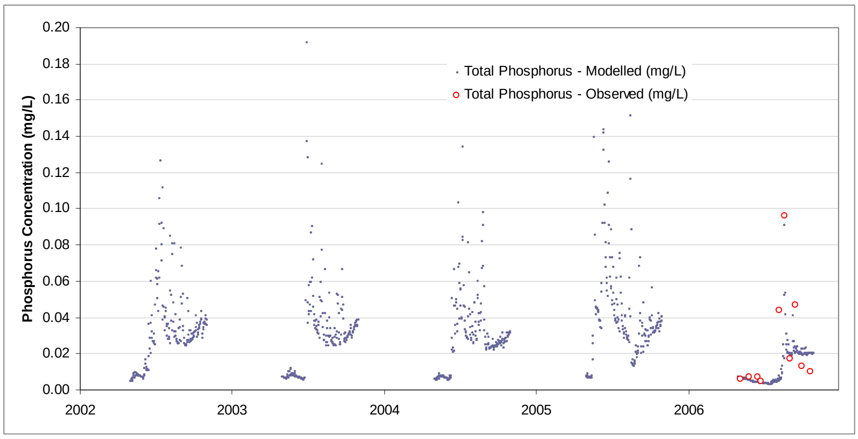

Nitrogen Concentration (mg/L)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2002
2003
2004
2005
2006
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)

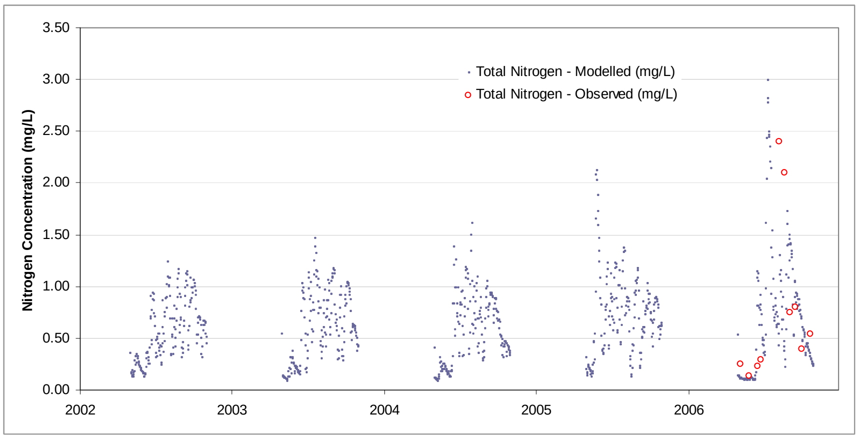
GBC02


Phosphorus Concentration (mg/L)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2002
2003
2004
2005
2006
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)

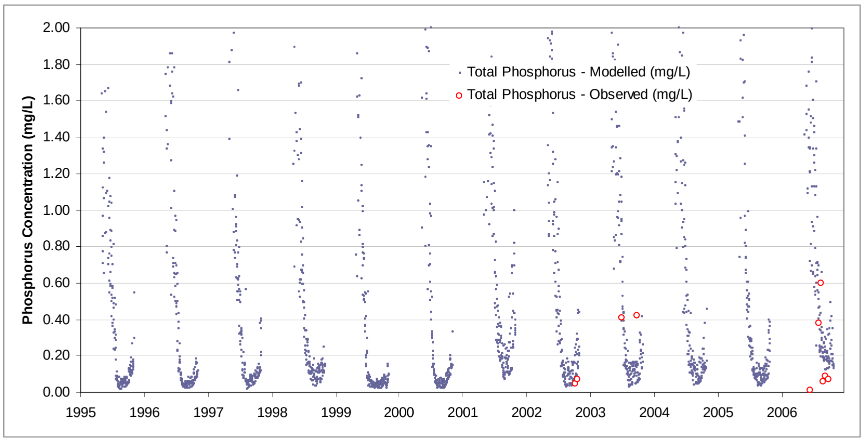

Nitrogen Concentration (mg/L)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)

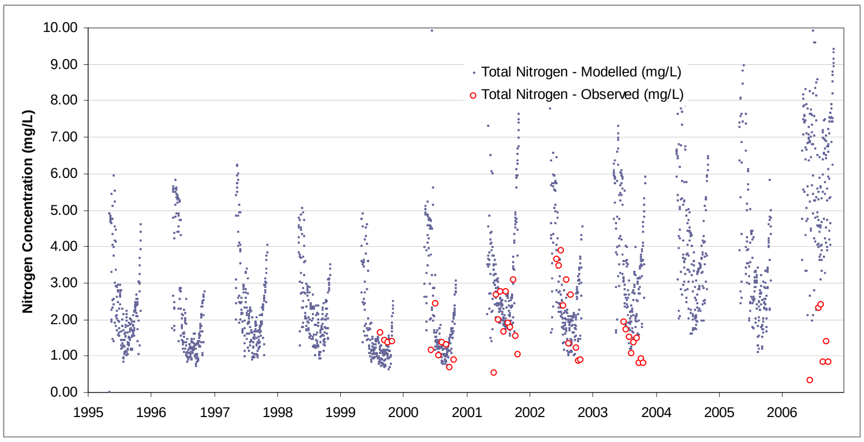
GBC03


Phosphorus Concentration (mg/L)
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2002
2003
2004
2005
2006

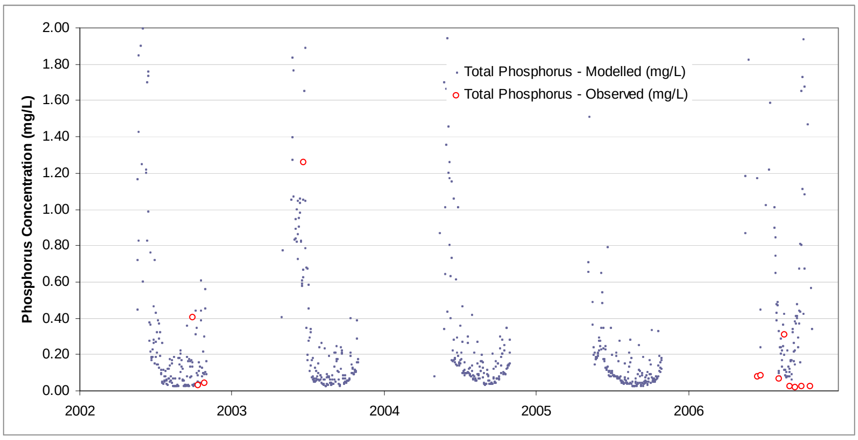

Nitrogen Concentration (mg/L)
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2002
2003
2004
2005
2006

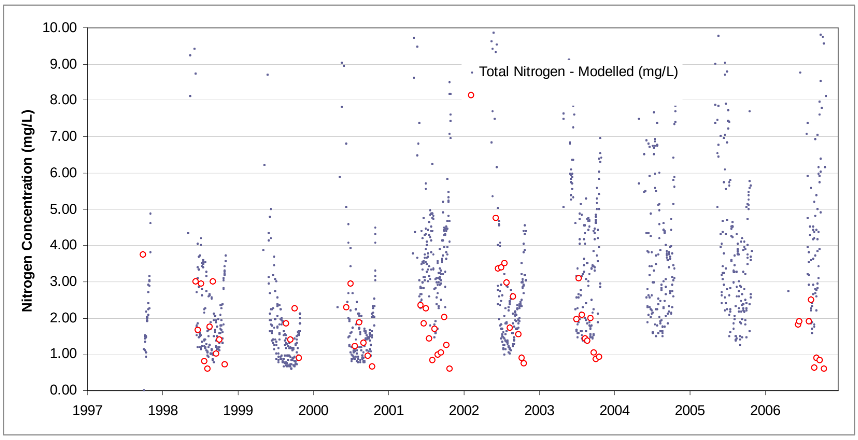
GBC05


Phosphorus Concentration (mg/L)
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

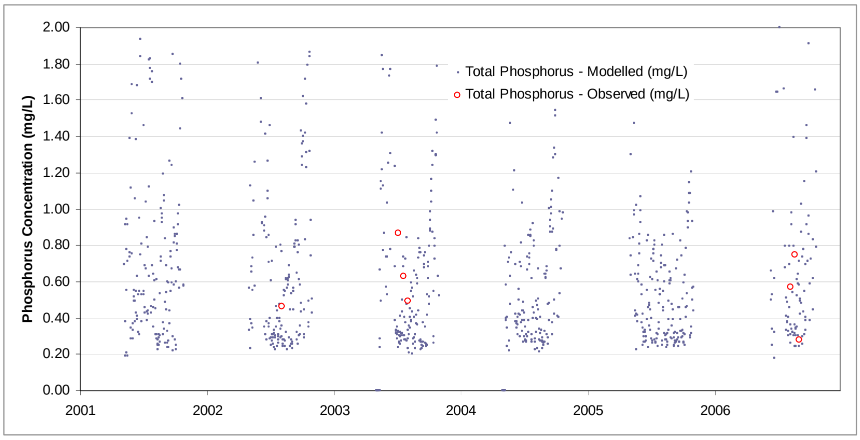

Nitrogen Concentration (mg/L)
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

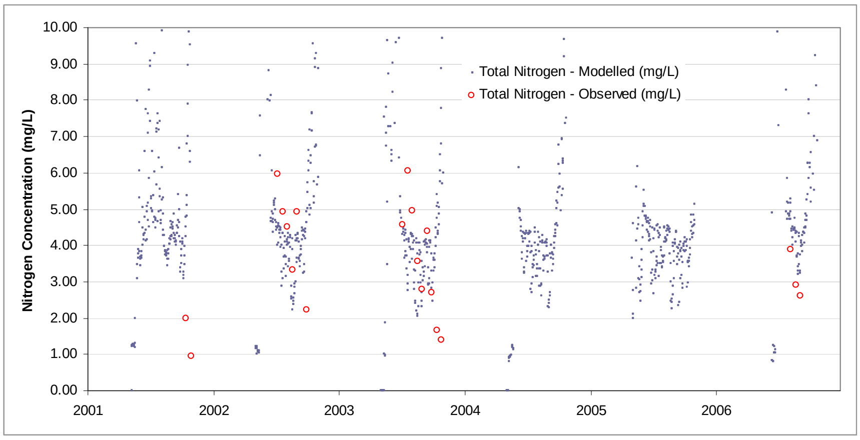
GBC06


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2002
2003
2004
2005
2006

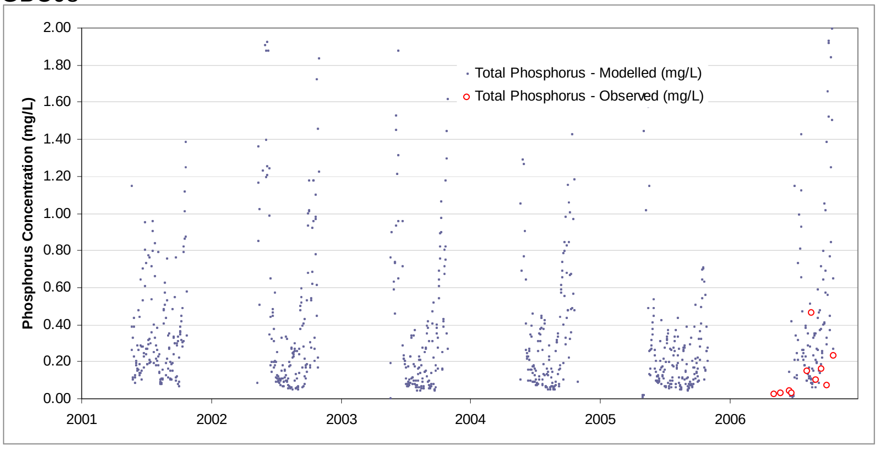

Total Nitrogen - Modelled (mg/L)
Nitrogen Concentration (mg/L)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

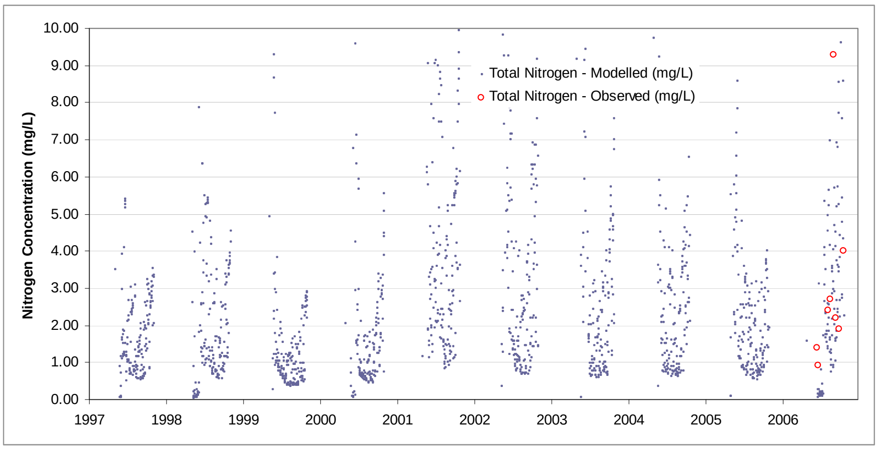
GBC07


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2001
2002
2003
2004
2005
2006

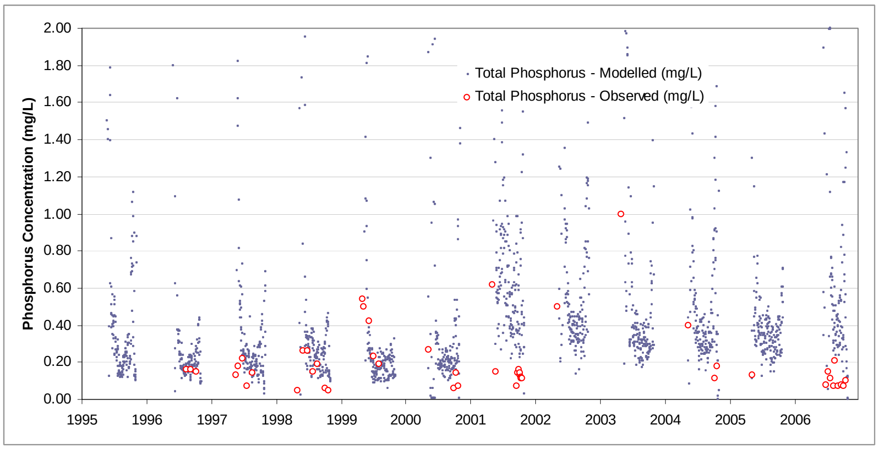

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2001
2002
2003
2004
2005
2006

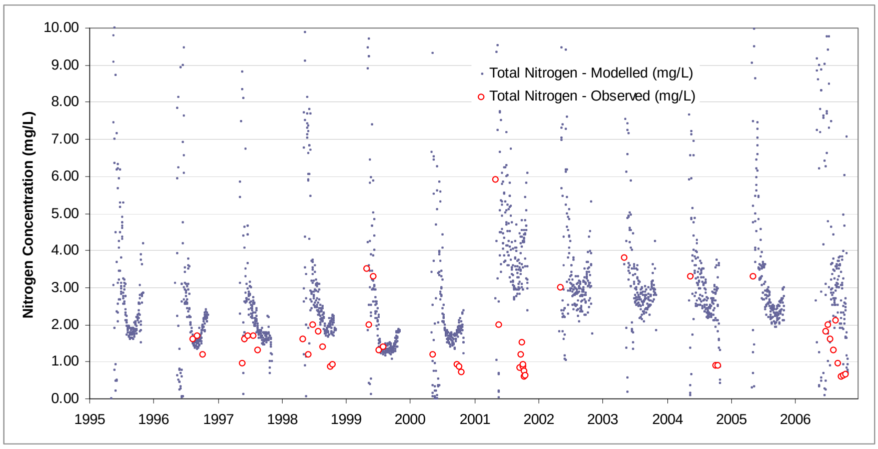
GBC08


Phosphorus Concentration (mg/L)
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2001
2002
2003
2004
2005
2006

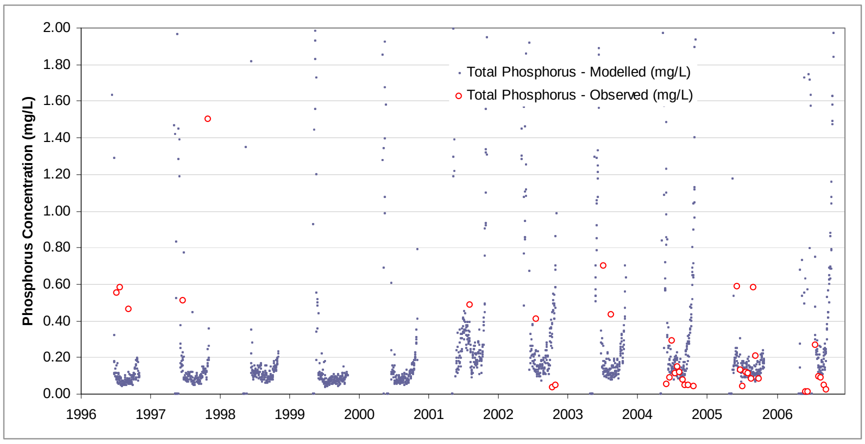

Nitrogen Concentration (mg/L)
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

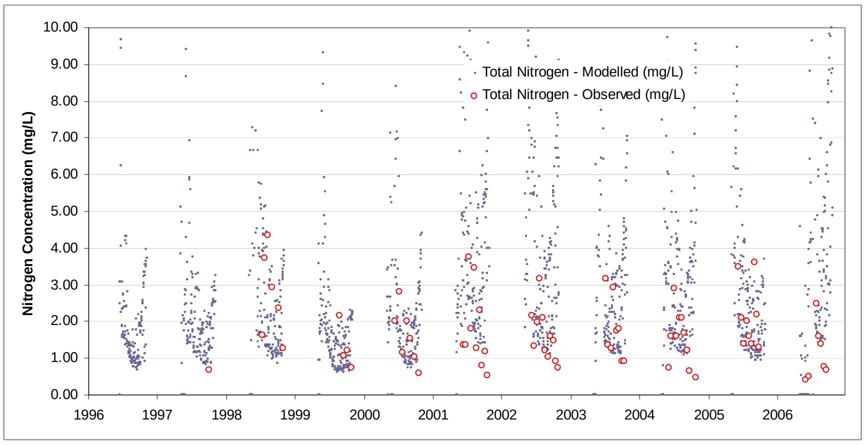
GBC09


Phosphorus Concentration (mg/L)
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

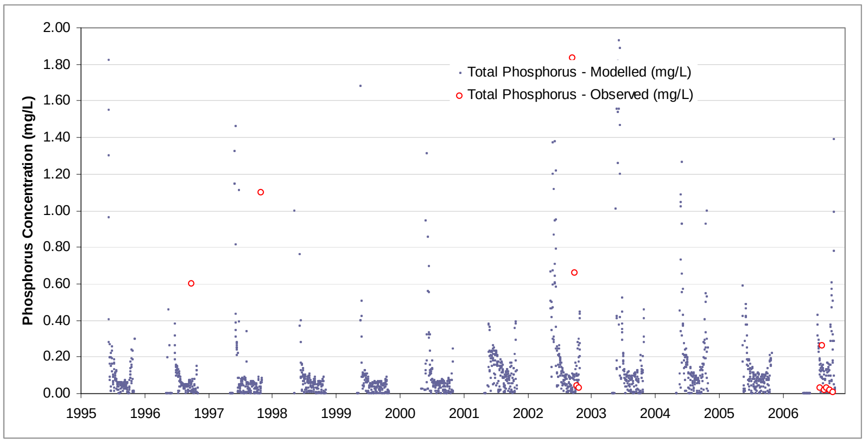

Nitrogen Concentration (mg/L)
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

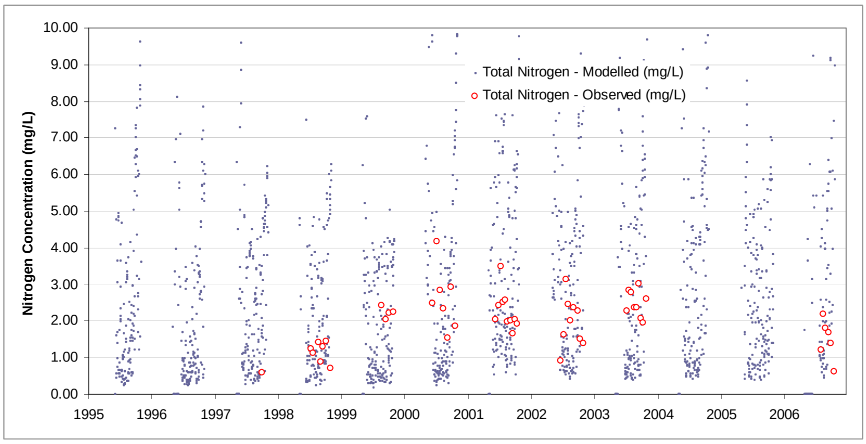
GBC10


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)

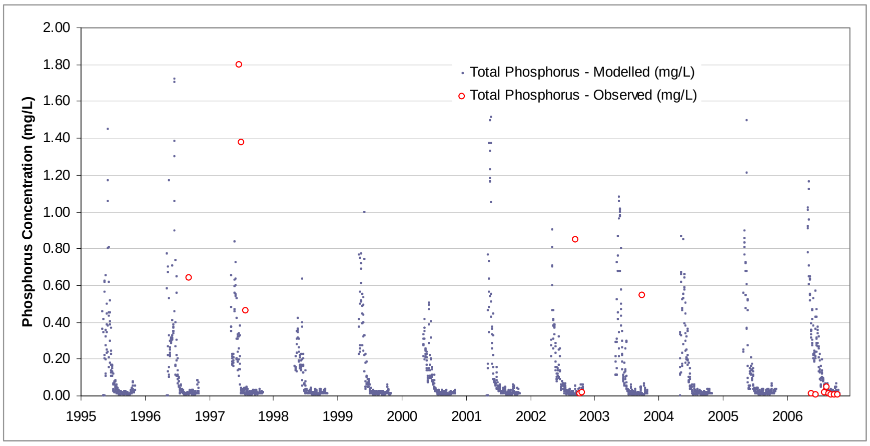

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)

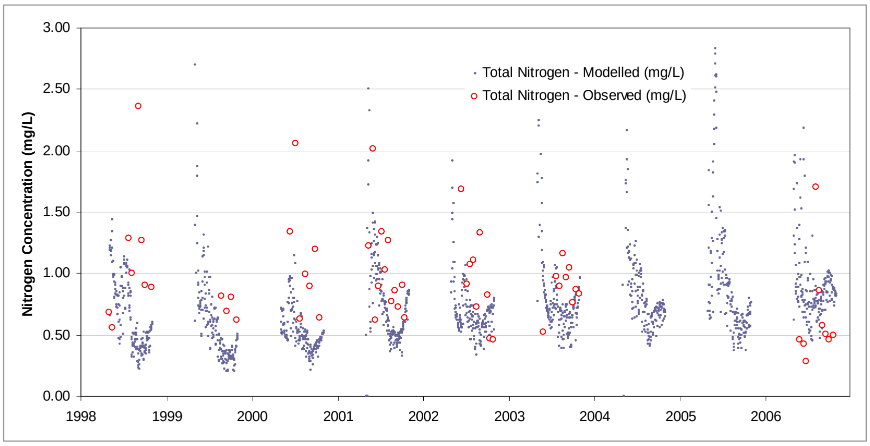
GBC12


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)

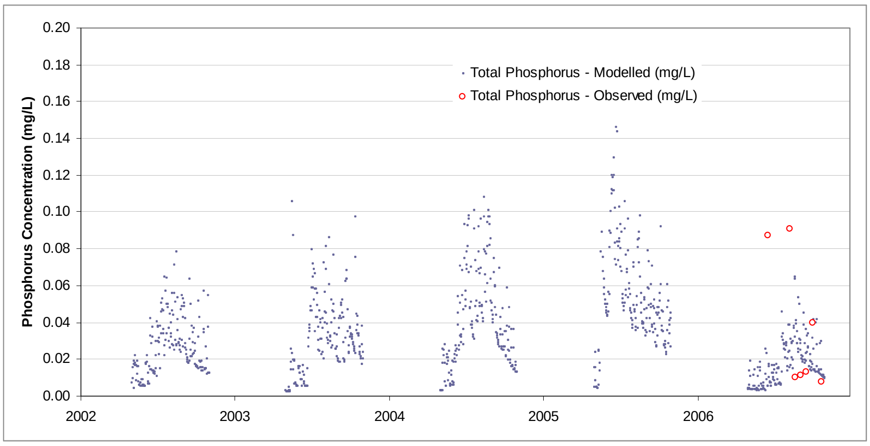

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)

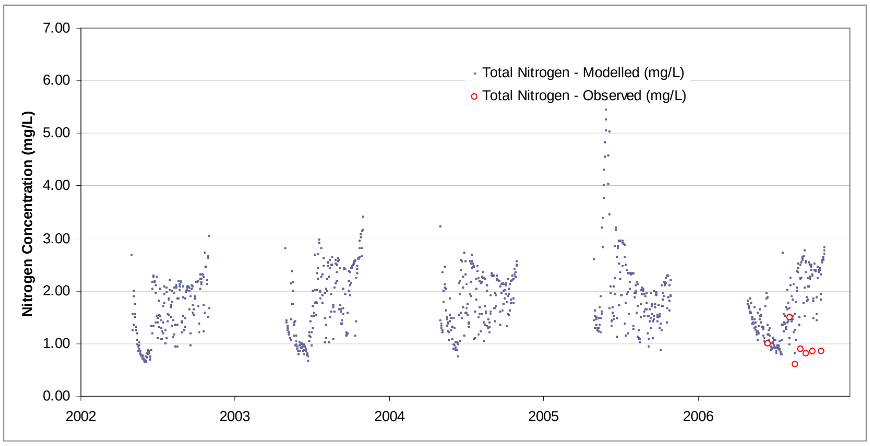
GBC13


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006

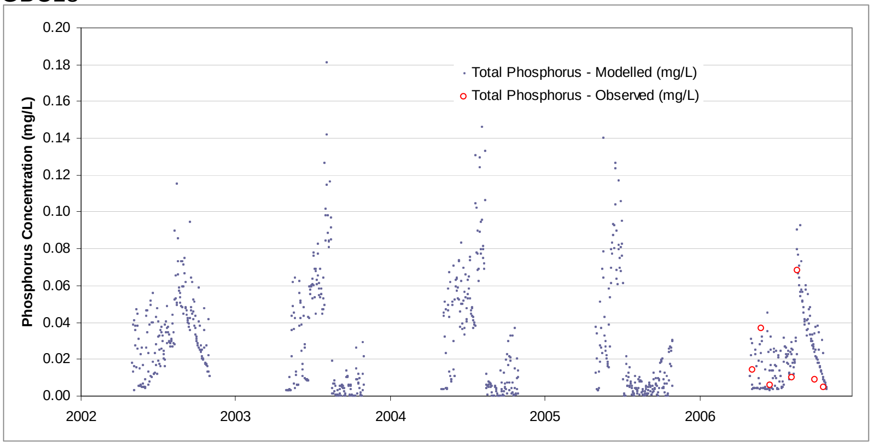

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)
0.00 0.50 1.00 1.50 2.00 2.50 3.00
1998 1999 2000 2001 2002 2003 2004 2005 2006

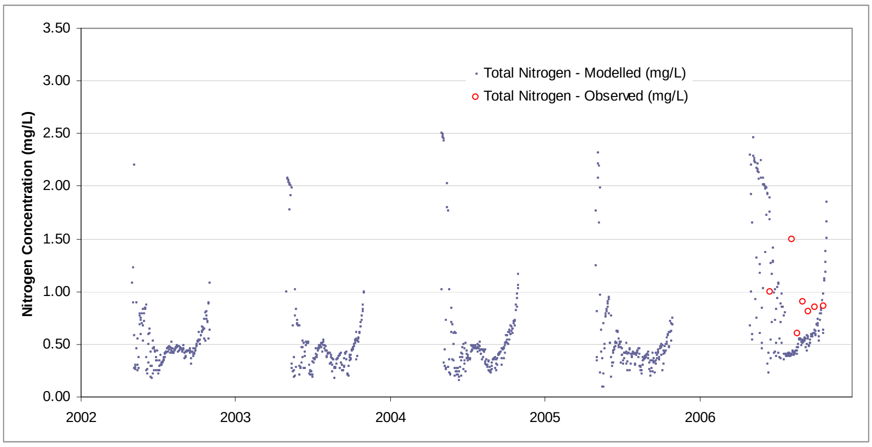
GBC15


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20
2002 2003 2004 2005 2006

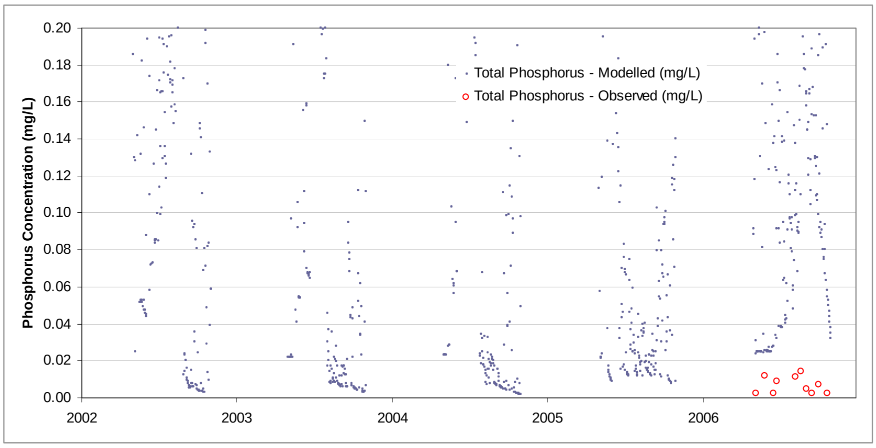

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00
2002 2003 2004 2005 2006

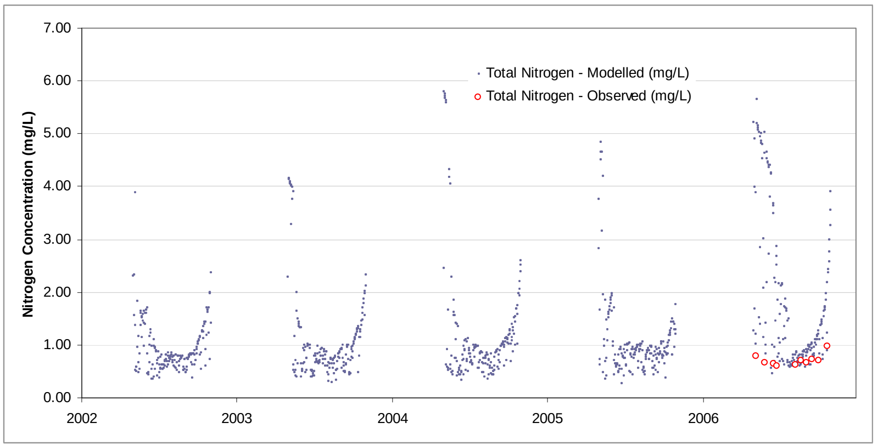
GBC18


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
2002
2003
2004
2005
2006

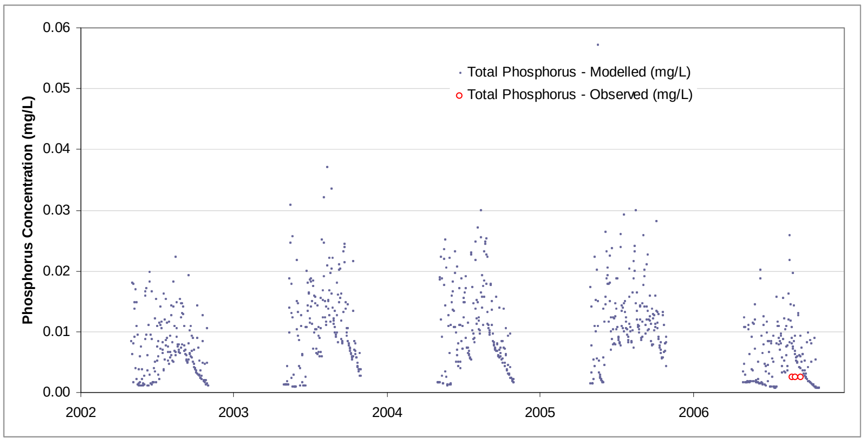

Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
2002
2003
2004
2005
2006

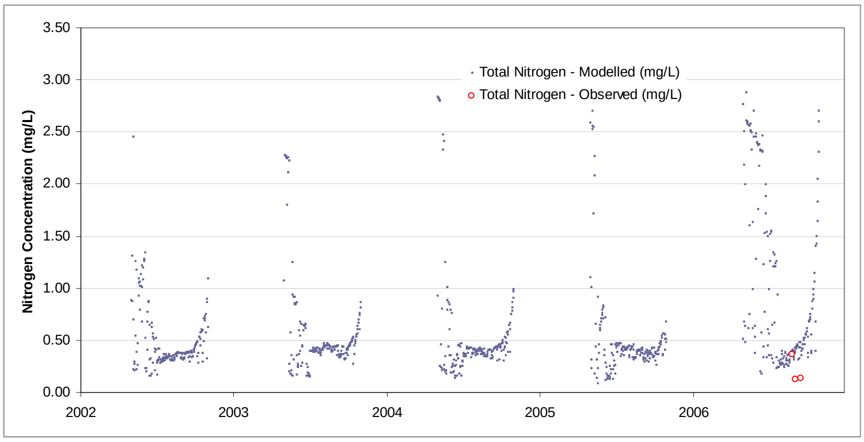
GBC19


Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)
Phosphorus Concentration (mg/L)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
2002
2003
2004
2005
2006


Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)
Nitrogen Concentration (mg/L)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
2002
2003
2004
2005
2006

GBC20


Phosphorus Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2002
2003
2004
2005
2006
Total Phosphorus - Modelled (mg/L)
Total Phosphorus - Observed (mg/L)


Nitrogen Concentration (mg/L)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2002
2003
2004
2005
2006
Total Nitrogen - Modelled (mg/L)
Total Nitrogen - Observed (mg/L)

Appendix B: Point source load calculations

Historical point sources

Assessment of historical point sources in the Geographe catchment was undertaking by analysing the dataset created by Hirschberg (1991). Hirschberg mapped point sources of groundwater contamination in the Perth Basin. Many of these point sources are no longer operational. Their residual contamination is difficult to assess and in many cases will be insignificant so they are considered to be non-contributory. The point sources highlighted by Hirschberg which are considered significant are the WWTP, the Capel and Busselton landfills and the unsewered caravan parks.

Feedlots

There are three major feedlots in the Geographe catchment. Two are on the Swan coastal plain, and the third is in the upper Carbunup catchment. The latter is on high PRI soils, is located away from any significant waterways and uses large lined treatment ponds for the effluent, and as such is unlikely to be influencing water quality in the Carbunup River. The two cattle feedlots that are assumed to be contributing to water quality are in the Vasse Diversion Drain (the Vasse Research station) and the Lower Vasse River subcatchments. To determine nutrient exports, Fahrner (2002) and Kelsey (2004) used rates of 8.665 kg/cow/year and 2.235 kg TP/cow/year. This rate is comparable to a rate of 3.876 kg TP/cow/year which is reported by The Royal Netherlands Institute for Sea Research (www.nioz.nl/loicz/firstpages/products/fp-products.htm).

Fahrner (2002) investigated the use of a bio-remediation trench to remove nitrogen in effluent from the cattle feedlot at the Vasse Research station. Her estimation of annual TN export from this 300 cow feedlot is 1,223 kg/year which is approximately 53% less than the expected export without the bio-remediation trench. The total export from cattle feedlots to the waterways of the Geographe catchment is estimated to be 2906 kg/year for TP and 9888 kg/year of TN.

Dairy shed effluent

Dairy shed effluent nutrient loads were estimated and attributed average TN and TP concentrations of 230mg/l and 40mg/l respectively (DAF W.A. 2000) to effluent quantities. Water Corporation assessed the fate of the nutrient at each site and estimated the transport off-site using some simple assumptions. Sites which discharge directly to surface drainage or to infiltration ponds on sandy soils are assumed to be contributing 100% of their nutrient to the environment. For partially sealed pond systems, it is assumed that 70% of the effluent recharges to groundwater, with a 30% reduction in nitrogen due to de-nitrification and 10% adsorbance of phosphorus due to the clay linings of the ponds. Sites with well-lined, sealing ponds which do not irrigate are assumed to contribute 30% of their nutrient to the environment due to overflow from the ponds. Estimation of the total nitrogen and phosphorus loads being delivered to land or directly to the waterways from dairy sheds are displayed in Table B1. A total of 45.9 tonnes of TN and 8.0 tonnes of TP are calculated to be exported from dairy sheds annually.

Table B1. Dairy effluent load calculations for the Geographe catchment.

Dairy ID	Effluent Quantity (L/Day)	Fertigation System	TN to Water (kg/yr)	TP to Water (kg/yr)	TN to Land (kg/yr)	TP to Land (kg/yr)	TN Total (kg/yr)	TP Total (kg/Yr)
1	18000	No	1058	184	0	0	1058	184
2	10000	No	588	102	0	0	588	102
3	14000	Yes	353	61	588	102	941	163
4	4800	No	282	49	0	0	282	49
5	12000	Yes	302	53	504	88	806	141
6	2700	No	227	39	0	0	227	39
7	20000	Yes	504	88	840	146	1344	234
8	16000	Yes	403	70	672	117	1075	187
9	3000	Yes	76	13	126	22	202	35
10	6000	Yes	151	26	252	44	403	70
11	12000	Yes	302	53	504	88	806	141
12	10000	No	840	146	0	0	840	146
13	4000	No	336	58	0	0	336	58
14	30000	Yes	756	131	1259	219	2015	350
15	4000	No	336	58	0	0	336	58
16	5000	No	84	15	0	0	84	15
17	10000	Yes	252	44	420	73	672	117
18	12000	Yes	302	53	504	88	806	141
19	60000	Yes	1511	263	2519	438	4030	701
20	4000	Yes	101	18	168	29	269	47
21	4000	Yes	101	18	168	29	269	47
22	12000	No	1007	175	0	0	1007	175
23	4000	No	252	44	0	0	252	44
24	4000	Yes	101	18	168	29	269	47
25	9000	Yes	227	39	378	66	605	105
26	9000	No	756	131	0	0	756	131
27	2000	Yes	50	9	84	15	134	24
28	9000	No	756	131	0	0	756	131
29	5000	No	168	30	0	0	168	30
30	8000	No	672	117	0	0	672	117
31	4000	Yes	101	18	168	29	269	47
32	4000	No	336	58	0	0	336	58
33	11000	Yes	277	48	462	80	739	128
34	45000	Yes	1133	197	1889	329	3022	526
35	6000	Yes	151	26	252	44	403	70
36	7000	Yes	176	31	0	0	176	31
37	4000	No	336	58	0	0	336	58
38	12000	Yes	302	53	504	88	806	141
39	7000	Yes	176	31	294	51	470	82
40	30000	Yes	756	131	1259	219	2015	350
41	30000	Yes	756	131	1259	219	2015	350
42	4000	Yes	101	18	168	29	269	47
43	1000	No	84	14	0	0	84	14
44	6000	Yes	151	26	252	44	403	70
45	6400	Yes	161	28	269	47	430	75
46	6000	Yes	151	26	252	44	403	70
47	36000	No	3022	526	0	0	3022	526
48	5000	No	42	7	0	0	42	7
49	8000	No	671	117	0	0	671	117
50	20000	Yes	504	88	840	146	1344	234
51	6000	Yes	151	26	252	44	403	70
52	8400	Yes	212	37	353	61	565	98
53	30000	Yes	756	131	1259	219	2015	350
54	6000	Yes	151	26	252	44	403	70
55	9000	Yes	227	39	378	66	605	105
56	5400	Yes	136	24	227	39	363	63
57	9000	Yes	227	39	378	66	605	105
58	9000	Yes	227	39	378	66	605	105
59	16000	Yes	403	69	672	117	1075	186
Total			**24731**	**4298**	**21171**	**3684**	**45902**	**7982**

Waste water treatment plants

There are three waste water treatment plants (WWTPs) in the Geographe catchment: The Busselton, Capel and Dunsborough WWTPs. The Busselton WWTP has a sequential batch reactor, after which the effluent undergoes pressurised sand filtration and UV disinfection. The wastewater is then discharged to two wetlands or a pond which supplies irrigation water to the golf course. The wetlands overflow to surface drains which are monitored for TN and TP concentrations and flow by the Water Corporation. The monitoring data is displayed in Figure B1 below, and was used to determine annual loads being delivered to the drain from the WWTP (Table B2). The treatment plant treats approximately 3.2 ML/Day (1200 ML/Year), and the of which the Golf Course uses approximately 180 ML per year in the summer months (November to March).

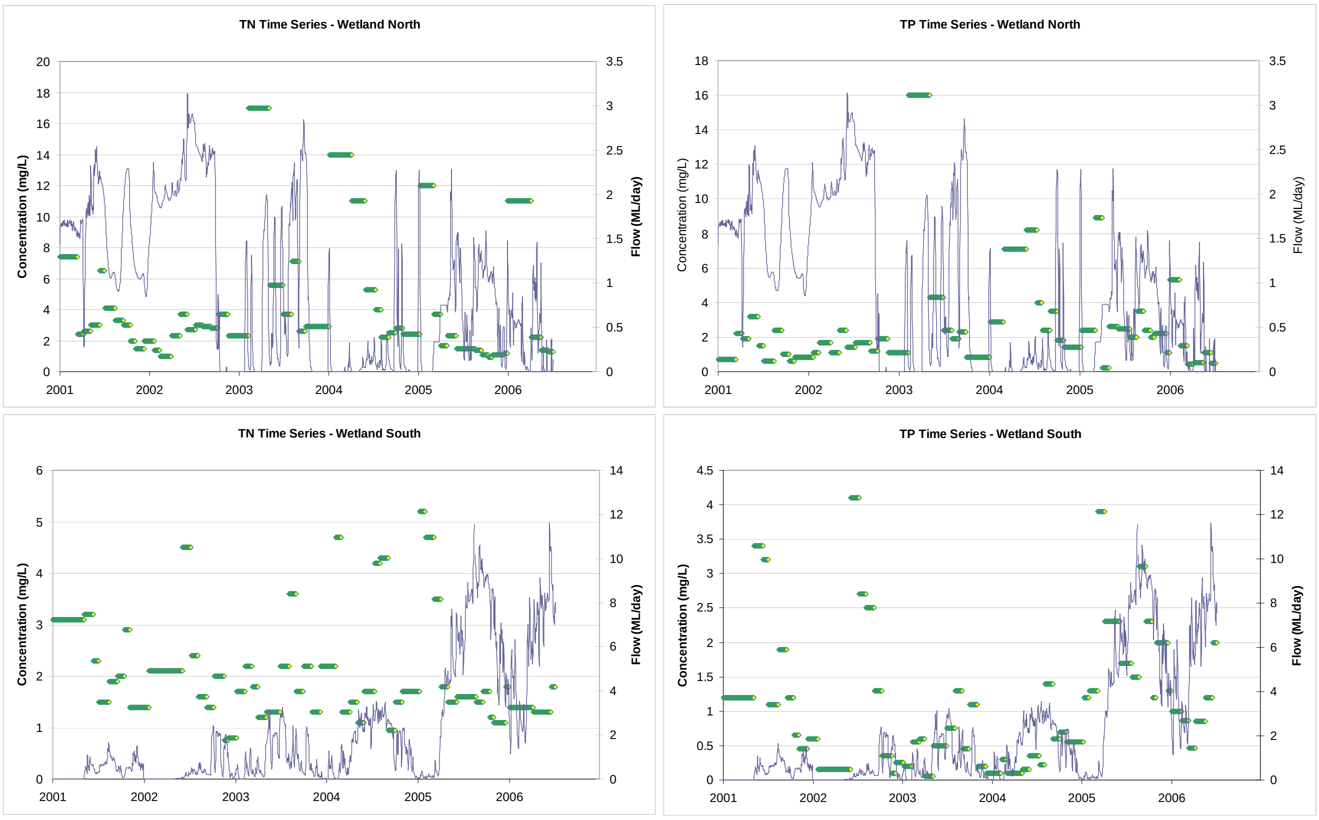


Figure B1. Flow and nutrient concentration data for water entering the drain adjacent to the Busselton WWTP.

Table B2. Annual nutrient export loads calculated for the Busselton WWTP.

Year	TP (kg)	TN (kg)	Nox (kg)	NH3 (kg)
2000 (2nd half)	121	1282	208	763
2001	1053	2588	719	687
2002	1092	1765	432	408
2003	1571	2487	146	1245
2004	503	1586	378	322
2005	4460	3310	155	675
2006 (1st half)	1353	2074	57	567
Average (2001-2005)	1736	2347	366	667

The Capel WWTP services the township of Capel, and consists of two adjacent settlement ponds. The waste water is disposed of via filtration into a basin downstream of the ponds. Water Corporation monitors the flow and nutrients that enter the infiltration basin and data is displayed in Figure B2. This was used to determine annual nutrient loads (Figure B3 and Table B3). The Capel WWTP delivers an average annual load of approximately 589 kg of TN and 318 kg of TP annually, however there is an increasing trend in the load being delivered. The Water Corporation plans to upgrade the facility. This will involve disinfection of the wastewater, which will then be delivered through a 3km pipeline to nearby wetlands which have been established as pard of Iluka's mining rehabilitation works. Care must be taken to limit the nutrient delivery to these wetlands to ensure that the systems do not become eutrophic.

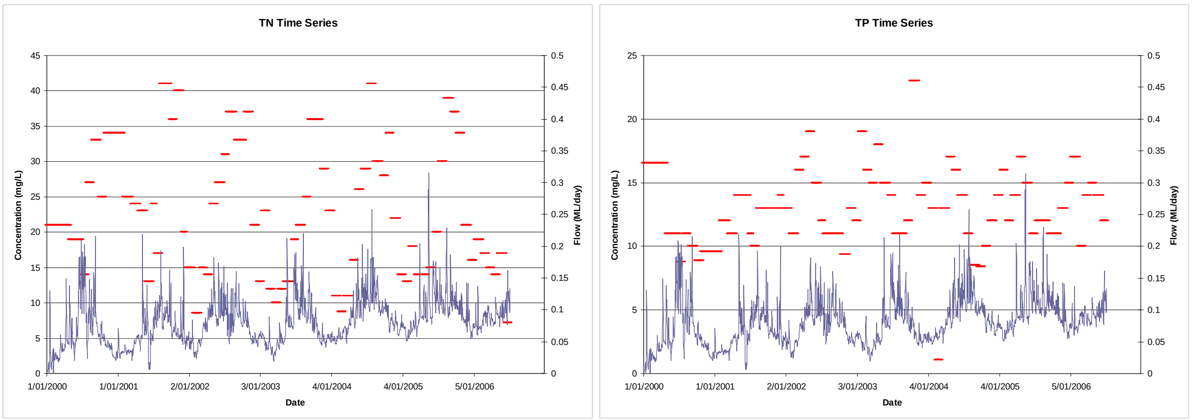


Figure B2. Water quality and flow monitoring data for the Capel WWTP

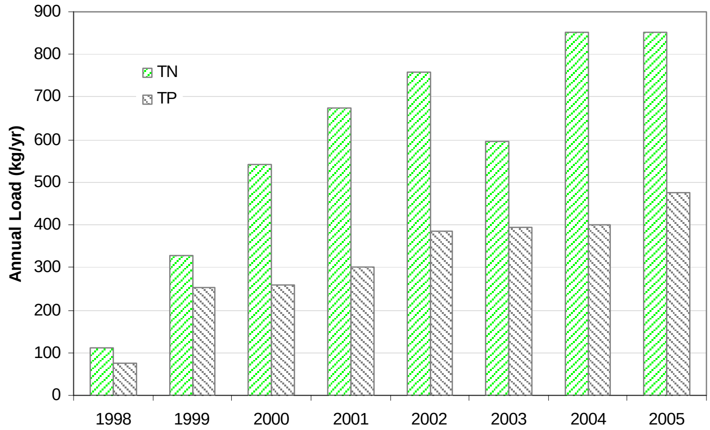


Figure B3. Annual load exports from the Capel WWTP

Table B3. Annual load exports from the Capel WWTP

Year	NH3	Nox	TN	TP
1998	4	19	111	75
1999	11	74	327	251
2000	160	74	543	260
2001	340	23	676	301
2002	479	10	758	384
2003	285	44	595	394
2004	637	11	853	402
2005	657	17	852	474
Average	322	34	589	318

The relatively newly commissioned Dunsborough WWTP enables the treatment and disposal of up to 4,000 kL per day of wastewater. The new system replaces the old pond-based wastewater treatment plant. The new wastewater treatment scheme features Intermittently Decanted Extended Aeration (IDEA) technology which produces a tertiary treated wastewater, and is used to irrigate a blue gum plantation in the dry months of the year.

The plantation site features a subsoil drainage system, as well as a soil moisture monitoring system and integrated weather station that is used to control the irrigation scheme. During winter the treated wastewater is filtered, disinfected with chlorine and released into the Station Gully Drain which runs through the treatment plant property.

Water quality monitoring and flow data from tree-lot drain was supplied by the Water Corporation (Figure B4), and analysed to determine annual loads for TN and TP entering the drain (Figure B5and Table B4). An average annual load of 797 kg of TN and 27 kg of TP enters the drain from the tree plantation drain.

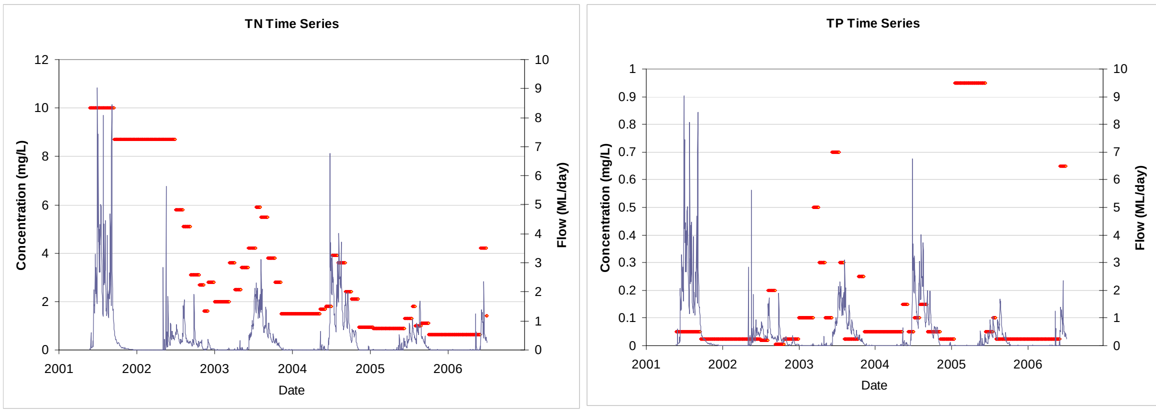


Figure B4. Water quality and flow monitoring data for the Dunsborough WWTP

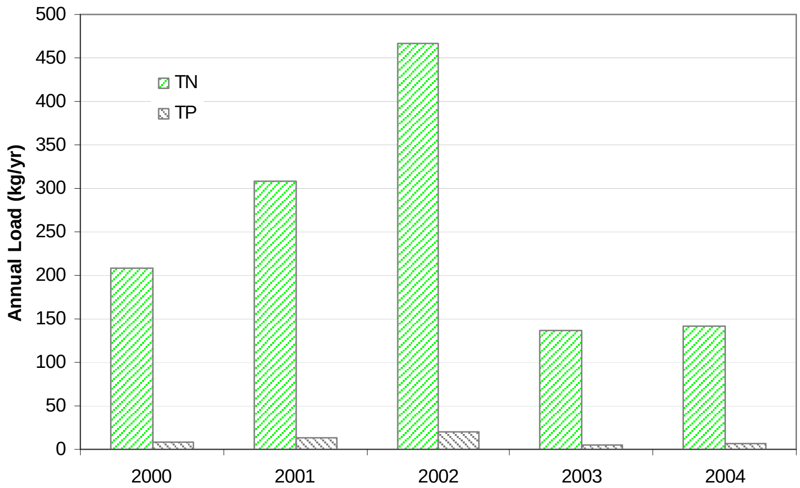


Figure B5. Annual load exports from the Dunsborough WWTP

Table B4. Annual load exports from the Dunsborough WWTP

Year	NH3 (kg)	Nox (kg)	TN (kg)	TP (kg)
2000	7	2703	2846	14
2001	3	471	512	5
2002	3	556	632	36
2003	21	402	596	19
2004	4	39	67	6
2005	6	36	127	83
Average	7	701	797	27

WWTPs contribute an estimated average of 3.5 tonnes of nitrogen and 1.80 tonnes of phosphorus annually.

Septic tanks from unsewered caravan parks and camp grounds

Whelan et al (1981), Whelan and Barrow (1984a, b) and Whelan (1988) examine the leaching of nitrogen and phosphorus from septic tanks located on sandy soils in Perth. They consider septic systems located on the three main Swan coastal plain soil types: Spearwood sands, Bassendean sands and the calcareous Quindalup sands. Similar soil types prevail in Busselton and much of the Geographe catchment.

Ammonium in septic tank effluent is generally oxidised to nitrate in the unsaturated soil zone beneath the soak well or leach drain. Nitrate is not adsorbed in the soil profile and travels with the water. Whelan et al (1981) and Whelan and Barrow (1984a) suggest that all nitrogen in septic tank effluent enters the groundwater except that lost in plant uptake. They consider that there is little chance of denitrification losses in these coarse sandy soils.

Whelan and Barrow (1984b) and Whelan (1988) examine the fate of phosphate in septic tank effluent. In sandy soils with low PRI's and high water tables such as those around Busselton, the soil profile becomes saturated with phosphate within a few years of operation after which the concentration of phosphate reaching the groundwater will be similar to the concentration of phosphate in the septic tank effluent. Phosphate is not transformed and reduced by microbial reactions (Gerritse, 2002); and once the soil profile is saturated with phosphorus, the only losses that may occur are due to plant uptake and these are considered to be minimal.

Estimates of nutrient loads in septic tank effluent of 1.1 kg/person/year of TP and 5.5 kg/person/year of TN are given by Whelan et al (1981).

The number of sites in each caravan park was obtained from the "Holiday Oz" website (www.holidayoz.com.au/wacp.htm). The procedure for determining loads from the septic tanks in unsewered caravan parks is outlined below:

Step 1: All caravan parks in Geographe catchment were located.

Step 2: All locations were checked for deep sewer connection.

Step 3: The number of sites for the unsewered parks were determined using websites.

Step 4: The annual TP and TN was determined by using the following equations:

$$TN(t) = \frac{5.5 * Occ * n * Sites}{1000} \qquad TP(t) = \frac{1.1 * Occ * n * Sites}{1000}$$

Where:

n = number of occupants per site

Occ = Occupancy rate

$Sites$ = number of sites in the caravan park

Assumptions:

- 1.1 kg phosphorus per person per year (Whelan and Barrow 1984b)
- 5.5 kg nitrogen per person per year (Whelan and Barrow 1984a)
- Phosphorus is entirely soluble reactive phosphorus.
- Nitrogen is 19% ammonium, 67% nitrate and 14% dissolved organic nitrogen.
- 3 people per site
- Occupancy is 48% annually (Figure B6)

17 CARAVAN PARKS(a), Total *continued*

Period	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Northern Territory	Australian Capital Territory	Australia
SITE OCCUPANCY RATE (%)									
2005									
June Quarter	55.9	48.2	55.5	38.1	47.1	35.9	38.1	34.0	50.4
September Quarter	54.9	48.3	65.7	35.3	52.6	np	50.8	np	52.5
December Quarter	57.0	50.4	51.1	39.3	46.6	np	np	np	50.1
2006									
March Quarter	60.4	55.5	47.1	44.4	45.4	50.3	np	np	52.1
June Quarter	55.1	48.0	55.8	37.8	49.4	np	37.8	np	50.2
TAKINGS FROM ACCOMMODATION ($'000)									
2005									
June Quarter	63 948	30 111	43 260	13 810	23 793	3 355	9 537	701	188 516
September Quarter	64 221	31 149	55 248	12 665	27 746	np	12 286	np	206 315
December Quarter	81 394	38 980	41 839	15 472	25 696	np	np	np	213 168
2006									
March Quarter	89 294	46 328	36 168	18 076	25 758	6 254	np	np	226 027
June Quarter	66 670	31 756	47 708	14 733	28 125	np	9 974	np	203 323

np not available for publication but included in totals where applicable, unless otherwise indicated

(a) Comprising establishments with 40 or more powered sites and cabins, flats, units and villas.

Figure B6. Site occupancy rates for caravan parks in Australia (from Australian Bureau of Statistics, 2006 www.abs.gov.au/).

The estimated average annual load of total phosphorus and total nitrogen being delivered from the septic systems of caravan parks in the Geogrpahe catchment is displayed in Table B5.

Table B5. Annual load deliveries for caravan parks in the Geographe catchment.

Name	District	Sites	Cabins	Septic	TP (kg/yr)	TN (kg/yr)
Acacia Caravan Park	Busselton	157	20	No	0	0
Geographe Bay Holiday Park	Busselton	0	60	No	0	0
Amblin Caravan Park	Busselton	142	22	No	0	0
Mandalay Holiday Resort	Busselton	121	17	Yes	223	1116
Beachlands Holiday Park	Busselton	39	10	Yes	79	396
Four Seasons Holiday Resort	Busselton	147	11	Yes	255	1277
Lazy Days Caravan Park	Busselton	38	0	Yes	61	307
Kookaburra Caravan Park	Busselton	65	0	No	0	0
Sandy Bay Holiday Park	Busselton	60	0	Yes	97	485
Siesta Park Holiday Resort	Busselton	0	30	Yes	49	243
Peppermint Grove Holiday Park	Capel	64	0	Yes	103	517
Dunsborough Lakes Holiday Resort	Dunsborough	103	9	No	0	0
Busselton Caravan Park	Busselton	60	0	No	0	0
Vasse Beachfront Caravan Park	Busselton	94	4	No	0	0
Total					**867**	**4341**

There are 16 unsewered coastal camp-grounds which are located along Geographe Bay coastline, between Busselton and Dunsborough (know locally as the 'Holy Mile'). There was an estimated average of twenty residents at each of these sites annually, which equated to a total annual load of 352kg of TP and 1760 kg of TN being delivered through septic leachate to Geographe catchment and waterways.

Landfill sites

The decommissioned Busselton Waste Facility and the Capel landfill were the only two landfills included in the point sources analysis. The new Busselton Waste Facility is located in the upper Jingarmup Brook catchment, and is situated on heavy soils with deep groundwater levels. An analysis of the bore data from this landfill indicated that it was not contributing significantly to nutrient levels in the Jingarmup Brook. There are various other small landfills in the catchment, which are not likely to be contributing significant levels of nutrient to the waterways of the Geographe catchment.

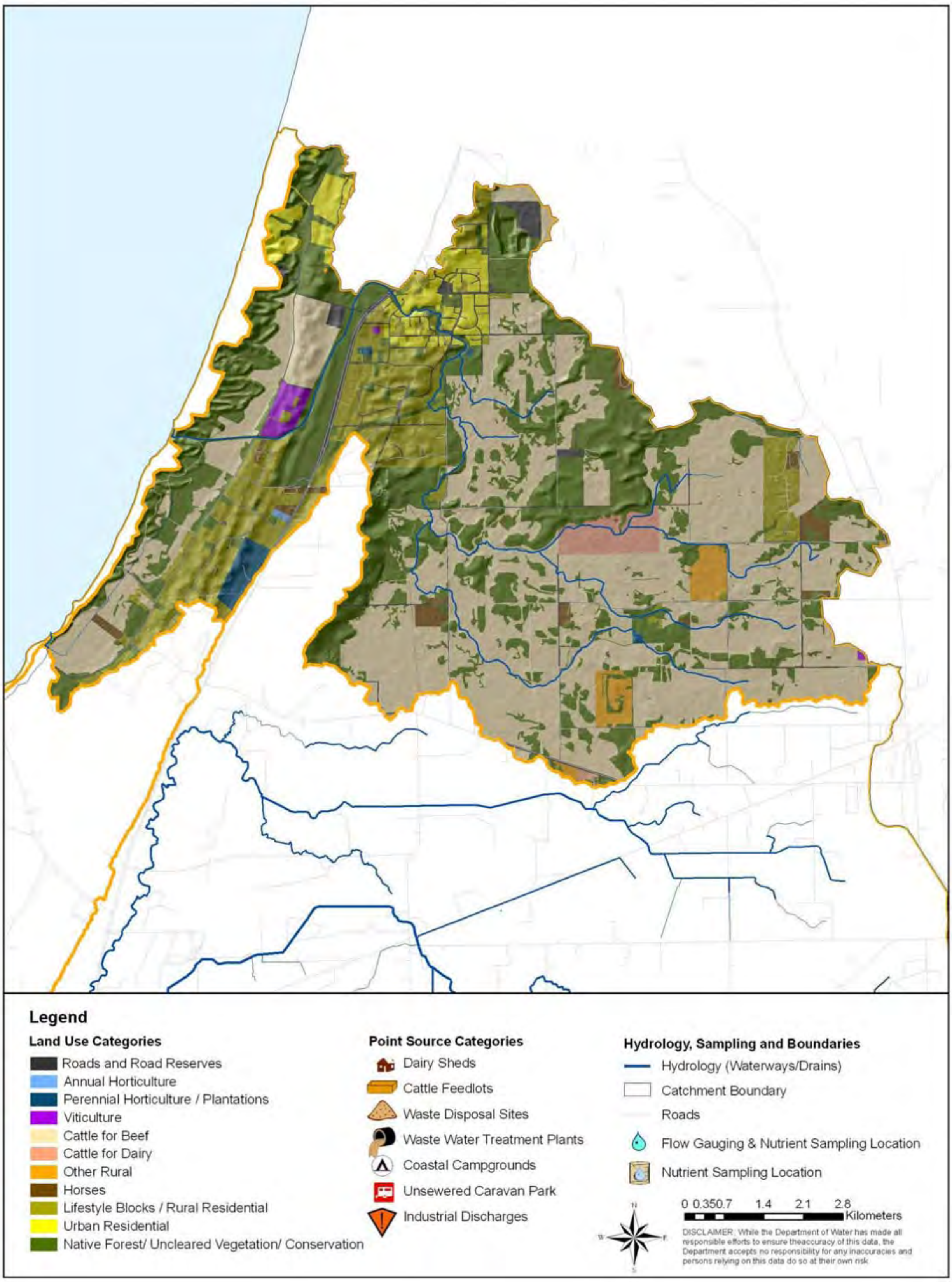
TN leaching from the Busselton rubbish tip was estimated to be between 148 and 356 kg/year, based on data in Lundstrom (2001) "Busselton Waste Facility Rendezvous Road, Post Closure Management Plan". The nutrient content of solid household waste was estimated to be 1.86 kg TN/person/year and 0.37 kg TP/person/year according to The Royal Netherlands Institute for Sea Research (www.nioz.nl/loicz/firstpages/products/fp-products.htm). The ratio of TP to TN in solid household waste was used to estimate TP leaching from the rubbish tip. This was approximately 30 to 71 kg/year. The Capel landfill disposes of 500 t of waste per year compared with Busselton's 4000 t. If similar leaching rates are applied for the Capel landfill, it is expected to contribute between 4 and 9 kg of TP per year and between 19 and 45 kg of TN per year. A total of 343 kg TN per year and 69 kg of TP per year estimated to be delivered to the Geographe catchment from landfills.

Industrial point sources

There are three facilities in the Geogrpahe catchment that pollute nutrients to water and trigger the Nutrient Pollution Inventory (NPI) emission thresholds and are compelled to report to the NPI. These three sites belong to Iluka Resources, and are associated with metal ore processing. According to the NPI database, in 2005 these sites contributed a total of 7296 kilograms of total nitrogen to waterways of the Geographe catchment.

Appendix C: Modelling results for reporting subcatchments

Five Mile Brook



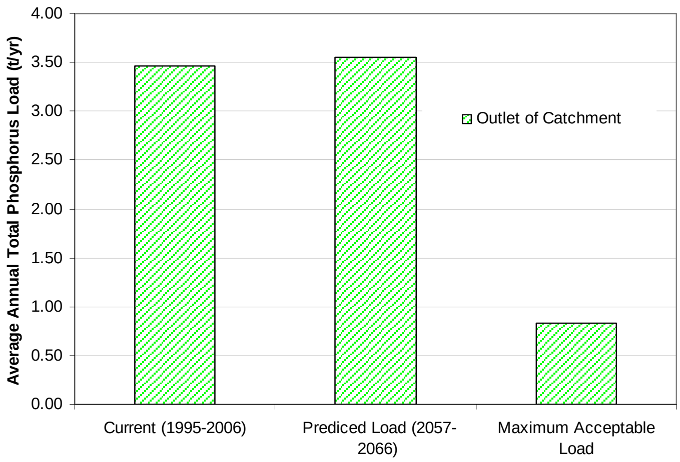
Five Mile Brook: Current loads, predicted loads and load reduction targets

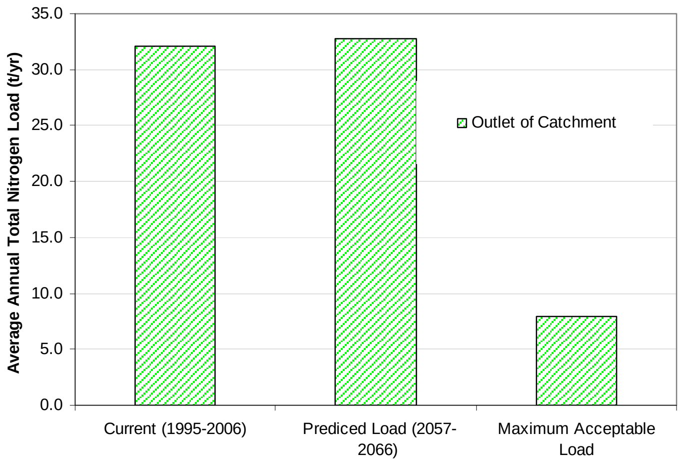
Phosphorus

	Year	Load (t/yr)	Current conditions	Load (t/yr)	80% P reduction	Load (t/yr)
			At Outlet To Geographe Bay			
	1995	3.25	2055	3.44	2055	0.82
	1996	3.80	2056	3.97	2056	0.93
	1997	3.68	2057	3.82	2057	0.90
	1998	2.97	2058	3.10	2058	0.74
	1999	5.68	2059	5.84	2059	1.36
	2000	3.57	2060	3.66	2060	0.86
	2001	1.51	2061	1.58	2061	0.39
	2002	3.22	2062	3.23	2062	0.77
	2003	4.06	2063	4.06	2063	0.94
	2004	3.40	2064	3.40	2064	0.81
	2005	5.61	2065	5.60	2065	1.30
	2006	0.84	2066	0.84	2066	0.21
Average load for rainfall sequence (t/yr)		**3.47**		**3.55**		**0.84**
Median winter concentration (mg/L)		**0.415**		0.437		0.100
Load-reduction target (t/yr)		**2.63**	*76%*			
Maximum acceptable load (t/yr)		**0.84**				
Time periods required to meet LRT		**1**				

Nitrogen

	Year	Load (t/yr)	Current Conditions	Load (t/yr)	81% N reduction	Load (t/yr)
			At Outlet To Geographe Bay			
	1995	38.1	2055	39.9	2055	9.7
	1996	45.8	2056	47.9	2056	11.5
	1997	32.9	2057	34.1	2057	8.2
	1998	26.4	2058	27.3	2058	6.6
	1999	52.3	2059	53.2	2059	12.7
	2000	33.2	2060	33.3	2060	8.0
	2001	12.9	2061	12.9	2061	3.3
	2002	27.2	2062	27.3	2062	6.6
	2003	32.8	2063	32.9	2063	7.9
	2004	28.4	2064	28.5	2064	6.9
	2005	45.9	2065	46.0	2065	11.0
	2006	9.5	2066	9.5	2066	2.4
Average load for rainfall sequence (t/yr)		**32.1**		**32.7**		**7.9**
Median winter concentration (mg/L)		**4.09**		4.27		1.00
Load-reduction target (t/yr)		**24.2**	*75%*			
Maximum acceptable load (t/yr)		**7.9**				
Time periods required to meet LRT		**2**				





Five Mile Brook: Source separation

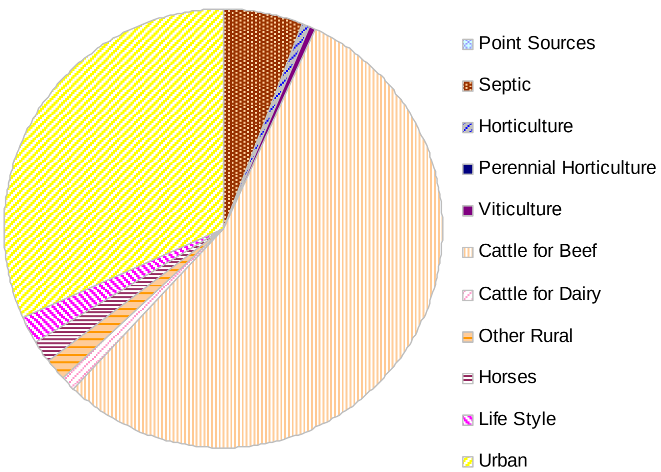
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	3.25	0.00	0.20	0.01	0.00	0.01	1.67	0.02	0.05	0.05	0.05	0.98
1996	3.80	0.00	0.21	0.01	0.00	0.01	1.89	0.03	0.05	0.06	0.06	1.19
1997	3.68	0.00	0.21	0.01	0.00	0.02	2.01	0.03	0.06	0.06	0.06	1.01
1998	2.97	0.00	0.18	0.01	0.00	0.01	1.42	0.02	0.04	0.05	0.04	1.03
1999	5.68	0.00	0.29	0.02	0.00	0.02	3.17	0.08	0.10	0.10	0.10	1.46
2000	3.57	0.00	0.20	0.01	0.00	0.02	2.01	0.06	0.06	0.06	0.06	0.87
2001	1.51	0.00	0.11	0.00	0.00	0.01	0.57	0.00	0.01	0.01	0.02	0.68
2002	3.22	0.00	0.19	0.02	0.00	0.01	1.63	0.02	0.05	0.05	0.06	1.06
2003	4.06	0.00	0.20	0.02	0.00	0.01	2.25	0.07	0.07	0.06	0.10	1.16
2004	3.40	0.00	0.20	0.02	0.00	0.02	1.75	0.02	0.05	0.05	0.09	1.10
2005	5.61	0.00	0.28	0.04	0.00	0.02	3.05	0.07	0.09	0.10	0.15	1.61
2006	0.84	0.00	0.07	0.00	0.00	0.00	0.33	0.00	0.01	0.01	0.02	0.37
Load (non adj)	3.47	0.00	0.20	0.02	0.00	0.01	1.81	0.04	0.05	0.06	0.07	1.04
Load (t/yr)	**3.47**	**0.00**	**0.21**	**0.02**	**0.00**	**0.01**	**1.91**	**0.04**	**0.06**	**0.06**	**0.07**	**1.10**
Load (%)	**100.0%**	**0.0%**	**5.9%**	**0.5%**	**0.0%**	**0.4%**	**55.0%**	**1.1%**	**1.6%**	**1.7%**	**2.1%**	**31.6%**

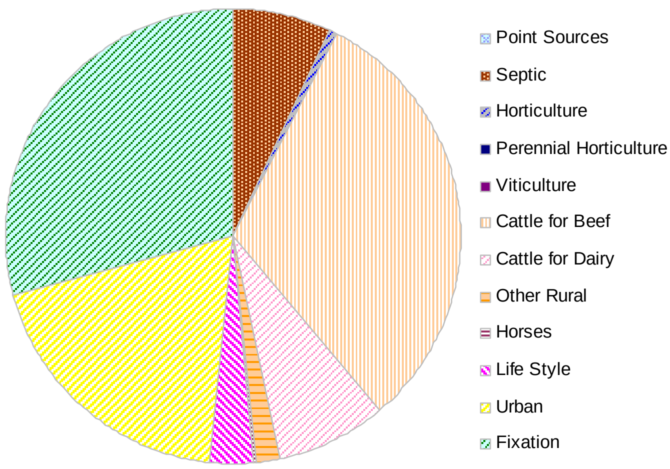
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	38.1	0.0	2.4	0.1	0.0	0.0	10.4	2.6	0.5	0.1	1.1	5.8	10.3
1996	45.8	0.0	2.8	0.1	0.0	0.0	12.5	3.1	0.6	0.1	1.3	6.7	12.6
1997	32.9	0.0	2.0	0.1	0.0	0.0	9.5	2.4	0.4	0.1	0.9	4.8	8.8
1998	26.4	0.0	1.7	0.1	0.0	0.0	7.4	1.9	0.4	0.1	0.7	4.5	6.7
1999	52.3	0.0	3.1	0.2	0.0	0.0	14.9	3.7	0.7	0.1	1.4	7.4	14.3
2000	33.2	0.0	2.0	0.1	0.0	0.0	9.4	2.3	0.4	0.1	0.9	4.9	8.8
2001	12.9	0.0	1.0	0.0	0.0	0.0	2.9	0.7	0.1	0.0	0.3	3.1	2.8
2002	27.2	0.0	1.7	0.1	0.0	0.0	7.9	2.1	0.4	0.1	0.7	5.0	6.7
2003	32.8	0.0	2.0	0.1	0.0	0.0	9.7	2.5	0.5	0.1	0.9	6.4	8.1
2004	28.4	0.0	1.8	0.1	0.0	0.0	8.0	2.0	0.4	0.1	0.8	5.9	7.3
2005	45.9	0.0	2.8	0.2	0.1	0.0	13.3	3.4	0.6	0.1	1.3	9.0	12.2
2006	9.5	0.0	0.8	0.0	0.0	0.0	2.1	0.6	0.1	0.0	0.3	2.9	2.1
Load (non adj)	32.1	0.0	2.0	0.1	0.0	0.0	9.0	2.3	0.4	0.1	0.9	5.5	8.4
Load (t/yr)	**32.1**	**0.0**	**2.2**	**0.1**	**0.0**	**0.0**	**10.1**	**2.5**	**0.5**	**0.1**	**1.0**	**6.2**	**9.4**
Load (%)	**100.0%**	**0.0%**	**7.0%**	**0.4%**	**0.1%**	**0.1%**	**31.3%**	**7.9%**	**1.5%**	**0.3%**	**3.1%**	**19.3%**	**29.2%**

Total phosphorus



Total nitrogen



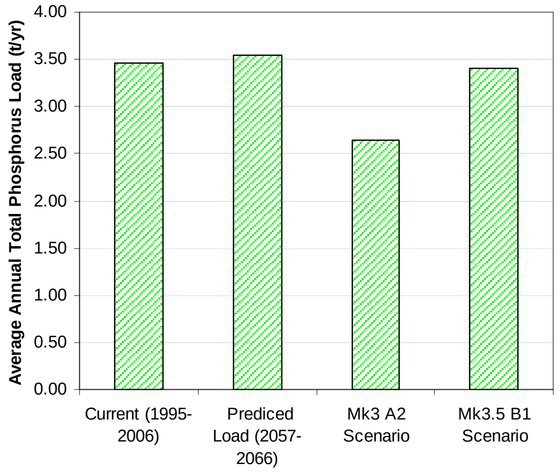
Five Mile Brook: Climate change scenarios

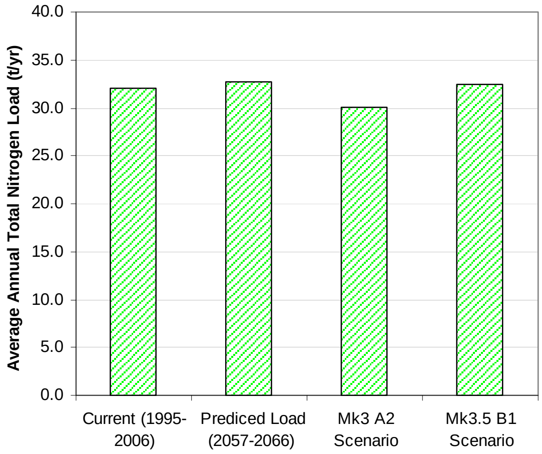
Phosphorus

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	3.25	2055	3.44	2055	2.68	2055	3.31
1996	3.80	2056	3.97	2056	3.45	2056	3.91
1997	3.68	2057	3.82	2057	3.13	2057	3.66
1998	2.97	2058	3.10	2058	2.12	2058	2.94
1999	5.68	2059	5.84	2059	4.80	2059	5.66
2000	3.57	2060	3.66	2060	2.97	2060	3.61
2001	1.51	2061	1.58	2061	0.94	2061	1.42
2002	3.22	2062	3.23	2062	2.14	2062	3.08
2003	4.06	2063	4.06	2063	2.78	2063	3.88
2004	3.40	2064	3.40	2064	2.33	2064	3.26
2005	5.61	2065	5.60	2065	3.88	2065	5.25
2006	0.84	2066	0.84	2066	0.55	2066	0.81
Average load (t/yr)	3.47		**3.55**		2.65		3.40

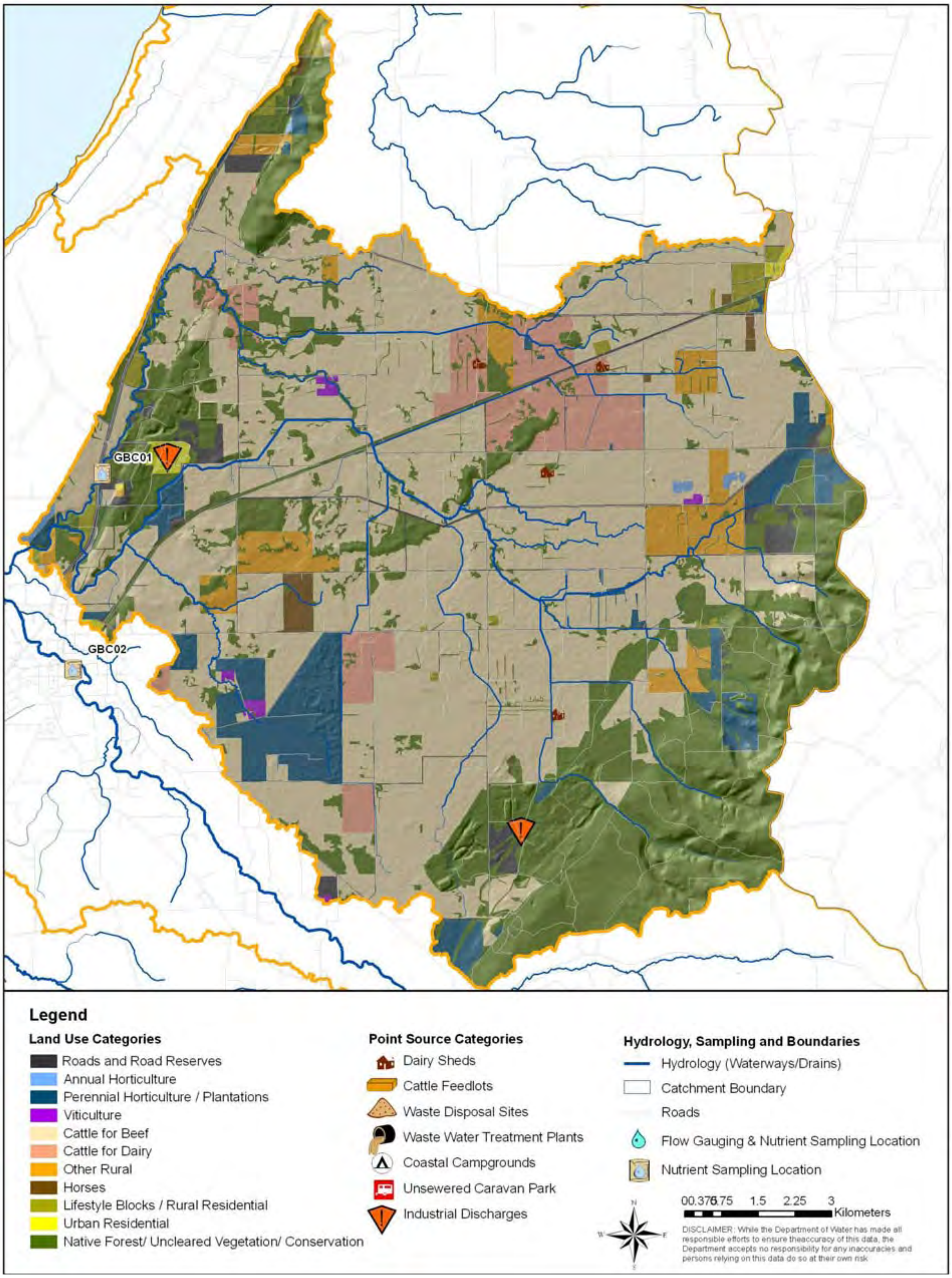
Nitrogen

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	38.1	2055	39.9	2055	38.1	2055	40.0
1996	45.8	2056	47.9	2056	50.8	2056	48.6
1997	32.9	2057	34.1	2057	33.8	2057	33.9
1998	26.4	2058	27.3	2058	23.3	2058	26.8
1999	52.3	2059	53.2	2059	52.9	2059	53.1
2000	33.2	2060	33.3	2060	33.4	2060	33.5
2001	12.9	2061	12.9	2061	9.0	2061	12.1
2002	27.2	2062	27.3	2062	21.6	2062	26.7
2003	32.8	2063	32.9	2063	27.0	2063	32.2
2004	28.4	2064	28.5	2064	23.4	2064	28.1
2005	45.9	2065	46.0	2065	40.5	2065	45.0
2006	9.5	2066	9.5	2066	7.6	2066	9.5
Average load (t/yr)	32.1		**32.7**		30.1		32.5





Gynudup Brook



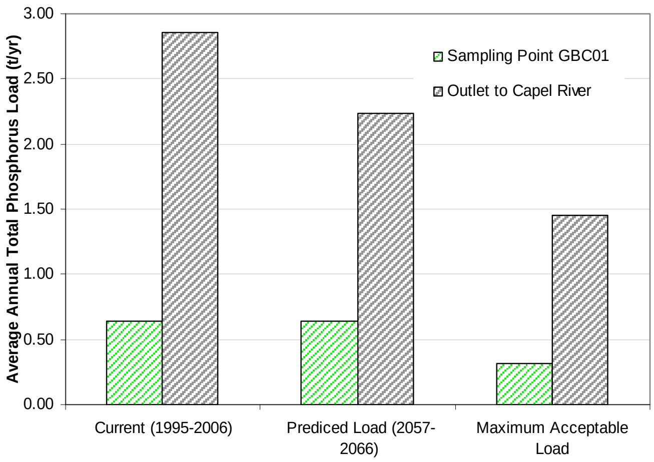
Gynudup Brook: Current loads, predicted loads and load-reduction targets

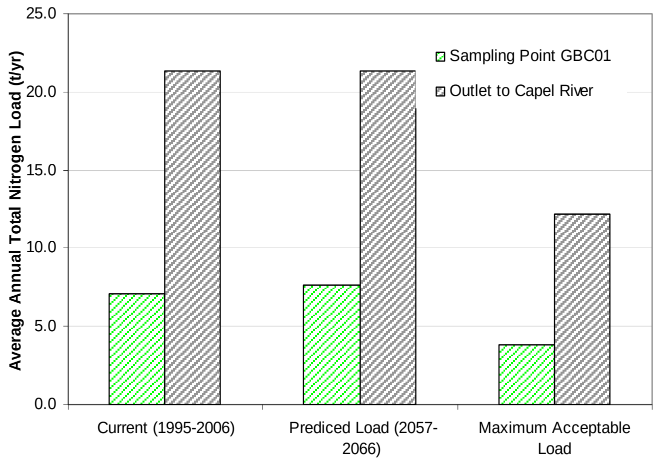
Phosphorus

	At outlet to Capel River						At sampling point GBC01					
	Year	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**58% P reduction**	**Load (t/yr)**	**Year**	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**58% P Reduction**	**Load (t/yr)**
	1995	0.65	2055	0.80	2055	0.34	1995	0.47	2055	0.43	2055	0.18
	1996	0.75	2056	0.96	2056	0.41	1996	0.56	2056	0.56	2056	0.24
	1997	0.76	2057	0.96	2057	0.41	1997	0.58	2057	0.58	2057	0.25
	1998	0.49	2058	0.65	2058	0.28	1998	0.35	2058	0.35	2058	0.15
	1999	25.59	2059	14.79	2059	10.95	1999	2.66	2059	2.46	2059	1.48
	2000	2.90	2060	4.77	2060	3.36	2000	0.79	2060	0.98	2060	0.52
	2001	0.27	2061	0.39	2061	0.17	2001	0.18	2061	0.18	2061	0.08
	2002	0.47	2062	0.63	2062	0.27	2002	0.33	2062	0.33	2062	0.14
	2003	0.63	2063	0.79	2063	0.34	2003	0.48	2063	0.48	2063	0.20
	2004	0.52	2064	0.66	2064	0.28	2004	0.36	2064	0.36	2064	0.15
	2005	1.11	2065	1.33	2065	0.57	2005	0.86	2065	0.86	2065	0.37
	2006	0.11	2066	0.16	2066	0.07	2006	0.06	2066	0.06	2066	0.03
Average load for rainfall sequence (t/yr)		**2.85**		2.24		**1.45**		0.64		0.64		0.32
Median winter concentration (mg/L)		**0.204**		0.237		0.1		0.189		0.183		0.078
Load-reduction target (t/yr)		**1.40**	49%									
Maximum acceptable load (t/yr)		**1.45**										
Time periods required to meet LRT		**1**										

Nitrogen

	At outlet to Capel River						At sampling point GBC01					
	Year	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**61% N reduction**	**Load (t/yr)**	**Year**	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**61% N reduction**	**Load (t/yr)**
	1995	8.2	2055	10.3	2055	3.6	1995	6.0	2055	6.5	2055	2.6
	1996	9.6	2056	11.7	2056	4.2	1996	7.1	2056	7.7	2056	3.0
	1997	7.3	2057	8.7	2057	3.1	1997	5.5	2057	5.8	2057	2.3
	1998	5.4	2058	6.6	2058	2.3	1998	4.1	2058	4.2	2058	1.7
	1999	174.3	2059	138.5	2059	93.0	1999	32.1	2059	32.6	2059	20.4
	2000	20.9	2060	43.5	2060	27.8	2000	6.9	2060	10.9	2060	6.1
	2001	2.1	2061	2.9	2061	0.9	2001	1.6	2061	1.6	2061	0.6
	2002	5.4	2062	6.4	2062	2.2	2002	4.2	2062	4.2	2062	1.7
	2003	6.7	2063	7.8	2063	2.7	2003	5.1	2063	5.2	2063	2.0
	2004	5.7	2064	6.7	2064	2.3	2004	4.3	2064	4.3	2064	1.7
	2005	9.8	2065	11.1	2065	3.9	2005	7.5	2065	7.6	2065	3.0
	2006	1.1	2066	1.5	2066	0.4	2006	0.8	2066	0.8	2066	0.3
Average load for rainfall sequence (t/yr)		**21.4**		21.3		**12.2**		7.1		7.6		3.8
Median winter concentration (mg/L)		**2.55**		2.86		1.00		2.29		2.35		0.93
Load-reduction target (t/yr)		**9.2**	43%									
Maximum acceptable load (t/yr)		**12.2**										
Time periods required to meet LRT		**1**										





Gynudup Brook: Source separation

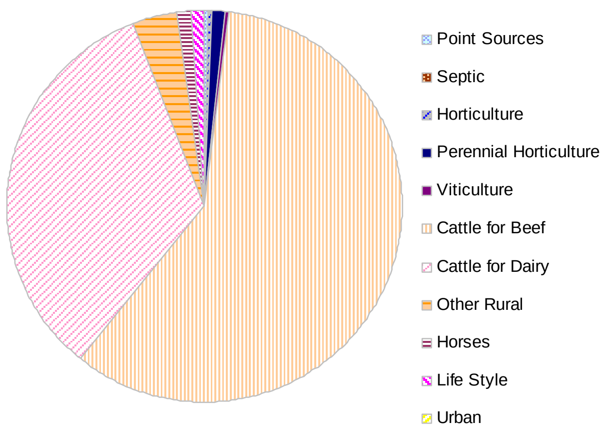
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	0.65	0.00	0.00	0.00	0.02	0.00	0.50	0.03	0.01	0.00	0.03	0.00
1996	0.75	0.00	0.00	0.00	0.02	0.00	0.57	0.03	0.01	0.00	0.04	0.00
1997	0.76	0.00	0.00	0.00	0.01	0.00	0.59	0.03	0.01	0.00	0.04	0.00
1998	0.49	0.00	0.00	0.00	0.01	0.00	0.38	0.02	0.01	0.00	0.03	0.00
1999	25.59	0.51	0.44	0.44	0.61	0.53	13.38	10.20	1.34	0.77	0.50	0.44
2000	2.90	0.04	0.04	0.04	0.06	0.04	1.72	0.89	0.13	0.06	0.07	0.04
2001	0.27	0.00	0.00	0.00	0.01	0.00	0.21	0.01	0.00	0.00	0.01	0.00
2002	0.47	0.00	0.00	0.01	0.01	0.00	0.36	0.02	0.01	0.00	0.03	0.00
2003	0.63	0.00	0.00	0.01	0.01	0.00	0.50	0.02	0.01	0.00	0.03	0.00
2004	0.52	0.00	0.00	0.02	0.01	0.00	0.39	0.02	0.01	0.00	0.03	0.00
2005	1.11	0.00	0.00	0.05	0.02	0.00	0.87	0.04	0.02	0.00	0.05	0.00
2006	0.11	0.00	0.00	0.00	0.01	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Load (non adj)	2.85	0.05	0.04	0.05	0.07	0.05	1.63	0.94	0.13	0.07	0.07	0.04
Load (t/yr)	**2.85**	**0.01**	**0.00**	**0.01**	**0.03**	**0.01**	**1.68**	**0.95**	**0.10**	**0.03**	**0.03**	**0.00**
Load (%)	**100.0%**	**0.2%**	**0.1%**	**0.3%**	**1.0%**	**0.3%**	**58.9%**	**33.5%**	**3.4%**	**1.1%**	**1.2%**	**0.0%**

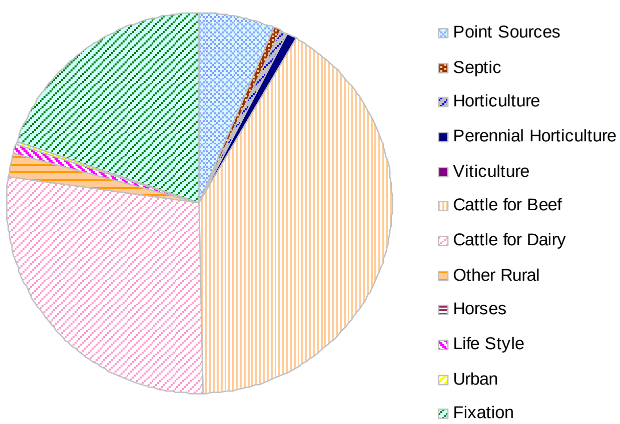
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	8.2	0.0	0.1	0.0	0.1	0.0	3.6	0.3	0.1	0.0	0.2	0.0	2.4
1996	9.6	0.0	0.1	0.0	0.1	0.0	4.2	0.4	0.1	0.0	0.3	0.0	2.9
1997	7.3	0.0	0.1	0.0	0.1	0.0	3.3	0.3	0.1	0.0	0.2	0.0	2.2
1998	5.4	0.0	0.1	0.0	0.1	0.0	2.5	0.2	0.1	0.0	0.1	0.0	1.6
1999	174.3	17.8	2.6	2.2	3.7	2.2	74.6	66.7	5.8	2.5	2.7	2.8	31.6
2000	20.9	1.5	0.3	0.2	0.4	0.2	9.1	5.9	0.6	0.2	0.4	0.2	4.5
2001	2.1	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.1	0.0	0.6
2002	5.4	0.0	0.1	0.1	0.1	0.0	2.6	0.2	0.1	0.0	0.2	0.0	1.6
2003	6.7	0.0	0.1	0.3	0.1	0.0	3.2	0.3	0.1	0.0	0.2	0.0	1.9
2004	5.7	0.0	0.1	0.3	0.1	0.0	2.6	0.2	0.1	0.0	0.2	0.0	1.6
2005	9.8	0.0	0.1	0.6	0.1	0.0	4.5	0.4	0.1	0.0	0.3	0.0	2.9
2006	1.1	0.0	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.3
Load (non adj)	21.4	1.6	0.3	0.3	0.4	0.2	9.3	6.3	0.6	0.2	0.4	0.3	4.5
Load (t/yr)	**21.4**	**1.4**	**0.1**	**0.1**	**0.2**	**0.0**	**8.9**	**5.9**	**0.4**	**0.0**	**0.2**	**0.1**	**4.2**
Load (%)	**100.0%**	**6.4%**	**0.4%**	**0.5%**	**0.9%**	**0.0%**	**41.4%**	**27.6%**	**1.8%**	**0.1%**	**0.9%**	**0.3%**	**19.6%**

Total phosphorus



Total nitrogen



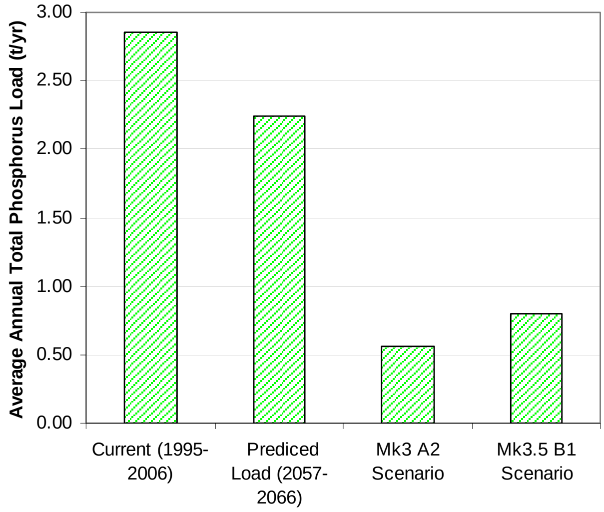
Gynudup Brook: Climate change scenarios

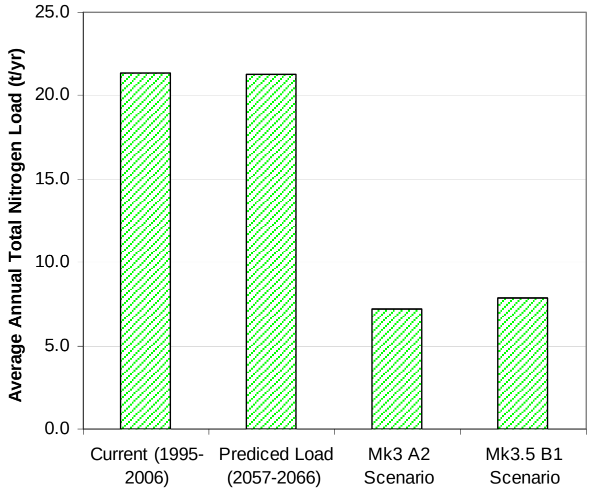
Phosphorus

	At catchment outlet						
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	0.65	2055	0.80	2055	0.56	2055	0.77
1996	0.75	2056	0.96	2056	0.76	2056	0.93
1997	0.76	2057	0.96	2057	0.73	2057	0.92
1998	0.49	2058	0.65	2058	0.43	2058	0.61
1999	25.59	2059	14.79	2059	1.17	2059	1.72
2000	2.90	2060	4.77	2060	0.79	2060	1.07
2001	0.27	2061	0.39	2061	0.20	2061	0.34
2002	0.47	2062	0.63	2062	0.41	2062	0.59
2003	0.63	2063	0.79	2063	0.45	2063	0.75
2004	0.52	2064	0.66	2064	0.40	2064	0.62
2005	1.11	2065	1.33	2065	0.69	2065	1.18
2006	0.11	2066	0.16	2066	0.10	2066	0.15
Average load (t/yr)	2.85		2.24		0.56		0.80

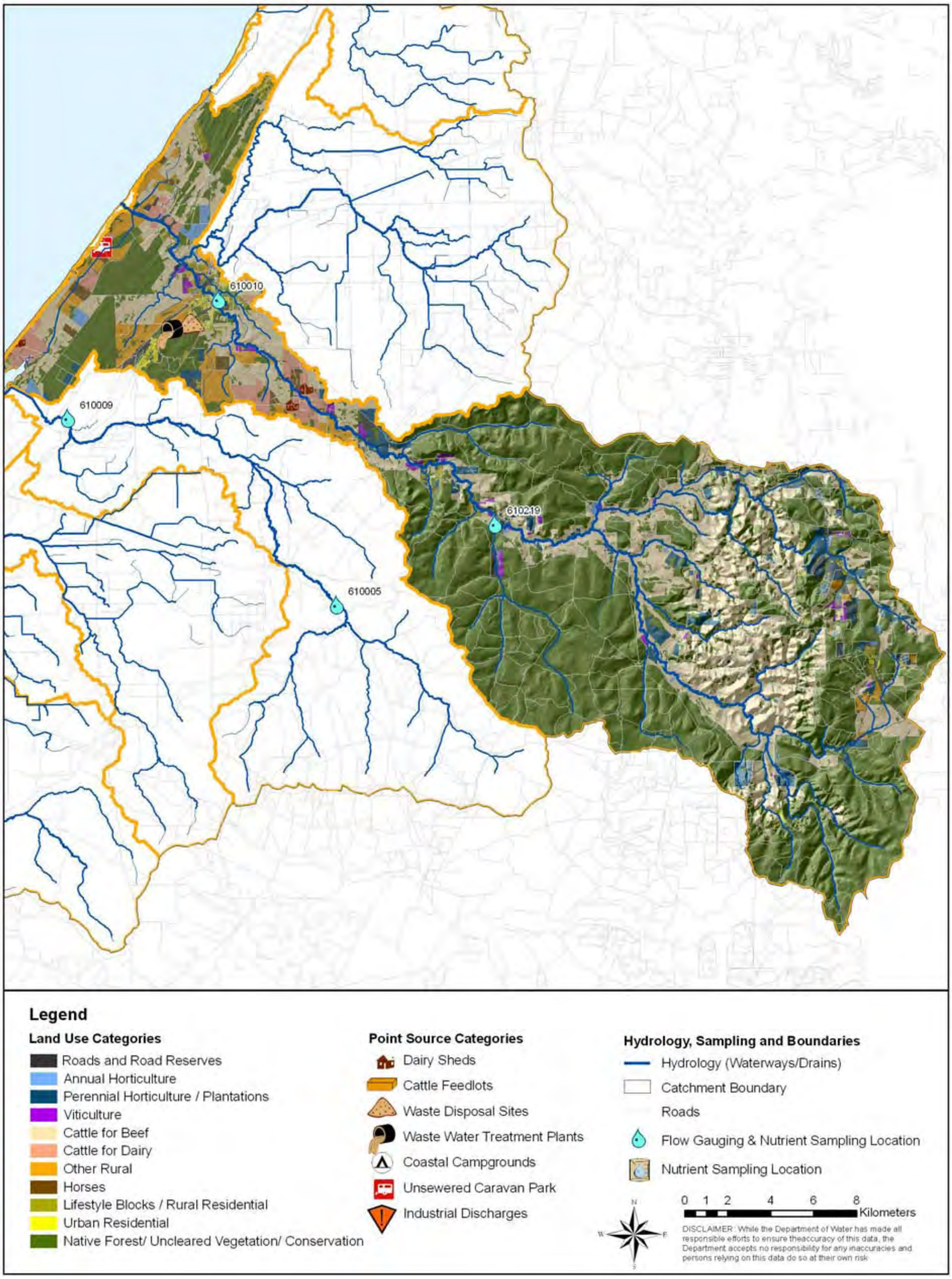
Nitrogen

	At catchment outlet						
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	8.2	2055	10.3	2055	10.1	2055	10.4
1996	9.6	2056	11.7	2056	12.6	2056	11.9
1997	7.3	2057	8.7	2057	8.6	2057	8.6
1998	5.4	2058	6.6	2058	5.5	2058	6.5
1999	174.3	2059	138.5	2059	13.3	2059	13.7
2000	20.9	2060	43.5	2060	7.9	2060	8.0
2001	2.1	2061	2.9	2061	1.7	2061	2.6
2002	5.4	2062	6.4	2062	4.9	2062	6.3
2003	6.7	2063	7.8	2063	6.1	2063	7.6
2004	5.7	2064	6.7	2064	5.2	2064	6.6
2005	9.8	2065	11.1	2065	9.3	2065	10.8
2006	1.1	2066	1.5	2066	0.9	2066	1.5
Average load (t/yr)	21.4		21.3		7.2		7.9





Capel River


610010
610009
610219
610005
Legend
Land Use Categories
Roads and Road Reserves
Annual Horticulture
Perennial Horticulture / Plantations
Viticulture
Cattle for Beef
Cattle for Dairy
Other Rural
Horses
Lifestyle Blocks / Rural Residential
Urban Residential
Native Forest/ Uncleared Vegetation/ Conservation
Point Source Categories
Dairy Sheds
Cattle Feedlots
Waste Disposal Sites
Waste Water Treatment Plants
Coastal Campgrounds
Unsewered Caravan Park
Industrial Discharges
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary
Roads
Flow Gauging & Nutrient Sampling Location
Nutrient Sampling Location
0 1 2 4 6 8
Kilometers
DISCLAIMER: While the Department of Water has made all responsible efforts to ensure theaccuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk

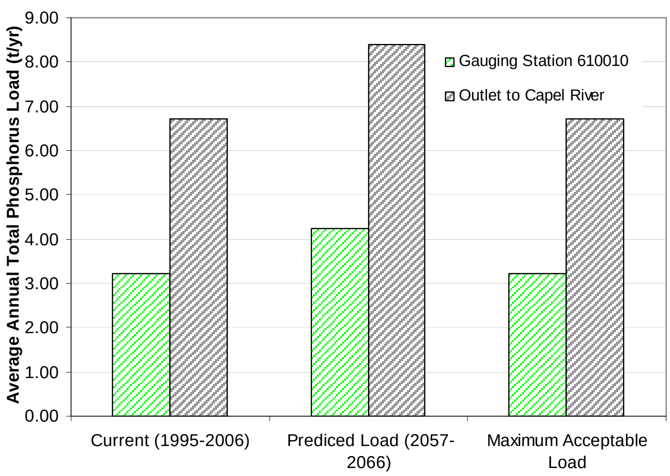
Capel River: Current loads, predicted loads and load-reduction targets

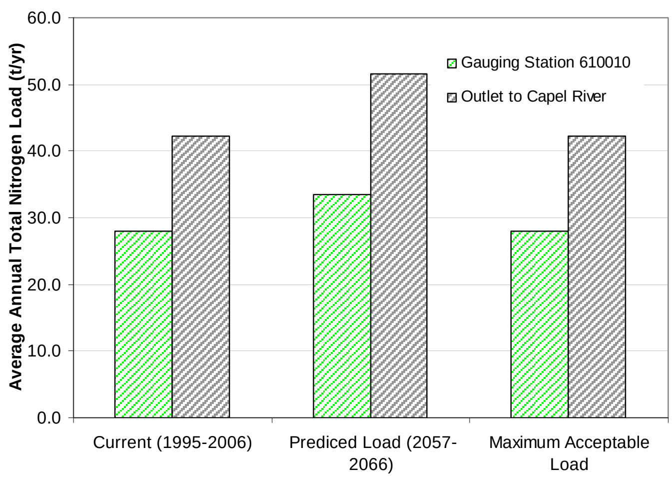
Phosphorus

	At outlet to Geographe Bay						At gauging station 610010/GBC02					
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% P reduction*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% P reduction*	*Load (t/yr)*
	1995	9.90	2055	12.48	2055	9.90	1995	4.31	2055	5.78	2055	4.31
	1996	10.16	2056	12.27	2056	10.16	1996	4.95	2056	6.20	2056	4.95
	1997	8.09	2057	9.74	2057	8.09	1997	3.90	2057	4.89	2057	3.90
	1998	4.22	2058	5.77	2058	4.22	1998	1.83	2058	2.75	2058	1.83
	1999	16.50	2059	19.62	2059	16.50	1999	7.74	2059	9.44	2059	7.74
	2000	7.93	2060	9.71	2060	7.93	2000	3.97	2060	5.01	2060	3.97
	2001	1.86	2061	3.27	2061	1.86	2001	0.62	2061	1.49	2061	0.62
	2002	4.24	2062	5.42	2062	4.24	2002	2.33	2062	3.13	2062	2.33
	2003	4.95	2063	6.31	2063	4.95	2003	2.63	2063	3.44	2063	2.63
	2004	4.07	2064	5.19	2064	4.07	2004	1.98	2064	2.68	2064	1.98
	2005	7.04	2065	8.58	2065	7.04	2005	3.89	2065	4.75	2065	3.89
	2006	1.72	2066	2.52	2066	1.72	2006	0.62	2066	1.20	2066	0.62
Average load for rainfall sequence (t/yr)		**6.72**		8.41		**6.72**		3.23		4.23		3.23
Median winter concentration (mg/L)		**-**		-		-		0.051		0.061		0.051
Load-reduction target (t/yr)		**0.00**	0%									
Maximum acceptable load (t/yr)		**6.72**										
Time periods required to meet LRT		***0***										

Nitrogen

	At outlet to Geographe Bay						At gauging station 610010/GBC02					
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% N reduction*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% N reduction*	*Load (t/yr)*
	1995	51.1	2055	62.7	2055	51.1	1995	33.4	2055	39.8	2055	33.4
	1996	62.6	2056	75.5	2056	62.6	1996	41.4	2056	48.2	2056	41.4
	1997	45.4	2057	56.2	2057	45.4	1997	29.2	2057	35.4	2057	29.2
	1998	34.8	2058	43.3	2058	34.8	1998	22.3	2058	27.4	2058	22.3
	1999	76.1	2059	90.6	2059	76.1	1999	49.6	2059	57.4	2059	49.6
	2000	49.5	2060	58.9	2060	49.5	2000	33.0	2060	38.3	2060	33.0
	2001	17.7	2061	23.3	2061	17.7	2001	11.1	2061	14.9	2061	11.1
	2002	35.2	2062	41.8	2062	35.2	2002	25.5	2062	29.6	2062	25.5
	2003	38.6	2063	46.7	2063	38.6	2003	26.8	2063	31.4	2063	26.8
	2004	33.4	2064	41.7	2064	33.4	2004	22.4	2064	27.4	2064	22.4
	2005	48.9	2065	59.5	2065	48.9	2005	33.0	2065	39.1	2065	33.0
	2006	13.7	2066	18.4	2066	13.7	2006	9.3	2066	12.7	2066	9.3
Average load for rainfall sequence (t/yr)		**42.2**		51.6		**42.2**		28.1		33.5		28.1
Median winter concentration (mg/L)		**-**		-		-		0.87		1.03		0.87
Load-reduction target (t/yr)		**0.00**	0%									
Maximum acceptable load (t/yr)		**42.2**										
Time periods required to meet LRT		**0**										





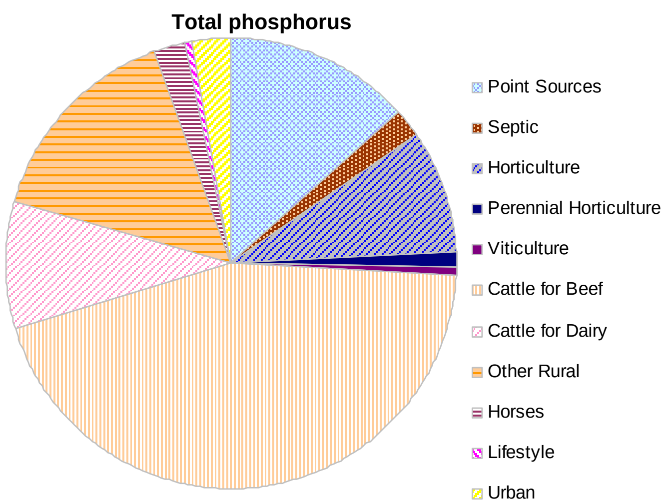
Capel River: Source separation

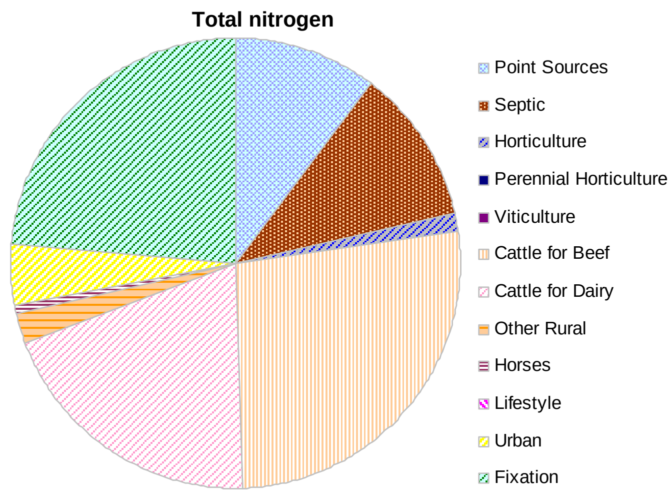
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	9.90	0.87	0.23	1.14	0.11	0.05	4.16	0.85	1.77	0.19	0.05	0.26
1996	10.16	0.87	0.20	0.98	0.13	0.07	4.65	0.88	1.59	0.20	0.05	0.24
1997	8.09	0.87	0.20	0.62	0.07	0.07	3.62	0.72	1.29	0.17	0.05	0.25
1998	4.22	0.87	0.10	0.29	0.04	0.03	1.63	0.31	0.59	0.12	0.04	0.13
1999	16.50	0.87	0.38	1.55	0.19	0.13	7.34	1.66	3.10	0.33	0.08	0.48
2000	7.93	0.87	0.16	0.60	0.08	0.05	3.75	0.64	1.22	0.17	0.04	0.17
2001	1.86	0.87	0.07	0.06	0.01	0.01	0.38	0.08	0.19	0.06	0.03	0.09
2002	4.24	0.87	0.08	0.29	0.05	0.03	2.00	0.22	0.41	0.09	0.03	0.11
2003	4.95	0.87	0.10	0.38	0.06	0.05	2.19	0.45	0.48	0.10	0.04	0.15
2004	4.07	0.87	0.08	0.35	0.05	0.04	1.61	0.39	0.38	0.09	0.04	0.12
2005	7.04	0.87	0.11	0.57	0.09	0.08	3.13	0.89	0.75	0.17	0.05	0.19
2006	1.72	0.87	0.05	0.08	0.01	0.01	0.35	0.08	0.12	0.05	0.03	0.07
Load (non adj)	6.72	0.87	0.15	0.58	0.07	0.05	2.90	0.60	0.99	0.14	0.04	0.19
Load (t/yr)	**6.72**	**0.89**	**0.15**	**0.59**	**0.07**	**0.05**	**2.98**	**0.61**	**1.02**	**0.14**	**0.04**	**0.19**
Load (%)	**100.0%**	**13.2%**	**2.2%**	**8.7%**	**1.1%**	**0.7%**	**44.3%**	**9.1%**	**15.1%**	**2.1%**	**0.6%**	**2.8%**

Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	51.1	5.1	6.5	2.8	2.6	2.5	10.5	8.5	3.3	2.7	2.6	4.0	10.8
1996	62.6	5.2	7.6	2.9	2.6	2.6	12.4	10.1	3.5	2.8	2.7	4.3	12.7
1997	45.4	5.3	5.8	3.1	2.8	2.8	9.8	8.7	3.4	2.9	2.8	3.9	8.6
1998	34.8	5.2	4.5	2.8	2.6	2.6	7.8	7.1	3.1	2.7	2.6	3.5	6.7
1999	76.1	5.2	8.9	3.1	2.7	2.7	14.6	11.8	3.7	3.0	2.7	4.8	14.7
2000	49.5	5.1	6.1	2.8	2.5	2.5	10.3	8.1	3.2	2.7	2.5	3.8	9.9
2001	17.7	5.1	2.8	2.6	2.5	2.5	4.6	4.4	2.7	2.6	2.5	3.0	3.6
2002	35.2	5.4	4.9	3.1	2.9	2.9	9.2	6.7	3.3	2.9	2.9	3.5	8.0
2003	38.6	5.2	4.8	3.1	2.6	2.6	8.8	6.9	3.1	2.7	2.7	3.5	7.7
2004	33.4	5.4	4.5	3.3	2.8	2.8	8.1	6.4	3.2	2.9	2.8	3.7	7.4
2005	48.9	5.4	5.6	3.7	2.8	2.8	11.3	8.4	3.4	3.0	2.8	4.1	8.8
2006	13.7	5.1	2.6	2.6	2.5	2.5	4.1	3.5	2.6	2.5	2.5	2.8	3.5
Load (non adj)	42.2	5.2	5.4	3.0	2.6	2.6	9.3	7.6	3.2	2.8	2.7	3.7	8.5
Load (t/yr)	**42.2**	**4.4**	**4.6**	**0.6**	**0.0**	**0.0**	**11.3**	**8.3**	**0.9**	**0.2**	**0.0**	**1.8**	**10.0**
Load (%)	**100.0%**	**10.4%**	**11.0%**	**1.4%**	**0.0%**	**0.0%**	**26.7%**	**19.7%**	**2.2%**	**0.6%**	**0.1%**	**4.4%**	**23.6%**





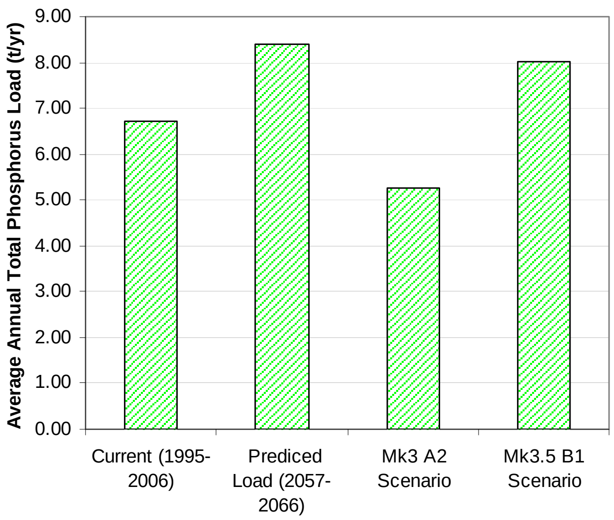
Capel River: Climate change scenarios

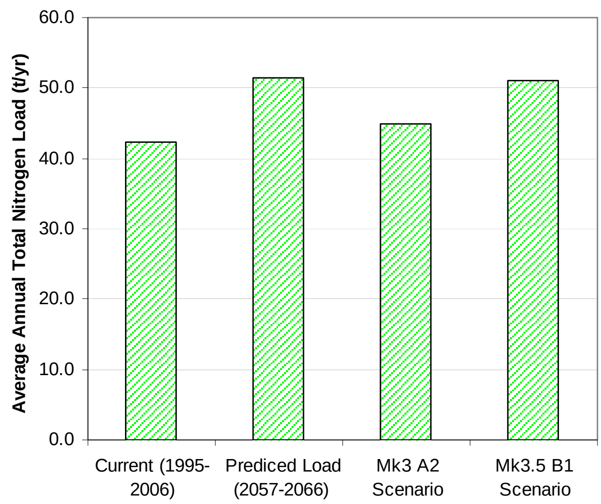
Phosphorus

	At catchment outlet							
	Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
	1995	9.90	2055	12.48	2055	7.29	2055	11.92
	1996	10.16	2056	12.27	2056	7.86	2056	11.93
	1997	8.09	2057	9.74	2057	5.59	2057	9.19
	1998	4.22	2058	5.77	2058	4.01	2058	5.58
	1999	16.50	2059	19.62	2059	10.52	2059	18.72
	2000	7.93	2060	9.71	2060	6.06	2060	9.32
	2001	1.86	2061	3.27	2061	2.72	2061	3.13
	2002	4.24	2062	5.42	2062	3.78	2062	5.21
	2003	4.95	2063	6.31	2063	4.16	2063	5.81
	2004	4.07	2064	5.19	2064	3.66	2064	4.96
	2005	7.04	2065	8.58	2065	5.21	2065	7.84
	2006	1.72	2066	2.52	2066	2.24	2066	2.50
	Average load (t/yr)	**6.72**		8.41		5.26		8.01

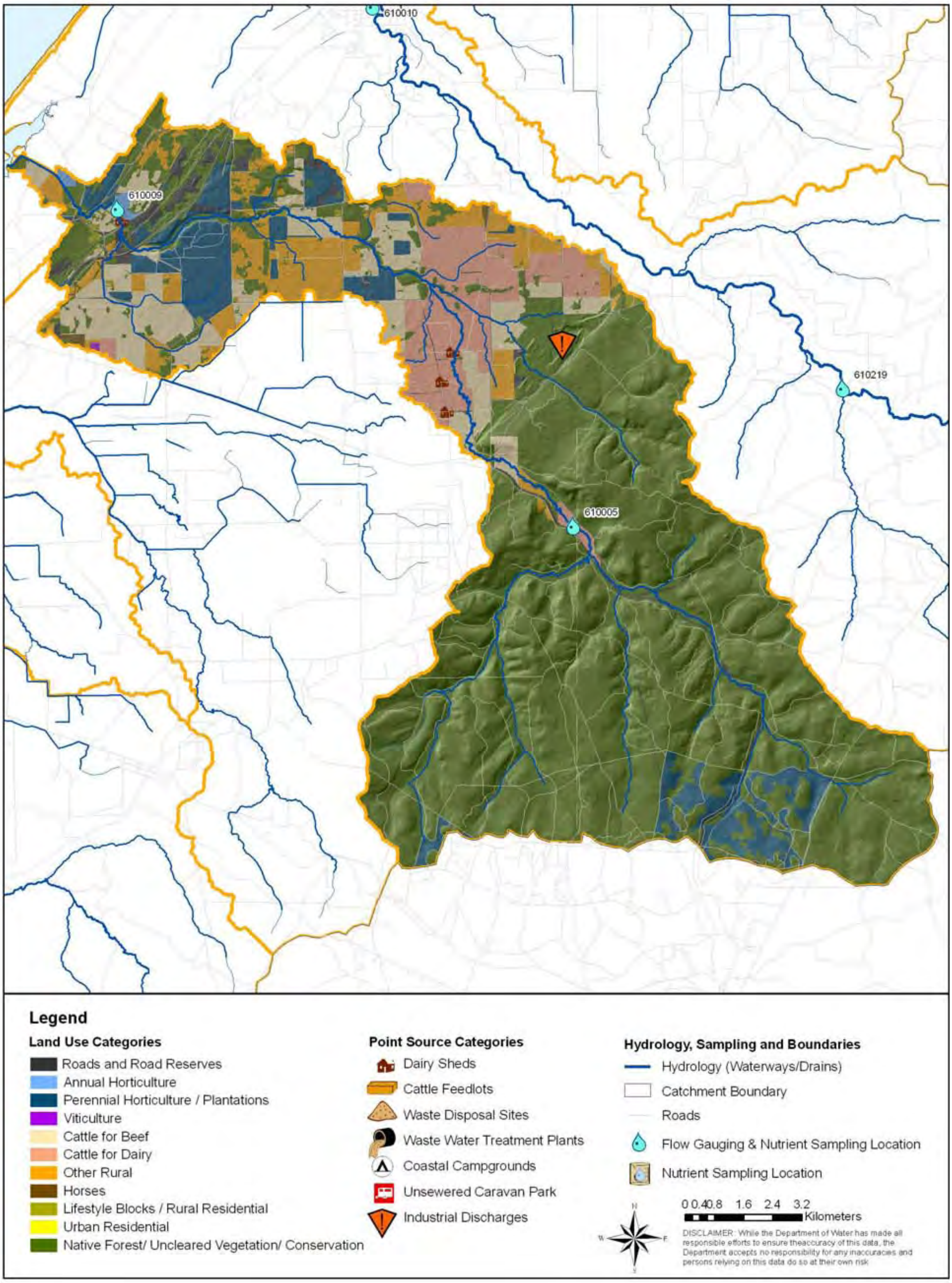
Nitrogen

	At catchment outlet							
	Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
	1995	51.1	2055	62.7	2055	56.0	2055	62.2
	1996	62.6	2056	75.5	2056	73.3	2056	76.6
	1997	45.4	2057	56.2	2057	51.3	2057	55.6
	1998	34.8	2058	43.3	2058	36.1	2058	42.9
	1999	76.1	2059	90.6	2059	81.9	2059	90.1
	2000	49.5	2060	58.9	2060	55.5	2060	59.5
	2001	17.7	2061	23.3	2061	18.7	2061	22.4
	2002	35.2	2062	41.8	2062	33.2	2062	41.0
	2003	38.6	2063	46.7	2063	37.1	2063	45.5
	2004	33.4	2064	41.7	2064	32.5	2064	40.6
	2005	48.9	2065	59.5	2065	47.4	2065	57.9
	2006	13.7	2066	18.4	2066	15.3	2066	18.4
	Average load (t/yr)	**42.2**		51.6		44.9		51.1





Ludlow River



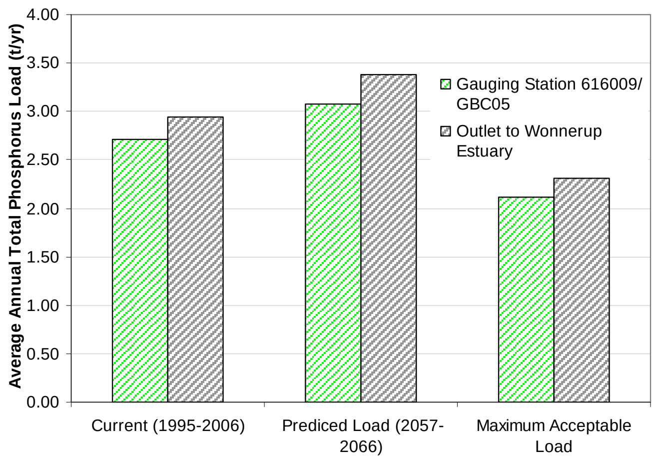
Ludlow River: Current loads, predicted loads and load reduction targets

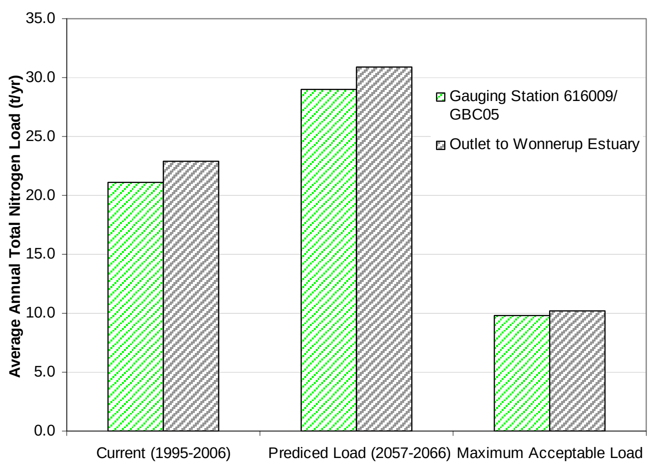
Phosphorus

	At outlet to Wonnerup Estuary						At gauging station 610009/GBC05					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	34% P reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	34% P reduction	Load (t/yr)
	1995	2.60	2055	3.07	2055	2.10	1995	2.30	2055	2.70	2055	1.86
	1996	3.00	2056	3.58	2056	2.44	1996	2.73	2056	3.21	2056	2.20
	1997	3.23	2057	3.88	2057	2.64	1997	2.99	2057	3.54	2057	2.42
	1998	1.65	2058	2.00	2058	1.39	1998	1.57	2058	1.86	2058	1.30
	1999	9.03	2059	10.62	2059	7.10	1999	8.12	2059	9.31	2059	6.24
	2000	3.69	2060	4.57	2060	3.10	2000	3.45	2060	4.17	2060	2.83
	2001	1.23	2061	1.58	2061	1.12	2001	1.19	2061	1.54	2061	1.08
	2002	1.22	2062	1.50	2062	1.06	2002	1.15	2062	1.44	2062	1.02
	2003	1.51	2063	1.59	2063	1.12	2003	1.42	2063	1.52	2063	1.07
	2004	1.50	2064	1.52	2064	1.07	2004	1.43	2064	1.44	2064	1.02
	2005	6.09	2065	6.10	2065	4.11	2005	5.69	2065	5.70	2065	3.85
	2006	0.57	2066	0.57	2066	0.44	2006	0.55	2066	0.55	2066	0.43
Average load for rainfall sequence (t/yr)		**2.94**		3.38		**2.31**		2.72		3.08		2.11
Median winter concentration (mg/L)		**0.138**		0.147		0.100		0.142		0.151		0.10
Load-reduction target (t/yr)		**0.63**	22%									
Maximum acceptable load (t/yr)		**2.31**										
Time periods required to meet LRT		**1**										

Nitrogen

	At outlet to Wonnerup Estuary						At gauging station 610009/GBC05					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	66% N reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	66% N reduction	Load (t/yr)
	1995	30.4	2055	42.4	2055	13.7	1995	27.6	2055	39.6	2055	12.9
	1996	36.6	2056	51.6	2056	16.4	1996	33.3	2056	48.2	2056	15.5
	1997	26.0	2057	38.0	2057	12.4	1997	23.9	2057	35.7	2057	11.8
	1998	15.9	2058	23.8	2058	8.1	1998	14.5	2058	22.3	2058	7.7
	1999	50.0	2059	70.5	2059	22.6	1999	45.4	2059	65.7	2059	21.3
	2000	25.4	2060	36.6	2060	12.1	2000	23.2	2060	34.3	2060	11.5
	2001	4.8	2061	7.9	2061	3.2	2001	4.6	2061	7.6	2061	3.2
	2002	12.0	2062	18.7	2062	6.6	2002	11.5	2062	18.0	2062	6.4
	2003	17.8	2063	21.7	2063	7.4	2003	16.9	2063	20.6	2063	7.2
	2004	16.4	2064	18.1	2064	6.3	2004	15.5	2064	17.1	2064	6.0
	2005	33.7	2065	35.7	2065	11.7	2005	31.9	2065	33.8	2065	11.2
	2006	5.3	2066	5.6	2066	2.4	2006	5.2	2066	5.5	2066	2.5
Average load for rainfall sequence (t/yr)		**22.9**		30.9		**10.2**		21.1		29.0		9.8
Median winter concentration (mg/L)		**2.16**		2.90		1.00		2.25		3.04		1.06
Load-reduction target (t/yr)		**12.62**	55%									
Maximum acceptable load (t/yr)		**10.2**										
Time periods required to meet LRT		**1**										





Ludlow River: Source separation

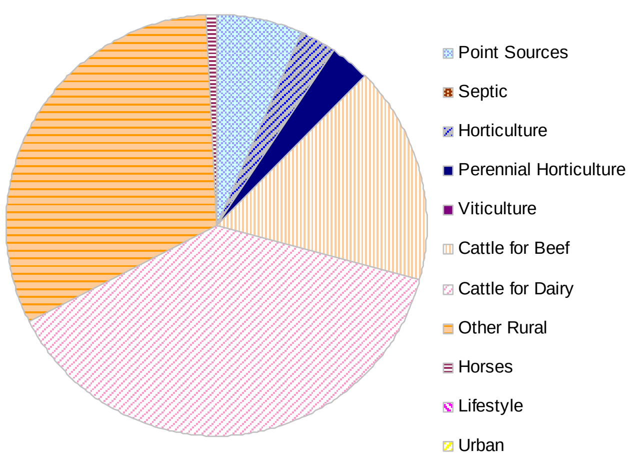
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	2.60	0.20	0.00	0.16	0.08	0.00	0.41	0.76	0.98	0.02	0.00	0.00
1996	3.00	0.20	0.00	0.12	0.13	0.00	0.44	0.86	1.24	0.03	0.00	0.00
1997	3.23	0.20	0.00	0.09	0.13	0.00	0.48	1.02	1.29	0.02	0.00	0.00
1998	1.65	0.19	0.00	0.02	0.06	0.00	0.26	0.44	0.67	0.02	0.00	0.00
1999	9.03	0.21	0.00	0.36	0.32	0.00	1.24	3.31	3.52	0.08	0.00	0.00
2000	3.69	0.20	0.00	0.07	0.12	0.00	0.58	1.40	1.29	0.04	0.00	0.00
2001	1.23	0.19	0.00	0.01	0.03	0.00	0.18	0.51	0.30	0.01	0.00	0.00
2002	1.22	0.19	0.00	0.03	0.03	0.00	0.17	0.36	0.44	0.01	0.00	0.00
2003	1.51	0.19	0.00	0.04	0.03	0.00	0.27	0.64	0.34	0.01	0.00	0.00
2004	1.50	0.19	0.00	0.03	0.04	0.00	0.29	0.70	0.25	0.01	0.00	0.00
2005	6.09	0.19	0.00	0.08	0.11	0.01	1.43	3.43	0.79	0.06	0.00	0.00
2006	0.57	0.19	0.00	0.02	0.03	0.00	0.08	0.20	0.06	0.00	0.00	0.00
Load (non adj)	2.94	0.20	0.00	0.09	0.09	0.00	0.48	1.13	0.93	0.03	0.00	0.00
Load (t/yr)	**2.94**	**0.19**	**0.00**	**0.08**	**0.09**	**0.00**	**0.48**	**1.13**	**0.93**	**0.02**	**0.00**	**0.00**
Load (%)	**100.0%**	**6.6%**	**0.0%**	**2.9%**	**3.1%**	**0.0%**	**16.4%**	**38.5%**	**31.6%**	**0.8%**	**0.0%**	**0.0%**

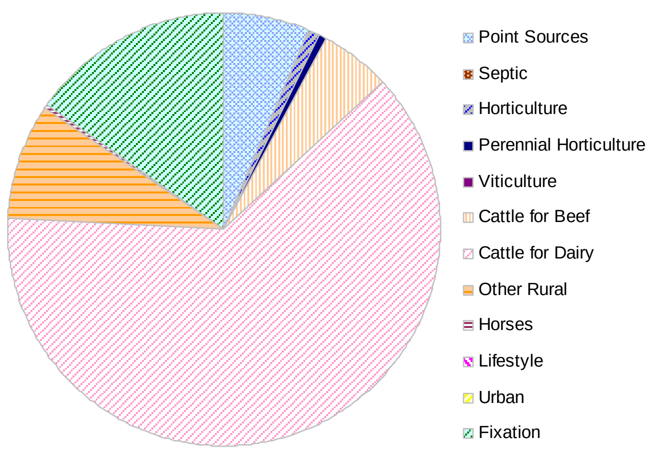
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	30.5	1.4	0.2	0.4	0.4	0.2	1.3	13.9	2.9	0.2	0.2	0.2	5.0
1996	36.7	1.5	0.2	0.4	0.5	0.2	1.6	16.8	3.4	0.3	0.2	0.2	6.0
1997	26.1	1.3	0.1	0.3	0.3	0.1	1.2	12.5	2.4	0.2	0.1	0.1	3.8
1998	16.0	1.3	0.1	0.2	0.2	0.1	0.8	7.9	1.4	0.1	0.1	0.1	1.8
1999	50.2	1.5	0.3	0.6	0.8	0.3	2.4	23.3	4.9	0.4	0.3	0.3	8.7
2000	25.5	1.3	0.1	0.3	0.3	0.1	1.2	12.1	2.4	0.2	0.1	0.1	3.8
2001	4.8	1.2	0.0	0.0	0.0	0.0	0.2	2.4	0.3	0.0	0.0	0.0	0.2
2002	12.1	1.3	0.1	0.2	0.1	0.1	0.5	6.5	0.9	0.1	0.1	0.1	1.2
2003	17.9	1.3	0.1	0.2	0.1	0.1	1.0	10.8	0.8	0.1	0.1	0.1	1.6
2004	16.5	1.3	0.1	0.2	0.1	0.1	0.9	10.5	0.5	0.1	0.1	0.1	1.1
2005	33.8	1.3	0.1	0.4	0.2	0.1	2.0	22.7	1.0	0.1	0.1	0.1	2.6
2006	5.3	1.1	0.0	0.0	0.0	0.0	0.2	3.3	0.1	0.0	0.0	0.0	0.1
Load (non adj)	23.0	1.3	0.1	0.3	0.3	0.1	1.1	11.9	1.8	0.1	0.1	0.1	3.0
Load (t/yr)	**23.0**	**1.5**	**0.0**	**0.2**	**0.2**	**0.0**	**1.2**	**14.4**	**2.0**	**0.0**	**0.0**	**0.0**	**3.5**
Load (%)	**100.0%**	**6.4%**	**0.0%**	**0.7%**	**0.7%**	**0.0%**	**5.3%**	**62.8%**	**8.7%**	**0.1%**	**0.0%**	**0.0%**	**15.3%**

Total phosphorus



Total nitrogen



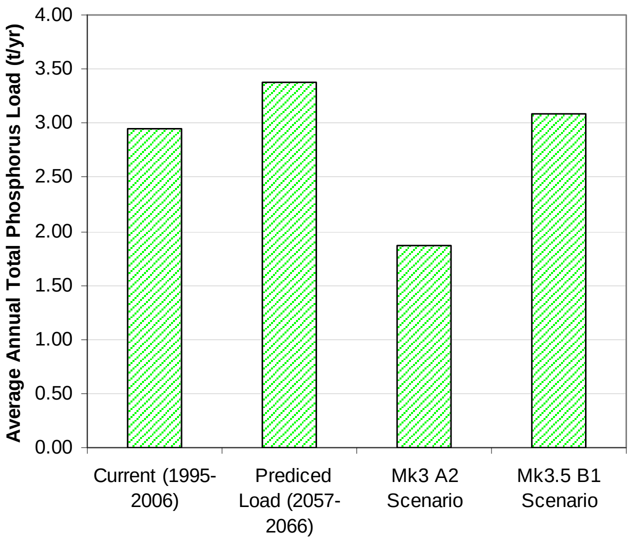
Ludlow river: Climate change scenarios

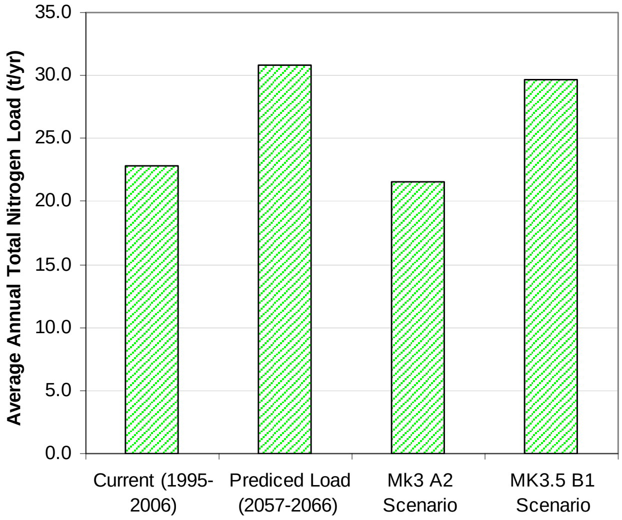
Phosphorus

At catchment outlet							
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	2.60	2055	3.07	2055	1.83	2055	2.87
1996	3.00	2056	3.58	2056	2.54	2056	3.43
1997	3.23	2057	3.88	2057	2.51	2057	3.64
1998	1.65	2058	2.00	2058	1.22	2058	1.87
1999	9.03	2059	10.62	2059	6.05	2059	9.79
2000	3.69	2060	4.57	2060	3.16	2060	4.58
2001	1.23	2061	1.58	2061	0.57	2061	1.15
2002	1.22	2062	1.50	2062	0.85	2062	1.39
2003	1.51	2063	1.59	2063	0.92	2063	1.47
2004	1.50	2064	1.52	2064	0.82	2064	1.40
2005	6.09	2065	6.10	2065	1.63	2065	4.85
2006	0.57	2066	0.57	2066	0.39	2066	0.55
Average load (t/yr)	**2.94**		3.38		1.87		3.08

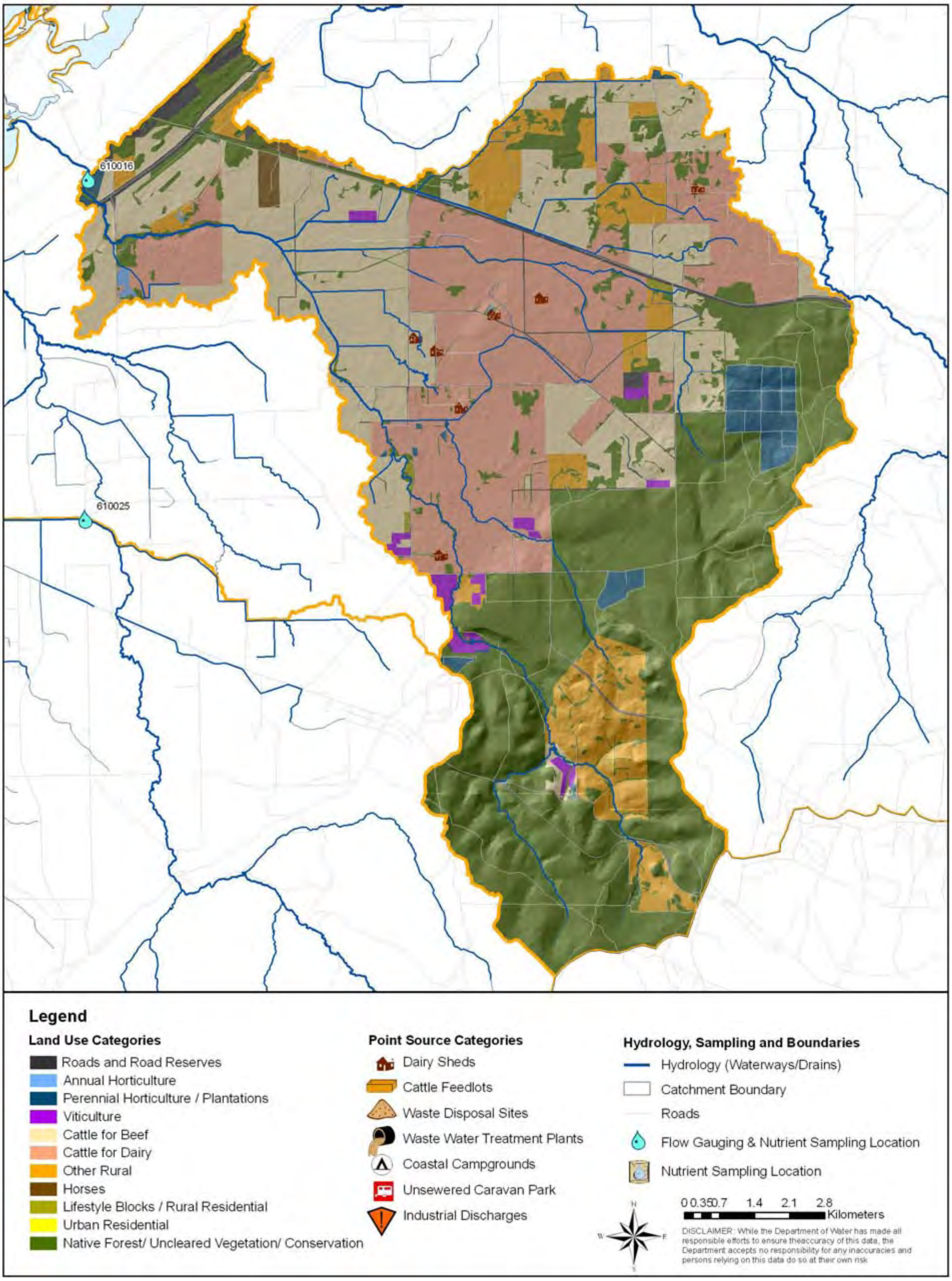
Nitrogen

At catchment outlet							
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	30.4	2055	42.4	2055	31.3	2055	41.4
1996	36.6	2056	51.6	2056	41.3	2056	51.2
1997	26.0	2057	38.0	2057	28.8	2057	37.1
1998	15.9	2058	23.8	2058	15.9	2058	22.9
1999	50.0	2059	70.5	2059	50.6	2059	67.4
2000	25.4	2060	36.6	2060	27.0	2060	36.1
2001	4.8	2061	7.9	2061	4.5	2061	7.1
2002	12.0	2062	18.7	2062	11.4	2062	17.7
2003	17.8	2063	21.7	2063	13.7	2063	20.7
2004	16.4	2064	18.1	2064	10.8	2064	17.2
2005	33.7	2065	35.7	2065	20.1	2065	32.3
2006	5.3	2066	5.6	2066	4.0	2066	5.4
Average load (t/yr)	**22.9**		30.9		21.6		29.7





Abba River


610016
610025
Legend
Land Use Categories
Roads and Road Reserves
Annual Horticulture
Perennial Horticulture / Plantations
Viticulture
Cattle for Beef
Cattle for Dairy
Other Rural
Horses
Lifestyle Blocks / Rural Residential
Urban Residential
Native Forest/ Uncleared Vegetation/ Conservation
Point Source Categories
Dairy Sheds
Cattle Feedlots
Waste Disposal Sites
Waste Water Treatment Plants
Coastal Campgrounds
Unsewered Caravan Park
Industrial Discharges
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary
Roads
Flow Gauging & Nutrient Sampling Location
Nutrient Sampling Location
0 0.35 0.7 1.4 2.1 2.8
Kilometers
DISCLAIMER: While the Department of Water has made all responsible efforts to ensure theaccuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk

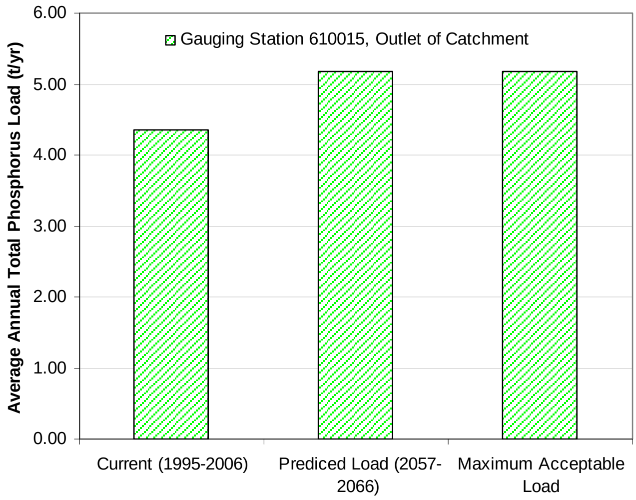
Abba River: Current loads, predicted loads and load reduction targets

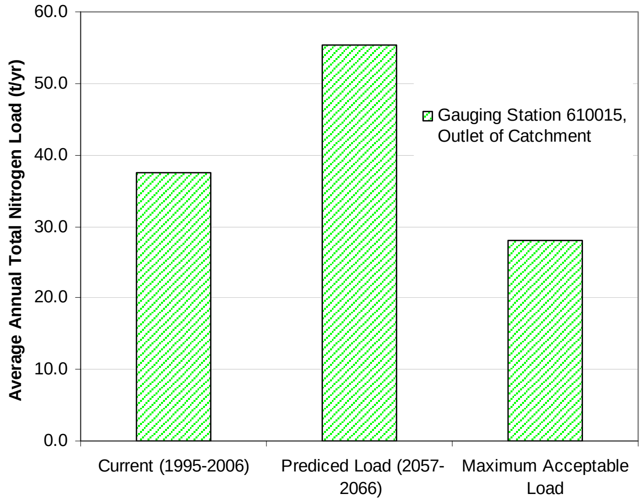
Phosphorus

	Year	Load (t/yr)	Current conditions	Load (t/yr)	0% P reduction	Load (t/yr)
			At 610015/catchment outlet			
	1995	2.25	2055	2.78	2055	2.78
	1996	2.59	2056	3.21	2056	3.21
	1997	2.99	2057	3.89	2057	3.89
	1998	1.45	2058	1.68	2058	1.68
	1999	19.31	2059	24.98	2059	24.98
	2000	4.65	2060	5.96	2060	5.96
	2001	1.78	2061	2.18	2061	2.18
	2002	1.25	2062	1.43	2062	1.43
	2003	1.40	2063	1.46	2063	1.46
	2004	1.62	2064	1.63	2064	1.63
	2005	11.83	2065	11.89	2065	11.89
	2006	1.05	2066	1.05	2066	1.05
Average load for rainfall sequence (t/yr)		**4.35**		5.18		5.18
Median winter concentration (mg/L)		**0.051**		0.051		0.051
Load-reduction target (t/yr)		**0.00**	0%			
Maximum acceptable load (t/yr)		**5.2**				
Time periods required to meet LRT		**0**				

Nitrogen

	Year	Load (t/yr)	Current conditions	Load (t/yr)	62% N reduction	Load (t/yr)
			At 610015/catchment outlet			
	1995	34.0	2055	55.3	2055	22.8
	1996	45.5	2056	73.6	2056	28.1
	1997	43.1	2057	72.2	2057	37.0
	1998	16.3	2058	31.4	2058	12.8
	1999	113.8	2059	187.8	2059	110.1
	2000	32.7	2060	56.2	2060	25.8
	2001	8.5	2061	11.3	2061	8.2
	2002	13.0	2062	24.4	2062	11.4
	2003	23.8	2063	28.7	2063	12.5
	2004	25.2	2064	26.0	2064	12.0
	2005	86.0	2065	89.3	2065	49.5
	2006	8.5	2066	8.5	2066	6.5
Average load for rainfall sequence (t/yr)		**37.5**		55.4		28.1
Median winter concentration (mg/L)		**2.09**		3.12		1.00
Load-reduction target (t/yr)		**9.5**	25%			
Maximum acceptable load (t/yr)		**28.1**				
Time periods required to meet LRT		**1**				





Abba River: Source separation

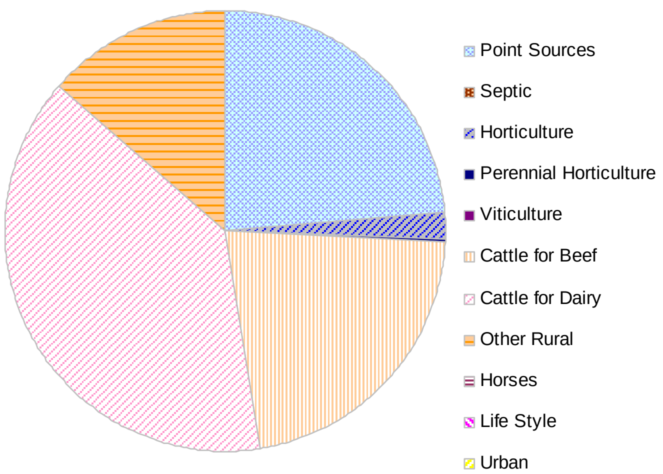
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	2.25	0.99	0.00	0.05	0.00	0.00	0.29	0.49	0.22	0.00	0.00	0.00
1996	2.59	0.99	0.00	0.04	0.01	0.00	0.34	0.57	0.35	0.00	0.00	0.00
1997	2.99	0.99	0.00	0.05	0.00	0.00	0.54	0.79	0.42	0.00	0.00	0.00
1998	1.45	0.99	0.00	0.02	0.00	0.00	0.13	0.17	0.05	0.00	0.00	0.00
1999	19.31	0.99	0.00	0.37	0.04	0.00	4.99	7.99	4.42	0.02	0.00	0.00
2000	4.65	0.99	0.00	0.10	0.01	0.00	0.97	1.55	0.80	0.00	0.00	0.00
2001	1.78	0.99	0.00	0.02	0.00	0.00	0.23	0.37	0.13	0.00	0.00	0.00
2002	1.25	0.99	0.00	0.00	0.00	0.00	0.07	0.11	0.02	0.00	0.00	0.00
2003	1.40	0.99	0.00	0.01	0.00	0.00	0.11	0.20	0.01	0.00	0.00	0.00
2004	1.62	0.99	0.00	0.02	0.00	0.00	0.16	0.35	0.01	0.00	0.00	0.00
2005	11.83	0.99	0.00	0.33	0.02	0.04	2.92	6.95	0.36	0.01	0.00	0.00
2006	1.05	0.99	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
Load (non adj)	4.35	0.99	0.00	0.08	0.01	0.00	0.90	1.63	0.57	0.00	0.00	0.00
Load (t/yr)	**4.35**	**1.03**	**0.00**	**0.09**	**0.01**	**0.00**	**0.93**	**1.69**	**0.59**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**23.7%**	**0.0%**	**2.0%**	**0.2%**	**0.1%**	**21.4%**	**39.0%**	**13.5%**	**0.1%**	**0.0%**	**0.0%**

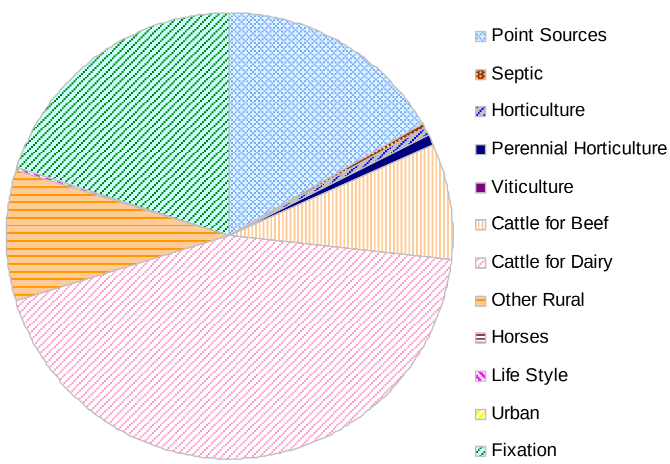
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	34.0	6.2	0.6	0.7	0.6	0.5	3.0	13.5	2.7	0.5	0.6	0.5	6.9
1996	45.5	8.8	3.1	3.2	3.2	3.1	5.8	17.7	6.9	3.1	3.1	3.1	12.9
1997	43.1	8.4	3.0	3.2	3.0	2.8	7.4	20.9	8.1	2.8	2.8	2.8	11.0
1998	16.2	5.8	0.1	0.2	0.1	0.1	0.7	6.1	0.4	0.1	0.1	0.1	1.3
1999	113.8	21.9	16.9	16.4	18.2	16.2	27.6	51.0	31.9	16.2	16.3	16.2	48.8
2000	32.7	7.4	1.8	1.8	1.8	1.7	4.6	13.2	4.6	1.7	1.7	1.7	7.4
2001	8.5	6.0	0.3	0.3	0.3	0.3	0.6	1.6	0.6	0.3	0.3	0.3	0.8
2002	13.0	5.8	0.0	0.1	0.0	0.0	0.6	4.4	0.3	0.0	0.0	0.0	0.6
2003	23.7	5.8	0.1	0.1	0.1	0.1	1.1	13.5	0.5	0.1	0.1	0.1	1.2
2004	25.2	6.3	0.6	0.6	0.6	0.6	1.4	15.6	0.8	0.6	0.6	0.6	1.3
2005	86.0	14.6	9.1	9.7	9.7	8.9	15.4	53.0	16.3	8.8	8.9	8.8	24.3
2006	8.5	5.6	0.0	0.0	0.0	0.0	0.1	2.3	0.0	0.0	0.0	0.0	0.1
Load (non adj)	37.5	8.6	3.0	3.0	3.1	2.9	5.7	17.7	6.1	2.9	2.9	2.9	9.7
Load (t/yr)	**37.5**	**6.3**	**0.1**	**0.2**	**0.3**	**0.0**	**3.1**	**16.4**	**3.6**	**0.0**	**0.0**	**0.0**	**7.5**
Load (%)	**100.0%**	**16.7%**	**0.3%**	**0.5%**	**0.8%**	**0.0%**	**8.3%**	**43.7%**	**9.5%**	**0.0%**	**0.0%**	**0.0%**	**20.1%**

Total phosphorus



Total nitrogen



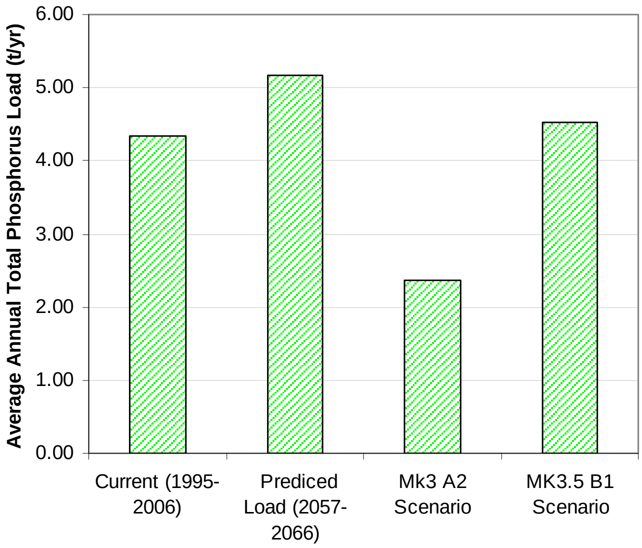
Abba River: Climate change scenarios

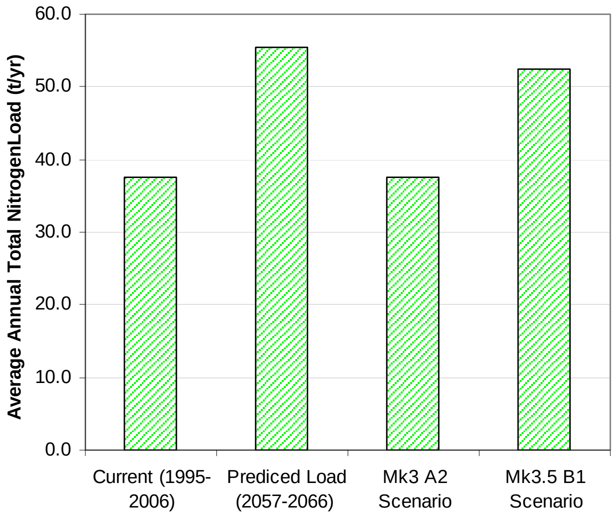
Phosphorus

At Catchment Outlet							
Year	***Load (t/yr)***	***Current conditions***	***Load (t/yr)***	***Mk3 A2 climate change scenario***	***Load (t/yr)***	***Mk3.5 B1 climate change scenario***	***Load (t/yr)***
1995	2.25	2055	2.78	2055	1.89	2055	2.61
1996	2.59	2056	3.21	2056	2.17	2056	2.75
1997	2.99	2057	3.89	2057	2.56	2057	3.65
1998	1.45	2058	1.68	2058	1.23	2058	1.57
1999	19.31	2059	24.98	2059	9.54	2059	21.96
2000	4.65	2060	5.96	2060	3.85	2060	6.80
2001	1.78	2061	2.18	2061	0.99	2061	1.44
2002	1.25	2062	1.43	2062	1.11	2062	1.36
2003	1.40	2063	1.46	2063	1.16	2063	1.39
2004	1.62	2064	1.63	2064	1.17	2064	1.52
2005	11.83	2065	11.89	2065	1.77	2065	8.28
2006	1.05	2066	1.05	2066	1.00	2066	1.03
Average load (t/yr)	**4.35**		5.18		2.37		4.53

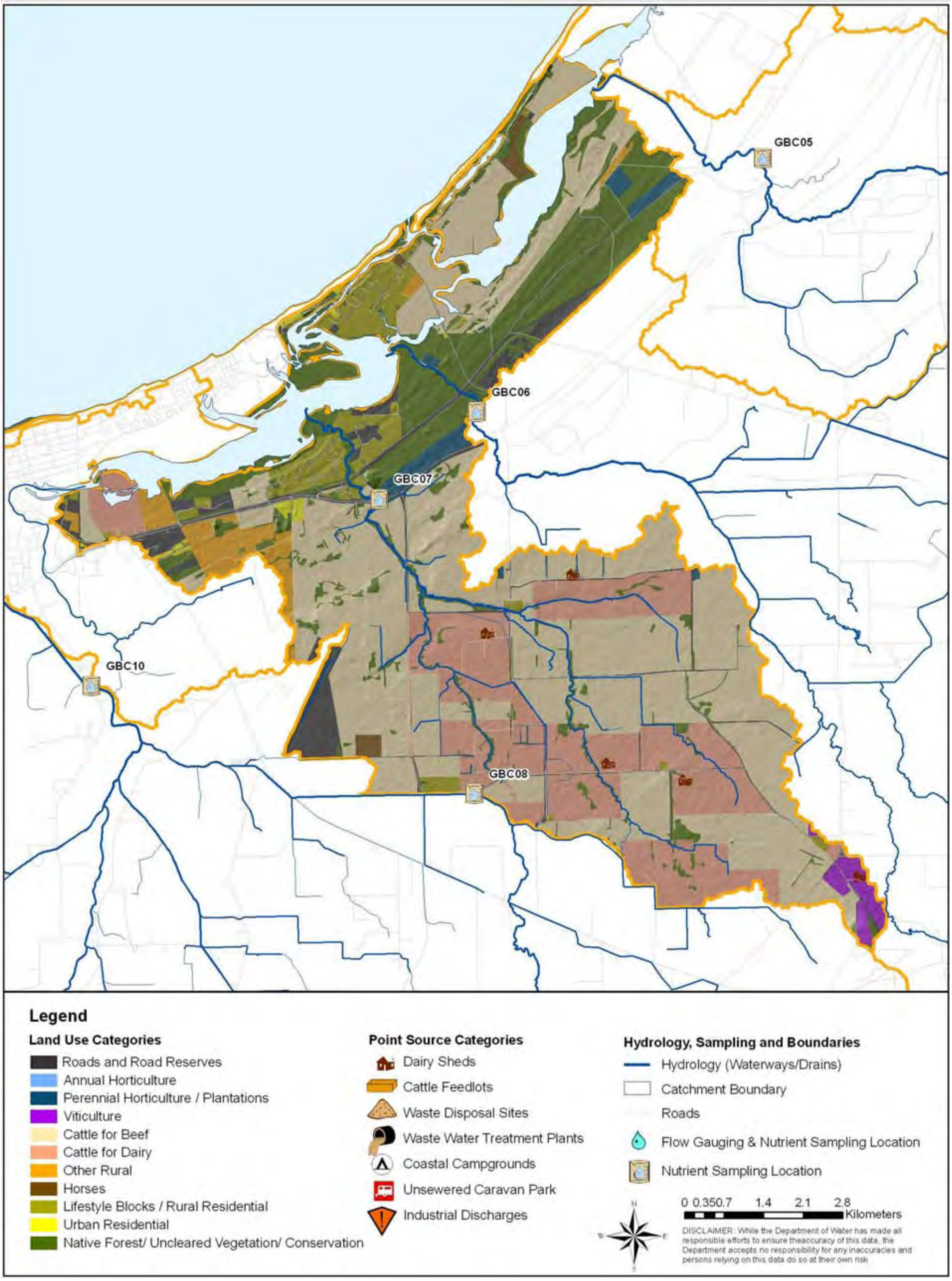
Nitrogen

At Catchment Outlet							
Year	***Load (t/yr)***	***Current conditions***	***Load (t/yr)***	***Mk3 A2 climate change scenario***	***Load (t/yr)***	***Mk3.5 B1 climate change scenario***	***Load (t/yr)***
1995	34.0	2055	55.3	2055	42.2	2055	55.1
1996	45.5	2056	73.6	2056	58.1	2056	66.6
1997	43.1	2057	72.2	2057	69.5	2057	77.3
1998	16.3	2058	31.4	2058	19.3	2058	29.8
1999	113.8	2059	187.8	2059	129.1	2059	179.6
2000	32.7	2060	56.2	2060	48.8	2060	57.4
2001	8.5	2061	11.3	2061	6.2	2061	9.0
2002	13.0	2062	24.4	2062	13.1	2062	22.4
2003	23.8	2063	28.7	2063	16.8	2063	26.7
2004	25.2	2064	26.0	2064	15.1	2064	24.5
2005	86.0	2065	89.3	2065	26.5	2065	73.7
2006	8.5	2066	8.5	2066	6.9	2066	8.3
Average load (t/yr)	**37.5**		55.4		37.6		52.5





Sabina River



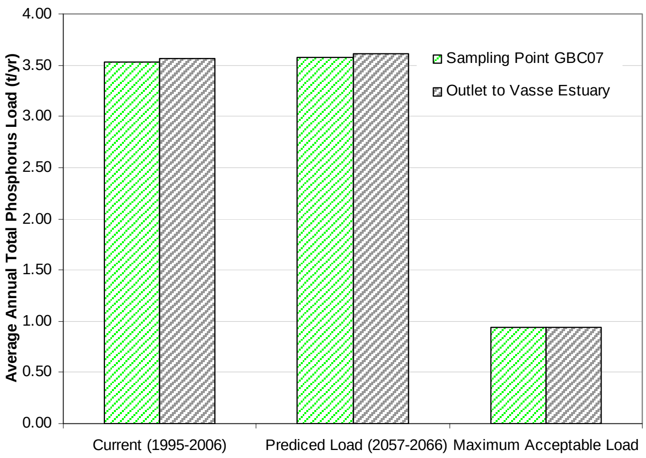
Sabina River: Current loads, predicted loads and load reduction targets

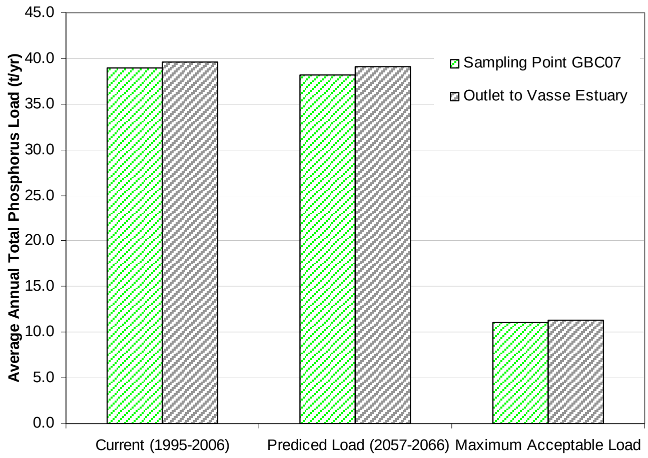
Phosphorus

	At outlet to Vasse Estuary						At sampling point GBC07					
	Year	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**79% P reduction**	**Load (t/yr)**	**Year**	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**79% P reduction**	**Load (t/yr)**
	1995	4.35	2055	4.84	2055	1.20	1995	4.30	2055	4.79	2055	1.19
	1996	4.65	2056	4.97	2056	1.25	1996	4.60	2056	4.92	2056	1.24
	1997	4.14	2057	4.29	2057	1.08	1997	4.10	2057	4.25	2057	1.07
	1998	3.13	2058	3.20	2058	0.87	1998	3.10	2058	3.18	2058	0.86
	1999	7.20	2059	7.13	2059	1.69	1999	7.07	2059	7.01	2059	1.67
	2000	3.79	2060	3.75	2060	0.97	2000	3.75	2060	3.71	2060	0.96
	2001	1.46	2061	1.48	2061	0.47	2001	1.45	2061	1.47	2061	0.47
	2002	2.32	2062	2.26	2062	0.66	2002	2.31	2062	2.25	2062	0.66
	2003	2.95	2063	2.85	2063	0.79	2003	2.93	2063	2.83	2063	0.78
	2004	2.93	2064	2.83	2064	0.78	2004	2.91	2064	2.81	2064	0.77
	2005	4.71	2065	4.51	2065	1.14	2005	4.64	2065	4.44	2065	1.13
	2006	1.20	2066	1.18	2066	0.42	2006	1.20	2066	1.18	2066	0.42
Average load for rainfall sequence (t/yr)		**3.57**		3.61		**0.94**		3.53		3.57		0.94
Median winter concentration (mg/L)		**0.387**		0.381		0.1		0.402		0.390		0.102
Load-reduction target (t/yr)		**2.6**	74%									
Maximum acceptable load (t/yr)		**0.94**										
Time periods required to meet LRT		**1**										

Nitrogen

	At outlet to Vasse Estuary						At sampling point GBC07					
	Year	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**71% N reduction**	**Load (t/yr)**	**Year**	**Load (t/yr)**	**Current conditions**	**Load (t/yr)**	**71% N reduction**	**Load (t/yr)**
	1995	51.9	2055	54.3	2055	15.2	1995	51.0	2055	52.7	2055	14.9
	1996	60.3	2056	60.1	2056	16.9	1996	59.2	2056	58.3	2056	16.6
	1997	41.1	2057	40.2	2057	11.5	1997	40.5	2057	39.2	2057	11.3
	1998	35.9	2058	35.0	2058	10.2	1998	35.4	2058	34.2	2058	10.1
	1999	72.0	2059	70.4	2059	19.6	1999	70.7	2059	68.2	2059	19.2
	2000	40.8	2060	40.0	2060	11.5	2000	40.1	2060	38.8	2060	11.3
	2001	14.6	2061	14.3	2061	4.6	2001	14.5	2061	14.1	2061	4.5
	2002	27.9	2062	26.2	2062	7.9	2002	27.7	2062	25.8	2062	7.8
	2003	35.5	2063	34.5	2063	10.1	2003	35.1	2063	33.9	2063	10.0
	2004	33.1	2064	32.8	2064	9.6	2004	32.7	2064	32.2	2064	9.5
	2005	48.5	2065	48.1	2065	13.7	2005	48.0	2065	47.3	2065	13.6
	2006	13.0	2066	13.1	2066	4.3	2006	13.0	2066	13.0	2066	4.3
Average load for rainfall sequence (t/yr)		**39.5**		39.1		**11.3**		39.0		38.1		11.1
Median winter concentration (mg/L)		**3.62**		3.50		1.00		3.84		3.69		1.00
Load-reduction target (t/yr)		**28.3**	72%									
Maximum acceptable load (t/yr)		**11.3**										
Time periods required to meet LRT		**1**										





Sabina River: Source separation

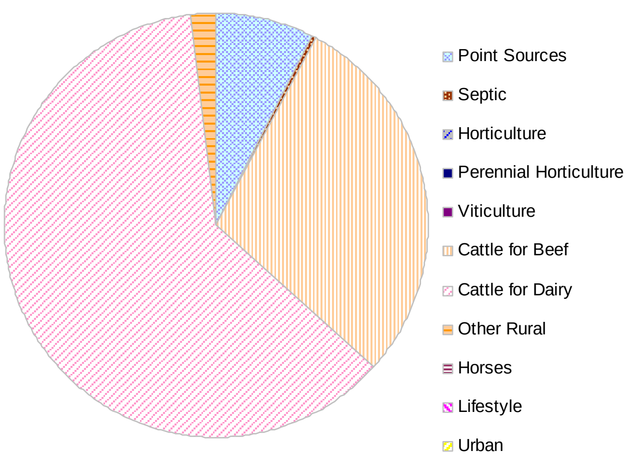
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	4.35	0.34	0.09	0.09	0.10	0.09	1.21	2.49	0.15	0.09	0.09	0.09	
1996	4.65	0.36	0.09	0.09	0.09	0.09	1.26	2.60	0.16	0.09	0.09	0.09	
1997	4.14	0.31	0.07	0.07	0.07	0.07	1.14	2.36	0.13	0.07	0.07	0.07	
1998	3.13	0.30	0.05	0.05	0.05	0.05	0.83	1.72	0.10	0.05	0.05	0.05	
1999	7.20	0.39	0.13	0.13	0.13	0.13	2.03	4.16	0.25	0.13	0.13	0.13	
2000	3.79	0.29	0.05	0.05	0.05	0.05	1.04	2.07	0.12	0.05	0.05	0.05	
2001	1.46	0.23	0.02	0.02	0.02	0.02	0.35	0.77	0.05	0.02	0.02	0.02	
2002	2.32	0.26	0.02	0.02	0.02	0.02	0.59	1.27	0.07	0.02	0.02	0.02	
2003	2.95	0.27	0.03	0.03	0.03	0.03	0.78	1.62	0.09	0.03	0.03	0.03	
2004	2.93	0.26	0.03	0.03	0.03	0.03	0.81	1.60	0.08	0.03	0.03	0.03	
2005	4.71	0.31	0.06	0.06	0.06	0.06	1.33	2.68	0.15	0.06	0.06	0.06	
2006	1.20	0.23	0.01	0.01	0.01	0.01	0.30	0.57	0.03	0.01	0.01	0.01	
Load (non adj*)	3.57	0.30	0.05	0.05	0.06	0.05	0.97	1.99	0.11	0.05	0.05	0.05	
Load (t/yr)	**3.57**	**0.27**	**0.00**	**0.00**	**0.00**	**0.00**	**1.04**	**2.19**	**0.07**	**0.00**	**0.00**	**0.00**	
Load (%)	**100.0%**	**7.6%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**29.0%**	**61.2%**	**1.9%**	**0.0%**	**0.0%**	**0.0%**	

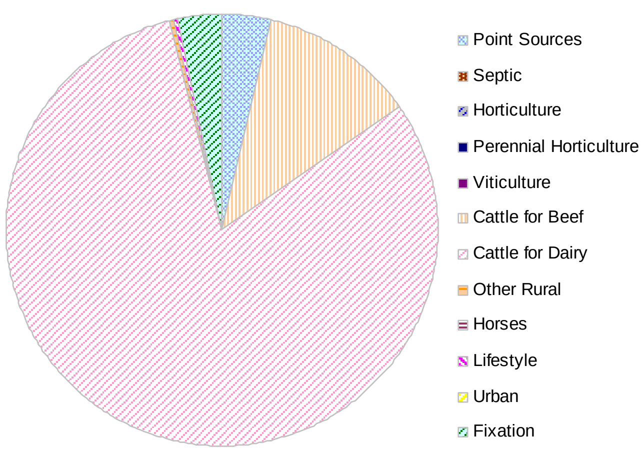
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	51.9	1.4	0.0	0.0	0.0	0.0	5.6	40.9	0.3	0.0	0.1	0.0	1.8
1996	60.3	1.6	0.0	0.0	0.0	0.0	6.5	47.5	0.3	0.0	0.1	0.0	2.1
1997	41.1	1.3	0.0	0.0	0.0	0.0	4.3	32.3	0.2	0.0	0.0	0.0	1.4
1998	35.9	1.5	0.0	0.0	0.0	0.0	3.7	28.0	0.2	0.0	0.0	0.0	1.2
1999	72.0	1.5	0.0	0.0	0.0	0.0	7.7	57.2	0.4	0.0	0.1	0.0	2.5
2000	40.8	1.3	0.0	0.0	0.0	0.0	4.3	31.9	0.3	0.0	0.1	0.0	1.4
2001	14.6	1.1	0.0	0.0	0.0	0.0	1.4	11.1	0.1	0.0	0.0	0.0	0.4
2002	27.9	1.3	0.0	0.0	0.0	0.0	2.8	22.0	0.1	0.0	0.0	0.0	0.8
2003	35.5	1.4	0.0	0.0	0.0	0.0	4.0	27.6	0.1	0.0	0.0	0.0	1.1
2004	33.1	1.3	0.0	0.0	0.0	0.0	4.2	25.2	0.1	0.0	0.0	0.0	1.1
2005	48.5	1.4	0.0	0.0	0.0	0.0	6.7	37.0	0.1	0.0	0.1	0.0	1.5
2006	13.0	1.2	0.0	0.0	0.0	0.0	1.8	9.2	0.0	0.0	0.0	0.0	0.4
Load (non adj)	39.5	1.4	0.0	0.0	0.0	0.0	4.4	30.8	0.2	0.0	0.0	0.0	1.3
Load (t/yr)	**39.5**	**1.4**	**0.0**	**0.0**	**0.0**	**0.0**	**4.6**	**31.9**	**0.2**	**0.0**	**0.0**	**0.0**	**1.3**
Load (%)	**100.0%**	**3.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**11.6%**	**80.8%**	**0.5%**	**0.0%**	**0.1%**	**0.0%**	**3.4%**

Total phosphorus



Total nitrogen



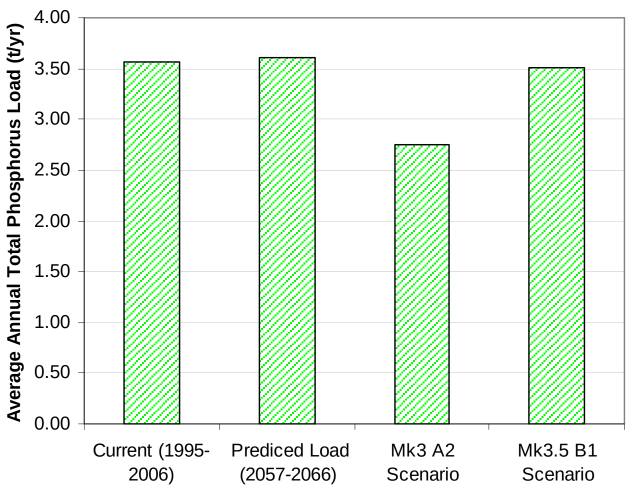
Sabina River: Climate change scenarios

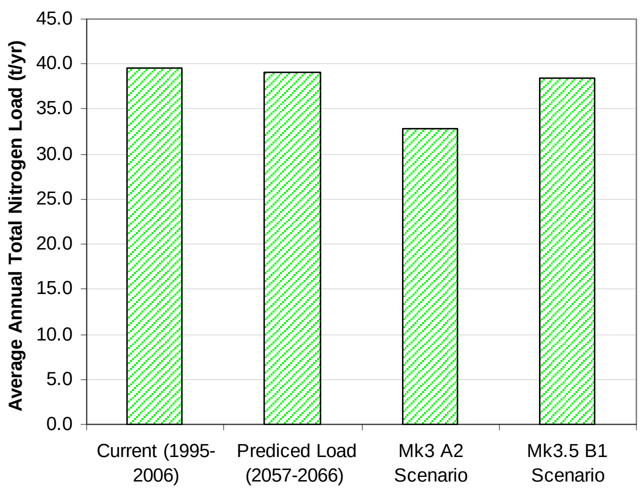
Phosphorus

Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	4.35	2055	4.84	2055	3.91	2055	4.80
1996	4.65	2056	4.97	2056	4.21	2056	4.95
1997	4.14	2057	4.29	2057	3.40	2057	4.21
1998	3.13	2058	3.20	2058	2.42	2058	3.11
1999	7.20	2059	7.13	2059	5.88	2059	6.98
2000	3.79	2060	3.75	2060	3.21	2060	3.72
2001	1.46	2061	1.48	2061	0.98	2061	1.39
2002	2.32	2062	2.26	2062	1.54	2062	2.15
2003	2.95	2063	2.85	2063	1.98	2063	2.71
2004	2.93	2064	2.83	2064	1.97	2064	2.70
2005	4.71	2065	4.51	2065	2.72	2065	4.16
2006	1.20	2066	1.18	2066	0.85	2066	1.16
Average load (t/yr)	**3.57**		3.61		2.76		3.50

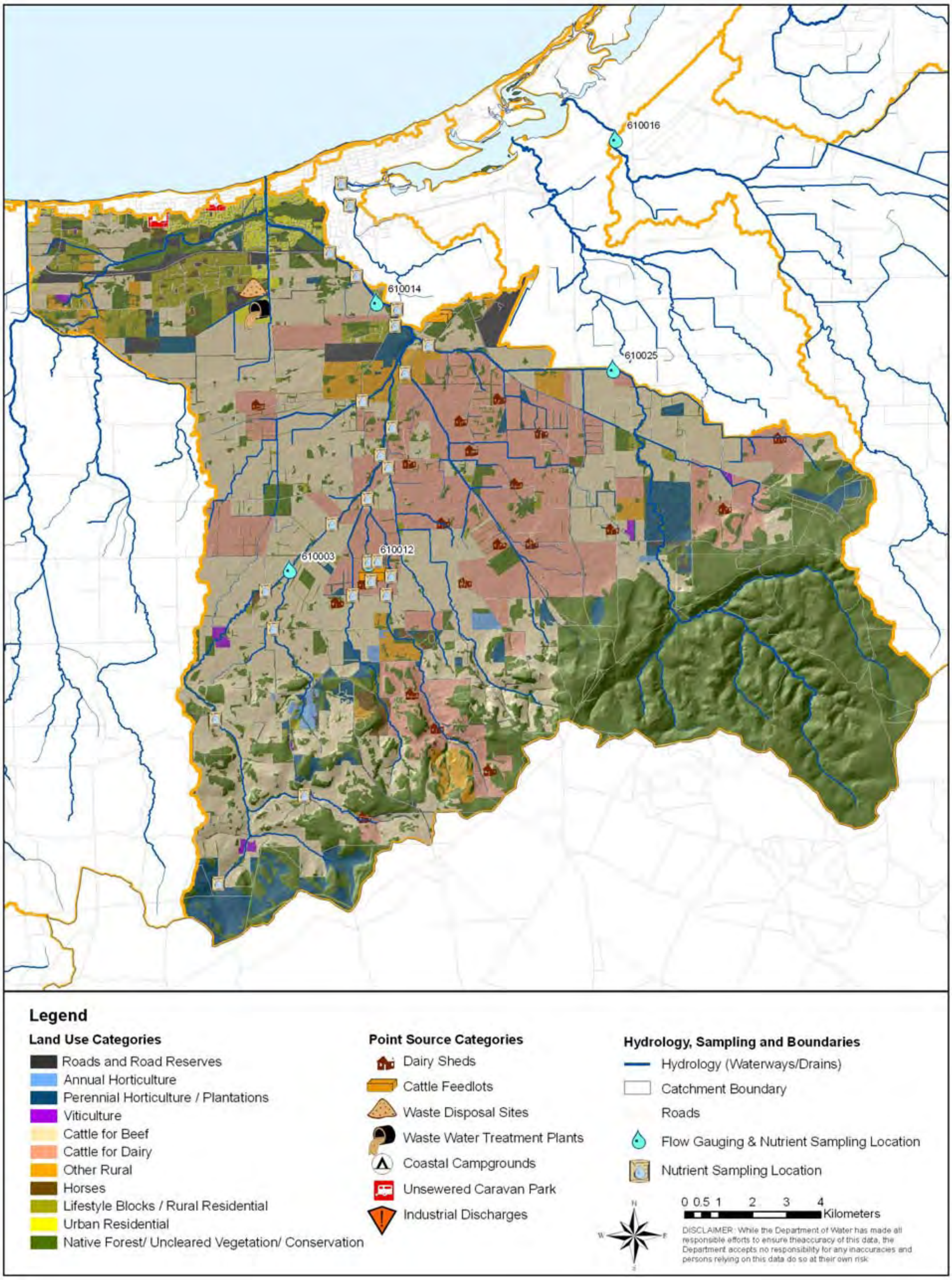
Nitrogen

Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	51.9	2055	54.3	2055	48.7	2055	54.3
1996	60.3	2056	60.1	2056	58.7	2056	60.9
1997	41.1	2057	40.2	2057	36.4	2057	39.8
1998	35.9	2058	35.0	2058	29.0	2058	34.2
1999	72.0	2059	70.4	2059	64.3	2059	69.4
2000	40.8	2060	40.0	2060	38.3	2060	41.1
2001	14.6	2061	14.3	2061	8.7	2061	13.3
2002	27.9	2062	26.2	2062	17.6	2062	25.0
2003	35.5	2063	34.5	2063	25.0	2063	33.2
2004	33.1	2064	32.8	2064	24.7	2064	31.6
2005	48.5	2065	48.1	2065	33.8	2065	45.7
2006	13.0	2066	13.1	2066	9.5	2066	13.0
Average load (t/yr)	**39.5**		39.1		32.9		38.5





Vasse Diversion Drain



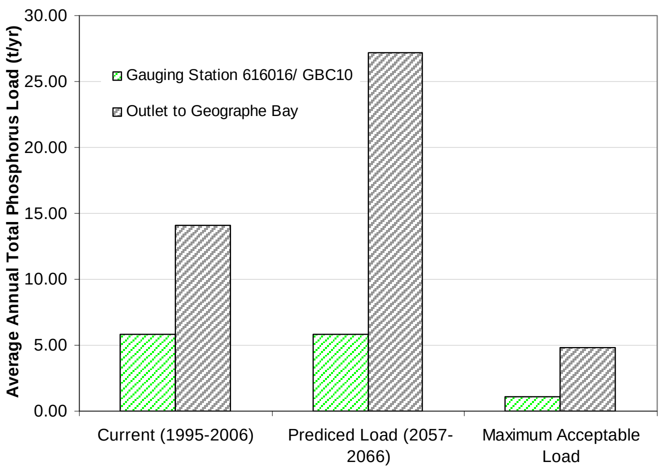
Vasse Diversion Drain: Current loads, predicted loads and load reduction targets

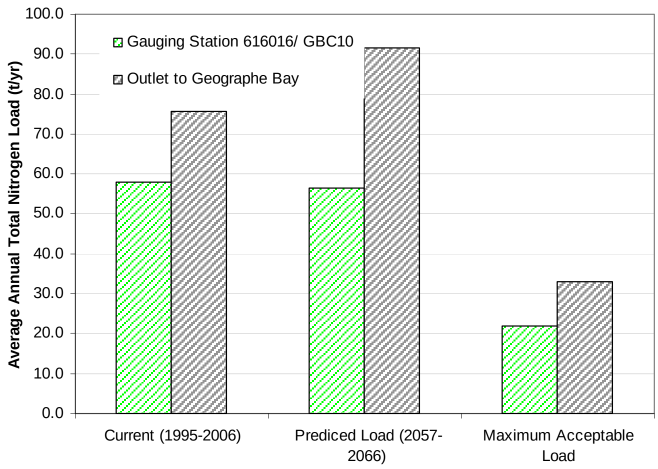
Phosphorus

	At outlet to Geographe Bay						At gauging station 610016/GBC10					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	% P reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	% P reduction	Load (t/yr)
	1995	14.56	2055	26.53	2055	5.46	1995	6.26	2055	6.26	2055	1.16
	1996	14.79	2056	28.08	2056	5.19	1996	6.29	2056	6.29	2056	1.16
	1997	15.90	2057	29.50	2057	5.43	1997	7.93	2057	7.93	2057	1.46
	1998	12.97	2058	24.35	2058	4.60	1998	4.70	2058	4.70	2058	0.87
	1999	20.35	2059	35.86	2059	6.48	1999	11.86	2059	11.86	2059	2.19
	2000	14.77	2060	23.17	2060	4.88	2000	6.72	2060	6.72	2060	1.24
	2001	10.82	2061	17.63	2061	3.87	2001	3.22	2061	3.22	2061	0.59
	2002	11.59	2062	19.53	2062	4.17	2002	3.56	2062	3.56	2062	0.66
	2003	12.41	2063	22.58	2063	4.29	2003	4.47	2063	4.47	2063	0.83
	2004	12.40	2064	23.07	2064	4.28	2004	4.25	2064	4.25	2064	0.78
	2005	17.01	2065	29.56	2065	5.54	2005	7.84	2065	7.84	2065	1.45
	2006	11.39	2066	21.49	2066	3.92	2006	2.62	2066	2.62	2066	0.48
Average load for rainfall sequence (t/yr)	**14.08**			25.11		**4.84**		5.81		5.81		1.07
Median winter concentration (mg/L)	**0.266**			0.561				0.138		0.138		
Load-reduction target (t/yr)	**9.2**	66%										
Maximum acceptable load (t/yr)	**4.84**											
Time periods required to meet LRT	**3**											

Nitrogen

	At outlet to Geographe Bay						At gauging station 610016/GBC10					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	71% N reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	71% N reduction	Load (t/yr)
	1995	95.4	2055	113.8	2055	43.8	1995	73.6	2055	73.6	2055	28.2
	1996	113.2	2056	128.6	2056	45.5	1996	89.0	2056	85.1	2056	32.7
	1997	88.2	2057	97.9	2057	35.3	1997	69.8	2057	66.0	2057	25.5
	1998	73.2	2058	85.4	2058	31.5	1998	54.5	2058	51.8	2058	20.0
	1999	140.9	2059	152.4	2059	52.5	1999	114.2	2059	106.7	2059	40.2
	2000	87.6	2060	97.5	2060	37.5	2000	68.5	2060	64.4	2060	24.7
	2001	37.7	2061	48.3	2061	21.2	2001	26.5	2061	25.7	2061	10.6
	2002	44.4	2062	54.6	2062	24.1	2002	31.5	2062	29.9	2062	12.5
	2003	58.8	2063	75.5	2063	27.7	2003	42.9	2063	43.8	2063	17.2
	2004	54.7	2064	71.5	2064	25.7	2004	39.9	2064	42.2	2064	16.6
	2005	83.1	2065	103.0	2065	37.3	2005	64.7	2065	67.0	2065	25.3
	2006	30.6	2066	43.5	2066	15.8	2006	20.0	2066	20.8	2066	8.8
Average load for rainfall sequence (t/yr)	**75.6**			89.3		33.2		57.9		56.4		21.9
Median winter concentration (mg/L)	**2.14**			2.50		1.00		2.13		2.10		0.84
Load-reduction target (t/yr)	**42.5**	56%										
Maximum acceptable load (t/yr)	**33.2**											
Time periods required to meet LRT	**3**											





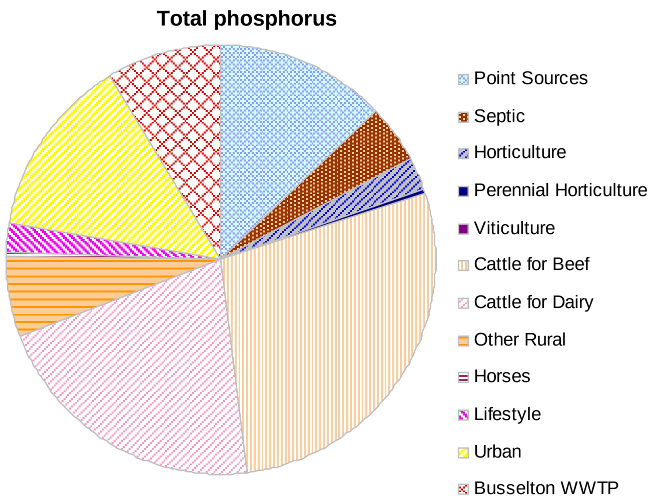
Vasse Diversion Drain: Source separation

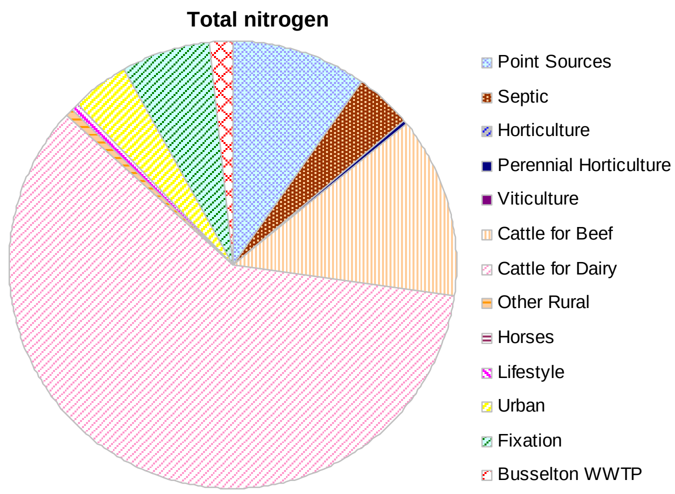
Phosphorus (t/yr)

Year	Current	Busselton WWTP	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	14.56	1.22	2.75	1.76	1.48	1.3	1.22	4.51	3.90	1.77	1.26	1.47	2.89
1996	14.79	1.31	3.05	1.86	1.55	1.35	1.31	4.68	3.72	1.92	1.36	1.57	2.98
1997	15.90	1.19	2.70	1.70	1.61	1.23	1.19	4.91	4.69	1.80	1.23	1.42	2.77
1998	12.97	0.81	2.38	1.35	0.96	0.84	0.81	3.69	2.63	1.43	0.86	1.05	2.47
1999	20.35	1.55	3.25	2.07	2.20	1.63	1.55	6.33	7.22	2.31	1.60	1.80	3.11
2000	14.77	0.97	2.41	1.42	1.17	0.93	0.89	4.21	3.89	1.61	0.93	1.13	2.49
2001	10.82	1.36	1.84	0.89	0.52	0.43	0.41	3.04	1.87	1.11	0.45	0.63	1.89
2002	11.59	1.49	2.12	1.06	0.63	0.55	0.52	3.26	1.88	1.34	0.57	0.78	2.18
2003	12.41	2.08	2.07	1.08	0.78	0.61	0.59	3.51	2.55	1.34	0.63	0.82	2.15
2004	12.40	1.04	2.00	1.06	0.82	0.59	0.57	3.57	2.45	1.29	0.61	0.81	2.20
2005	17.01	4.99	2.39	1.34	1.26	0.81	0.76	5.20	4.61	1.60	0.81	1.05	2.70
2006	11.39	4.36	1.59	0.87	0.55	0.36	0.42	3.42	1.25	1.07	0.39	0.66	2.11
Load (non adj)	14.08	1.86	2.38	1.37	1.13	0.88	0.85	4.19	3.39	1.55	0.89	1.10	2.49
Load (t/yr)	**14.08**	**1.31**	**1.98**	**0.68**	**0.36**	**0.05**	**0.01**	**4.32**	**3.28**	**0.91**	**0.06**	**0.32**	**2.12**
Load (%)	**100.0%**	**9.3%**	**14.0%**	**4.8%**	**2.6%**	**0.3%**	**0.1%**	**30.7%**	**23.3%**	**6.4%**	**0.4%**	**2.3%**	**15.1%**

Nitrogen (t/yr)

Year	Current	Busselton WWTP	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	95.40	1.3	8.1	5.2	1.3	1.6	1.3	12.0	54.4	1.8	1.3	1.7	4.6	7.3
1996	113.19	1.2	8.8	5.2	1.2	1.5	1.2	14.2	65.1	1.8	1.2	1.6	5.0	8.8
1997	88.19	1.3	8.0	4.0	1.3	1.5	1.3	11.6	50.9	1.8	1.3	1.6	3.9	6.9
1998	73.19	1.0	8.0	3.9	1.0	1.2	1.0	9.5	40.0	1.5	1.0	1.3	3.8	4.9
1999	140.90	1.5	8.9	5.5	1.5	2.0	1.5	17.9	85.5	2.4	1.5	2.0	5.6	11.1
2000	87.57	1.8	7.7	3.6	1.0	1.2	1.0	11.1	50.4	1.6	1.0	1.3	3.8	6.3
2001	37.69	2.7	7.1	2.4	0.9	0.9	0.9	4.7	19.2	1.2	0.9	1.0	2.4	2.0
2002	44.38	2.4	7.9	2.8	0.9	0.9	0.9	5.2	21.7	1.1	0.9	1.0	3.1	2.9
2003	58.82	3.0	7.2	3.2	0.7	0.9	0.7	8.0	29.7	0.9	0.7	0.9	3.8	3.9
2004	54.72	2.1	6.9	2.9	0.7	0.9	0.7	7.9	27.4	0.9	0.7	1.0	3.4	3.7
2005	83.09	4.1	8.3	3.6	1.0	1.5	1.0	12.8	45.9	1.4	1.1	1.4	4.6	5.4
2006	30.63	4.2	6.3	2.2	0.8	0.8	0.8	4.5	13.2	0.9	0.8	1.0	2.7	1.9
Load (non adj)	75.6	2.2	7.8	3.7	1.0	1.3	1.0	10.0	42.0	1.4	1.0	1.3	3.9	5.4
Load (t/yr)	**75.6**	**1.3**	**7.6**	**3.0**	**0.0**	**0.3**	**0.0**	**10.0**	**45.8**	**0.5**	**0.0**	**0.3**	**3.2**	**4.9**
Load (%)	**100.0%**	**1.8%**	**10.0%**	**4.0%**	**0.0%**	**0.3%**	**0.0%**	**13.2%**	**60.6%**	**0.6%**	**0.0%**	**0.4%**	**4.3%**	**6.5%**





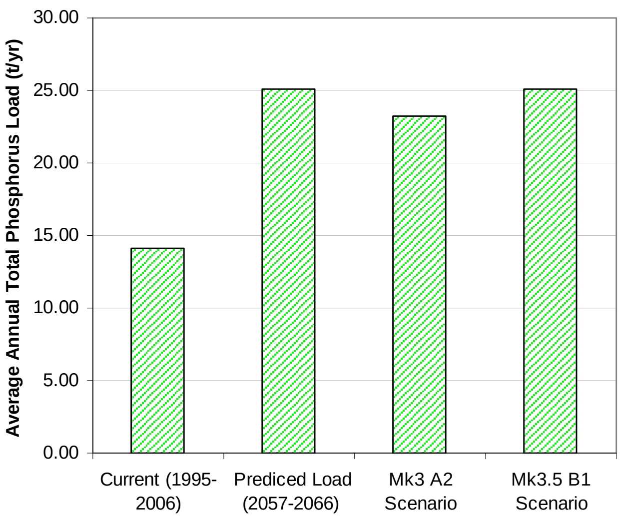
Vasse Diversion Drain: Climate change scenarios

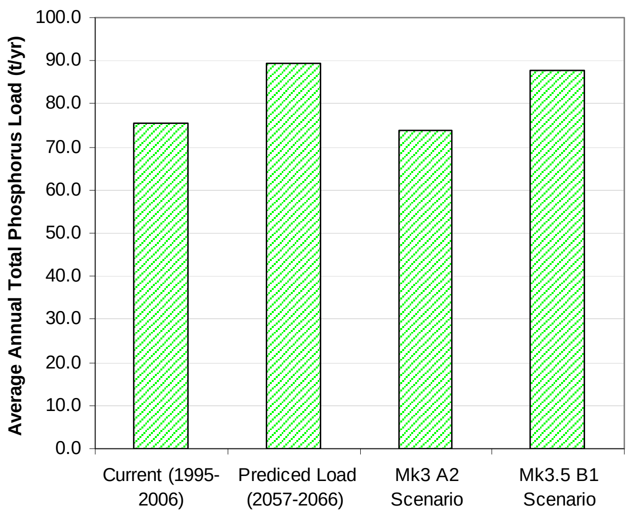
Phosphorus

			At catchment outlet				
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	14.56	2055	26.53	2055	30.35	2055	31.90
1996	14.79	2056	28.08	2056	24.42	2056	25.52
1997	15.90	2057	29.50	2057	24.62	2057	27.24
1998	12.97	2058	24.35	2058	21.15	2058	22.51
1999	20.35	2059	35.86	2059	27.53	2059	31.53
2000	14.77	2060	23.17	2060	27.85	2060	29.31
2001	10.82	2061	17.63	2061	21.13	2061	22.30
2002	11.59	2062	19.53	2062	22.83	2062	23.88
2003	12.41	2063	22.58	2063	19.08	2063	20.77
2004	12.40	2064	23.07	2064	19.31	2064	20.63
2005	17.01	2065	29.56	2065	23.20	2065	27.48
2006	11.39	2066	21.49	2066	17.40	2066	17.95
Average load (t/yr)	**14.08**		25.11		23.24		25.09

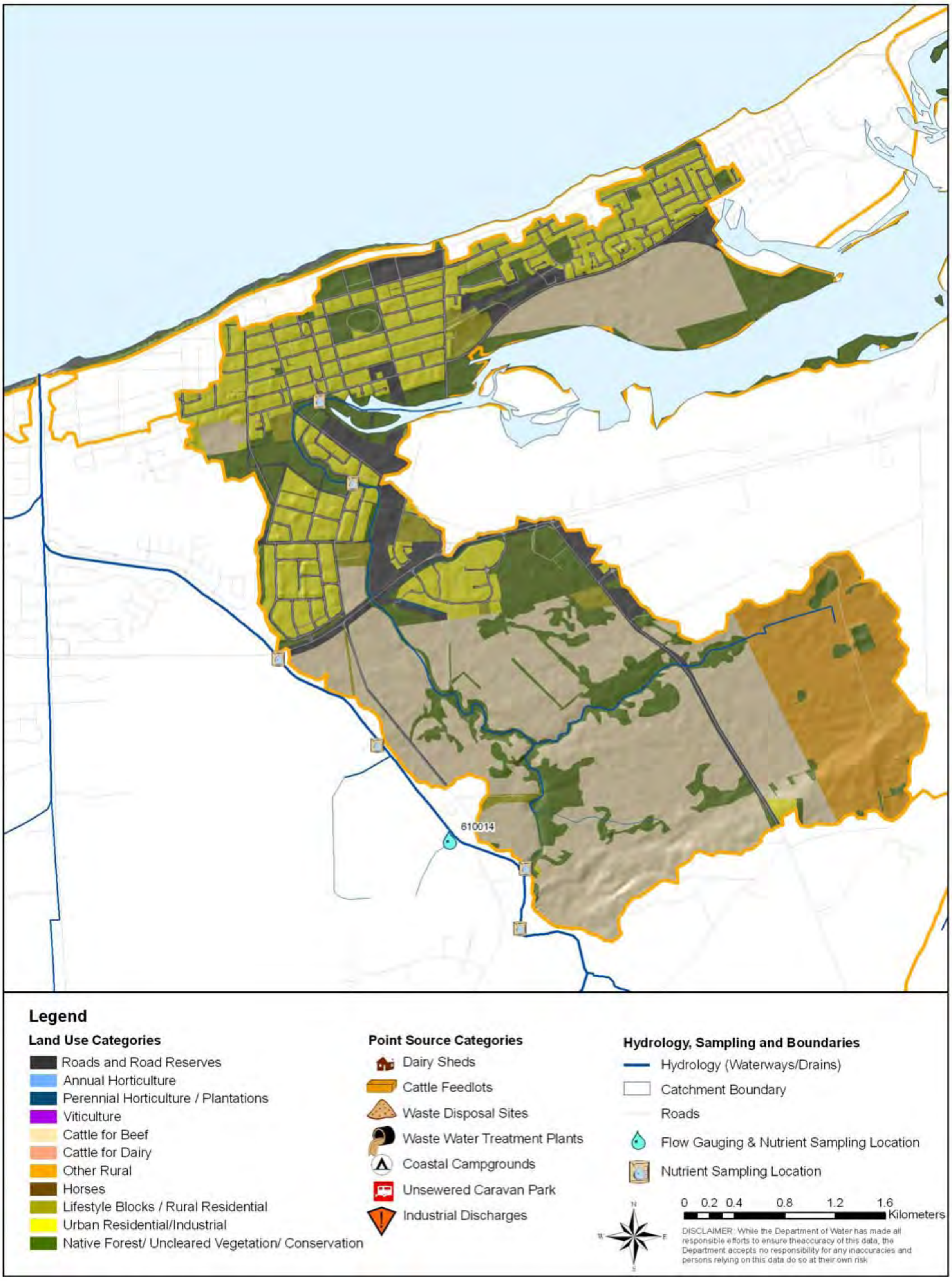
Nitrogen

			At catchment outlet				
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	95.40	2055	113.80	2055	102.8	2055	114.4
1996	113.19	2056	128.57	2056	116.3	2056	128.1
1997	88.19	2057	97.90	2057	82.6	2057	95.8
1998	73.19	2058	85.41	2058	71.6	2058	85.2
1999	140.90	2059	152.36	2059	126.0	2059	148.6
2000	87.57	2060	97.52	2060	85.0	2060	99.1
2001	37.69	2061	48.33	2061	32.1	2061	44.6
2002	44.38	2062	54.56	2062	43.1	2062	54.9
2003	58.82	2063	75.53	2063	60.9	2063	73.6
2004	54.72	2064	71.52	2064	55.7	2064	69.0
2005	83.09	2065	103.05	2065	73.7	2065	98.5
2006	30.63	2066	43.53	2066	34.5	2066	42.4
Average load (t/yr)	**75.6**		89.3		73.7		87.8





Lower Vasse River



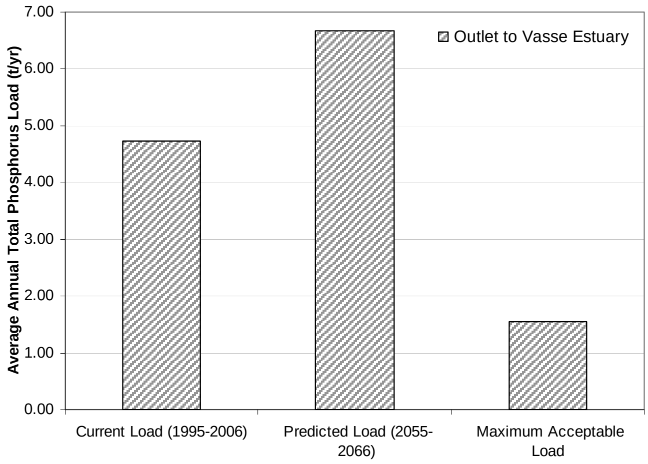
Lower Vasse River: Current loads, predicted loads and load reduction targets

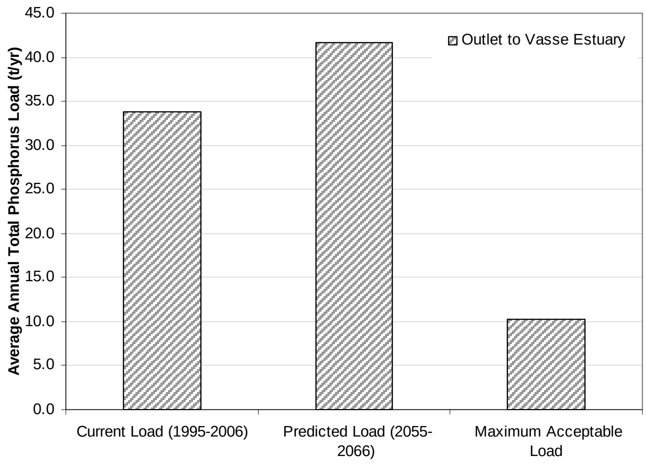
Phosphorus

			At outlet to Vasse Estuary			
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% P reduction*	*Load (t/yr)*
	1995	4.32	2055	6.60	2055	1.55
	1996	4.22	2056	6.30	2056	1.45
	1997	4.25	2057	6.30	2057	1.42
	1998	4.32	2058	6.42	2058	1.47
	1999	4.50	2059	6.65	2059	1.67
	2000	4.07	2060	6.06	2060	1.38
	2001	5.21	2061	7.22	2061	1.65
	2002	5.31	2062	6.92	2062	1.58
	2003	4.88	2063	6.52	2063	1.37
	2004	5.05	2064	6.72	2064	1.53
	2005	5.62	2065	8.18	2065	2.15
	2006	4.93	2066	6.05	2066	1.38
Average load for rainfall sequence (t/yr)		**4.72**		6.66		**1.55**
Median winter concentration (mg/L)		**0.251**		0.438		0.100
Load-reduction target (t/yr)		**3.2**	67%			
Maximum acceptable load (t/yr)		**1.55**				
Time periods required to meet LRT		**-**				

Nitrogen

			At outlet to Vasse Estuary			
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*% N reduction*	*Load (t/yr)*
	1995	21.4	2055	29.4	2055	10.3
	1996	21.4	2056	28.9	2056	10.0
	1997	20.4	2057	26.6	2057	9.6
	1998	21.7	2058	29.8	2058	10.7
	1999	24.1	2059	31.4	2059	10.9
	2000	19.3	2060	25.7	2060	8.8
	2001	22.9	2061	28.9	2061	10.3
	2002	20.3	2062	27.2	2062	9.8
	2003	20.7	2063	28.4	2063	10.4
	2004	20.7	2064	28.5	2064	10.6
	2005	28.6	2065	38.7	2065	14.8
	2006	15.0	2066	21.8	2066	7.3
Average load for rainfall sequence (t/yr)		**21.4**		28.8		10.3
Median winter concentration (mg/L)		**1.51**		2.44		1.00
Load-reduction target (t/yr)		**11.1**	52%			
Maximum acceptable load (t/yr)		**10.3**				
Time periods required to meet LRT		**-**				





Lower Vasse River: Source separation

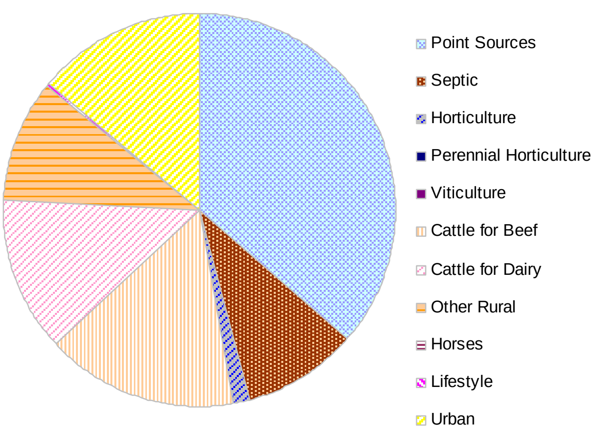
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	4.32	2.46	0.93	0.48	0.41	0.40	1.27	1.16	0.86	0.40	0.42	1.08
1996	4.22	2.51	0.96	0.50	0.43	0.42	1.29	1.10	0.91	0.42	0.45	1.12
1997	4.25	2.41	0.89	0.52	0.40	0.39	1.42	1.40	0.88	0.39	0.41	1.06
1998	4.32	2.33	0.79	0.30	0.27	0.26	1.01	0.76	0.75	0.26	0.28	0.98
1999	4.50	2.62	1.05	0.72	0.54	0.52	1.94	2.18	1.16	0.52	0.54	1.21
2000	4.07	2.30	0.81	0.37	0.29	0.28	1.19	1.14	0.82	0.28	0.31	1.00
2001	5.21	2.06	0.59	0.17	0.13	0.13	0.82	0.54	0.63	0.13	0.16	0.80
2002	5.31	2.25	0.69	0.20	0.17	0.17	0.89	0.54	0.75	0.17	0.20	0.95
2003	4.88	2.30	0.73	0.24	0.20	0.19	0.96	0.73	0.76	0.19	0.22	1.04
2004	5.05	2.21	0.71	0.24	0.19	0.18	0.96	0.70	0.74	0.19	0.21	1.03
2005	5.62	2.36	0.85	0.36	0.25	0.24	1.41	1.35	0.90	0.25	0.28	1.26
2006	4.93	1.94	0.63	0.12	0.10	0.10	0.75	0.32	0.69	0.10	0.13	1.02
Load (non adj)	4.72	2.31	0.80	0.35	0.28	0.27	1.16	0.99	0.82	0.27	0.30	1.05
Load (t/yr)	**4.72**	**1.72**	**0.45**	**0.07**	**0.01**	**0.00**	**0.75**	**0.61**	**0.46**	**0.00**	**0.02**	**0.65**
Load (%)	**100.0%**	**36.4%**	**9.4%**	**1.4%**	**0.1%**	**0.0%**	**15.8%**	**12.8%**	**9.8%**	**0.0%**	**0.5%**	**13.8%**

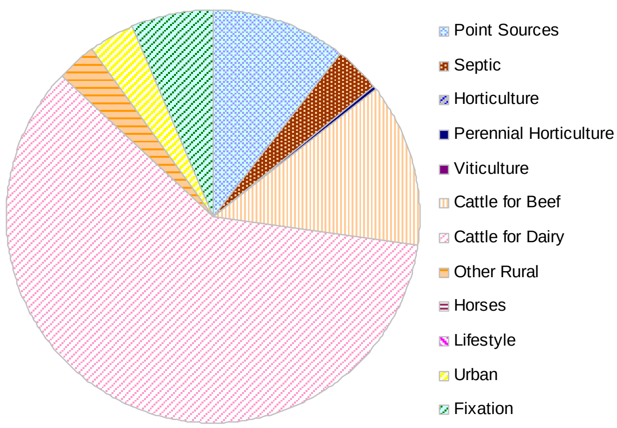
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	21.4	3.54	2.04	0.55	0.65	0.55	4.83	22.64	1.54	0.55	0.57	1.56	3.07
1996	21.4	3.83	1.90	0.51	0.65	0.51	5.67	27.12	1.65	0.51	0.53	1.57	3.69
1997	20.4	3.48	1.61	0.55	0.64	0.55	4.64	21.24	1.39	0.55	0.57	1.32	2.93
1998	21.7	3.51	1.61	0.44	0.51	0.44	3.71	16.55	1.18	0.44	0.46	1.31	2.01
1999	24.1	3.91	1.87	0.61	0.84	0.61	7.29	35.66	2.17	0.61	0.63	1.72	4.74
2000	19.3	3.37	1.38	0.42	0.51	0.42	4.47	20.98	1.40	0.42	0.44	1.32	2.67
2001	22.9	3.07	1.20	0.40	0.41	0.40	1.86	8.02	0.75	0.40	0.41	1.12	0.85
2002	20.3	3.42	1.27	0.38	0.41	0.38	2.14	9.11	0.78	0.38	0.40	1.20	1.24
2003	20.7	3.29	1.32	0.32	0.40	0.32	3.28	12.40	1.00	0.32	0.35	1.47	1.65
2004	20.7	3.13	1.22	0.32	0.42	0.32	3.25	11.43	1.03	0.32	0.35	1.40	1.59
2005	28.6	3.73	1.48	0.47	0.65	0.47	5.23	19.19	1.50	0.47	0.51	1.86	2.29
2006	15.0	2.75	0.98	0.24	0.26	0.24	1.73	5.42	0.70	0.24	0.26	1.14	0.69
Load (non adj)	21.4	3.4	1.5	0.4	0.5	0.4	4.0	17.5	1.3	0.4	0.5	1.4	2.3
Load (t/yr)	**21.4**	**2.2**	**0.8**	**0.0**	**0.1**	**0.0**	**2.7**	**12.8**	**0.6**	**0.0**	**0.0**	**0.7**	**1.4**
Load (%)	**100.0%**	**10.5%**	**3.7%**	**0.0%**	**0.3%**	**0.0%**	**12.6%**	**59.9%**	**2.9%**	**0.0%**	**0.1%**	**3.5%**	**6.5%**

Total phosphorus



Total nitrogen



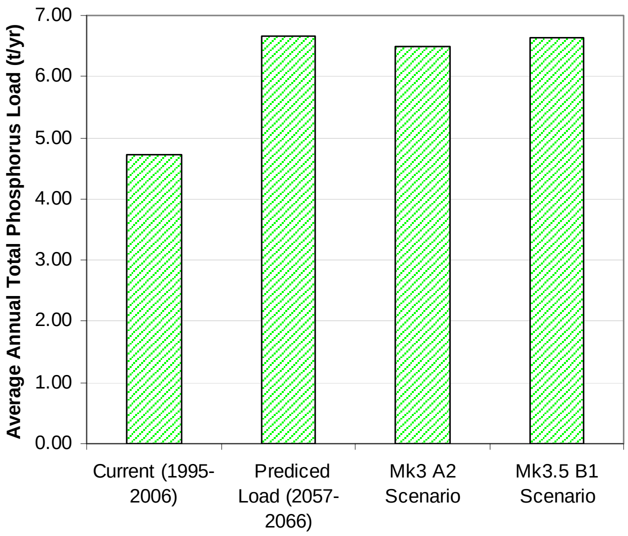
Lower Vasse River: Climate change scenarios

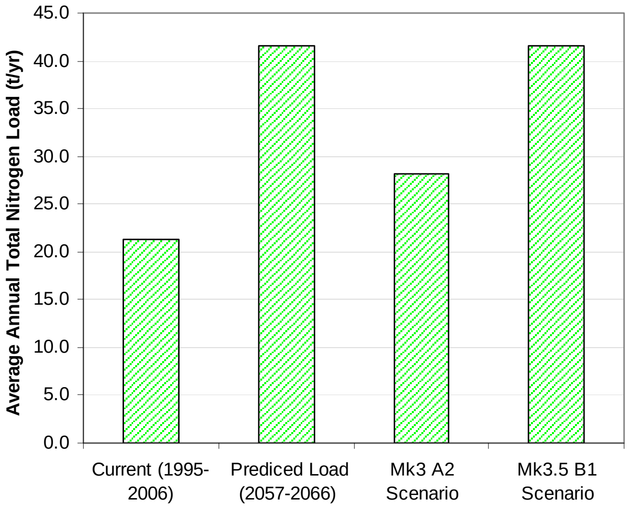
Phosphorus

	At catchment outlet						
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	4.32	2055	6.60	2055	6.46	2055	6.61
1996	4.22	2056	6.30	2056	6.30	2056	6.30
1997	4.25	2057	6.30	2057	6.38	2057	6.29
1998	4.32	2058	6.42	2058	6.28	2058	6.40
1999	4.50	2059	6.65	2059	7.36	2059	6.63
2000	4.07	2060	6.06	2060	6.75	2060	6.05
2001	5.21	2061	7.22	2061	5.83	2061	7.22
2002	5.31	2062	6.92	2062	6.53	2062	6.90
2003	4.88	2063	6.52	2063	6.23	2063	6.52
2004	5.05	2064	6.72	2064	6.34	2064	6.69
2005	5.62	2065	8.18	2065	7.76	2065	8.15
2006	4.93	2066	6.05	2066	5.76	2066	6.00
Average load (t/yr)	**4.72**		6.66		6.50		6.65

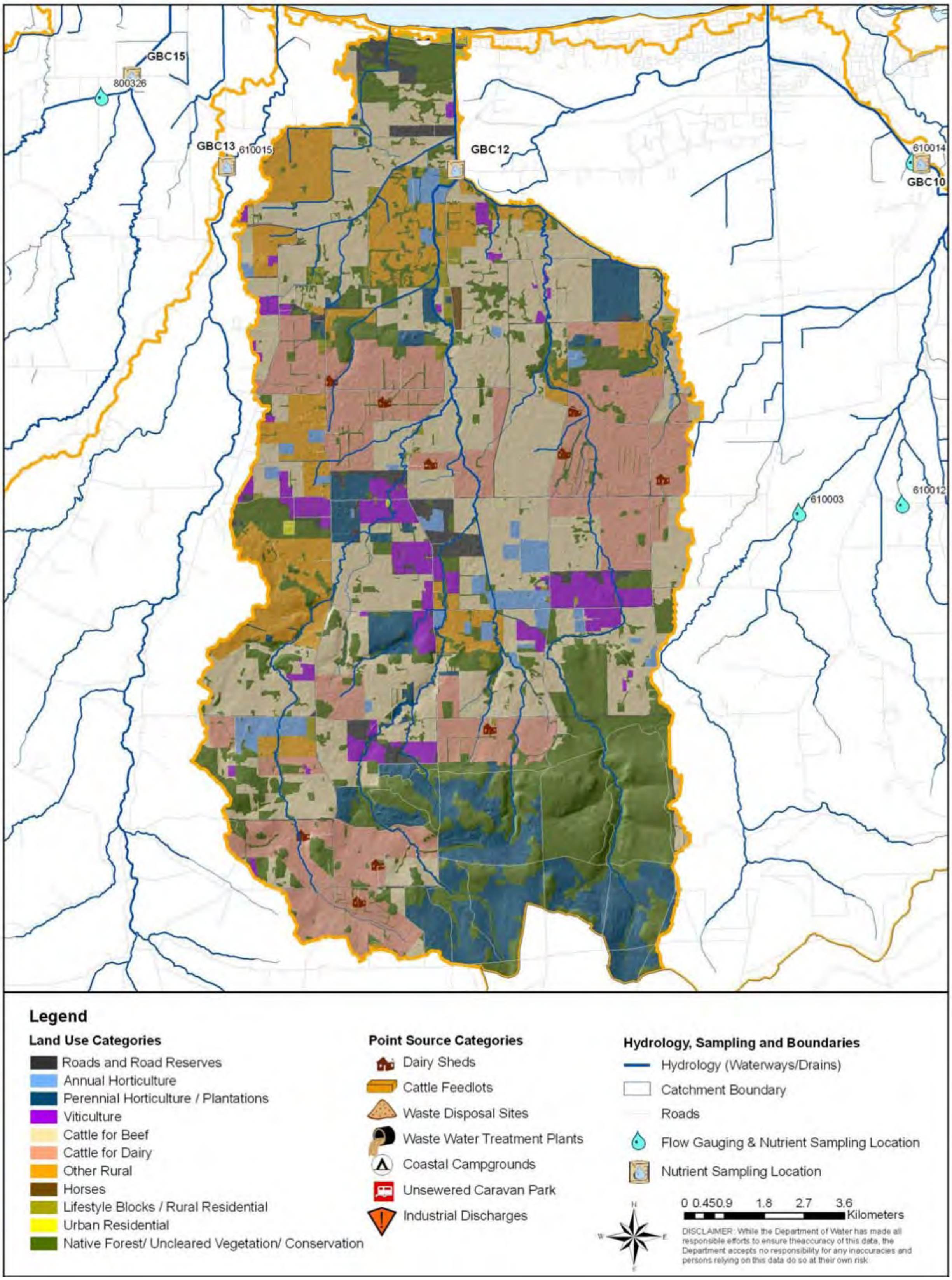
Nitrogen

	At catchment outlet						
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	21.4	2055	41.7	2055	29.8	2055	41.6
1996	21.4	2056	40.5	2056	31.2	2056	40.6
1997	20.4	2057	38.9	2057	27.9	2057	38.8
1998	21.7	2058	43.2	2058	29.9	2058	43.1
1999	24.1	2059	44.3	2059	34.9	2059	44.4
2000	19.3	2060	35.7	2060	27.9	2060	35.8
2001	22.9	2061	41.4	2061	20.0	2061	41.3
2002	20.3	2062	39.7	2062	25.0	2062	39.8
2003	20.7	2063	42.2	2063	28.8	2063	42.2
2004	20.7	2064	42.6	2064	27.2	2064	42.5
2005	28.6	2065	59.8	2065	36.5	2065	59.6
2006	15.0	2066	29.4	2066	19.4	2066	29.2
Average load (t/yr)	**21.4**		41.6		28.2		41.6





Buayanyup River



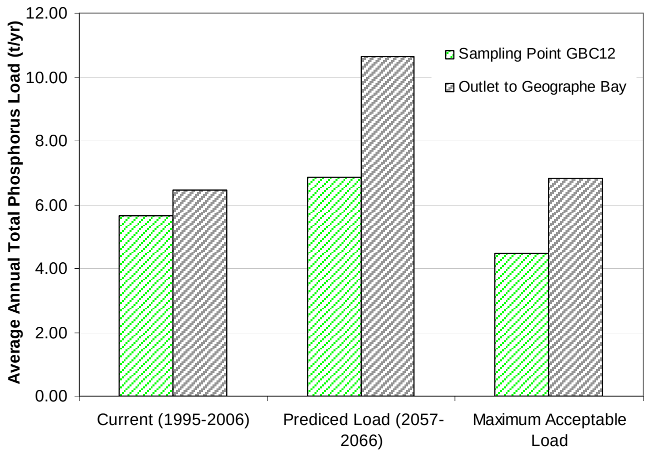
Buayanyup River: Current loads, predicted loads and load reduction targets

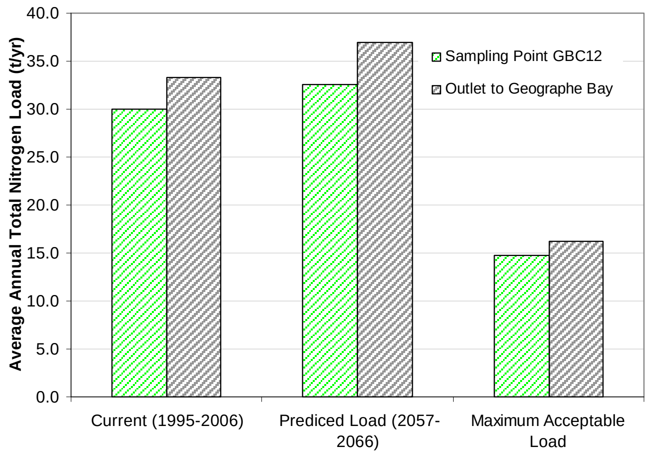
Phosphorus

	At outlet to Geographe Bay						At sampling location GBC12					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	38% P reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	38% P reduction	Load (t/yr)
	1995	3.90	2055	8.56	2055	5.54	1995	3.36	2055	4.92	2055	3.28
	1996	4.87	2056	9.78	2056	6.31	1996	4.21	2056	5.89	2056	3.90
	1997	7.20	2057	11.35	2057	7.26	1997	6.44	2057	7.71	2057	5.00
	1998	4.30	2058	9.27	2058	5.98	1998	3.71	2058	5.46	2058	3.61
	1999	29.05	2059	35.09	2059	22.03	1999	25.80	2059	27.97	2059	17.62
	2000	4.19	2060	8.68	2060	5.60	2000	3.62	2060	5.19	2060	3.44
	2001	2.90	2061	7.36	2061	4.78	2001	2.60	2061	4.01	2061	2.69
	2002	2.38	2062	6.46	2062	4.24	2002	2.02	2062	3.43	2062	2.36
	2003	3.78	2063	7.17	2063	4.67	2003	3.34	2063	3.88	2063	2.63
	2004	4.16	2064	7.31	2064	4.75	2004	3.67	2064	4.04	2064	2.72
	2005	8.72	2065	12.38	2065	7.92	2005	7.37	2065	7.78	2065	5.06
	2006	2.02	2066	4.48	2066	2.97	2006	1.70	2066	2.02	2066	1.44
Average load for rainfall sequence (t/yr)		**6.46**		10.66		**6.84**		5.65		6.86		4.48
Median winter concentration (mg/L)		**0.069**		0.101		0.069		0.068		0.081		0.056
Load-reduction target (t/yr)		**0.0**	0%									
Maximum acceptable load (t/yr)		**6.84**										
Time periods required to meet LRT		***1***										

Nitrogen

	At outlet to Geographe Bay						At sampling location GBC12					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	60% N reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	60% N reduction	Load (t/yr)
	1995	33.6	2055	37.9	2055	16.7	1995	30.2	2055	33.3	2055	15.1
	1996	44.5	2056	49.8	2056	21.3	1996	39.9	2056	43.8	2056	19.3
	1997	40.2	2057	44.8	2057	19.3	1997	36.1	2057	39.5	2057	17.5
	1998	38.1	2058	42.4	2058	18.4	1998	34.3	2058	37.4	2058	16.7
	1999	54.7	2059	60.9	2059	25.6	1999	49.1	2059	54.0	2059	23.3
	2000	36.8	2060	41.3	2060	17.8	2000	33.0	2060	36.4	2060	16.2
	2001	19.6	2061	22.0	2061	10.5	2001	17.8	2061	19.3	2061	9.5
	2002	22.5	2062	25.1	2062	11.8	2002	20.6	2062	22.2	2062	10.8
	2003	27.3	2063	30.2	2063	13.6	2003	24.7	2063	26.6	2063	12.4
	2004	27.5	2064	30.2	2064	13.6	2004	25.0	2064	26.5	2064	12.3
	2005	40.3	2065	43.6	2065	19.0	2005	36.4	2065	38.3	2065	17.2
	2006	13.9	2066	14.8	2066	7.5	2006	12.4	2066	12.9	2066	6.8
Average load for rainfall sequence (t/yr)		**33.2**		36.9		**16.3**		30.0		32.5		14.8
Median winter concentration (mg/L)		**2.11**		2.36		1.00		2.13		2.41		1.00
Load-reduction target (t/yr)		**17.0**	51%									
Maximum acceptable load (t/yr)		**16.3**										
Time periods required to meet LRT		**1**										





Buayanyup River: Source separation

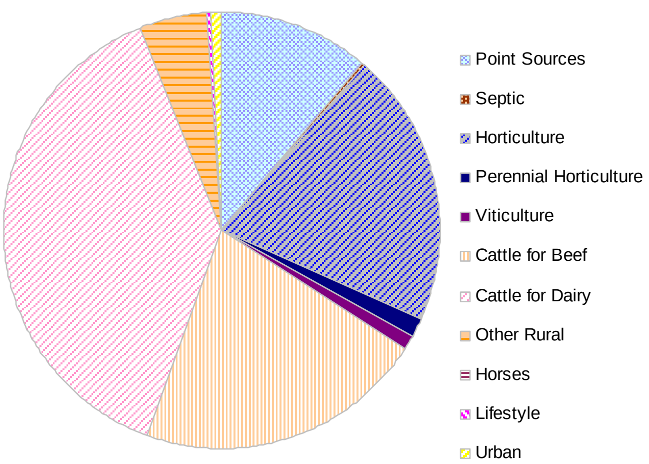
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	3.90	0.59	0.01	0.51	0.05	0.00	0.54	0.77	0.01	0.00	0.00	0.05
1996	4.87	0.65	0.02	0.60	0.06	0.01	0.62	0.91	0.01	0.00	0.00	0.05
1997	7.20	0.57	0.01	1.27	0.09	0.01	1.24	2.43	0.02	0.00	0.00	0.04
1998	4.30	0.59	0.02	0.56	0.06	0.01	0.62	0.93	0.01	0.00	0.00	0.05
1999	29.05	0.64	0.03	6.10	0.45	0.06	6.61	12.53	0.10	0.00	0.02	0.06
2000	4.19	0.57	0.01	0.55	0.06	0.01	0.60	0.85	0.01	0.00	0.00	0.05
2001	2.90	0.54	0.01	0.26	0.02	0.00	0.46	1.15	0.01	0.00	0.00	0.04
2002	2.38	0.59	0.01	0.31	0.02	0.00	0.31	0.45	0.01	0.00	0.00	0.05
2003	3.78	0.60	0.01	0.47	0.04	0.10	0.45	0.61	0.56	0.00	0.00	0.04
2004	4.16	0.58	0.01	0.53	0.05	0.12	0.45	0.73	0.81	0.00	0.00	0.04
2005	8.72	0.64	0.02	1.31	0.09	0.20	1.32	2.75	1.17	0.01	0.01	0.06
2006	2.02	0.48	0.01	0.21	0.01	0.08	0.23	0.20	0.42	0.00	0.00	0.04
Load (non adj)	6.46	0.59	0.02	1.06	0.08	0.05	1.12	2.03	0.26	0.00	0.00	0.05
Load (t/yr)	**6.46**	**0.72**	**0.02**	**1.30**	**0.10**	**0.06**	**1.38**	**2.49**	**0.32**	**0.00**	**0.00**	**0.06**
Load (%)	**100.0%**	**11.2%**	**0.3%**	**20.1%**	**1.6%**	**0.9%**	**21.3%**	**38.6%**	**5.0%**	**0.0%**	**0.1%**	**0.9%**

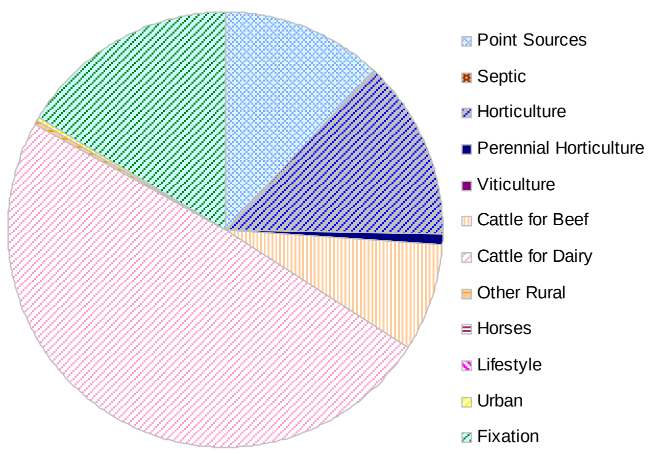
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	33.6	4.0	0.6	4.7	0.8	0.5	3.0	14.7	0.6	0.5	0.5	0.6	5.5
1996	44.5	4.4	0.6	6.1	0.9	0.6	3.9	19.6	0.7	0.6	0.6	0.7	7.6
1997	40.2	4.4	1.1	6.0	1.3	1.1	3.7	18.2	1.2	1.1	1.1	1.2	7.1
1998	38.1	4.4	0.9	5.5	1.1	1.0	3.4	16.8	1.0	1.0	0.9	1.0	6.6
1999	54.7	5.4	1.7	8.3	2.1	1.8	5.2	24.6	1.8	1.8	1.7	1.9	10.2
2000	36.8	3.6	0.4	4.9	0.6	0.4	3.1	15.9	0.4	0.4	0.4	0.4	6.3
2001	19.6	3.4	0.3	2.4	0.3	0.2	1.7	8.7	0.3	0.2	0.2	0.3	2.4
2002	22.5	3.6	0.2	2.8	0.3	0.2	1.9	9.7	0.2	0.2	0.2	0.3	3.1
2003	27.3	3.8	0.4	3.5	0.5	0.4	2.4	11.8	0.4	0.3	0.3	0.4	4.1
2004	27.5	3.8	0.4	3.4	0.5	0.4	2.4	12.0	0.5	0.4	0.4	0.4	4.1
2005	40.3	4.6	0.9	5.3	1.1	0.9	3.7	18.6	1.2	0.9	0.8	0.9	6.0
2006	13.9	3.3	0.5	1.8	0.5	0.5	1.5	5.9	0.6	0.4	0.4	0.5	2.0
Load (non adj)	33.2	4.1	0.7	4.6	0.8	0.7	3.0	14.7	0.7	0.7	0.6	0.7	5.4
Load (t/yr)	**33.2**	**3.9**	**0.0**	**4.5**	**0.2**	**0.0**	**2.7**	**16.2**	**0.1**	**0.0**	**0.0**	**0.1**	**5.5**
Load (%)	**100.0%**	**11.8%**	**0.1%**	**13.5%**	**0.7%**	**0.0%**	**8.1%**	**48.8%**	**0.3%**	**0.0%**	**0.0%**	**0.3%**	**16.5%**

Total phosphorus



Total nitrogen



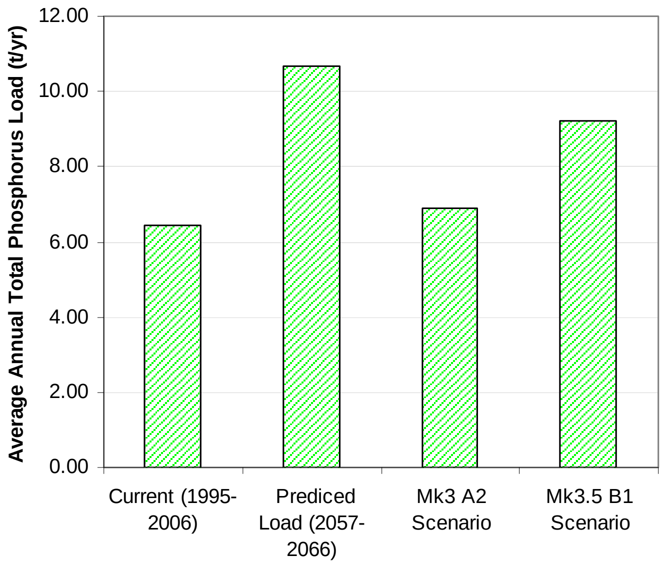
Buayanyup River: Climate change scenarios

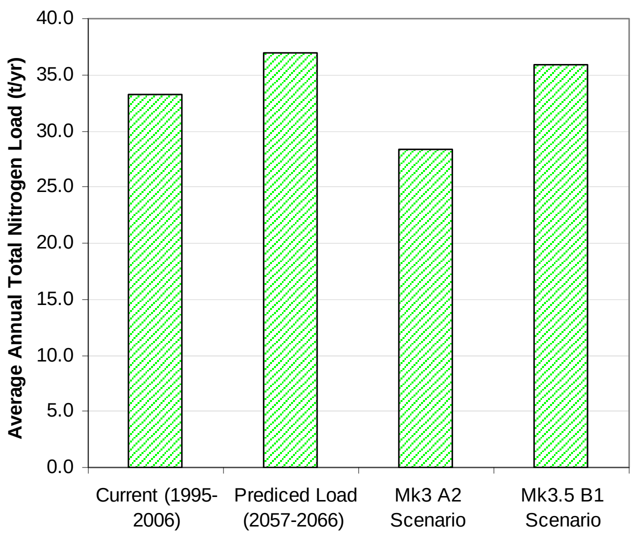
Phosphorus

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	3.90	2055	8.56	2055	7.31	2055	8.31
1996	4.87	2056	9.78	2056	8.51	2056	9.59
1997	7.20	2057	11.35	2057	7.53	2057	11.02
1998	4.30	2058	9.27	2058	7.75	2058	8.93
1999	29.05	2059	35.09	2059	10.00	2059	23.35
2000	4.19	2060	8.68	2060	7.71	2060	8.60
2001	2.90	2061	7.36	2061	5.15	2061	6.37
2002	2.38	2062	6.46	2062	5.38	2062	6.33
2003	3.78	2063	7.17	2063	5.91	2063	6.87
2004	4.16	2064	7.31	2064	6.06	2064	7.07
2005	8.72	2065	12.38	2065	7.65	2065	9.67
2006	2.02	2066	4.48	2066	3.85	2066	4.38
Average load (t/yr)	**6.46**		10.66		6.90		9.21

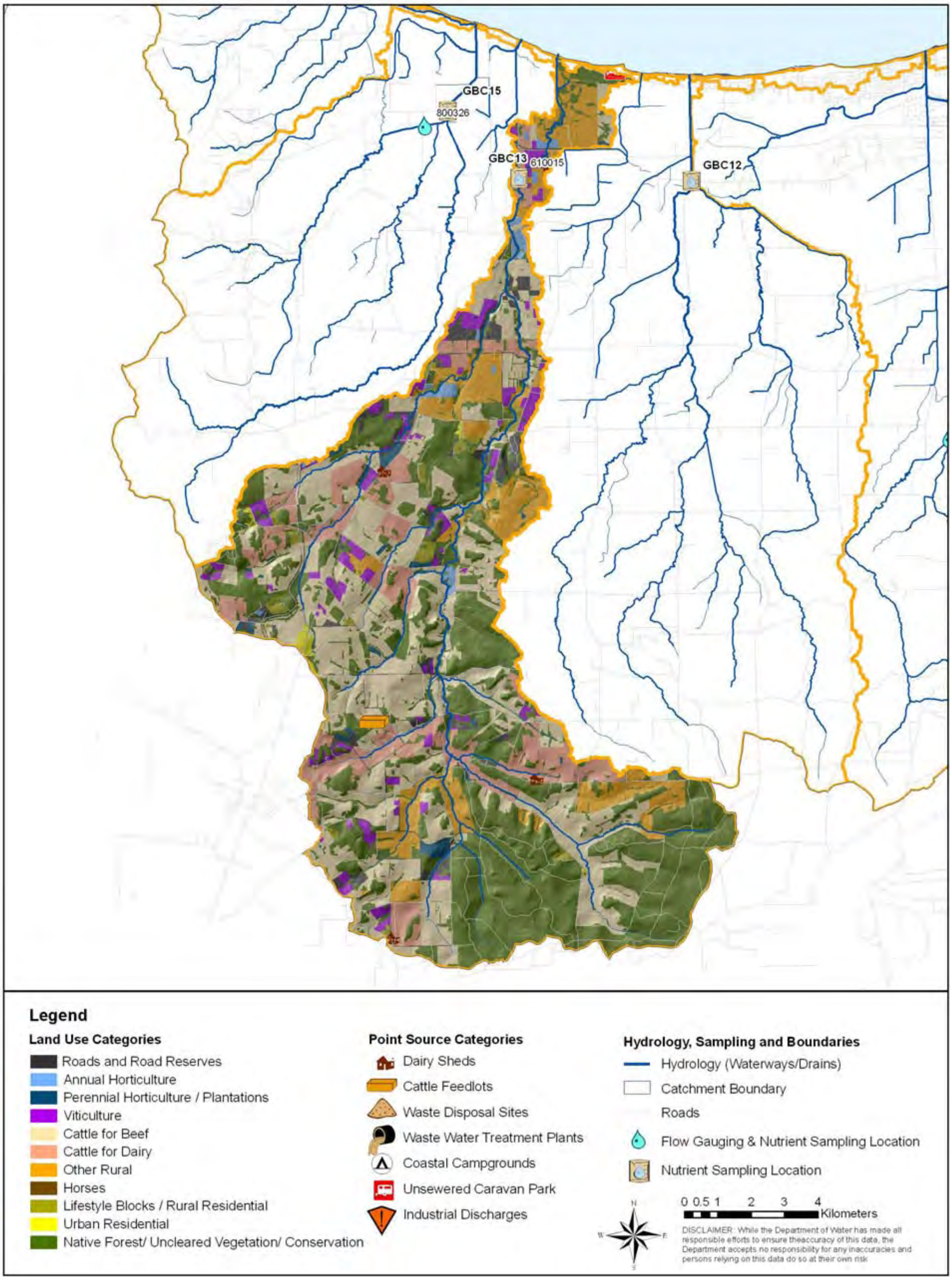
Nitrogen

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	33.6	2055	37.9	2055	30.1	2055	37.1
1996	44.5	2056	49.8	2056	41.3	2056	49.2
1997	40.2	2057	44.8	2057	36.0	2057	43.9
1998	38.1	2058	42.4	2058	33.6	2058	41.6
1999	54.7	2059	60.9	2059	50.4	2059	59.9
2000	36.8	2060	41.3	2060	35.2	2060	40.7
2001	19.6	2061	22.0	2061	12.1	2061	20.1
2002	22.5	2062	25.1	2062	16.4	2062	23.7
2003	27.3	2063	30.2	2063	22.2	2063	29.0
2004	27.5	2064	30.2	2064	21.9	2064	29.1
2005	40.3	2065	43.6	2065	29.9	2065	41.4
2006	13.9	2066	14.8	2066	10.2	2066	14.3
Average load (t/yr)	**33.2**		36.9		28.3		35.8





Carbunup River



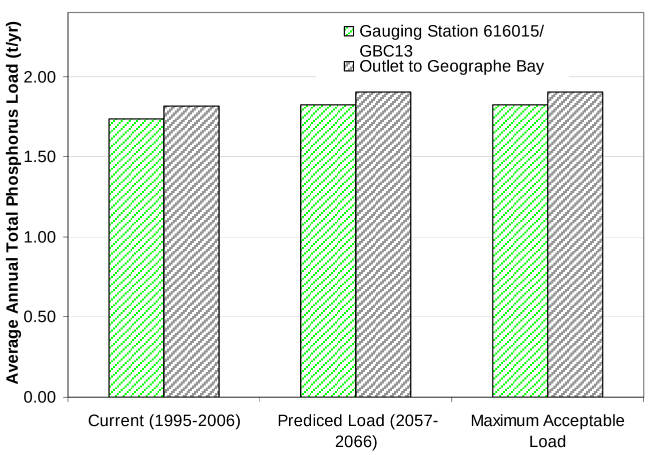
Carbunup River: Current loads, predicted loads and load reduction targets

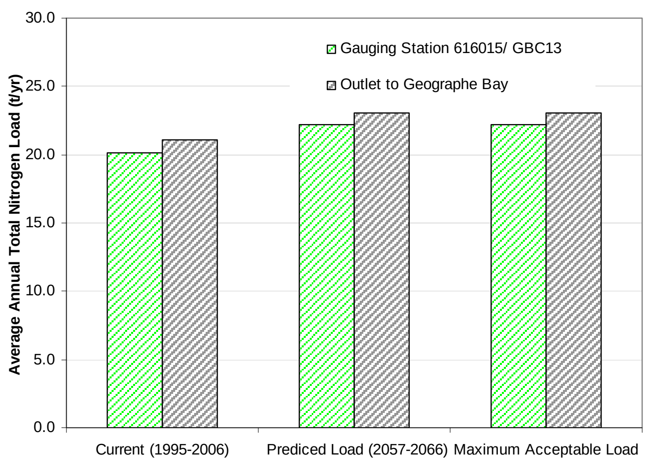
Phosphorus

	At outlet to Geographe Bay						At gauging station 610015/GBC13					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	0% P reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	0% P reduction	Load (t/yr)
	1995	1.52	2055	1.61	2055	1.61	1995	1.44	2055	1.53	2055	1.53
	1996	2.08	2056	2.24	2056	2.24	1996	1.98	2056	2.13	2056	2.13
	1997	2.03	2057	2.16	2057	2.16	1997	1.93	2057	2.05	2057	2.05
	1998	2.38	2058	2.55	2058	2.55	1998	2.29	2058	2.46	2058	2.46
	1999	3.13	2059	3.36	2059	3.36	1999	2.97	2059	3.19	2059	3.19
	2000	2.02	2060	2.15	2060	2.15	2000	1.92	2060	2.05	2060	2.05
	2001	1.43	2061	1.49	2061	1.49	2001	1.39	2061	1.45	2061	1.45
	2002	1.19	2062	1.27	2062	1.27	2002	1.15	2062	1.22	2062	1.22
	2003	1.47	2063	1.48	2063	1.48	2003	1.41	2063	1.42	2063	1.42
	2004	1.42	2064	1.42	2064	1.42	2004	1.37	2064	1.37	2064	1.37
	2005	2.46	2065	2.46	2065	2.46	2005	2.38	2065	2.38	2065	2.38
	2006	0.64	2066	0.64	2066	0.64	2006	0.61	2066	0.61	2066	0.61
Average load for rainfall sequence (t/yr)		**1.81**		1.90		**1.90**		1.74		1.82		1.82
Median winter concentration (mg/L)		**0.021**		0.022		0.022		0.020		0.021		0.02
Load-reduction target (t/yr)		**0.0**	0%									
Maximum acceptable load (t/yr)		**1.90**										
Time periods required to meet LRT		**0**										

Nitrogen

	At outlet to Geographe Bay						At gauging station 610015/GBC13					
	Year	Load (t/yr)	Current conditions	Load (t/yr)	0% N reduction	Load (t/yr)	Year	Load (t/yr)	Current conditions	Load (t/yr)	0% N reduction	Load (t/yr)
	1995	21.6	2055	25.6	2055	25.6	1995	20.5	2055	24.6	2055	24.6
	1996	27.5	2056	31.2	2056	31.2	1996	26.2	2056	29.9	2056	29.9
	1997	21.8	2057	24.2	2057	24.2	1997	20.8	2057	23.2	2057	23.2
	1998	25.3	2058	28.1	2058	28.1	1998	24.2	2058	27.1	2058	27.1
	1999	30.6	2059	33.7	2059	33.7	1999	29.2	2059	32.4	2059	32.4
	2000	22.9	2060	25.3	2060	25.3	2000	21.9	2060	24.4	2060	24.4
	2001	13.0	2061	14.6	2061	14.6	2001	12.5	2061	14.1	2061	14.1
	2002	16.2	2062	18.4	2062	18.4	2002	15.5	2062	17.8	2062	17.8
	2003	20.1	2063	21.3	2063	21.3	2003	19.3	2063	20.6	2063	20.6
	2004	18.2	2064	18.5	2064	18.5	2004	17.5	2064	17.8	2064	17.8
	2005	27.1	2065	27.2	2065	27.2	2005	26.0	2065	26.1	2065	26.1
	2006	8.8	2066	8.7	2066	8.7	2006	8.4	2066	8.4	2066	8.4
Average load for rainfall sequence (t/yr)		**21.1**		23.1		23.1		20.2		22.2		22.2
Median winter concentration (mg/L)		**0.67**		0.73		0.73		0.67		0.71		0.71
Load-reduction target (t/yr)		**0.0**	0%									
Maximum acceptable load (t/yr)		**23.1**										
Time periods required to meet LRT		**0**										





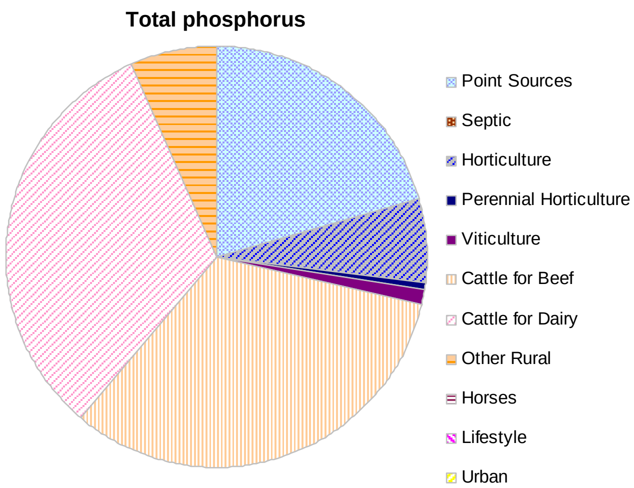
Carbunup River: Source separation

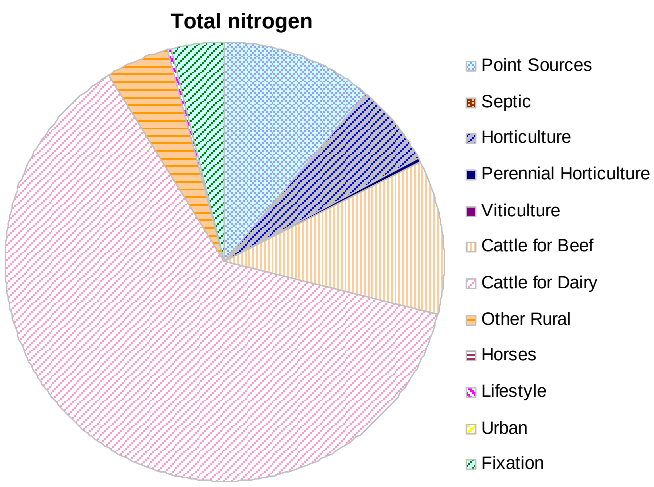
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	1.52	0.37	0.00	0.09	0.01	0.00	0.48	0.45	0.10	0.00	0.00	0.00
1996	2.08	0.44	0.00	0.14	0.02	0.01	0.66	0.63	0.15	0.00	0.00	0.00
1997	2.03	0.39	0.00	0.15	0.01	0.01	0.69	0.62	0.15	0.00	0.00	0.00
1998	2.38	0.40	0.00	0.16	0.01	0.01	0.80	0.79	0.18	0.00	0.00	0.00
1999	3.13	0.44	0.00	0.25	0.02	0.01	1.07	1.04	0.27	0.00	0.00	0.00
2000	2.02	0.41	0.00	0.15	0.01	0.00	0.65	0.62	0.15	0.00	0.00	0.00
2001	1.43	0.31	0.00	0.06	0.01	0.00	0.52	0.43	0.06	0.00	0.00	0.00
2002	1.19	0.34	0.00	0.05	0.01	0.02	0.35	0.34	0.07	0.00	0.00	0.00
2003	1.47	0.35	0.00	0.06	0.01	0.05	0.43	0.47	0.07	0.00	0.00	0.00
2004	1.42	0.33	0.00	0.06	0.01	0.04	0.41	0.47	0.08	0.00	0.00	0.00
2005	2.46	0.36	0.00	0.14	0.01	0.09	0.76	0.89	0.16	0.00	0.00	0.00
2006	0.64	0.29	0.00	0.03	0.00	0.02	0.14	0.13	0.02	0.00	0.00	0.00
Load (non adj)	1.81	0.37	0.00	0.11	0.01	0.02	0.58	0.57	0.12	0.00	0.00	0.00
Load (t/yr)	**1.81**	**0.37**	**0.00**	**0.11**	**0.01**	**0.02**	**0.59**	**0.58**	**0.12**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**20.7%**	**0.0%**	**6.2%**	**0.6%**	**1.2%**	**32.4%**	**32.1%**	**6.8%**	**0.0%**	**0.0%**	**0.0%**

Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	21.6	1.6	0.0	1.0	0.0	0.0	1.6	9.0	0.7	0.0	0.0	0.0	0.6
1996	27.5	1.7	0.0	1.3	0.1	0.0	2.3	11.6	1.0	0.0	0.0	0.0	1.0
1997	21.8	1.7	0.0	1.0	0.0	0.0	2.1	9.3	0.8	0.0	0.0	0.0	0.7
1998	25.3	1.7	0.0	1.1	0.0	0.0	2.4	11.3	1.0	0.0	0.0	0.0	0.7
1999	30.6	1.7	0.0	1.5	0.0	0.0	3.2	13.6	1.3	0.0	0.0	0.0	1.1
2000	22.9	1.7	0.0	1.1	0.0	0.0	2.1	9.9	0.9	0.0	0.0	0.0	0.7
2001	13.0	1.6	0.0	0.3	0.0	0.0	1.1	5.9	0.4	0.0	0.0	0.0	0.3
2002	16.2	1.7	0.0	0.5	0.0	0.0	1.1	6.9	0.5	0.0	0.0	0.0	0.4
2003	20.1	1.7	0.0	0.8	0.0	0.0	1.2	9.1	0.6	0.0	0.0	0.0	0.5
2004	18.2	1.6	0.0	0.7	0.0	0.0	1.1	8.4	0.5	0.0	0.0	0.0	0.4
2005	27.1	1.6	0.0	1.2	0.0	0.0	2.0	13.1	0.9	0.0	0.0	0.0	0.6
2006	8.8	1.6	0.0	0.2	0.0	0.0	0.5	3.8	0.2	0.0	0.0	0.0	0.2
Load (non adj)	21.1	1.7	0.0	0.9	0.0	0.0	1.7	9.3	0.7	0.0	0.0	0.0	0.6
Load (t/yr)	**21.1**	**2.3**	**0.0**	**1.3**	**0.0**	**0.0**	**2.4**	**13.1**	**1.0**	**0.0**	**0.0**	**0.0**	**0.8**
Load (%)	**100.0%**	**11.1%**	**0.1%**	**6.1%**	**0.2%**	**0.0%**	**11.5%**	**62.2%**	**4.9%**	**0.0%**	**0.0%**	**0.0%**	**4.0%**





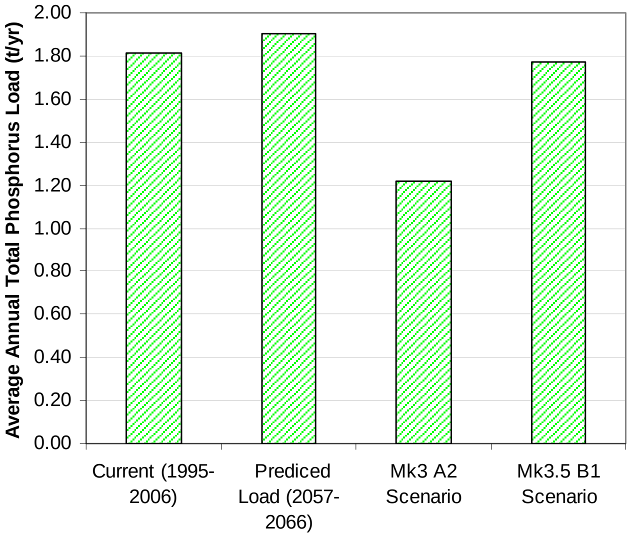
Carbunup River: Climate change scenarios

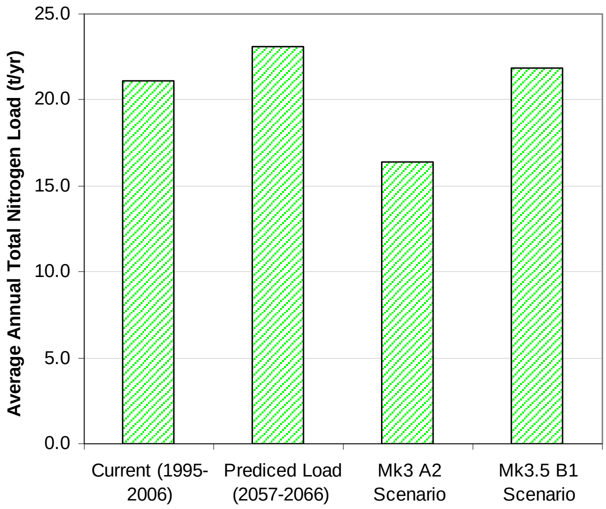
Phosphorus

				At catchment outlet			
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	1.52	2055	1.61	2055	1.03	2055	1.50
1996	2.08	2056	2.24	2056	1.59	2056	2.11
1997	2.03	2057	2.16	2057	1.48	2057	2.02
1998	2.38	2058	2.55	2058	1.69	2058	2.37
1999	3.13	2059	3.36	2059	2.22	2059	3.21
2000	2.02	2060	2.15	2060	1.40	2060	2.04
2001	1.43	2061	1.49	2061	0.86	2061	1.33
2002	1.19	2062	1.27	2062	0.79	2062	1.18
2003	1.47	2063	1.48	2063	0.92	2063	1.35
2004	1.42	2064	1.42	2064	0.84	2064	1.29
2005	2.46	2065	2.46	2065	1.40	2065	2.26
2006	0.64	2066	0.64	2066	0.41	2066	0.58
Average load (t/yr)	**1.81**		1.90		1.22		1.77

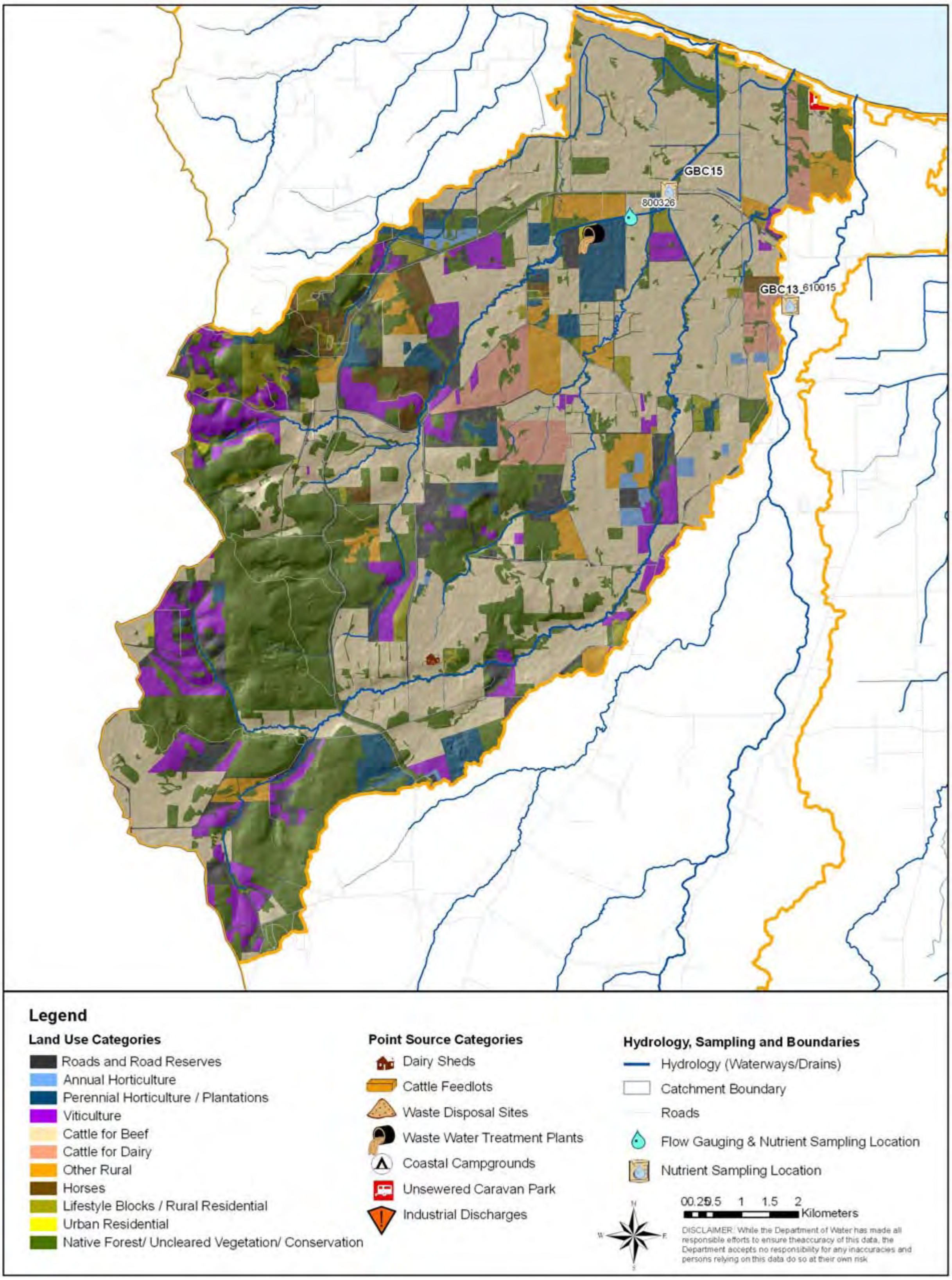
Nitrogen

				At catchment outlet			
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	21.6	2055	25.6	2055	19.0	2055	24.4
1996	27.5	2056	31.2	2056	25.8	2056	30.0
1997	21.8	2057	24.2	2057	18.5	2057	23.0
1998	25.3	2058	28.1	2058	20.9	2058	26.6
1999	30.6	2059	33.7	2059	26.4	2059	32.7
2000	22.9	2060	25.3	2060	18.6	2060	24.3
2001	13.0	2061	14.6	2061	6.8	2061	12.9
2002	16.2	2062	18.4	2062	11.6	2062	17.4
2003	20.1	2063	21.3	2063	14.9	2063	20.3
2004	18.2	2064	18.5	2064	11.8	2064	17.3
2005	27.1	2065	27.2	2065	17.6	2065	25.5
2006	8.8	2066	8.7	2066	4.5	2066	8.0
Average load (t/yr)	**21.1**		23.1		16.4		21.9





Annie Brook


GBC15
800326
GBC13
610015
Legend
Land Use Categories
Roads and Road Reserves
Annual Horticulture
Perennial Horticulture / Plantations
Viticulture
Cattle for Beef
Cattle for Dairy
Other Rural
Horses
Lifestyle Blocks / Rural Residential
Urban Residential
Native Forest/ Uncleared Vegetation/ Conservation
Point Source Categories
Dairy Sheds
Cattle Feedlots
Waste Disposal Sites
Waste Water Treatment Plants
Coastal Campgrounds
Unsewered Caravan Park
Industrial Discharges
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary
Roads
Flow Gauging & Nutrient Sampling Location
Nutrient Sampling Location
00.250.5 1 1.5 2
Kilometers
DISCLAIMER: While the Department of Water has made all responsible efforts to ensure theaccuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk

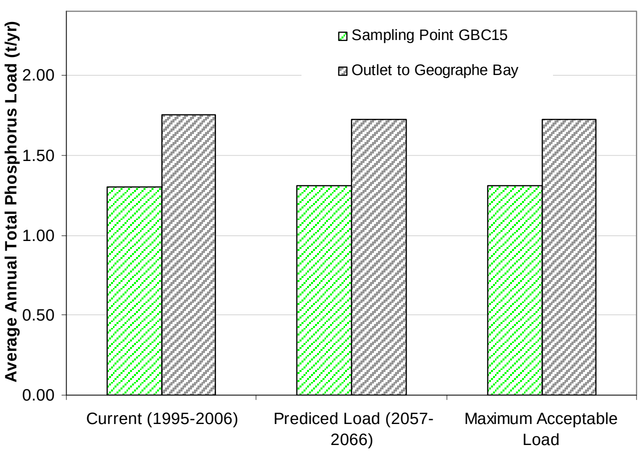
Annie Brook: Current loads, predicted loads and load reduction targets

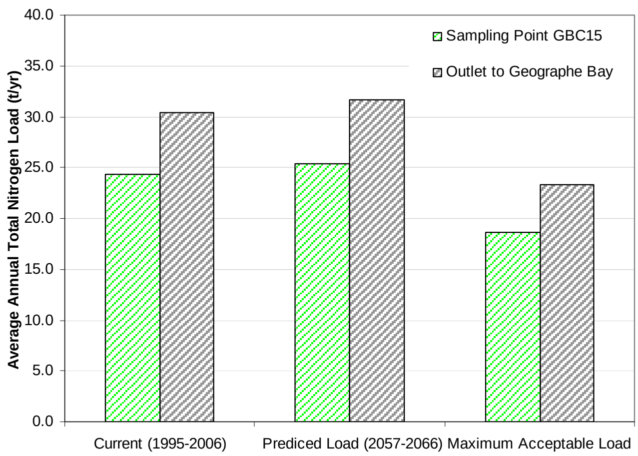
Phosphorus

	At outlet to Geographe Bay						At sampling point GBC15					
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*0% P reduction*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*0% P reduction*	*Load (t/yr)*
	1995	1.68	2055	1.48	2055	1.48	1995	1.23	2055	1.08	2055	1.08
	1996	3.10	2056	3.03	2056	3.03	1996	2.44	2056	2.43	2056	2.43
	1997	2.34	2057	2.30	2057	2.30	1997	1.72	2057	1.74	2057	1.74
	1998	2.33	2058	2.31	2058	2.31	1998	1.67	2058	1.72	2058	1.72
	1999	3.94	2059	3.88	2059	3.88	1999	2.83	2059	2.88	2059	2.88
	2000	2.12	2060	2.10	2060	2.10	2000	1.50	2060	1.54	2060	1.54
	2001	1.01	2061	1.01	2061	1.01	2001	0.76	2061	0.78	2061	0.78
	2002	0.47	2062	0.46	2062	0.46	2002	0.35	2062	0.36	2062	0.36
	2003	0.78	2063	0.79	2063	0.79	2003	0.57	2063	0.59	2063	0.59
	2004	0.93	2064	0.95	2064	0.95	2004	0.74	2064	0.76	2064	0.76
	2005	2.18	2065	2.15	2065	2.15	2005	1.68	2065	1.66	2065	1.66
	2006	0.19	2066	0.19	2066	0.19	2006	0.14	2066	0.14	2066	0.14
Average load for rainfall sequence (t/yr)		**1.76**		1.72		**1.72**		1.30		1.31		1.31
Median winter concentration (mg/L)		**0.039**		0.039		0.039		0.036		0.036		0.04
Load-reduction target (t/yr)		**0.00**										
Maximum acceptable load (t/yr)		**1.72**										
Time periods required to meet LRT		**0**										

Nitrogen

	At outlet to Geographe Bay						At sampling point GBC15					
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*25% N reduction*	*Load (t/yr)*	*Year*	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*25% N reduction*	*Load (t/yr)*
	1995	39.8	2055	46.7	2055	34.3	1995	31.7	2055	37.3	2055	27.4
	1996	46.6	2056	51.6	2056	37.7	1996	37.3	2056	41.4	2056	30.3
	1997	29.6	2057	31.2	2057	23.0	1997	23.7	2057	25.1	2057	18.5
	1998	33.4	2058	34.4	2058	25.2	1998	26.7	2058	27.6	2058	20.2
	1999	42.2	2059	43.0	2059	31.4	1999	33.7	2059	34.4	2059	25.2
	2000	27.8	2060	28.1	2060	20.6	2000	22.2	2060	22.5	2060	16.5
	2001	14.9	2061	14.9	2061	11.1	2001	11.9	2061	12.0	2061	8.9
	2002	19.8	2062	19.8	2062	14.6	2002	16.0	2062	16.1	2062	11.9
	2003	30.8	2063	31.0	2063	22.7	2003	24.6	2063	24.7	2063	18.2
	2004	27.9	2064	28.0	2064	20.6	2004	22.3	2064	22.4	2064	16.5
	2005	39.9	2065	40.0	2065	29.5	2005	31.9	2065	32.0	2065	23.6
	2006	11.8	2066	11.8	2066	8.7	2006	9.4	2066	9.4	2066	7.0
Average load for rainfall sequence (t/yr)		**30.4**		31.7		23.3		24.3		25.4		18.7
Median winter concentration (mg/L)		**1.36**		1.41		1.00		1.37		1.41		1.00
Load-reduction target (t/yr)		**8.4**										
Maximum acceptable load (t/yr)		**23.3**										
Time periods required to meet LRT		**0**										





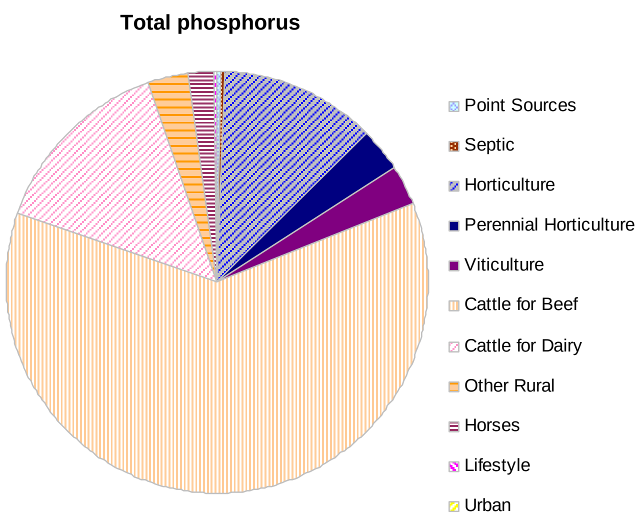
Annie Brook: Source separation

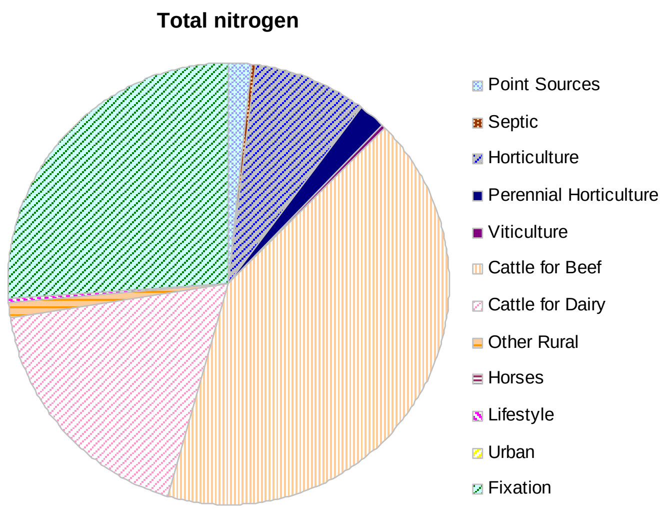
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	1.68	0.02	0.01	0.18	0.06	0.04	1.01	0.26	0.06	0.03	0.01	0.01
1996	3.10	0.02	0.02	0.41	0.11	0.07	1.85	0.44	0.09	0.05	0.02	0.02
1997	2.34	0.01	0.01	0.29	0.08	0.06	1.40	0.32	0.08	0.05	0.01	0.01
1998	2.33	0.01	0.01	0.25	0.08	0.07	1.40	0.32	0.08	0.05	0.01	0.01
1999	3.94	0.02	0.01	0.45	0.15	0.11	2.31	0.59	0.14	0.08	0.02	0.01
2000	2.12	0.01	0.01	0.21	0.08	0.06	1.27	0.32	0.07	0.04	0.01	0.01
2001	1.01	0.01	0.00	0.12	0.04	0.03	0.61	0.12	0.04	0.02	0.00	0.00
2002	0.47	0.01	0.00	0.05	0.02	0.01	0.28	0.06	0.01	0.01	0.00	0.00
2003	0.78	0.01	0.00	0.07	0.03	0.03	0.45	0.11	0.03	0.01	0.00	0.00
2004	0.93	0.01	0.00	0.12	0.03	0.04	0.54	0.13	0.03	0.01	0.00	0.00
2005	2.18	0.01	0.00	0.28	0.07	0.15	1.23	0.26	0.07	0.04	0.01	0.00
2006	0.19	0.00	0.00	0.02	0.01	0.01	0.11	0.02	0.00	0.00	0.00	0.00
Load (non adj)	1.76	0.01	0.01	0.21	0.06	0.06	1.04	0.25	0.06	0.03	0.01	0.01
Load (t/yr)	**1.76**	**0.01**	**0.00**	**0.21**	**0.06**	**0.05**	**1.08**	**0.25**	**0.06**	**0.03**	**0.01**	**0.00**
Load (%)	**100.0%**	**0.4%**	**0.1%**	**11.9%**	**3.5%**	**3.1%**	**61.4%**	**14.4%**	**3.2%**	**1.7%**	**0.3%**	**0.1%**

Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	39.8	0.4	0.0	2.6	0.6	0.0	13.1	5.7	0.3	0.1	0.0	0.0	8.0
1996	46.6	0.4	0.0	3.0	0.7	0.0	15.1	6.6	0.3	0.1	0.0	0.0	9.6
1997	29.6	0.4	0.1	1.9	0.6	0.1	9.9	4.2	0.4	0.1	0.1	0.1	6.4
1998	33.4	0.4	0.1	2.1	0.5	0.1	10.9	4.8	0.3	0.1	0.1	0.0	6.7
1999	42.2	0.4	0.1	2.7	0.8	0.1	13.7	5.9	0.5	0.1	0.1	0.1	8.7
2000	27.8	0.4	0.0	1.8	0.4	0.0	9.1	4.0	0.2	0.1	0.0	0.0	5.4
2001	14.9	0.4	0.1	0.9	0.3	0.1	5.1	2.2	0.2	0.1	0.0	0.0	3.0
2002	19.8	0.4	0.0	1.3	0.2	0.0	6.4	3.0	0.1	0.0	0.0	0.0	3.6
2003	30.8	0.4	0.0	2.1	0.4	0.0	9.7	4.2	0.2	0.0	0.0	0.0	6.1
2004	27.9	0.4	0.0	1.9	0.4	0.0	8.6	3.7	0.2	0.0	0.0	0.0	5.7
2005	39.9	0.4	0.1	2.9	0.7	0.2	12.5	5.3	0.4	0.1	0.1	0.0	8.5
2006	11.8	0.4	0.0	0.8	0.1	0.0	3.7	1.6	0.1	0.0	0.0	0.0	2.1
Load (non adj)	30.4	0.4	0.0	2.0	0.5	0.1	9.8	4.3	0.3	0.1	0.0	0.0	6.1
Load (t/yr)	**30.4**	**0.5**	**0.0**	**2.6**	**0.6**	**0.0**	**12.7**	**5.5**	**0.3**	**0.1**	**0.0**	**0.0**	**7.9**
Load (%)	**100.0%**	**1.7%**	**0.1%**	**8.5%**	**2.0%**	**0.2%**	**41.9%**	**18.2%**	**1.1%**	**0.2%**	**0.1%**	**0.1%**	**26.1%**





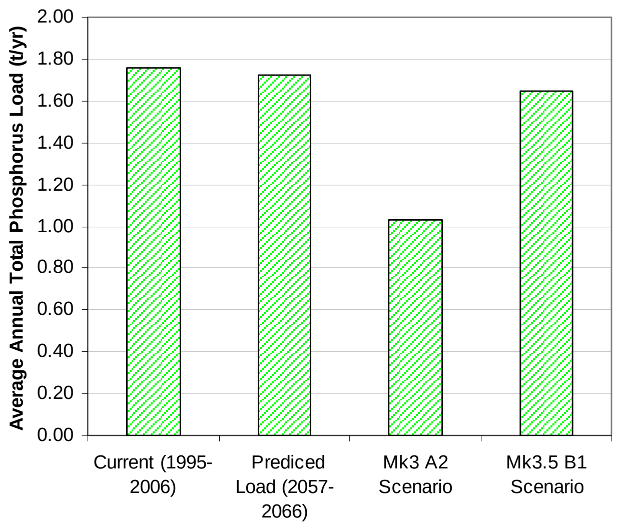
Annie Brook: Climate change scenarios

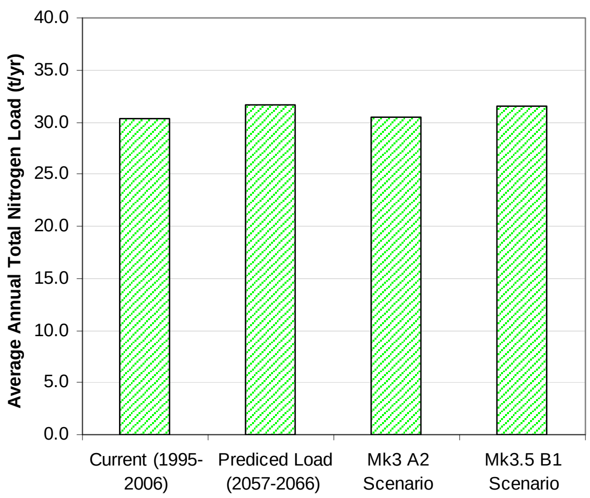
Phosphorus

				At catchment outlet			
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	1.68	2055	1.48	2055	1.03	2055	1.59
1996	3.10	2056	3.03	2056	1.97	2056	2.93
1997	2.34	2057	2.30	2057	1.44	2057	2.18
1998	2.33	2058	2.31	2058	1.31	2058	2.16
1999	3.94	2059	3.88	2059	2.69	2059	3.60
2000	2.12	2060	2.10	2060	1.58	2060	2.32
2001	1.01	2061	1.01	2061	0.27	2061	0.81
2002	0.47	2062	0.46	2062	0.23	2062	0.42
2003	0.78	2063	0.79	2063	0.45	2063	0.85
2004	0.93	2064	0.95	2064	0.42	2064	0.88
2005	2.18	2065	2.15	2065	0.85	2065	1.83
2006	0.19	2066	0.19	2066	0.09	2066	0.18
Average load (t/yr)	**1.76**		1.72		1.03		1.65

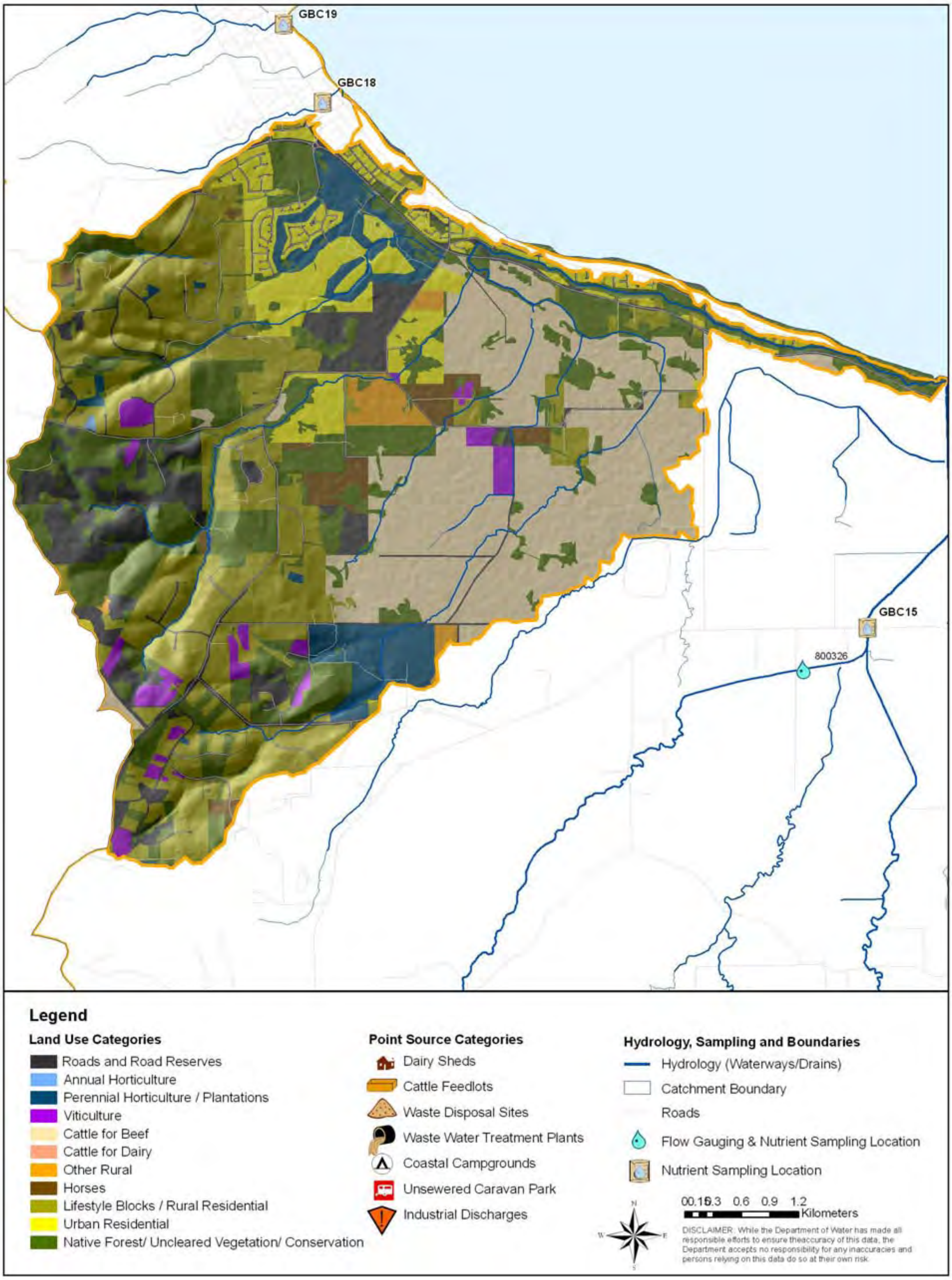
Nitrogen

				At catchment outlet			
Year	Load (t/yr)	Current conditions	Load (t/yr)	Mk3 A2 climate change scenario	Load (t/yr)	Mk3.5 B1 climate change scenario	Load (t/yr)
1995	39.8	2055	46.7	2055	46.7	2055	46.9
1996	46.6	2056	51.6	2056	57.1	2056	52.3
1997	29.6	2057	31.2	2057	32.5	2057	31.2
1998	33.4	2058	34.4	2058	33.6	2058	34.2
1999	42.2	2059	43.0	2059	44.1	2059	42.9
2000	27.8	2060	28.1	2060	27.8	2060	28.1
2001	14.9	2061	14.9	2061	10.4	2061	14.0
2002	19.8	2062	19.8	2062	15.5	2062	19.4
2003	30.8	2063	31.0	2063	27.7	2063	30.8
2004	27.9	2064	28.0	2064	24.6	2064	27.7
2005	39.9	2065	40.0	2065	36.6	2065	39.5
2006	11.8	2066	11.8	2066	9.6	2066	11.7
Average load (t/yr)	**30.4**		31.7		30.5		31.6





Toby Inlet


GBC19
GBC18
GBC15
800326
Legend
Land Use Categories
Roads and Road Reserves
Annual Horticulture
Perennial Horticulture / Plantations
Viticulture
Cattle for Beef
Cattle for Dairy
Other Rural
Horses
Lifestyle Blocks / Rural Residential
Urban Residential
Native Forest/ Uncleared Vegetation/ Conservation
Point Source Categories
Dairy Sheds
Cattle Feedlots
Waste Disposal Sites
Waste Water Treatment Plants
Coastal Campgrounds
Unsewered Caravan Park
Industrial Discharges
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary
Roads
Flow Gauging & Nutrient Sampling Location
Nutrient Sampling Location
00.150.3 0.6 0.9 1.2
Kilometers
DISCLAIMER: While the Department of Water has made all responsible efforts to ensure theaccuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

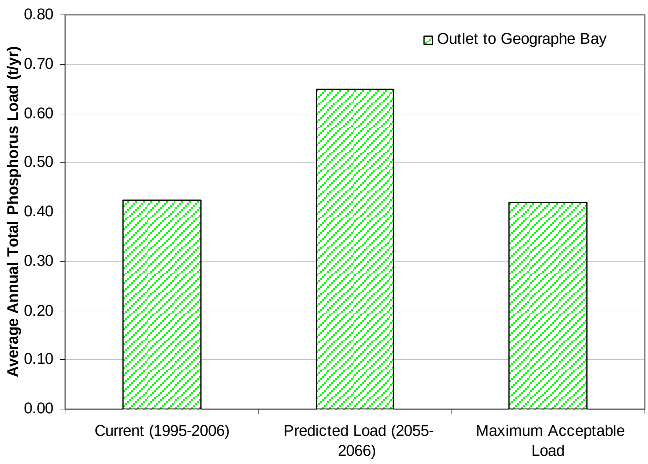
Toby Inlet: Current loads, predicted loads and load reduction targets

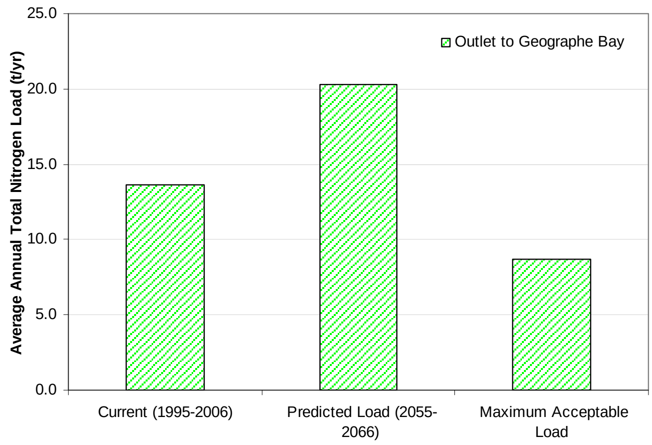
Phosphorus

	At Outlet to Geographe Bay					
	Year	***Load (t/yr)***	***Current conditions***	***Load (t/yr)***	***27% P reduction***	***Load (t/yr)***
	1995	0.36	2055	0.57	2055	0.37
	1996	0.55	2056	0.84	2056	0.54
	1997	0.52	2057	0.80	2057	0.52
	1998	0.58	2058	0.91	2058	0.59
	1999	0.91	2059	1.33	2059	0.86
	2000	0.50	2060	0.75	2060	0.48
	2001	0.27	2061	0.50	2061	0.32
	2002	0.17	2062	0.31	2062	0.20
	2003	0.27	2063	0.41	2063	0.26
	2004	0.26	2064	0.38	2064	0.25
	2005	0.58	2065	0.80	2065	0.51
	2006	0.13	2066	0.19	2066	0.12
Average load for rainfall sequence (t/yr)		**0.42**		0.65		**0.42**
Median winter concentration (mg/L)		**0.031**		0.045		0.031
Load-reduction target (t/yr)		**0.0**	0%			
Maximum acceptable load (t/yr)		**0.42**				
Time periods required to meet LRT		**0**				

Nitrogen

	At Outlet to Geographe Bay					
	Year	***Load (t/yr)***	***Current conditions***	***Load (t/yr)***	***51% N reduction***	***Load (t/yr)***
	1995	18.3	2055	29.5	2055	12.7
	1996	21.2	2056	32.6	2056	14.1
	1997	13.1	2057	19.6	2057	8.5
	1998	15.0	2058	22.1	2058	9.5
	1999	19.4	2059	27.8	2059	12.1
	2000	12.5	2060	18.1	2060	7.8
	2001	6.8	2061	10.2	2061	4.4
	2002	8.2	2062	12.3	2062	5.2
	2003	13.5	2063	19.7	2063	8.4
	2004	12.1	2064	17.7	2064	7.6
	2005	18.1	2065	25.4	2065	10.9
	2006	5.9	2066	8.4	2066	3.5
Average load for rainfall sequence (t/yr)		**13.7**		20.3		8.7
Median winter concentration (mg/L)		**1.74**		2.48		1.00
Load-reduction target (t/yr)		**4.9**	36%			
Maximum acceptable load (t/yr)		**8.7**				
Time periods required to meet LRT		**2**				





Toby Inlet: Source separation

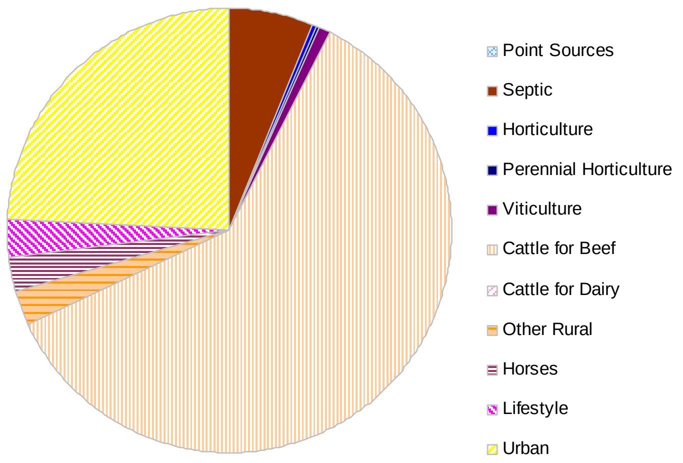
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	0.36	0.02	0.04	0.02	0.02	0.02	0.22	0.02	0.03	0.03	0.03	0.09
1996	0.55	0.04	0.07	0.04	0.04	0.04	0.35	0.04	0.05	0.05	0.05	0.13
1997	0.52	0.02	0.05	0.02	0.03	0.03	0.33	0.02	0.04	0.04	0.04	0.11
1998	0.58	0.03	0.06	0.03	0.03	0.03	0.37	0.03	0.04	0.04	0.04	0.12
1999	0.91	0.05	0.10	0.05	0.05	0.06	0.59	0.05	0.07	0.07	0.07	0.19
2000	0.50	0.03	0.06	0.03	0.03	0.03	0.32	0.03	0.04	0.04	0.04	0.11
2001	0.27	0.00	0.02	0.01	0.01	0.01	0.16	0.00	0.01	0.01	0.01	0.06
2002	0.17	0.00	0.01	0.00	0.00	0.00	0.08	0.00	0.01	0.01	0.01	0.06
2003	0.27	0.01	0.02	0.01	0.01	0.01	0.12	0.01	0.01	0.02	0.02	0.09
2004	0.26	0.01	0.02	0.01	0.01	0.01	0.12	0.01	0.01	0.01	0.01	0.09
2005	0.58	0.01	0.03	0.02	0.01	0.02	0.28	0.01	0.02	0.02	0.02	0.20
2006	0.13	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.07
Load (non adj)	0.42	0.02	0.04	0.02	0.02	0.02	0.25	0.02	0.03	0.03	0.03	0.11
Load (t/yr)	**0.42**	**0.00**	**0.03**	**0.00**	**0.00**	**0.00**	**0.26**	**0.00**	**0.01**	**0.01**	**0.01**	**0.10**
Load (%)	**100.0%**	**0.0%**	**6.0%**	**0.3%**	**0.3%**	**1.0%**	**60.5%**	**0.0%**	**2.5%**	**2.6%**	**2.6%**	**24.3%**

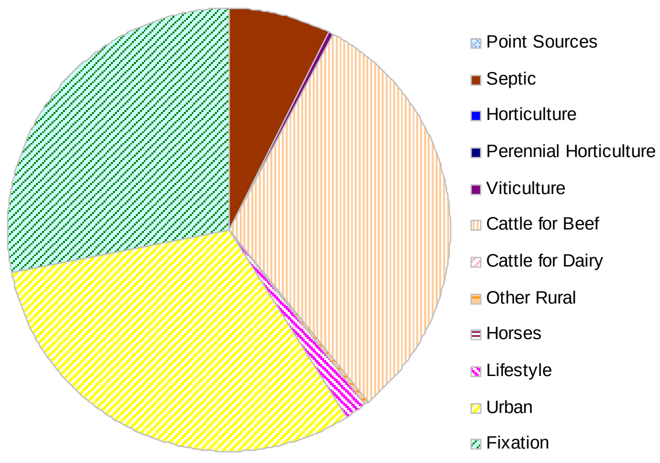
Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	18.3	0.0	0.8	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.1	2.3	3.1
1996	21.2	0.0	0.9	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.2	2.6	3.5
1997	13.1	0.0	0.7	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.2	1.7	2.3
1998	15.0	0.0	0.7	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.2	1.9	2.5
1999	19.4	0.0	1.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.2	2.4	3.3
2000	12.5	0.0	0.6	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.1	1.6	2.0
2001	6.8	0.0	0.3	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.1	0.9	1.1
2002	8.2	0.0	0.3	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.1	1.5	1.2
2003	13.5	0.0	0.5	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.1	3.2	2.2
2004	12.1	0.0	0.5	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.1	3.4	2.1
2005	18.1	0.0	0.8	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.3	6.0	3.1
2006	5.9	0.0	0.2	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.1	2.5	0.8
Load (non adj)	13.7	0.0	0.6	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.1	2.5	2.3
Load (t/yr)	**13.7**	**0.0**	**1.0**	**0.0**	**0.0**	**0.0**	**4.3**	**0.0**	**0.0**	**0.0**	**0.2**	**4.2**	**3.8**
Load (%)	**100.0%**	**0.0%**	**7.5%**	**0.0%**	**0.1%**	**0.1%**	**31.5%**	**0.0%**	**0.2%**	**0.1%**	**1.7%**	**30.9%**	**28.0%**

Total phosphorus



Total nitrogen



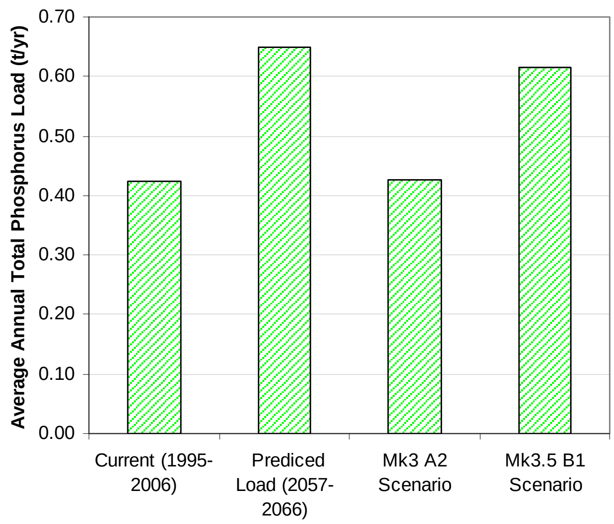
Toby Inlet: Climate change scenarios

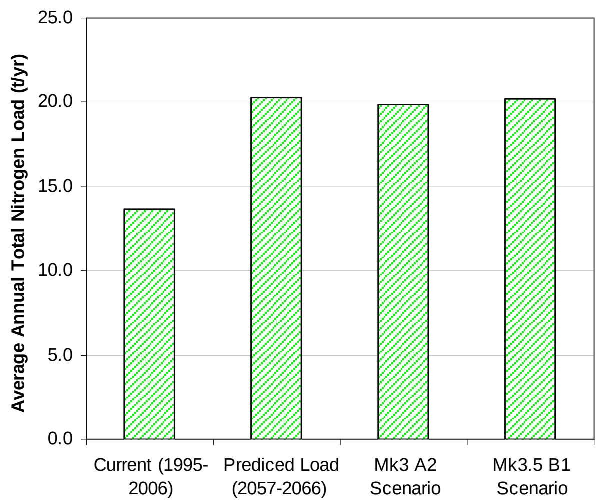
Phosphorus

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	0.36	2055	0.57	2055	0.39	2055	0.54
1996	0.55	2056	0.84	2056	0.62	2056	0.87
1997	0.52	2057	0.80	2057	0.53	2057	0.76
1998	0.58	2058	0.91	2058	0.56	2058	0.86
1999	0.91	2059	1.33	2059	0.86	2059	1.25
2000	0.50	2060	0.75	2060	0.54	2060	0.74
2001	0.27	2061	0.50	2061	0.27	2061	0.44
2002	0.17	2062	0.31	2062	0.22	2062	0.29
2003	0.27	2063	0.41	2063	0.28	2063	0.38
2004	0.26	2064	0.38	2064	0.26	2064	0.36
2005	0.58	2065	0.80	2065	0.43	2065	0.71
2006	0.13	2066	0.19	2066	0.15	2066	0.18
Average load (t/yr)	**0.42**		0.65		0.43		0.61

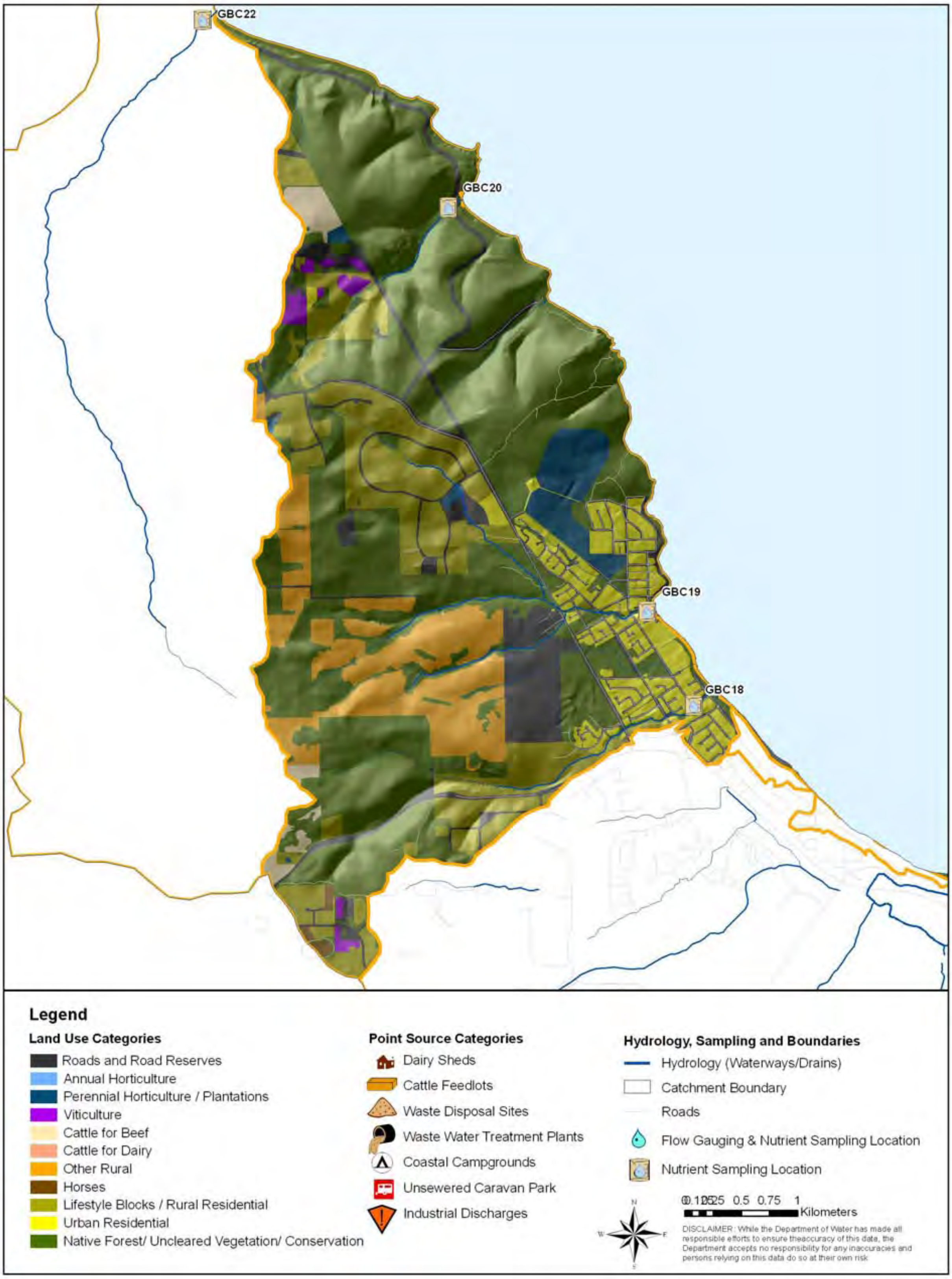
Nitrogen

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	18.3	2055	29.5	2055	29.6	2055	29.6
1996	21.2	2056	32.6	2056	35.7	2056	33.1
1997	13.1	2057	19.6	2057	20.5	2057	19.6
1998	15.0	2058	22.1	2058	21.9	2058	22.0
1999	19.4	2059	27.8	2059	28.8	2059	27.8
2000	12.5	2060	18.1	2060	18.3	2060	18.1
2001	6.8	2061	10.2	2061	8.3	2061	9.8
2002	8.2	2062	12.3	2062	10.1	2062	12.0
2003	13.5	2063	19.7	2063	17.8	2063	19.6
2004	12.1	2064	17.7	2064	15.7	2064	17.5
2005	18.1	2065	25.4	2065	23.6	2065	25.1
2006	5.9	2066	8.4	2066	7.8	2066	8.4
Average load (t/yr)	**13.7**		20.3		19.8		20.2





Dunsborough region



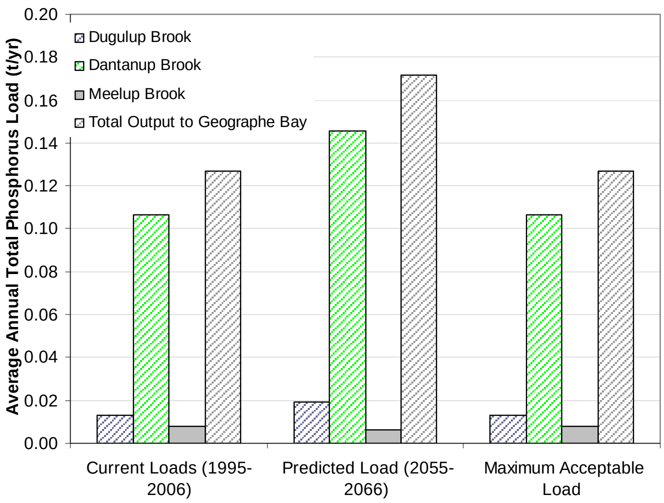
Dunsborough region: Current loads, predicted loads and load reduction targets

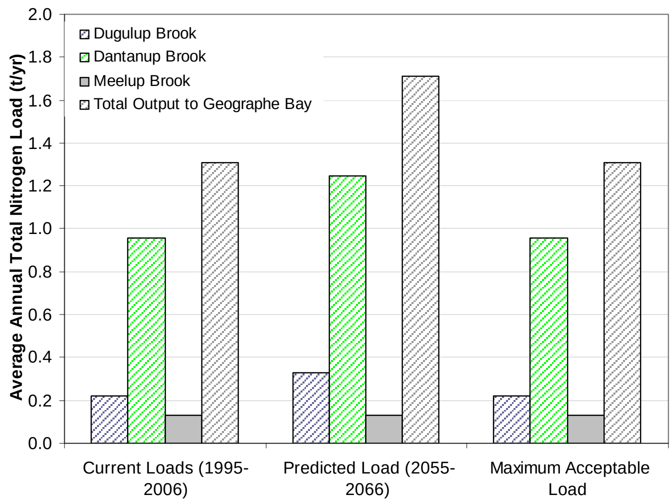
Phosphorus

	At outlet to Geographe Bay													
Year	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Current conditions	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	P reduction	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)
1995	0.01	0.10	0.01	**0.12**	2055	0.03	0.16	0.01	**0.20**	2055	0.01	0.10	0.01	**0.12**
1996	0.01	0.12	0.01	**0.14**	2056	0.02	0.16	0.01	**0.19**	2056	0.01	0.12	0.01	**0.14**
1997	0.01	0.12	0.01	**0.14**	2057	0.02	0.16	0.01	**0.19**	2057	0.01	0.12	0.01	**0.14**
1998	0.01	0.13	0.01	**0.16**	2058	0.02	0.17	0.01	**0.21**	2058	0.01	0.13	0.01	**0.16**
1999	0.02	0.16	0.01	**0.18**	2059	0.03	0.20	0.01	**0.24**	2059	0.02	0.16	0.01	**0.18**
2000	0.01	0.11	0.01	**0.13**	2060	0.02	0.15	0.01	**0.18**	2060	0.01	0.11	0.01	**0.13**
2001	0.01	0.10	0.01	**0.12**	2061	0.02	0.13	0.01	**0.16**	2061	0.01	0.10	0.01	**0.12**
2002	0.01	0.08	0.00	**0.10**	2062	0.01	0.12	0.00	**0.13**	2062	0.01	0.08	0.00	**0.10**
2003	0.02	0.09	0.00	**0.11**	2063	0.02	0.12	0.00	**0.14**	2063	0.02	0.09	0.00	**0.11**
2004	0.02	0.09	0.00	**0.11**	2064	0.02	0.12	0.00	**0.14**	2064	0.02	0.09	0.00	**0.11**
2005	0.02	0.13	0.01	**0.16**	2065	0.02	0.18	0.01	**0.21**	2065	0.02	0.13	0.01	**0.16**
2006	0.00	0.05	0.00	**0.06**	2066	0.00	0.08	0.00	**0.08**	2066	0.00	0.05	0.00	**0.06**
Average load for rainfall sequence (t/yr)	0.01	0.11	0.01	**0.13**		0.02	0.15	0.01	**0.17**		0.01	0.11	0.01	**0.13**
Median winter concentration (mg/L)	0.008	0.036	0.008			0.011	0.047	0.007			0.0011	0.036	0.008	
Load-reduction target (t/yr)	**0.0**	0%												
Maximum acceptable load (t/yr)	**0.13**													
Time periods required to meet LRT	**0**													

Nitrogen

	At outlet to Geographe Bay													
Year	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Current conditions	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	N reduction	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)
1995	0.2	1.1	0.2	**1.5**	2055	0.3	1.4	0.2	**1.9**	2055	0.2	1.1	0.2	**1.5**
1996	0.3	1.4	0.2	**1.9**	2056	0.4	1.8	0.2	**2.5**	2056	0.3	1.4	0.2	**1.9**
1997	0.3	1.1	0.1	**1.6**	2057	0.4	1.5	0.1	**2.0**	2057	0.3	1.1	0.1	**1.6**
1998	0.3	1.2	0.2	**1.6**	2058	0.4	1.5	0.2	**2.1**	2058	0.3	1.2	0.2	**1.6**
1999	0.3	1.6	0.2	**2.1**	2059	0.5	2.1	0.2	**2.8**	2059	0.3	1.6	0.2	**2.1**
2000	0.2	1.2	0.2	**1.6**	2060	0.4	1.5	0.2	**2.1**	2060	0.2	1.2	0.2	**1.6**
2001	0.2	0.7	0.1	**1.0**	2061	0.3	0.9	0.1	**1.2**	2061	0.2	0.7	0.1	**1.0**
2002	0.1	0.5	0.1	**0.6**	2062	0.2	0.6	0.1	**0.8**	2062	0.1	0.5	0.1	**0.6**
2003	0.2	0.7	0.1	**1.0**	2063	0.2	1.0	0.1	**1.3**	2063	0.2	0.7	0.1	**1.0**
2004	0.2	0.7	0.1	**1.0**	2064	0.3	0.9	0.1	**1.3**	2064	0.2	0.7	0.1	**1.0**
2005	0.3	1.0	0.1	**1.4**	2065	0.4	1.4	0.1	**1.9**	2065	0.3	1.0	0.1	**1.4**
2006	0.1	0.4	0.0	**0.5**	2066	0.1	0.5	0.0	**0.6**	2066	0.1	0.4	0.0	**0.5**
Average Load for RF Sequence (t/yr)	0.2	1.0	0.1	**1.3**		0.3	1.2	0.1	**1.7**		0.2	1.0	0.1	**1.3**
Median Winter Concentration (mg/L)	0.38	0.74	0.34			0.60	0.98	0.34			0.38	0.74	0.34	
Load Reduction Target (t/yr)	**0.0**	0%												
Maximum Acceptable Load (t/yr)	**1.3**													
Time Periods Required to Meet LRT	**0**													





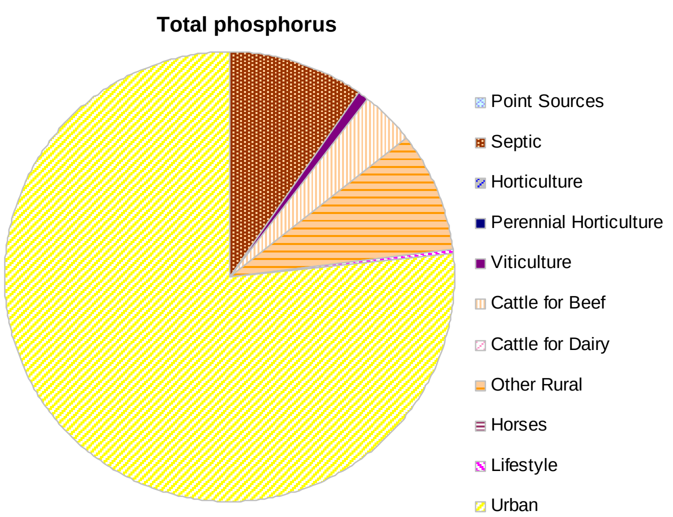
Dunsborough region: Source separation

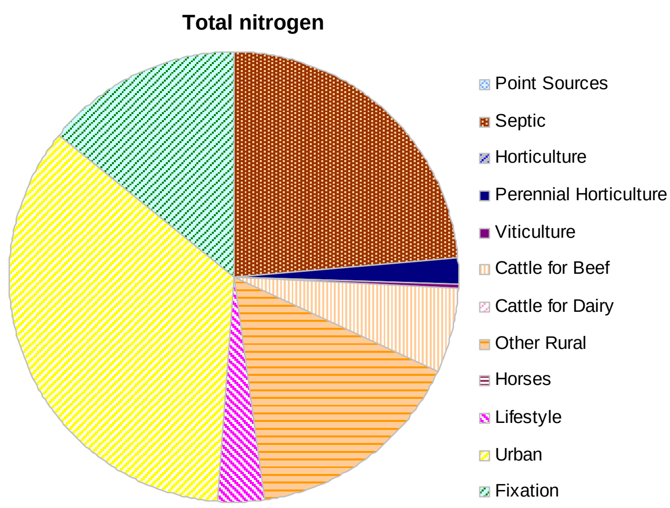
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	0.12	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.08
1996	0.14	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.10
1997	0.14	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.09
1998	0.16	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.10
1999	0.18	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.11
2000	0.13	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.10
2001	0.12	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.07
2002	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
2003	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
2004	0.11	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
2005	0.16	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.11
2006	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Load (non adj)	0.13	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.09
Load (t/yr)	**0.13**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.10**
Load (%)	**100.0%**	**0.0%**	**9.6%**	**0.0%**	**0.0%**	**0.9%**	**3.8%**	**0.0%**	**8.6%**	**0.0%**	**0.3%**	**76.7%**

Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	1.5	0.1	0.4	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.6	0.3
1996	1.9	0.1	0.5	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.8	0.3
1997	1.6	0.1	0.5	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.6	0.3
1998	1.6	0.1	0.5	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.6	0.3
1999	2.1	0.1	0.6	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.8	0.4
2000	1.6	0.1	0.4	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.6	0.2
2001	1.0	0.0	0.4	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.3	0.3
2002	0.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.1
2003	1.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.1	0.5	0.2
2004	1.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.4	0.2
2005	1.4	0.0	0.5	0.0	0.1	0.0	0.1	0.0	0.4	0.0	0.2	0.6	0.3
2006	0.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.1
Load (non adj)	1.3	0.0	0.4	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.5	0.2
Load (t/yr)	**1.3**	**0.0**	**0.3**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.2**	**0.0**	**0.0**	**0.5**	**0.2**
Load (%)	**100.0%**	**0.0%**	**23.7%**	**0.0%**	**1.9%**	**0.1%**	**6.2%**	**0.0%**	**15.8%**	**0.0%**	**3.2%**	**34.9%**	**14.1%**





Dunsborough region: Climate change scenarios

Phosphorus

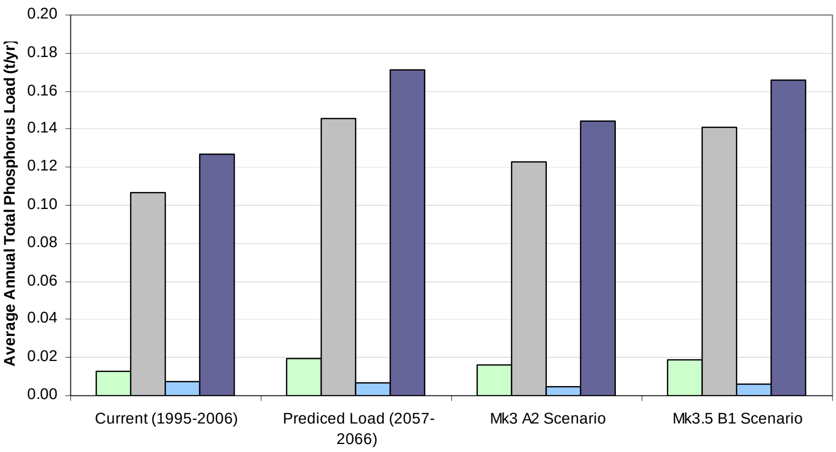
At outlet to Geographe Bay

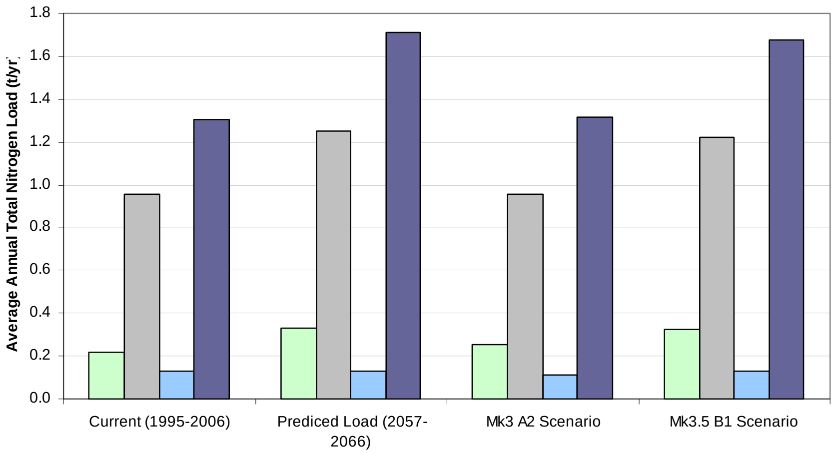
Year	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Current conditions	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Mk3 A2 climate change scenario	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Mk3.5 B1 climate change scenario	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)
1995	0.01	0.10	0.01	**0.12**	2055	0.03	0.16	0.01	**0.20**	2055	0.04	0.18	0.01	**0.23**	2055	0.03	0.16	0.01	**0.20**
1996	0.01	0.12	0.01	**0.14**	2056	0.02	0.16	0.01	**0.19**	2056	0.03	0.14	0.01	**0.17**	2056	0.02	0.15	0.01	**0.18**
1997	0.01	0.12	0.01	**0.14**	2057	0.02	0.16	0.01	**0.19**	2057	0.02	0.13	0.01	**0.15**	2057	0.02	0.15	0.01	**0.18**
1998	0.01	0.13	0.01	**0.16**	2058	0.02	0.17	0.01	**0.21**	2058	0.02	0.14	0.01	**0.17**	2058	0.02	0.17	0.01	**0.20**
1999	0.02	0.16	0.01	**0.18**	2059	0.03	0.20	0.01	**0.24**	2059	0.02	0.16	0.01	**0.20**	2059	0.03	0.19	0.01	**0.23**
2000	0.01	0.11	0.01	**0.13**	2060	0.02	0.15	0.01	**0.18**	2060	0.02	0.13	0.01	**0.15**	2060	0.02	0.15	0.01	**0.18**
2001	0.01	0.10	0.01	**0.12**	2061	0.02	0.13	0.01	**0.16**	2061	0.01	0.10	0.00	**0.11**	2061	0.02	0.13	0.01	**0.15**
2002	0.01	0.08	0.00	**0.10**	2062	0.01	0.12	0.00	**0.13**	2062	0.00	0.06	0.00	**0.07**	2062	0.01	0.12	0.00	**0.13**
2003	0.02	0.09	0.00	**0.11**	2063	0.02	0.12	0.00	**0.14**	2063	0.01	0.15	0.00	**0.17**	2063	0.02	0.11	0.00	**0.14**
2004	0.02	0.09	0.00	**0.11**	2064	0.02	0.12	0.00	**0.14**	2064	0.01	0.11	0.00	**0.12**	2064	0.02	0.12	0.00	**0.14**
2005	0.02	0.13	0.01	**0.16**	2065	0.02	0.18	0.01	**0.21**	2065	0.02	0.14	0.00	**0.16**	2065	0.02	0.17	0.01	**0.20**
2006	0.00	0.05	0.00	**0.06**	2066	0.00	0.08	0.00	**0.08**	2066	0.00	0.03	0.00	**0.03**	2066	0.00	0.07	0.00	**0.07**
Average load (t/yr)	0.01	0.11	0.01	**0.13**		0.02	0.15	0.01	**0.17**		0.02	0.12	0.00	**0.14**		0.02	0.14	0.01	**0.17**

Nitrogen

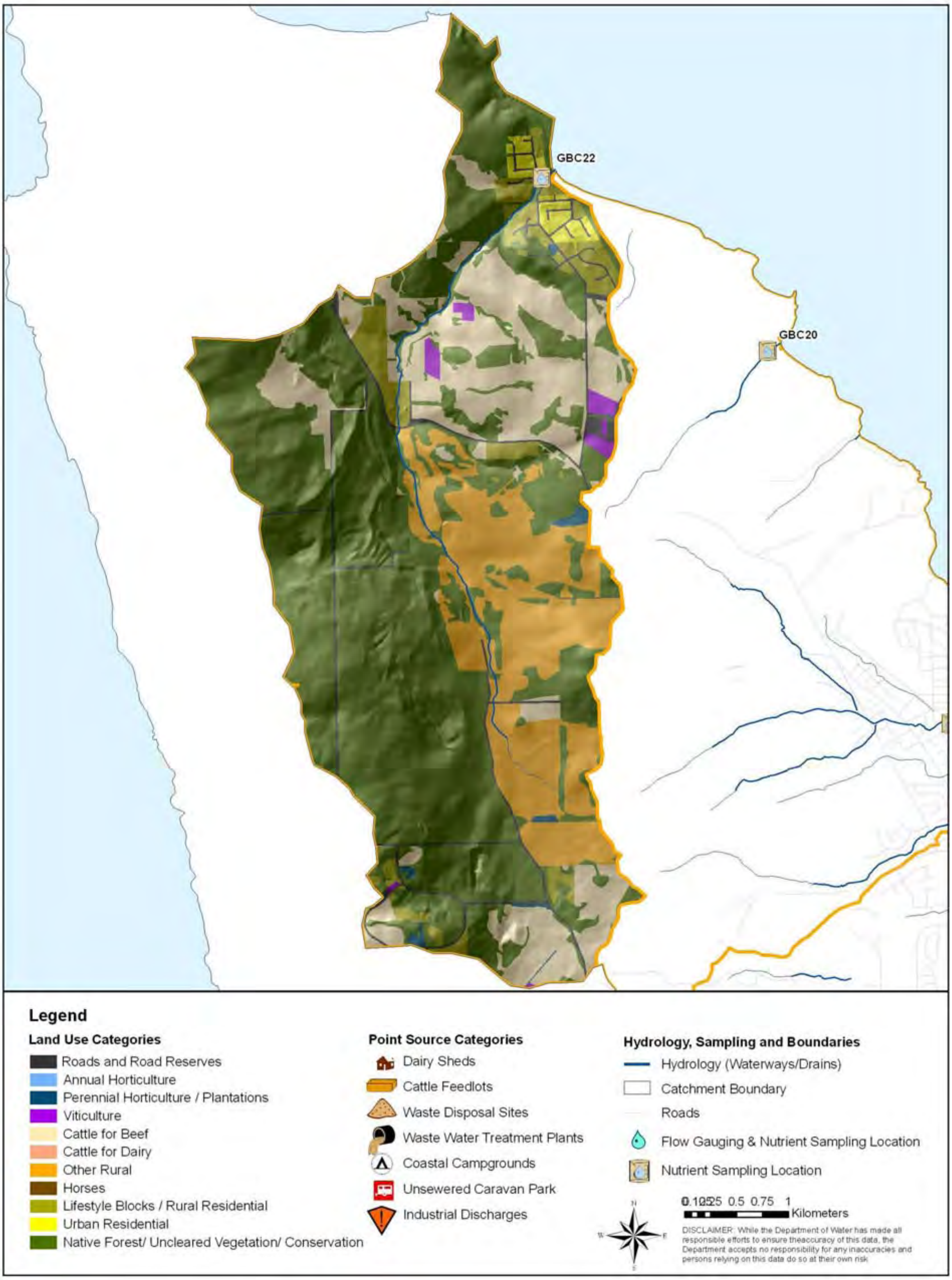
At outlet to Geographe Bay

Year	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Current conditions	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Mk3 A2 climate change scenario	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)	Mk3.5 B1 climate change scenario	Dugalup Brook load (t/yr)	Dandatup Brook load (t/yr)	Meelup Brook load (t/yr)	Total load (t/yr)
1995	0.2	1.1	0.2	**1.5**	2055	0.3	1.4	0.2	**1.9**	2055	0.3	1.1	0.2	**1.5**	2055	0.4	1.3	0.2	**1.9**
1996	0.3	1.4	0.2	**1.9**	2056	0.4	1.8	0.2	**2.5**	2056	0.4	1.5	0.2	**2.1**	2056	0.4	1.8	0.2	**2.5**
1997	0.3	1.1	0.1	**1.6**	2057	0.4	1.5	0.1	**2.0**	2057	0.3	1.2	0.1	**1.6**	2057	0.4	1.4	0.1	**2.0**
1998	0.3	1.2	0.2	**1.6**	2058	0.4	1.5	0.2	**2.1**	2058	0.3	1.2	0.1	**1.7**	2058	0.4	1.5	0.2	**2.0**
1999	0.3	1.6	0.2	**2.1**	2059	0.5	2.1	0.2	**2.8**	2059	0.4	1.7	0.2	**2.3**	2059	0.5	2.0	0.2	**2.8**
2000	0.2	1.2	0.2	**1.6**	2060	0.4	1.5	0.2	**2.1**	2060	0.3	1.2	0.1	**1.7**	2060	0.4	1.5	0.2	**2.0**
2001	0.2	0.7	0.1	**1.0**	2061	0.3	0.9	0.1	**1.2**	2061	0.2	0.6	0.1	**0.8**	2061	0.2	0.8	0.1	**1.2**
2002	0.1	0.5	0.1	**0.6**	2062	0.2	0.6	0.1	**0.8**	2062	0.1	0.4	0.0	**0.5**	2062	0.2	0.6	0.1	**0.8**
2003	0.2	0.7	0.1	**1.0**	2063	0.2	1.0	0.1	**1.3**	2063	0.2	0.7	0.1	**1.0**	2063	0.3	0.9	0.1	**1.3**
2004	0.2	0.7	0.1	**1.0**	2064	0.3	0.9	0.1	**1.3**	2064	0.2	0.6	0.1	**0.9**	2064	0.2	0.9	0.1	**1.2**
2005	0.3	1.0	0.1	**1.4**	2065	0.4	1.4	0.1	**1.9**	2065	0.3	0.9	0.1	**1.3**	2065	0.4	1.3	0.1	**1.8**
2006	0.1	0.4	0.0	**0.5**	2066	0.1	0.5	0.0	**0.6**	2066	0.1	0.3	0.0	**0.4**	2066	0.1	0.5	0.0	**0.6**
Average load (t/yr)	0.2	1.0	0.1	**1.3**		0.3	1.2	0.1	**1.7**		0.3	1.0	0.1	**1.3**		0.3	1.2	0.1	**1.7**





Jingarmup Brook



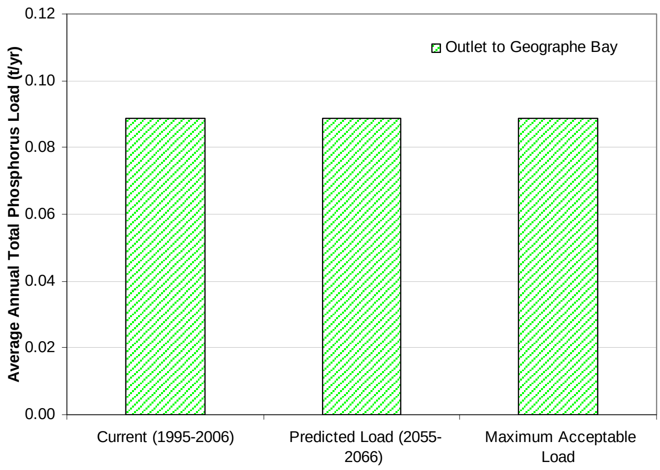
Jingarmup Brook: Current loads, predicted loads and load reduction targets

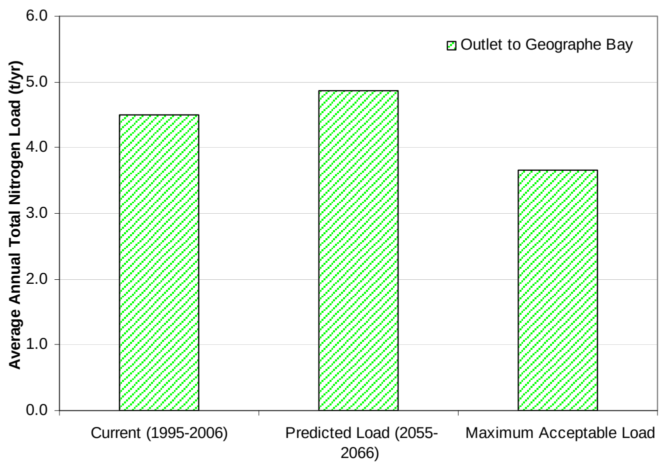
Phosphorus

			At Outlet to Geographe Bay			
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*0% P reduction*	*Load (t/yr)*
	1995	0.08	2055	0.08	2055	0.08
	1996	0.13	2056	0.13	2056	0.13
	1997	0.14	2057	0.14	2057	0.14
	1998	0.15	2058	0.15	2058	0.15
	1999	0.27	2059	0.27	2059	0.27
	2000	0.09	2060	0.09	2060	0.09
	2001	0.10	2061	0.10	2061	0.10
	2002	0.01	2062	0.01	2062	0.01
	2003	0.01	2063	0.01	2063	0.01
	2004	0.01	2064	0.01	2064	0.01
	2005	0.07	2065	0.07	2065	0.07
	2006	0.00	2066	0.00	2066	0.00
Average load for rainfall sequence (t/yr)		**0.09**		0.09		**0.09**
Median winter concentration (mg/L)		**0.008**		0.007		
Load-reduction target (t/yr)		**0.0**	0%			
Maximum acceptable load (t/yr)		**0.09**				
Time periods required to meet LRT		**0**				

Nitrogen

			At Outlet to Geographe Bay			
	Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*25% N reduction*	*Load (t/yr)*
	1995	6.5	2055	8.0	2055	6.0
	1996	7.8	2056	9.1	2056	6.9
	1997	4.7	2057	5.2	2057	3.9
	1998	5.3	2058	5.6	2058	4.3
	1999	7.2	2059	7.5	2059	5.6
	2000	4.2	2060	4.3	2060	3.2
	2001	2.0	2061	2.1	2061	1.6
	2002	1.1	2062	1.1	2062	0.8
	2003	4.2	2063	4.2	2063	3.1
	2004	3.5	2064	3.5	2064	2.6
	2005	6.2	2065	6.2	2065	4.7
	2006	1.4	2066	1.4	2066	1.0
Average Load for RF Sequence (t/yr)		**4.5**		4.9		3.7
Median Winter Concentration (mg/L)		**1.31**		1.37		1.00
Load Reduction Target (t/yr)		**0.8**	19%			
Maximum Acceptable Load (t/yr)		**3.7**				
Time Periods Required to Meet LRT		**0**				





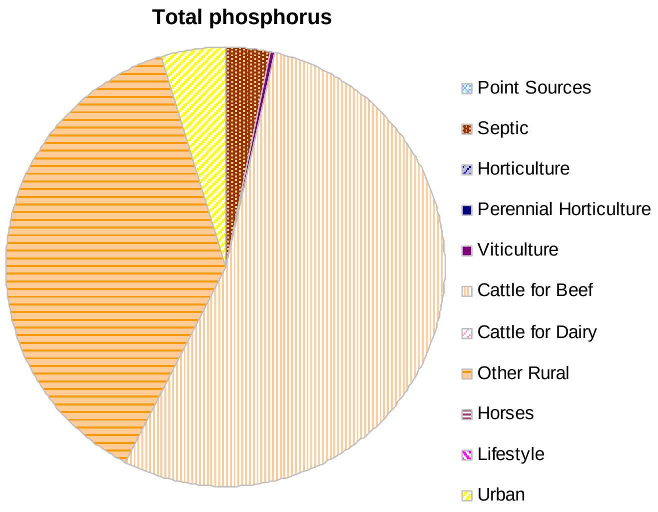
Jingarmup Brook: Source separation

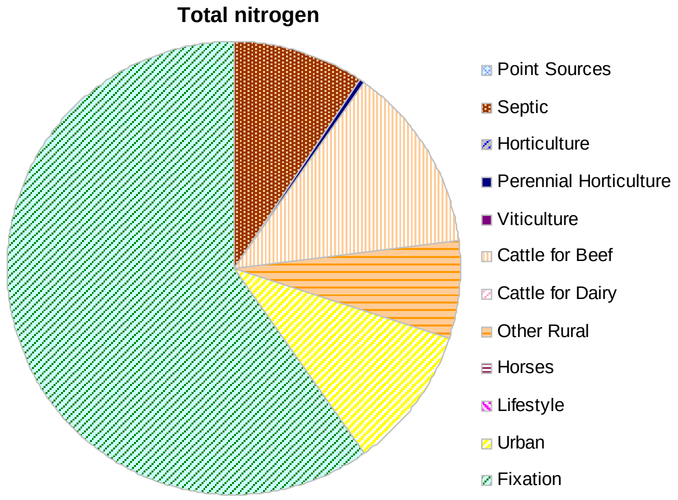
Phosphorus (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban
1995	0.08	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.02	0.00	0.00	0.00
1996	0.13	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.03	0.00	0.00	0.00
1997	0.14	0.00	0.01	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.00	0.01
1998	0.15	0.00	0.01	0.00	0.00	0.00	0.06	0.00	0.06	0.00	0.00	0.01
1999	0.27	0.00	0.01	0.00	0.00	0.00	0.13	0.00	0.09	0.00	0.00	0.01
2000	0.09	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.00
2001	0.10	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.01
2002	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
2004	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	0.07	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.00
2006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Load (non adj)	0.09	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.00	0.00	0.00
Load (t/yr)	**0.09**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**	**0.00**	**0.03**	**0.00**	**0.00**	**0.00**
Load (%)	**100.0%**	**0.0%**	**3.4%**	**0.0%**	**0.0%**	**0.1%**	**54.0%**	**0.0%**	**37.7%**	**0.0%**	**0.0%**	**4.8%**

Nitrogen (t/yr)

Year	Current	Point sources	Septic	Horticulture	Perennial horticulture	Viticulture	Cattle for beef	Cattle for dairy	Other rural	Horses	Lifestyle	Urban	Fixation
1995	6.5	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.0	0.4	2.8
1996	7.8	0.0	0.5	0.0	0.0	0.0	0.7	0.0	0.4	0.0	0.0	0.5	3.4
1997	4.7	0.0	0.4	0.0	0.0	0.0	0.5	0.0	0.3	0.0	0.0	0.4	2.1
1998	5.3	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.3	0.0	0.0	0.4	2.3
1999	7.2	0.0	0.5	0.0	0.0	0.0	0.7	0.0	0.4	0.0	0.0	0.5	3.0
2000	4.2	0.0	0.3	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.3	1.7
2001	2.0	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.2	0.9
2002	1.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.5
2003	4.2	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.3	1.7
2004	3.5	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.3	1.5
2005	6.2	0.0	0.4	0.0	0.0	0.0	0.6	0.0	0.4	0.0	0.0	0.5	2.8
2006	1.4	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.6
Load (non adj)	4.5	0.0	0.3	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.3	1.9
Load (t/yr)	**4.5**	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.6**	**0.0**	**0.3**	**0.0**	**0.0**	**0.5**	**2.7**
Load (%)	**100.0%**	**0.0%**	**9.6%**	**0.0%**	**0.1%**	**0.0%**	**13.2%**	**0.0%**	**7.1%**	**0.0%**	**0.0%**	**10.2%**	**59.7%**





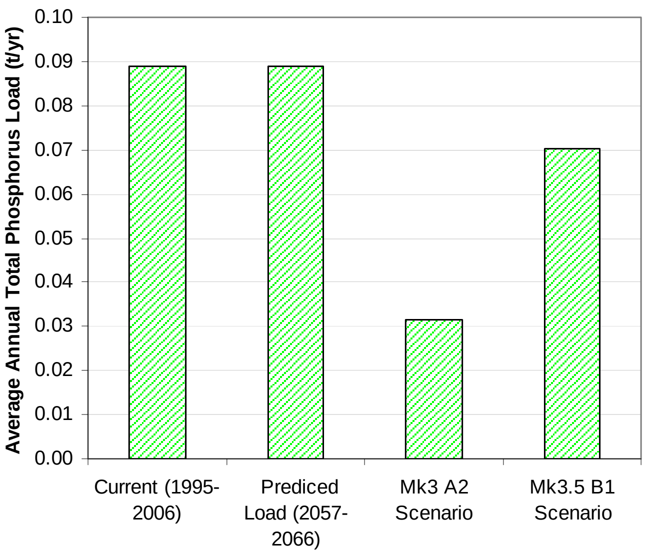
Jingarmup Brook: Climate change scenarios

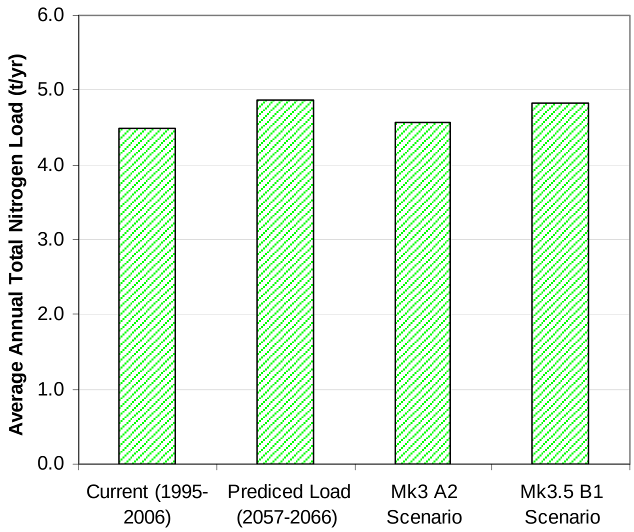
Phosphorus

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	0.08	2055	0.08	2055	0.02	2055	0.05
1996	0.13	2056	0.13	2056	0.04	2056	0.08
1997	0.14	2057	0.14	2057	0.05	2057	0.10
1998	0.15	2058	0.15	2058	0.05	2058	0.12
1999	0.27	2059	0.27	2059	0.12	2059	0.23
2000	0.09	2060	0.09	2060	0.04	2060	0.08
2001	0.10	2061	0.10	2061	0.03	2061	0.08
2002	0.01	2062	0.01	2062	0.00	2062	0.01
2003	0.01	2063	0.01	2063	0.01	2063	0.01
2004	0.01	2064	0.01	2064	0.00	2064	0.01
2005	0.07	2065	0.07	2065	0.01	2065	0.06
2006	0.00	2066	0.00	2066	0.00	2066	0.00
Average load (t/yr)	**0.09**		0.09		0.03		0.07

Nitrogen

At catchment outlet							
Year	*Load (t/yr)*	*Current conditions*	*Load (t/yr)*	*Mk3 A2 climate change scenario*	*Load (t/yr)*	*Mk3.5 B1 climate change scenario*	*Load (t/yr)*
1995	6.5	2055	8.0	2055	7.8	2055	8.0
1996	7.8	2056	9.1	2056	10.1	2056	9.3
1997	4.7	2057	5.2	2057	5.4	2057	5.2
1998	5.3	2058	5.6	2058	5.6	2058	5.6
1999	7.2	2059	7.5	2059	7.9	2059	7.5
2000	4.2	2060	4.3	2060	4.4	2060	4.4
2001	2.0	2061	2.1	2061	1.3	2061	1.9
2002	1.1	2062	1.1	2062	0.6	2062	1.1
2003	4.2	2063	4.2	2063	3.2	2063	4.1
2004	3.5	2064	3.5	2064	2.4	2064	3.4
2005	6.2	2065	6.2	2065	5.0	2065	6.0
2006	1.4	2066	1.4	2066	1.0	2066	1.4
Average load (t/yr)	**4.5**		4.9		4.6		4.8





Appendix D: Lower Vasse River culvert flow calculations

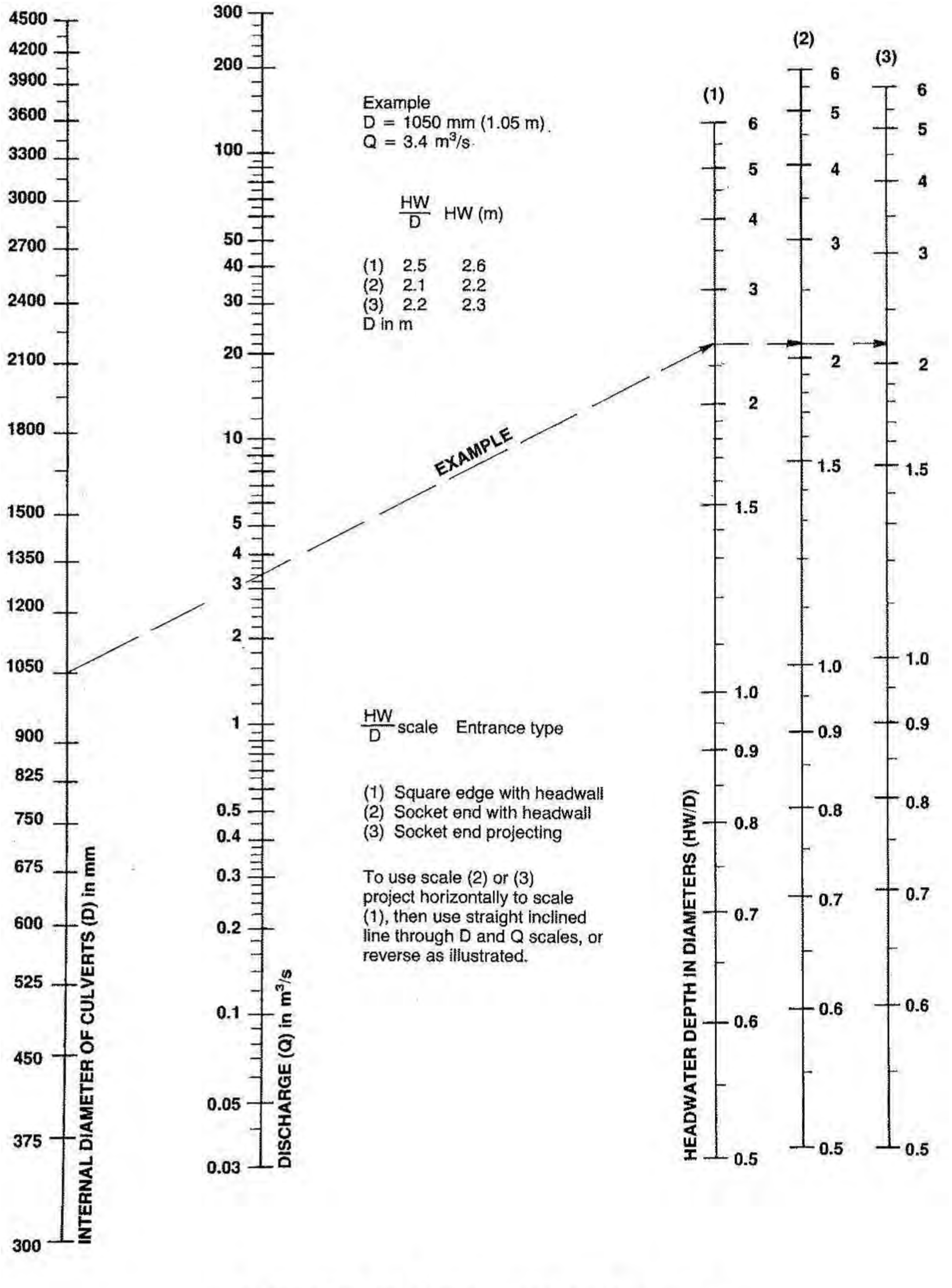
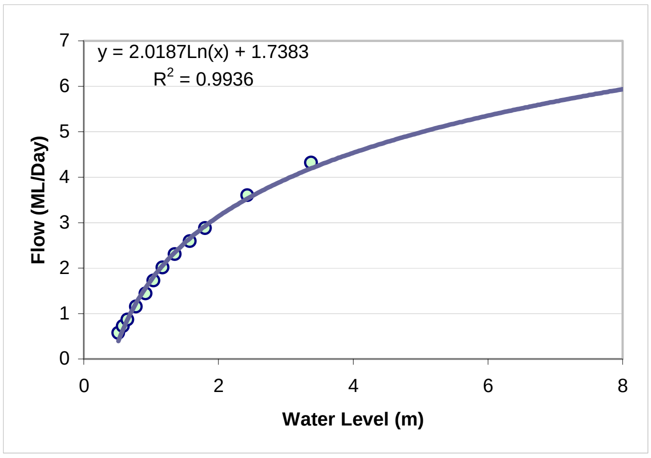


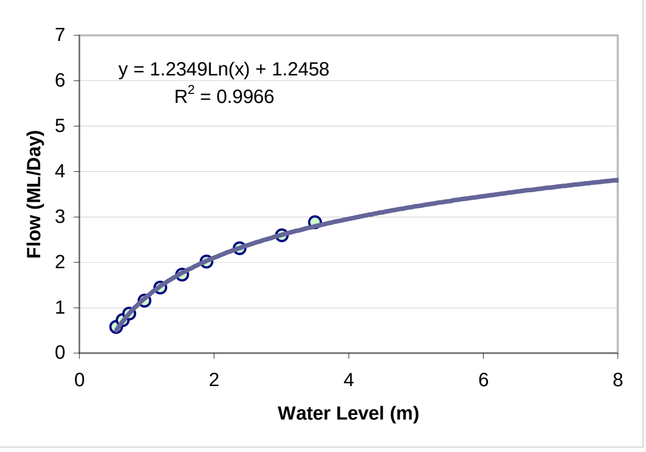
Figure C1. From Hydraulics of Precast Concrete Conduits, Concrete Pipe Association of Australasia, 1991

Flow (KL/sec)	Water Level / Diameter	Water Level	Flow (ML/Day)	Flow (KL/sec)	Water Level / Diameter	Water Level	Flow (ML/Day)
0.4	0.570	0.513	0.576	0.4	0.780	0.546	0.576
0.5	0.645	0.581	0.720	0.5	0.920	0.644	0.720
0.6	0.720	0.648	0.864	0.6	1.060	0.742	0.864
0.8	0.860	0.774	1.152	0.8	1.380	0.966	1.152
1.0	1.020	0.918	1.440	1.0	1.720	1.204	1.440
1.2	1.150	1.035	1.728	1.2	2.180	1.526	1.728
1.4	1.300	1.170	2.016	1.4	2.700	1.890	2.016
1.6	1.500	1.350	2.304	1.6	3.400	2.380	2.304
1.8	1.750	1.575	2.592	1.8	4.300	3.010	2.592
2.0	2.000	1.800	2.880	2.0	5.000	3.500	2.880
2.5	2.700	2.430	3.600				
3.0	3.750	3.375	4.320				

Diameter (mm): 900

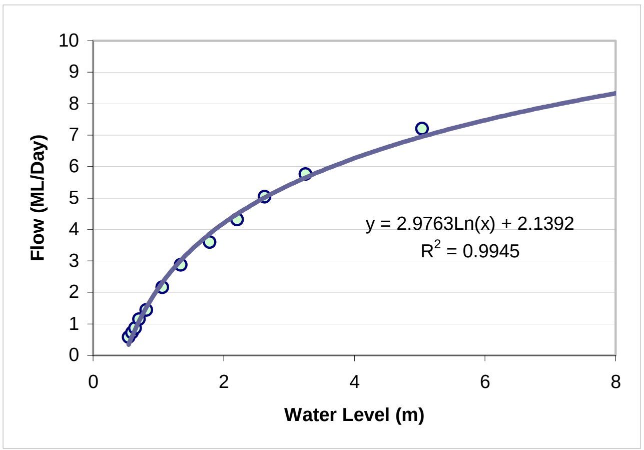


Diameter (mm): 700



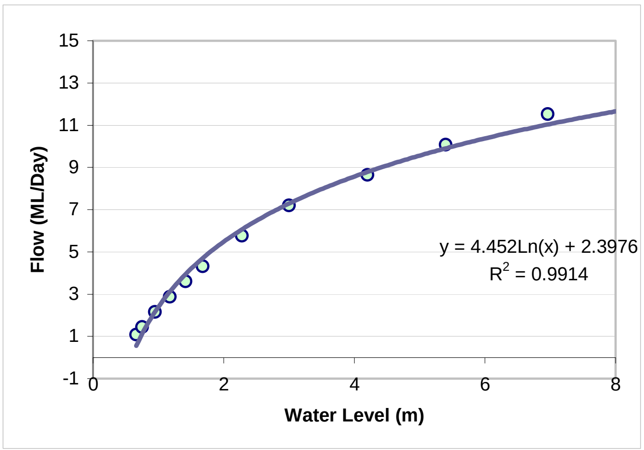
Flow (KL/sec)	Water Level / Diameter	Water Level	Flow (ML/Day)
0.4	0.520	0.546	0.576
0.5	0.570	0.599	0.720
0.6	0.615	0.646	0.864
0.8	0.670	0.704	1.152
1.0	0.775	0.814	1.440
1.5	1.010	1.061	2.160
2.0	1.280	1.344	2.880
2.5	1.700	1.785	3.600
3.0	2.100	2.205	4.320
3.5	2.500	2.625	5.040
4.0	3.100	3.255	5.760
5.0	4.800	5.040	7.200

Diameter (mm): 1050



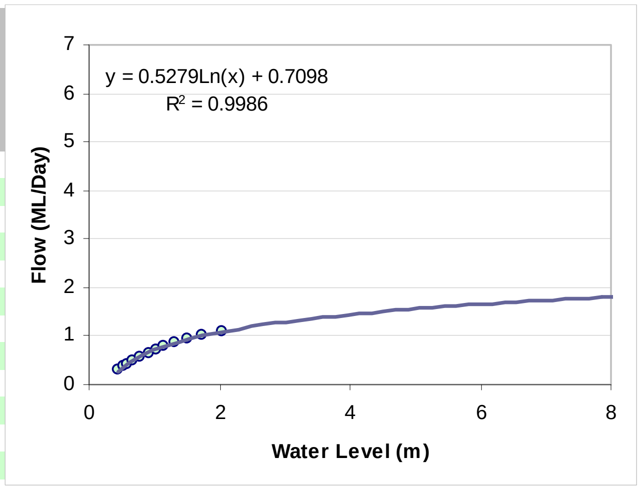
Flow (KL/sec)	Water Level / Diameter	Water Level	Flow (ML/Day)
0.8	0.550	0.660	1.080
1.0	0.625	0.750	1.440
1.5	0.790	0.948	2.160
2.0	0.980	1.176	2.880
2.5	1.180	1.416	3.600
3.0	1.400	1.680	4.320
4.0	1.900	2.280	5.760
5.0	2.500	3.000	7.200
6.0	3.500	4.200	8.640
7.0	4.500	5.400	10.080
8.0	5.800	6.960	11.520

Diameter (mm): 1200

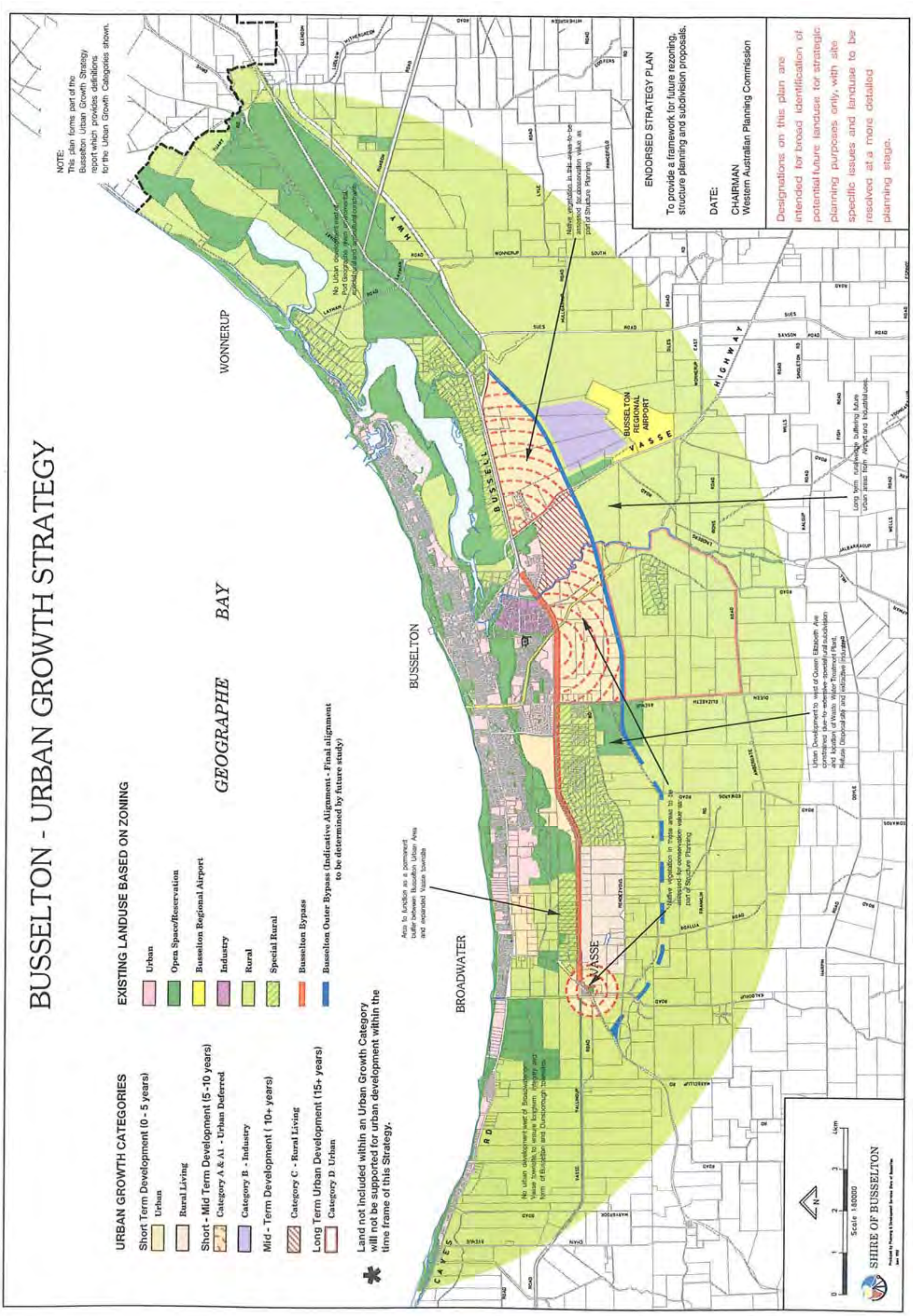


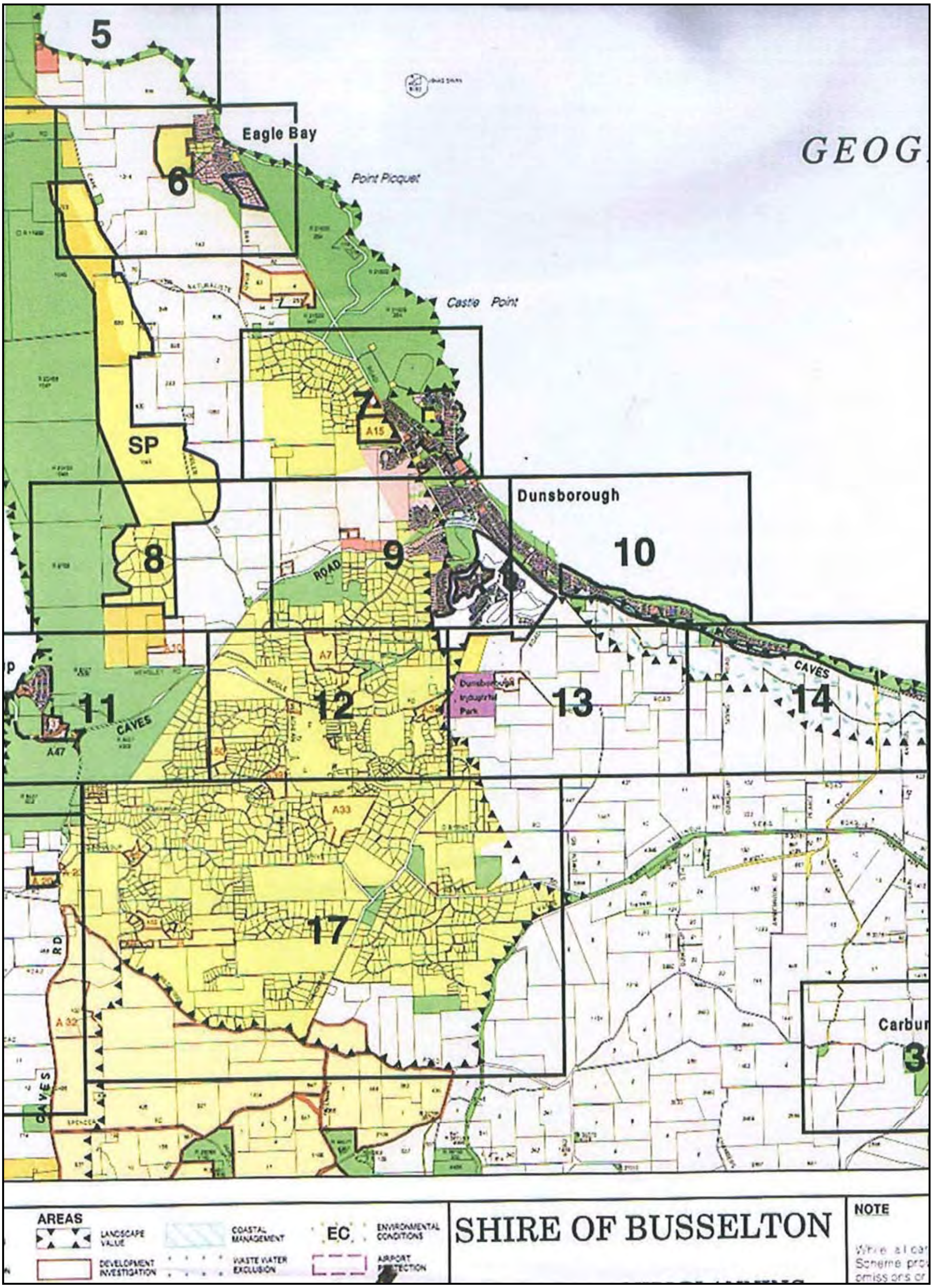
Flow (KL/sec)	Water Level / Diameter	Water Level	Flow (ML/Day)
0.20	0.830	0.436	0.288
0.25	1.000	0.525	0.360
0.30	1.120	0.588	0.432
0.35	1.300	0.683	0.504
0.40	1.500	0.788	0.576
0.45	1.750	0.919	0.648
0.50	1.950	1.024	0.720
0.55	2.200	1.155	0.792
0.60	2.500	1.313	0.864
0.65	2.900	1.523	0.936
0.70	3.300	1.733	1.008
0.75	3.900	2.048	1.080

Diameter (mm): 525



Appendix E: Structure plans and urban growth strategies


BUSSELTON - URBAN GROWTH STRATEGY
URBAN GROWTH CATEGORIES
Short Term Development (0 - 5 years)
Urban
Rural Living
Short - Mid Term Development (5 -10 years)
Category A & A1 - Urban Deferred
Category B - Industry
Mid - Term Development (10+ years)
Category C - Rural Living
Long Term Urban Development (15+ years)
Category D Urban
Land not included within an Urban Growth Category will not be supported for urban development within the time frame of this Strategy.
EXISTING LANDUSE BASED ON ZONING
Urban
Open Space/Reservation
Busselton Regional Airport
Industry
Rural
Special Rural
Busselton Bypass
Busselton Outer Bypass (Indicative Alignment - Final alignment to be determined by future study)
GEOGRAPHE
BAY
WONNERUP
BUSSELTON
BROADWATER
VASSE
BUSSELTON REGIONAL AIRPORT
NOTE:
This plan forms part of the Busselton Urban Growth Strategy report which provides definitions for the Urban Growth Categories shown.
ENDORSED STRATEGY PLAN
To provide a framework for future rezoning, structure planning and subdivision proposals.
DATE:
CHAIRMAN
Western Australian Planning Commission
Designations on this plan are intended for broad identification of potential future landuse for strategic planning purposes only, with site specific issues and landuse to be resolved at a more detailed planning stage.
Scale 1:80000
SHIRE OF BUSSELTON


5
Eagle Bay
6
Point Picquet
GEOG
Castle Point
7
A15
SP
Dunsborough
8
9
10
ROAD
11
CAVES
A47
12
A7
13
Dunsborough Industrial Park
14
CAVES
17
A33
A32
CAVES
RD
Carbu
AREAS
LANDSCAPE VALUE
DEVELOPMENT INVESTIGATION
COASTAL MANAGEMENT
WASTE WATER EXCLUSION
EC
ENVIRONMENTAL CONDITIONS
AIRPORT PROTECTION
SHIRE OF BUSSELTON
NOTE

WaterScience technical series

Looking after all our water needs

Department of **Water**
168 St Georges Terrace, Perth, Western Australia
PO Box K822 Perth Western Australia 6842
Phone: (08) 6364 7600
Fax: (08) 6364 7601
www.water.wa.gov.au