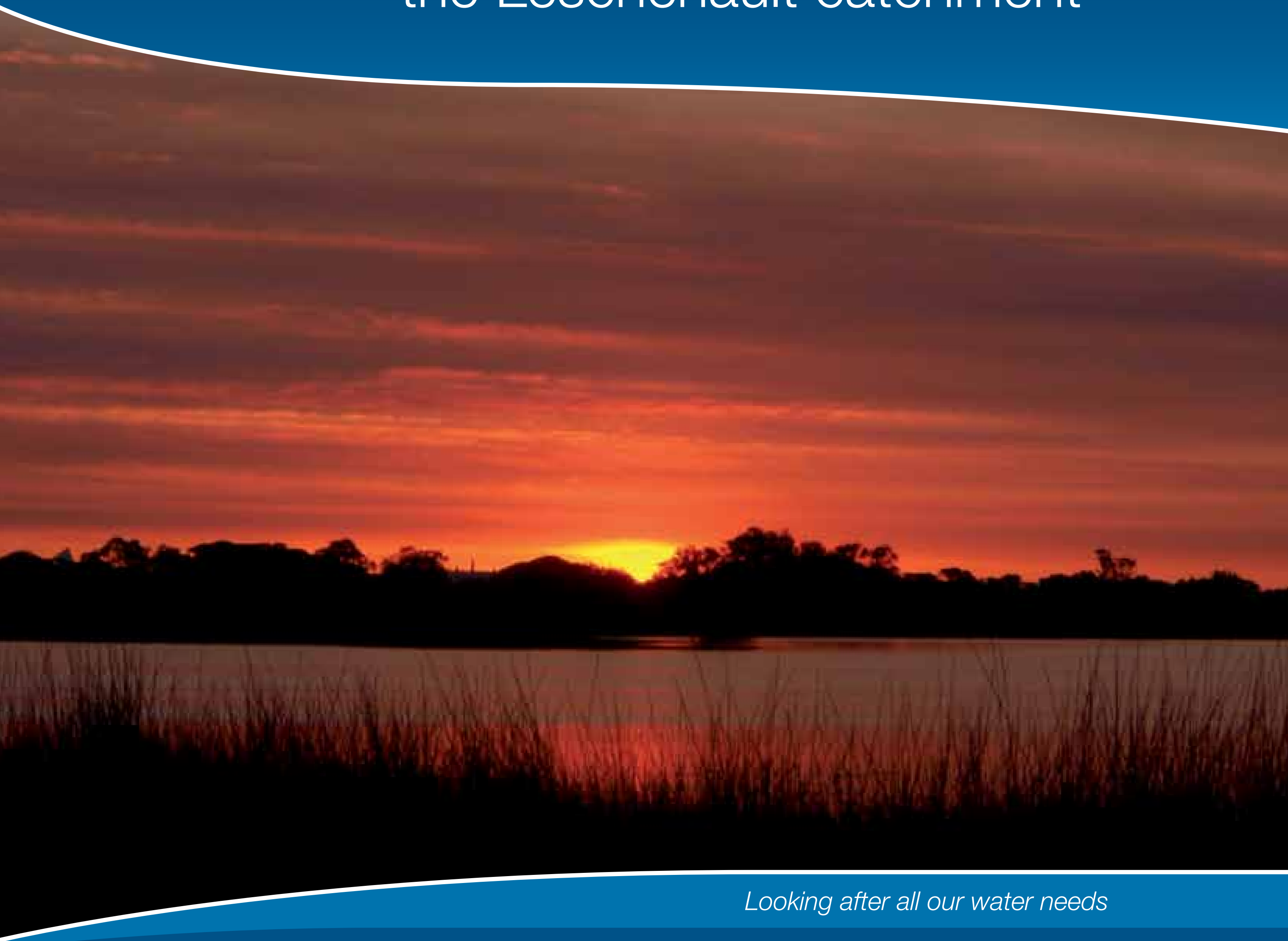
Government of **Western Australia**
Department of **Water**

Nutrient export modelling of the Leschenault catchment



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Cover photograph: Leschenault Estuary (Joel Hall)

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The Leschenault catchment, which drains to the Leschenault Inlet and then the ocean, has an area of approximately 2020 km^2 and includes the catchments of the Wellesley, Brunswick, Ferguson and Preston rivers, as well as the Collie River catchment below Wellington Reservoir. Artificial drains have been introduced into the flat coastal plain areas to enable agricultural and urban land uses. An irrigation drainage network also supplies water to the catchment from the Stirling, Harvey and Wellington dams (Harvey and Collie irrigation districts). This has led to a complex hydrological network of drains and natural rivers.

Although the catchment has a large area of native vegetation in its upper reaches, the land uses on the Swan Coastal Plain and in the broad river valleys east of the Darling Scarp include cattle raising for beef and dairy, horticulture and viticulture. The catchment's population is approximately 65 000, with most people living in areas between the lower reaches of the four major rivers and either the coast or the eastern shore of Leschenault Estuary in the towns of Australind and Bunbury.

The intense agricultural and urban land uses have eutrophied many of the catchment's waterways, which has led to algal blooms and fish kills in the lower Collie and Brunswick rivers. The Department of Water monitoring program has highlighted many sites on the coastal plain that have 'high' and 'very high' status for total nitrogen (TN) and total phosphorus (TP). These data are presented in the accompanying water quality status and trends report (Kelsey 2010).

The Catchment Management Support System (CMSS) model was used to estimate the average annual export of nutrients to the waterways draining to the Leschenault Inlet and the ocean for the period 1998 to 2007. An estimated annual load of 359 tonnes of TN and 29 tonnes of TP discharges to the inlet and a further 13.5 tonnes of TN and 1.4 tonnes of TP discharges directly to the ocean from abutting land.

The main sources of nutrients are from 'beef cattle' (60 per cent of TN; 48 per cent of TP) and 'cattle for dairy' (19 per cent of TN; 24 per cent of TP). The point sources of septic tanks and wastewater treatment plants (WWTPs) contribute 11 per cent of both the TN and TP. Urban sources (excluding the septic tank and WWTP emissions, and the 'recreation' land uses) contribute 3 per cent of TN and 4.2 per cent of TP. Horticulture, viticulture and tree plantations contribute 3 per cent of TN and 8 per cent of TP. There are other land uses in the catchment that are just as intensive, or more intensive than dairy farming and urban uses on a load per unit area basis. However, because of their relatively small area and the whole-of-catchment modelling, they have not emerged as issues. From a catchment management perspective, land uses with high fertilisation rates and/or high stocking rates should always be sited and managed appropriately. In the Leschenault catchment these land uses include 'piggery', 'turf farms', 'recreation – turf and grass'.

Modelling was conducted on 14 subcatchments. The subcatchment with the greatest nutrient loads is the Wellesley – even though it is only the fourth largest subcatchment. This is because of intensive land uses (21 per cent of the area is devoted to dairy farming), poor

soils and large amounts of irrigation. The catchments with the greatest loads per unit area besides the Wellesley are Estuary and Coast (due to urban and horticultural contributions), and Brunswick Middle, Brunswick Lower and Collie Lower 1 (due to poor soils, and beef and dairy cattle). The horticultural area north of the inlet, which drains to the inlet through Parkfield Drain, is only small but contributes significant loads.

Management actions modelled include the removal of septic tanks and WWTPs, fertiliser management and the application of soil amendment.

The removal of septic tanks and appropriate effluent disposal from Kemerton WWTP has the potential to significantly reduce nutrient export from all catchments that contain portions of Australind and Bunbury. The subcatchments Coast, Estuary, Brunswick Lower and Preston Lower have predicted TN reductions of 50, 50, 45 and 18 per cent respectively and predicted TP reductions of 53, 44, 33 and 18 per cent respectively.

On a whole-of-catchment basis, implementation of the *Fertiliser action plan* has the potential to decrease the phosphorus export to the waterways by 20 per cent. This is significant because phosphorus fertilisation changes have only been made in five subcatchments, which constitute 65 337 ha or 32 per cent of the catchment. Clearly the *Fertiliser action plan* has a role to play in the reduction of fertiliser leaching to the catchment's waterways.

If soil amendment were applied to half of the agricultural land uses on low phosphorus-retention index (PRI) soils, the TP load to the estuary would reduce from 30 to 24 tonnes – a decrease of about 20 per cent. The catchments most affected by this management action would be Brunswick Middle, Wellesley, Collie Lower 1 and Preston Lower, where application of soil amendment to half of the low PRI soils could potentially reduce phosphorus export by about 25 per cent. As such, this management action should be considered in strategic locations.

A scenario to examine how the intensification of dairy farming, horticulture and viticulture would impact on the catchment was modelled by increasing the nutrient input rates on existing properties by 50 per cent. The greatest impacts are from the intensification of dairy farming (because this has a much greater area than horticulture and viticulture). On a whole-of-catchment basis, the intensification of these land uses would result in a 10 per cent increase in TN export (from 372 to 411 tonnes) and a 14 per cent increase in TP export (from 30 to 34 tonnes).

The impact of this intensification would be greatest in the Wellesley catchment, which has 21 per cent of its area under dairy farming (potentially leads to a 25 per cent increase in both TN and TP export). The expected increases in the Brunswick Middle, Collie Lower 1 and Ferguson catchments are 15, 16 and 14 per cent for TN export respectively and 18, 15 and 13 per cent for TP export respectively (mainly due to dairy farming). The Estuary catchment also displays potential increases of 8 per cent for TN and 15 per cent for TP export, due to the intensification of the horticultural region to the north of the estuary which drains to the estuary through Parkfield Drain. All the areas subject to intensification under this scenario already have poor water quality because of the current land uses. Increased nutrient loads would therefore exacerbate the existing problems.

1 Introduction

The Leschenault catchment, which drains to the Leschenault Inlet and then the ocean, is located approximately 160 km south of Perth, in Western Australia's south west. Its area is approximately 2020 km^2 and includes the catchments of the Wellesley, Brunswick, Ferguson and Preston rivers, as well as the Collie River catchment below Wellington Reservoir. Artificial drains have been introduced into the flat coastal plain areas to enable agricultural and urban land uses. An irrigation drainage network also supplies water to the catchment from the Stirling, Harvey and Wellington dams (Harvey and Collie irrigation districts). This has led to a complex hydrological network of drains and natural rivers.

Although the catchment has a large area of native vegetation in its upper reaches, the land uses on the Swan Coastal Plain and in the broad river valleys east of the Darling Scarp include cattle raising for beef and dairy, horticulture and viticulture. The catchment's population is approximately 65 000 (ABS 2009), with most people living in areas between the lower reaches of the four major rivers and either the coast or the eastern shore of Leschenault Estuary in the towns of Australind and Bunbury.

The intense agricultural and urban land uses have eutrophied many of the catchment's waterways, which has led to algal blooms and fish kills in the Lower Collie and Brunswick rivers. The Department of Water monitoring program has highlighted many sites on the coastal plain that have 'high' and 'very high' status for total nitrogen (TN) and total phosphorus (TP). These data are presented in the accompanying water quality status and trends report (Kelsey 2010).

This report examines the annual loads of TN and TP being exported to the catchment's waterways. Average annual TN and TP loads for the period 1998 to 2008 are quantified and the relative contributions of various land uses, including the point sources of septic tanks and WWTPs, are estimated. Also presented are the modelling results for the impact of the following scenarios:

- removal of point sources
- fertilisation changes
- the application of soil amendment
- the intensification of dairy farming, viticulture and horticulture.

The average annual TN and TP loads are estimated using the Catchment Management Support System (CMSS) model, as discussed in Letcher et al. (1999).

2 Catchment description

2.1 Geography and topography

The Leschenault Estuary is located approximately 160 km south of Perth, in Western Australia's south west. Since European settlement, the catchment has undergone many changes in land use and hydrology (DoW 2007), including the construction of Wellington Reservoir on the Collie River in 1933. The Leschenault catchment (as defined for this study) is 2020 km^2 and includes areas below the reservoir that drain to the Lower Collie River, as well as the Wellesley, Brunswick, Ferguson and Preston river catchments (see Figure 2.1).

About one-third of the catchment lies on the Swan Coastal Plain and has elevations of between 0 and 30 m, as displayed in Figure 2.2. At the Darling Scarp, which is parallel to the coast and about 17 km to the east, the elevation increases to about 80 m. The remainder of the catchment is on the Darling Plateau, with elevations gradually increasing from west to east to between 300 and 400 m.

2.2 Climate

The area has a Mediterranean climate with warm, dry summers and cool, wet winters. Rainfall is highest just east of the Darling Scarp, receiving an average of 1200 mm/year. This tapers away in both eastern and western directions to below 900 mm at the coast and the eastern edge of the Preston catchment. Usually more than 90 per cent of the rainfall occurs in the May to October period, although this can be lower (between 80 and 85 per cent) during dry years. The average annual potential evaporation (Class A pan evaporation) varies from 1300 mm near the catchment's southern edge to 1400 mm in the northern and eastern fringes. At Bunbury the monthly average daily maximum temperature varies between 27.8^{o} C in summer (February) to 16.8^{o} C in winter (July). Further inland, temperature ranges are more extreme with monthly average daily maximum temperatures at Collie varying from 30.5^{o} C in summer (January) to 15.5^{o} C in winter (July).

2.3 Soils and geology

The catchment can be divided into three main physiographic regions: the Swan Coastal Plain, the Donnybrook Sunkland and the Darling Plateau. The main soil types are displayed in Figure 2.3 and a brief description of the physiographic units from Weaving (1998) is included below.

Phosphorus-retention index (PRI) information (McPharlin et al. 1990) was obtained from the Department of Agriculture and Food Western Australia (DAFWA). It should be noted that PRI is not only related to soil type, but subsoil characteristics, the depth of the first two soil layers and the soil's fertiliser history. Figure 2.4 contains a phosphorus risk map for the catchment. Soils with a PRI of less than or equal to 5 have a high risk of phosphorus loss to waterways; soils with a PRI of between 5 and 15 have a moderate risk; whereas soils with a PRI of greater than 15 have a low risk.

2.3.1 Western Darling Plateau

The western section of the Darling Range is a lateritic plateau characterised by steep slopes and deeply incised valleys that become broader further to the east. The area consists of lateritic sandy to loamy gravel soils with deep sand. PRI in this area is mostly high, usually between 50 and 200, reducing to 30 at the catchment's eastern edge. However, along the Preston valley, in farmed areas of the floodplain, PRI may fall to as low as 10.

2.3.2 Donnybrook Sunkland zone

The north-eastern tip of the Donnybrook Sunkland zone wedges between the western Darling Plateau and the Swan Coastal Plain, in the southern half of the catchment. The landscape is similar to that of the Darling Plateau, although with less altitude, broader valleys and more sandy soil. The soil PRIs are moderate to high in this zone, at around 20, and even higher in riparian areas where values of over 100 are typical.

2.3.3 Swan Coastal Plain

The Swan Coastal Plain makes up the remainder of the Leschenault catchment adjacent to the coast and is split into six soil types, as shown in Figure 2.3. The three soil types closest to the coast include two coastal dune systems overlying either calcareous sand (Quindalup) or limestone (Spearwood), as well as estuarine flats found between the dune systems (Vasse). Soil PRIs in these three areas vary slightly, but are usually between 5 and 10.

The remainder of the coastal plain is extremely flat and poorly drained. Bassendean Sands are coarse and have very limited phosphorus retention ability, with PRIs of around zero and below being common. Pinjarra zone soils tend to be duplex with higher clay content than the other coastal plain soils. Soil PRIs vary greatly: some areas have low PRIs of between 1 and 3; others have PRIs as high as 50 to 70.

2.4 Hydrology

Four major rivers, which are displayed in Figure 2.1, drain the Leschenault catchment. These are the Brunswick and Collie rivers in the north and the Ferguson and Preston rivers in the south. All four have headwaters in mainly forested areas of the Darling Plateau. The Collie River has been dammed by the Wellington Reservoir, so the catchment considered in this report includes only those areas of the Collie River catchment below the reservoir. The Lower Collie River (below dam) is regularly supplemented with outflow from the Wellington Reservoir. Several other major tributaries drain mostly upland catchments; the important exception is the Wellesley River, a tributary of the Brunswick River, which has a catchment that lies mostly on the Swan Coastal Plain.

Irrigation supply and artificial drainage channels have significantly altered the Leschenault catchment's natural drainage. Extensive irrigation takes place on the Swan Coastal Plain between Mandurah and Bunbury and is split into three districts based on the supply source. Parts of the Harvey district (fed by the Stirling, Harvey and Logue Brook dams) and all of the Collie district (fed by the Wellington Dam) are within the Leschenault catchment area, which results in the Wellesley River receiving irrigation runoff that originates from the Harvey catchment. The irrigation system is gravity fed and its main features include a pipe in the Harvey district and a concrete-lined channel in the Collie district running north-south along the base of the Darling Scarp. This channel is piped under or over major watercourses such as the Brunswick River, but during the summer irrigation season, smaller watercourses are fed into the main supply channel. Historically, around 30 per cent of irrigation water was lost en route, through seepage (in earth-lined channels) and evaporation. This loss has been almost eliminated in the Harvey district because concrete supply channels have been replaced with pipes. However, the Collie district is unlikely to be piped until salinity in Wellington Dam is substantially reduced. The Preston Valley Irrigation Cooperative (PVIC) also operates a small irrigation district from the Glen Mervyn Dam in the Preston catchment.

In general, drains run from east to west until they meet a major tributary. To enhance drainage, some rivers have been de-snagged and straightened (e.g. the Wellesley River). A further complicating feature of the drainage network is that some supply channels act as drains in winter.

For CMSS modelling the catchment was divided into 14 subcatchments defined by the major tributaries and rivers and their confluences. Land adjacent to the Leschenault Inlet that drains directly to the inlet has been defined as a subcatchment: Estuary. For completeness, areas of land that drain directly to the ocean – that are adjacent to the subcatchments draining to the Leschenault Inlet – have been included. These are named Coastal North and Coastal South but are lumped together as Coastal for reporting purposes. The subcatchments are displayed in Figure 2.5.

The Department of Water, and to a lesser extent the Water Corporation, have a network of flow gauging and water quality sampling sites in the Leschenault catchment. These are displayed in Figure 2.5. A separate report (Kelsey 2010) discusses water quality status and trends in the catchment. Annual loads of TN and TP have been calculated at sites where there is concurrent water quality and flow monitoring. These are listed in Appendix 2.

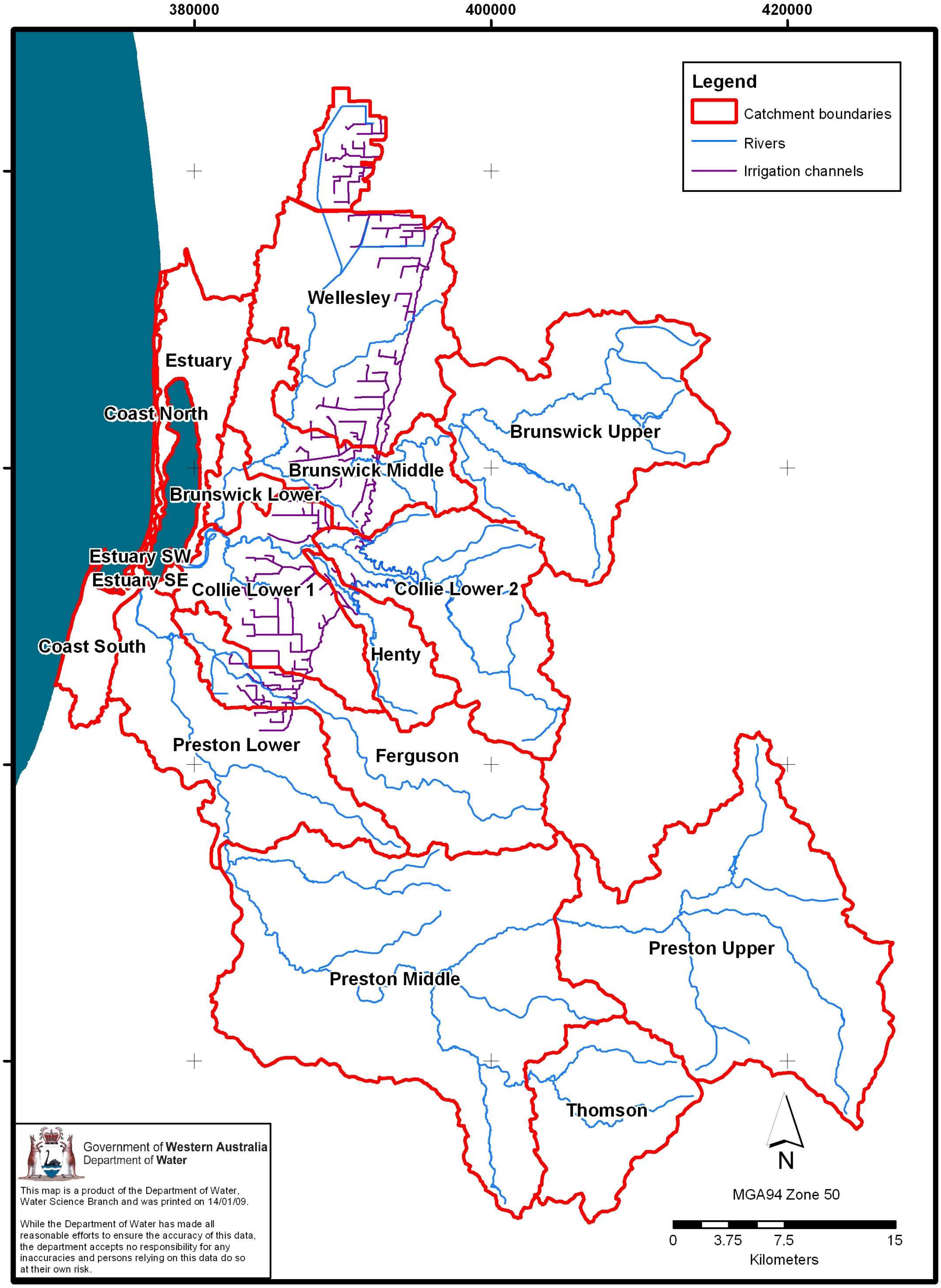


Figure 2.1 Rivers, irrigation supply and drainage channels, and subcatchment boundaries of the Leschenault catchment

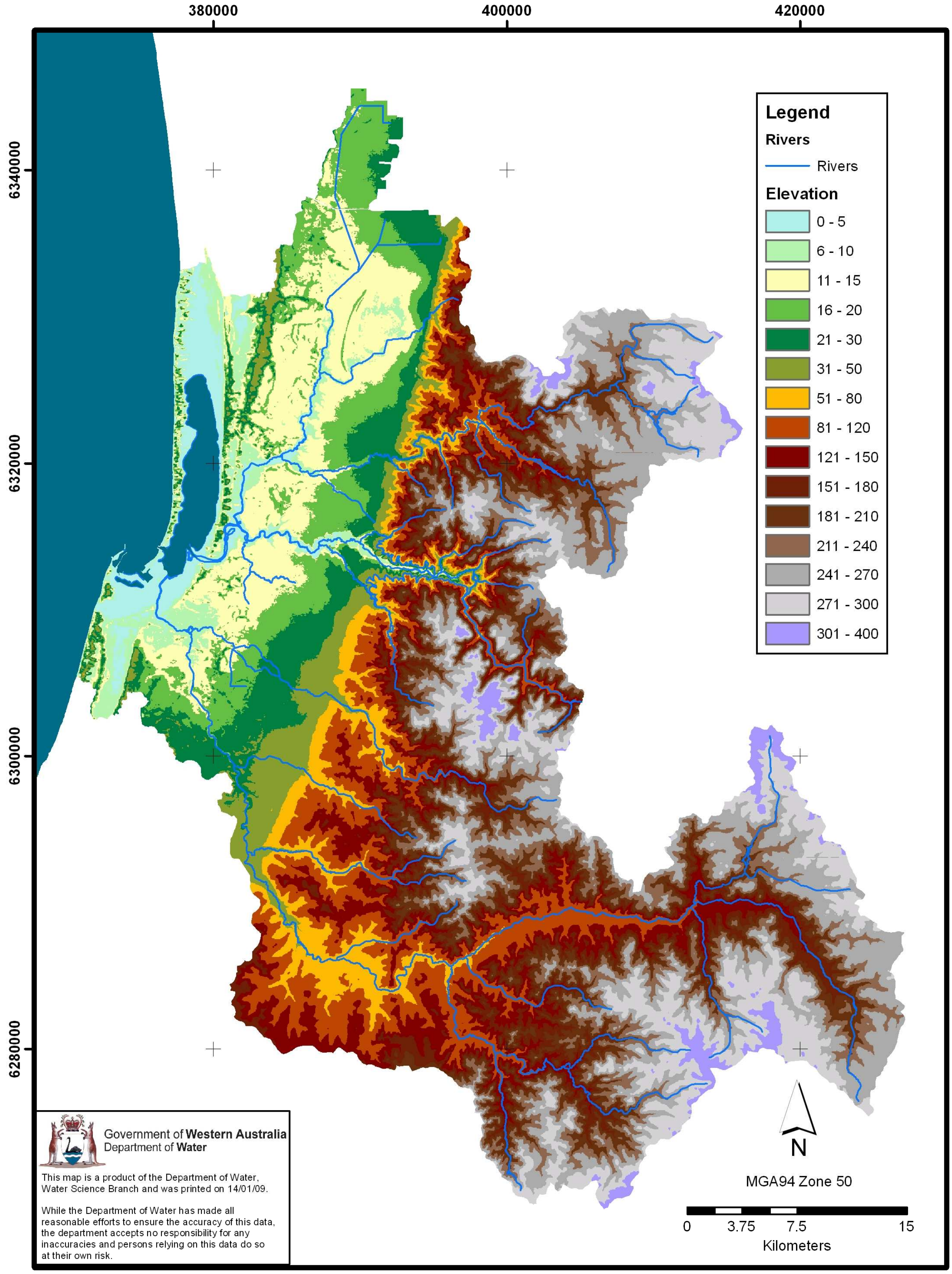


Figure 2.2 Topography of the Leschenault catchment

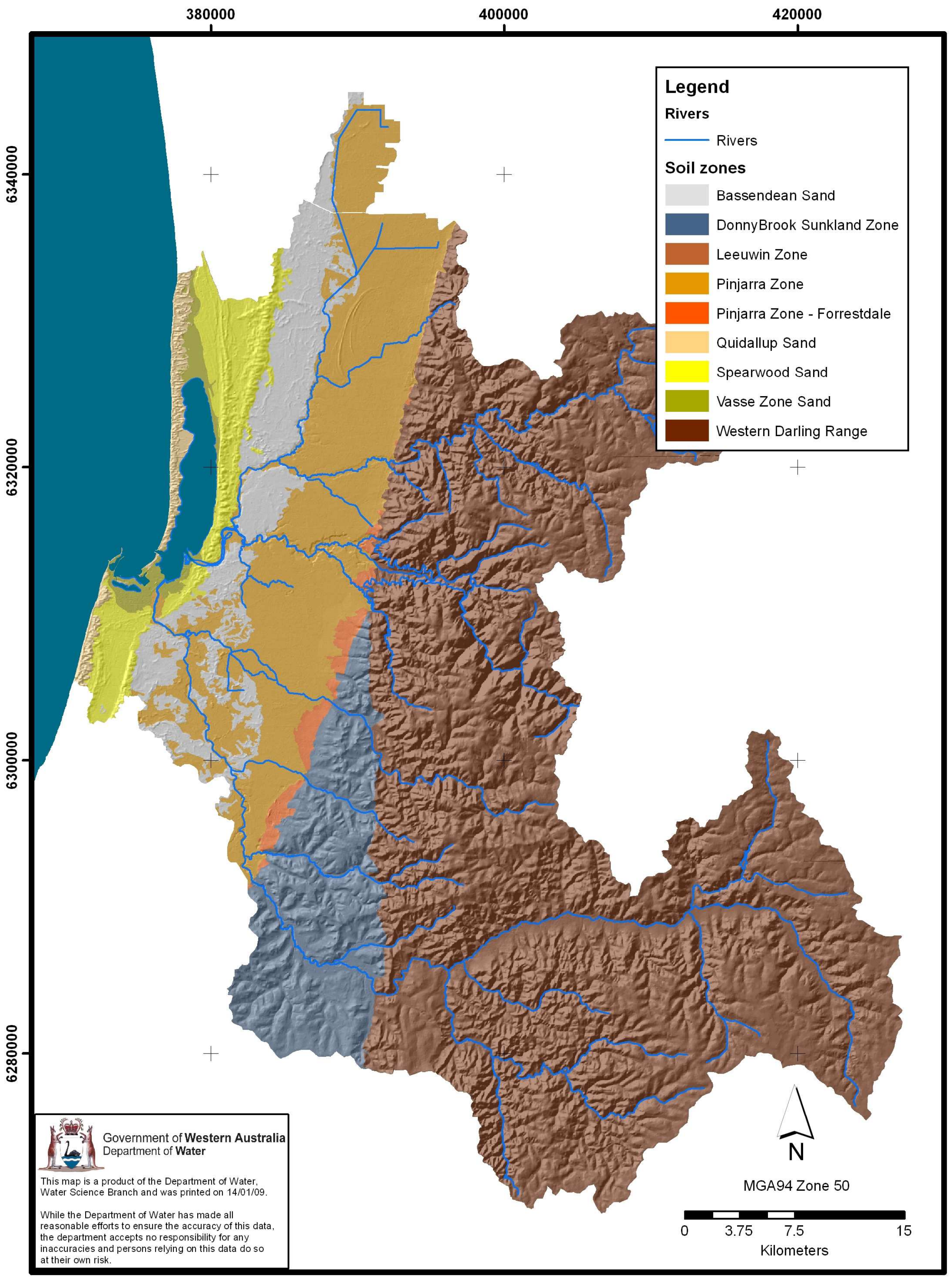


Figure 2.3 Soils types of the Leschenault catchment

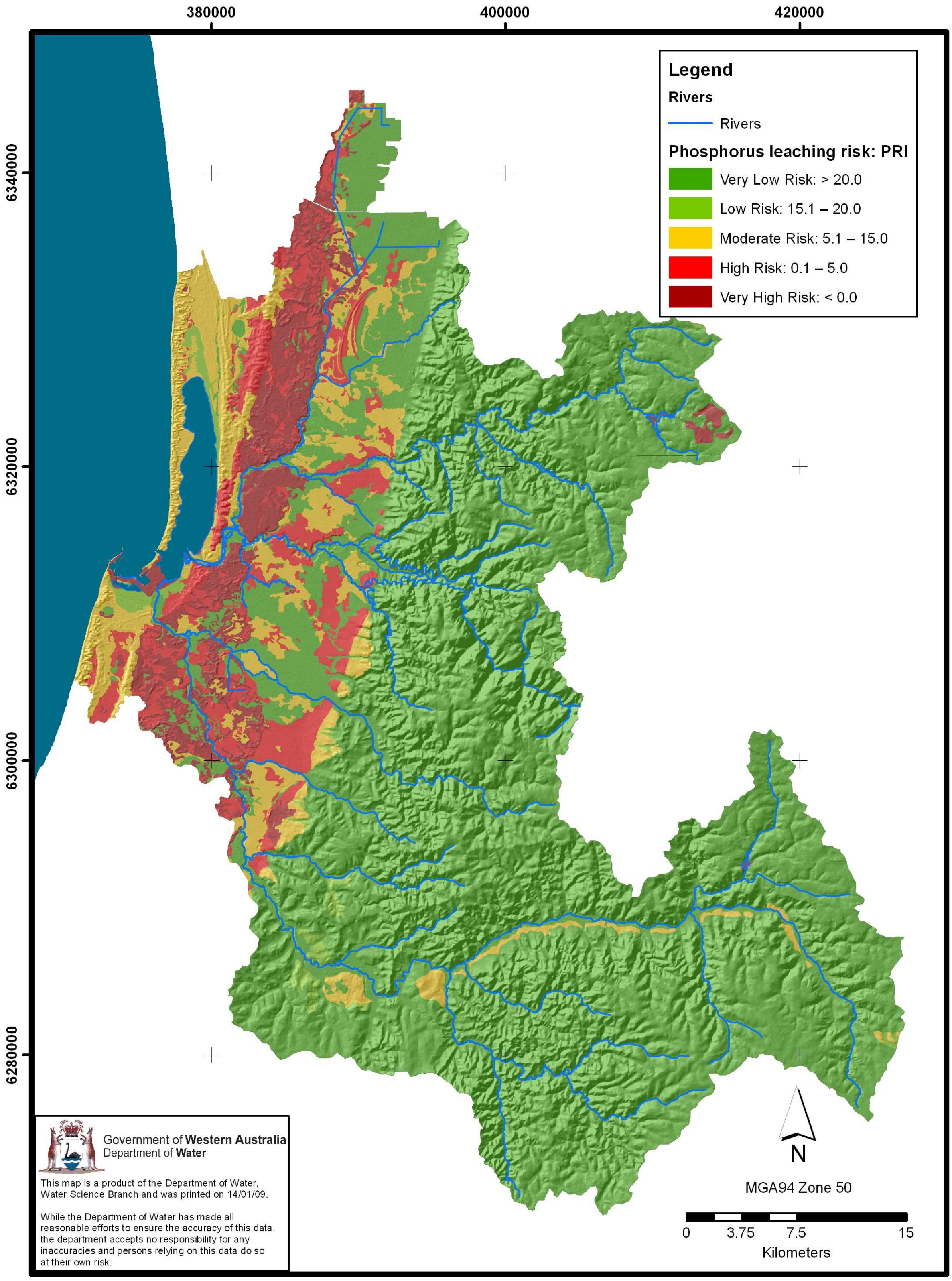


Figure 2.4 Phosphorus risk map of the Leschenault catchment

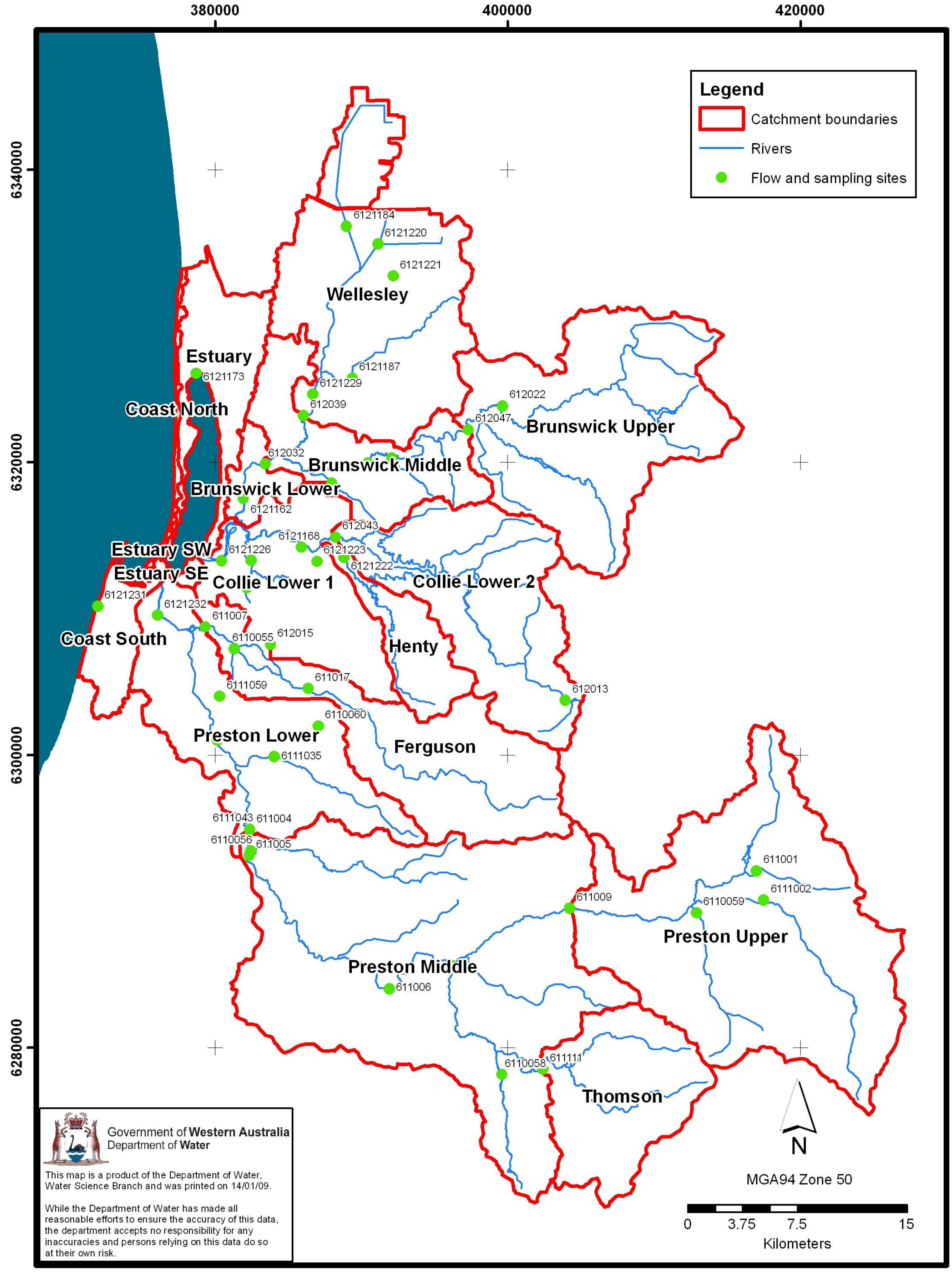


Figure 2.5 Flow and water quality sampling sites of the Leschenault catchment

2.5 Land use

2.5.1 Land-use mapping

The land-use map in Figure 2.6 was developed in partnership with DAFWA using a combination of existing information and 2003 aerial photography. The urban areas have been updated using 2006 aerial photography. Table 2.1 contains the land-use areas and percentage of the catchment occupied by each of the land uses. Appendix 1 contains the land-use areas for each of the subcatchments.

Native vegetation ('recreation/conservation') occupies about 50 per cent of the catchment and is mainly located on the Darling Plateau. 'Cattle for beef' occupies about 30 per cent of the catchment and occurs on the Swan Coastal Plain and in the major river valleys. The major river valleys are characterised by gentle slopes and broad flood plains. This has allowed rural developments to encroach onto and east of the Darling Scarp. It is likely that areas set aside for pasture are grazed in summer, with the cattle being moved onto higher ground as low-lying fields become waterlogged in winter.

'Cattle for dairy' is generally an irrigated land use and occupies about 4.4 per cent of the catchment (nearly 9000 ha), almost all of which is on the coastal plain. The next largest land use is 'tree plantation', which occupies 3.7 per cent of the catchment and generally occurs in areas adjacent to native forest, mainly on the Darling Plateau. The urban land uses: 'urban residential', 'commercial' and 'community facility – non-education' together occupy less than 2 per cent of the catchment area. The largest horticultural area in the catchment is on the coastal plain just north of the inlet. Viticulture is scattered throughout the catchment but mainly in the Henty, Ferguson and Preston subcatchments.

The Leschenault catchment's population is approximately 65 000 (ABS 2009). Most people live between the lower reaches of the four major rivers and either the coast or the eastern shore of Leschenault Estuary in the towns of Australind and Bunbury (in the Estuary, Coastal and lower parts of the Brunswick Lower, Collie Lower 1 and Preston Lower catchments).

Table 2.2 contains the populations (2007) of the shires that encompass most of the Leschenault catchment. The Shire of Harvey overlaps both the Leschenault and Peel-Harvey catchments and less than one-third of its population is likely to be in the Leschenault.

2.5.2 Point sources of nutrient pollution

The common point sources of nutrient pollution in Western Australia's coastal plain catchments include abattoirs, aquaculture, cattle feedlots and livestock holding pens, dairies, landfill sites, piggeries, poultry farming, septic tanks and waste water treatment plants (WWTPs), as well as industries such as food and milk processing, and fertiliser and compost manufacturing. However, in Western Australia most of these industries are small enough that stringent monitoring of their outputs is neither required nor commercially viable. The sites identified as important for this study include abattoirs, WWTPs and septic tanks (see Figure 2.7). Output data from abattoirs was not available, so abattoirs have not been included in the CMSS model. Note that future modelling will include other point sources, such as the ice creamery that is allegedly discharging to Elvira Gully.

Table 2.1 Areas of land use in the Leschenault catchment

Land use	Area (ha)	%
Abattoir	8	0.0
Annual horticulture	679	0.3
Aquaculture	2	0.0
Cattle for beef	61 281	30.3
Cattle for dairy	8812	4.4
Commercial	188	0.1
Community facility – non-education	199	0.1
Dam	1204	0.6
Garden centre/nursery	18	0.0
Horses	444	0.2
Lifestyle block/hobby farm	3360	1.7
Manufacturing/processing	1529	0.8
Pasture for hay	1368	0.7
Perennial horticulture – trees	251	0.1
Piggery	12	0.0
Quarry/extraction	1588	0.8
Recreation – grass	322	0.2
Recreation – turf	92	0.0
Recreation/conservation	101 013	50.0
Rural residential/bush block	315	0.2
Transport/access	3334	1.6
Tree plantation	7570	3.7
Turf farm	7	0.0
Unused – cleared – grass	4240	2.1
Unused – uncleared – trees/shrubs	268	0.1
Urban residential	2662	1.3
Utility	102	0.1
Viticulture	796	0.4
Waterbody	50	0.0
Wetland	461	0.2
Total area (ha)	**202 173**	**100**

Table 2.2 Population of local government authorities in the Leschenault catchment

Local government area	Estimated resident population at 30 June 2007
Bunbury, City of	31 638
Collie, Shire of	9 067
Dardanup, Shire of	11 418
Donnybrook-Balingup, Shire of	5092
Harvey, Shire of	21 310
Total	**64 318***

** includes one-third of population of Harvey Shire*

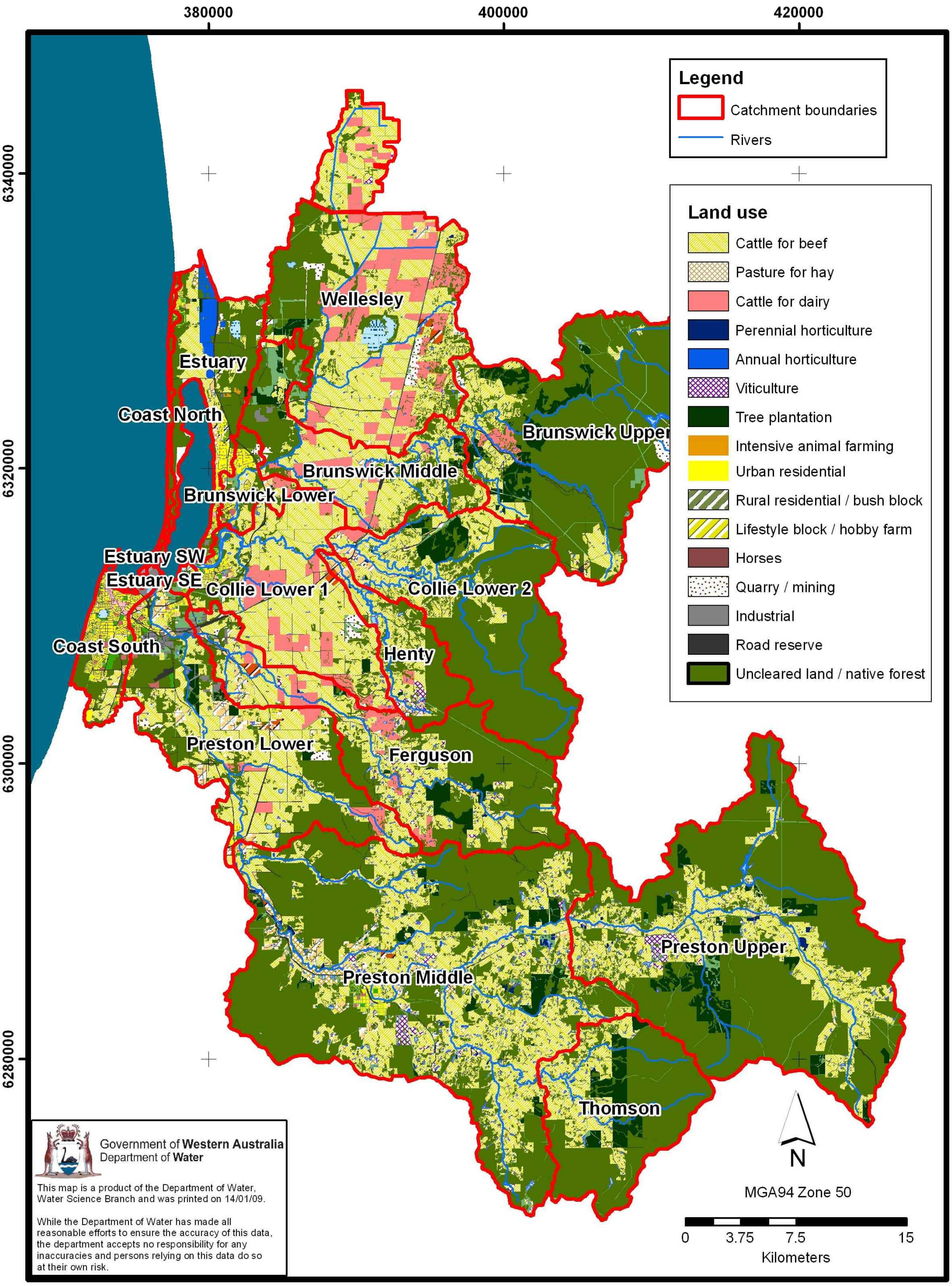


Figure 2.6 Land uses of the Leschenault catchment

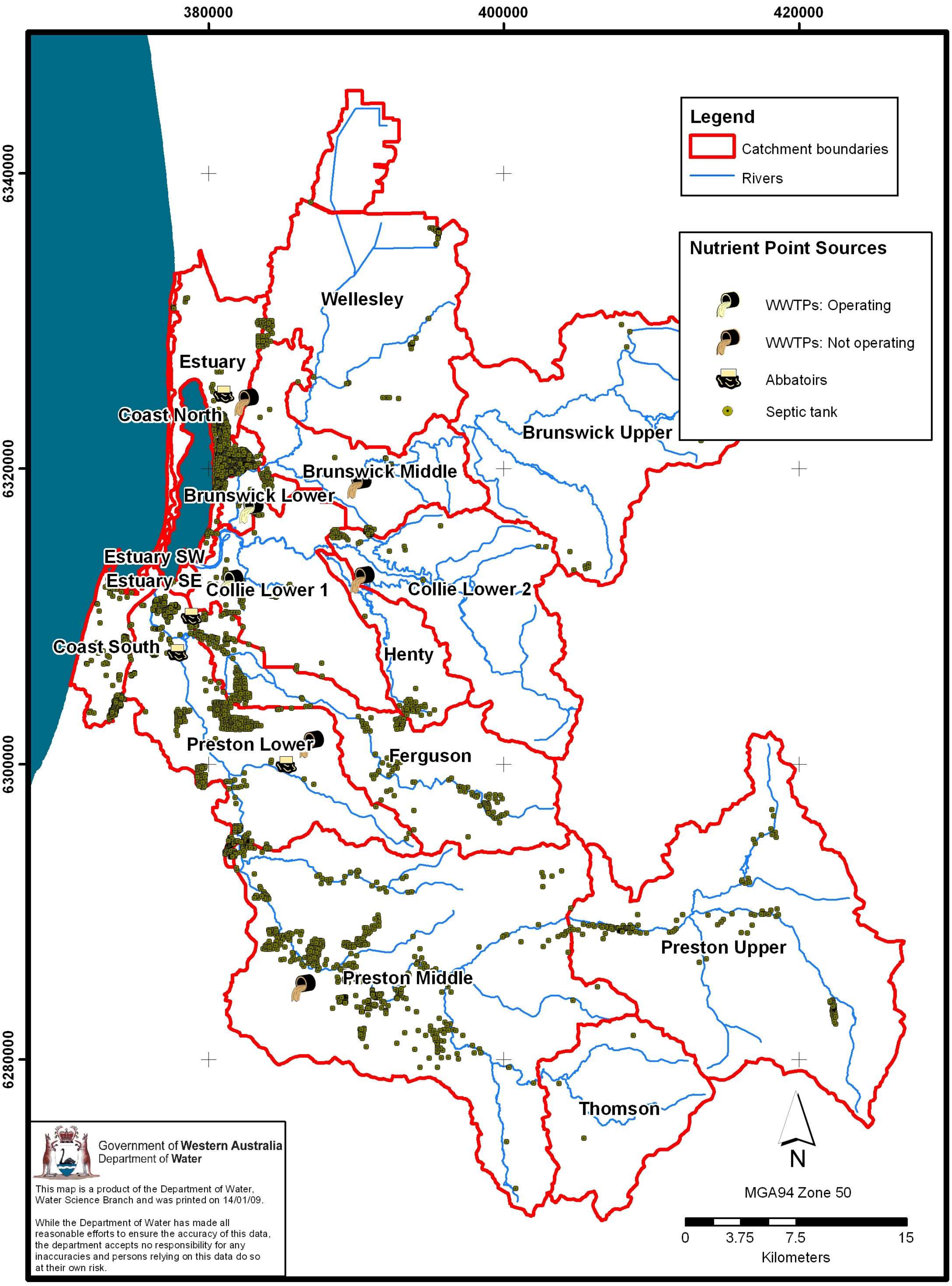


Figure 2.7 WWTPs, septic tanks and abattoirs in the Leschenault catchment

The WWTPs included in the modelling are Burekup, Brunswick Junction, Dardanup, Donnybrook and Kemerton. (The Eaton and Australind WWTPs are no longer operating and have not been included.) The Water Corporation supplied outflow data including daily flows, weekly TN and TP data at Kemerton, and monthly TN and TP data at the other sites). This data enabled the average annual loads (emissions) from the WWTPs, which are displayed in Table 2.3, to be calculated. The Donnybrook WWTP is relatively small and sited on high PRI soils, so is unlikely to be a risk. The other sites are on low PRI soils and may be polluting adjacent waterways. The Brunswick Junction WWTP discharges to Elvira Gully and is likely to be polluting this waterway. The sampling site at Elvira Gully (6121203) has ‘very high’ status for both TN and TP (Kelsey 2010).

Table 2.3 Average annual outputs from the WWTPs

WWTP	Subcatchment	Average annual outflow (ML/year)	Average annual TP load (tonnes/year)	Average annual TN load (tonnes/year)	Soil PRI
Burekup	Collie Lower 2	8.3	0.08	0.09	Low
Brunswick Junction	Brunswick Middle	67	0.55	1.29	Low
Dardanup	Preston Lower	20	0.40	0.55	Low
Donnybrook	Preston Middle	42	0.47	1.65	High
Kemerton	Estuary	875	1.59	11	Low
Total WWTP input		**1,012**	**3.1**	**15**	

The Kemerton WWTP is discharging effluent to an adjacent woodlot and an infiltration basin. It is likely the WWTP’s groundwater plume has reached the estuary because of the site’s age (established 2001), its proximity to the inlet (2.8 km away) and the inability of the poor coastal plain soils to process or retain nutrients. More work is required to determine the groundwater plume’s extent and to estimate the site’s impact on the estuary.

Septic-tank mapping was created using the Department of Land Information’s 2008 cadastral spatial coverage and infill-sewerage mapping supplied by the Water Corporation. All urban residential, rural residential and lifestyle blocks that were not included in the infill-sewerage area were assumed to have a septic tank. The cadastral parcels thus selected were checked against aerial photography to confirm the existence of a dwelling on the property. The septic-tank emissions were estimated following the research of Whelan and Barrow (1984a; 1984b) and Whelan et al. (1981), which found nitrogen and phosphorus emissions from septic tanks to be 5.5 and 1.1 kg/person/year respectively. Occupancy rates were taken to be an average of 2.4 people in houses, 6 people in commercial and industrial properties and 150 people in schools. A connection rate to infill sewerage of 74 per cent (Water Corporation 2006) was assumed. The number of septic tanks and estimated average annual TN and TP emissions are listed in Table 2.4. Table 2.5 contains the estimated septic-tank emissions for each of the Leschenault subcatchments. Table 2.6 shows the estimated number of septic tanks and average annual TN and TP emissions on low and high PRI soils.

The average annual nutrient load emitted to the catchment from septic tanks is much greater than that of the WWTPs. Septic tanks emit approximately 74 tonnes of nitrogen and 15 tonnes of phosphorus, while WWTPs emit approximately 15 tonnes of nitrogen and 3.1

tonnes of phosphorus. The estimated average annual septic-tank emissions for the Estuary catchment, which is adjacent to the inlet, are 12 tonnes of TN and 2.5 tonnes of TP; for the Coast catchment, which drains to the ocean, the emissions are 14 tonnes of TN and 3 tonnes of TP. The estimated septic-tank emissions from these catchments are both greater than the average annual emissions from the Kemerton WWTP, which are approximately 11 tonnes of TN and 1.6 tonnes of TP.

Table 2.4 Number of septic tanks and estimated average annual TN and TP emissions

Landuse	Sewered premises count **	Septic premises count	Total count	Number of people per premises	TP load* (tonnes/year)	TN load* (tonnes/year)
Commercial	628	13	641	6	0.2	1.0
Community – education	19	5	24	150	1.1	5.6
Community – non-education	26	8	34	6	0.1	0.3
Lifestyle	5	1235	1240	2.4	3.3	16.3
Manufacturing/processing	377	147	524	6	1.0	4.9
Residential	18 535	1675	20 210	2.4	9.2	45.8
Total	**19 590**	**3083**	**22 673**		**14.8**	**74**

** From Whelan and Barrow (1984a, 1984b), 1.1 kg per person per year TP and 5.5 kg per person per year TN*
*** Assuming 74% connection rate for infilled regions (Water Corporation 2006)*

Table 2.5 Estimated average annual TN and TP emissions from septic tanks in each subcatchment

Subcatchment	TP load (tonnes/year)	TN load (tonnes/year)
Brunswick Lower	1.4	7.1
Brunswick Middle	0.2	0.9
Brunswick Upper	0.0	0.2
Coast North	0.1	0.4
Coast South	2.9	14
Collie Lower 1	1.1	5.3
Collie Lower 2	0.1	0.6
Estuary	2.5	12
Estuary SE	0.2	1.1
Ferguson	0.9	4.5
Henty	0.1	0.4
Preston Lower	2.6	13
Preston Middle	2.2	11
Preston Upper	0.4	1.8
Thomson	0.0	0.0
Wellesley	0.2	0.9
Total	**15**	**74**

Table 2.6 Estimated average annual TN and TP emissions from septic tanks on low and high PRI soils

Soil PRI	Septic tank count	TP input load (tonnes/year)	TN input load (tonnes/year)
High PRI	1926	9.6	48
PRI < 5	1156	5.1	26
Total	**3083**	**15**	**74**

Since the Water Corporation's infill-sewerage program began in 1994, 1026 properties in the Leschenault catchment have been connected to deep-sewerage and a further 1257 properties are planned for connection (Water Corporation 2006). This modelling study highlights the importance of the infill-sewerage program and the requirement for all properties close to the inlet or ocean to be connected to the deep-sewerage system or an aerobic treatment unit with nutrient-stripping capability (where reticulated sewerage is not feasible). In particular, the 74 per cent connection rate to the deep-sewerage system by individual property owners following infill needs to be addressed.

3 Catchment management support system

3.1 Description of CMSS model

The Catchment Management Support System (CMSS) (Davis et al. 1996; Letcher et al. 1999) is a simple catchment-scale empirical model that may be used to estimate average annual TN and TP loads delivered to streams and rivers. Nutrient generation or export rates are specified for each land use. Land use may be designated as either a diffuse source, in which case the export rate is given as the amount of nutrient exported per unit area of the land use per year (i.e. kg/ha/yr); or as a point source, in which case the nutrient export rate is given as the amount of nutrient exported per facility per year (i.e. kg/source/yr). These export rates often need refinement to reflect the soil type or landscape position of the particular land use. CMSS sums the product of these export rates and associated land-use areas, along with point source contributions to produce the total nutrient export from the catchment. The export rates represent average annual values, as CMSS does not model processes such as rainfall runoff.

Large catchments may be divided into subcatchments and average annual TN and TP export estimated for each one. CMSS then routes the river flows and these nutrient loads through the river system and attenuates the nutrient loads in the process. For large catchments, the in-stream assimilation of nutrients needs to be included in the modelling to allow validation against nutrient loads calculated from observed data.

CMSS applications in the Blackwood and Scott catchments in Western Australia (WRC 2002) included in-stream assimilation. The CMSS exponential decay parameter was estimated from comparison between CMSS loads and loads calculated from observed flow and concentration data at various sites along the rivers. In most catchments little assimilation was observed, except for the loss of particulate phosphorus due to sedimentation. As phosphorus bound to soil particles may be re-mobilised in high flows, and there is little data from which to estimate in-stream attenuation in the Leschenault catchment, the assimilation component of CMSS has not been used in this study.

3.2 Diffuse land-use export rates

In this study the diffuse land-use export rates are based on the assumption that a portion of the applied fertiliser leaches to the waterways. Comparison between the observed loads in streams (calculated from flow and concentration data) and those estimated by CMSS was used to determine the portion of nutrient leached to the stream. The calculated annual TN and TP loads at the sites for which flow and nutrient data are collected concurrently are displayed in Appendix 2. The average annual TN and TP loads for these sites for the period 1998 to 2007 are displayed in Table 3.1.

DAFWA has surveyed agricultural properties in the Swan, Peel-Harvey, Leschenault and Geographe Bay catchments over recent years to determine nutrient inputs in terms of fertiliser, food and animals, and nutrient outputs (which are mainly produce). This work has been undertaken to determine ‘farm-gate’ surpluses and fertiliser-application rates for nitrogen and phosphorus for agricultural land uses (Neville et al. 2004). In 2006 the Department of Water carried out a similar survey of urban-residential land use to determine fertilisation inputs and practices, and to investigate nutrient contributions from other sources such as car washing and pet effluent. The median annual nitrogen and phosphorus fertilisation rates (including nitrogen fixation), thus derived for the Leschenault catchment modelling, are listed in Table 3.2.

Table 3.1 Average annual flow, TN and TP loads for the period 1998 to 2007

Site	Flow (ML)	TN load (tonnes)	TP load (tonnes)
612032	101,999	154	18
612039	54 354	116	14
612043	54 918	32	1.1
612013	82 244	40	0.34
612047	39 802	24[1]	1.2[1]
611004	75 553	74	2.3
611009*	20 560	24[2]	0.40[2]
611007	20 533	28	1.8
611111	8984	10	0.18[3]

** Also uses data from 6111046*

[1] Average (2001–2007)

[2] Average (2000–2007)

[3] Average (2002–2007)

As mentioned previously, the annual export rates used in CMSS were refined by comparing the nutrient loads calculated from observed flow and nutrient concentration data at the gauging stations with those deduced by CMSS. The average annual nitrogen export rates (kg/ha/yr) for diffuse land uses are (mostly) equivalent to 5 per cent leaching of the applied fertiliser to the waterways. Other authors (Kinhill 1995; Kelsey 2001) have deduced similar nitrogen leaching factors. However, for ‘recreation – grass’ and ‘urban residential’, the export rates were decreased slightly to match more closely the export rates applied to these land uses in other catchments. That is, the nitrogen export rate for ‘recreation – grass’ was decreased from 8.75 to 6 kg/ha/yr and the rate for ‘urban residential’ was decreased from 5.5 to 4 kg/ha/yr. The nitrogen export rate for ‘recreation/conservation’ was set to 0.01 kg/ha/yr even though there is no applied nutrient. This is to allow for nitrogen fixation by some native (mainly acacia) species.

The phosphorus export rates were derived in a similar manner, except that they depend on the soil’s PRI as well as the rates of phosphorus fertiliser application. For diffuse land uses with low (≤ 5) PRI soils, most of the phosphorus export rates (kg/ha/yr) were calculated using 7 per cent leaching of applied phosphorus; while for high PRI soils, 1 per cent leaching of applied phosphorus was assumed. The export rates for ‘recreation – grass’, ‘recreation – turf’ and ‘urban residential’ on low PRI soils were adjusted to about half of the given value (using the 7 per cent leaching assumption) to match more closely the export rates applied to these land uses in other catchments.

Land-use category	High risk soil (PRI<5)	Nitrogen fertiliser input rate (kg/ha/yr)	TN export rate (kg/ha/yr)	Phosphorus fertiliser input rate (kg/ha/yr)	TP export rate (kg/ha/yr)
Abattoir	No	0	0	0	0
	Yes	0	0	0	0
Annual horticulture	No	143	7.1	127	1.27
Aquaculture	No	1.3	0.065	0.1	0.001
Cattle for beef	No	72.0	3.60	9.7	0.10
	Yes	72.0	3.60	9.7	0.68
Cattle for dairy	No	161	8.07	24.7	0.25
	Yes	161	8.07	24.7	1.73
Commercial	No	0	0	0	0
	Yes	0	0	0	0
Community facility – non-education	No	54.8	2.74	13.1	0.13
	Yes	54.8	2.74	13.1	0.92
Dam	No	0	0	0	0
	Yes	0	0	0	0
Garden centre/nursery	No	28.7	1.44	5.3	0.05
Horses	No	70.1	3.51	13.2	0.13
	Yes	70.1	3.51	13.2	0.92
Lifestyle block/hobby farm	No	49.2	2.46	3.4	0.03
	Yes	49.2	2.46	3.4	0.24
Manufacturing/processing	No	0	0	0	0
	Yes	0	0	0	0
Pasture for hay	No	66.6	3.33	8.6	0.09
	Yes	66.6	3.33	8.6	0.60
Perennial horticulture – trees	No	9.4	0.47	5.4	0.05
	Yes	9.4	0.47	5.4	0.38
Piggery	No	722	36.1	163.0	1.63
	Yes	722	36.1	163.0	11.4
Quarry/extraction	No	0	0	0	0
	Yes	0	0	0	0
Recreation – grass	No	175	6	35.0	0.35
	Yes	175	6	35.0	1.1
Recreation – turf	No	350	17.5	70.0	0.7
	Yes	350	17.5	70.0	2
Recreation/conservation	No	1.6	0.01	0	0
	Yes	1.6	0.01	0	0
Rural residential/bush block	No	5	0.25	2.5	0.03
	Yes	5	0.25	2.5	0.18
Transport/access	No	0	0	2.5	0.03
	Yes	0	0	2.5	0.18
Tree plantation	No	12.6	0.63	8.2	0.08
	Yes	12.6	0.63	8.2	0.57
Turf farm	No	433	21.64	14.5	0.15
	Yes	433	21.64	14.5	1.02
Unused – cleared – grass	No	0	0	0	0
	Yes	0	0	0	0
Unused – uncleared – trees/shrubs	No	1.6	0.08	0	0
	Yes	1.6	0.08	0	0
Urban residential	No	110	4.00	26.2	0.26
	Yes	110	4.00	26.2	0.80
Utility	No	0	0	0	0
	Yes	0	0	0	0
Viticulture	No	23.5	1.18	25.4	0.25
	Yes	23.5	1.18	25.4	1.78
Waterbody	No	0	0	0	0
	Yes	0	0	0	0
Wetland	No	0	0	0	0
	Yes	0	0	0	0

Table 3.2 Nitrogen and phosphorus fertiliser application (input) rates (medians) and CMSS TN and TP export rates for the Leschenault catchment

Determining export rates for the urban land uses in the Leschenault catchment is problematic because there are no gauging stations downstream of the urban centres of Bunbury and Australind. Areas that receive no fertilisation (such as native forests) were assumed to export no phosphorus. Streams emanating from natural environments may contain measurable concentrations of phosphorus, but loads from these areas are generally insignificant compared with loads from fertilised land uses. The average annual TN and TP export rates used in the CMSS modelling are listed in Table 3.2.

As discussed previously, the average annual TN and TP exports estimated by CMSS were compared with the annual loads generated from observed flows and concentrations at the gauging stations listed in Table 3.1. The CMSS TP load was much less than the observed loads at sites 612039 and 612032 at the outlets of the Wellesley and Brunswick Middle catchments respectively. The CMSS model does not allow for the irrigation water supplied to the catchment. Possibly these irrigated subcatchments have land uses that are more intensive than elsewhere in the catchment, or the large amount of irrigation water imported to these subcatchments may mobilise greater amounts of phosphorus than in other areas. To better match estimated TP loads in the Wellesley and Brunswick Middle catchments, the TP export rates for these catchments and Brunswick Upper were doubled. The percentage leaching of applied fertiliser and point source emissions and the exceptional export rates are summarised in Table 3.3.

Table 3.3 Percentage leaching and exceptional export rates used in CMSS modelling

	TN		TP	
Land use	**High PRI soils (>5)**	**Low PRI soils (≤5)**	**High PRI soils (>5)**	**Low PRI soils (≤5)**
	Per cent leaching:			
Septic tanks	25%	50%	0%	25%
WWTPs	25%	50%	0%	25%
Diffuse land uses	5%	5%	1%[1]	7%[1]
Special rates:	CMSS export rates (kg/ha/yr):			
Recreation – grass	6	6		1.1[1]
Recreation – turf				2[1]
Urban residential	4	4		0.8[1]
Recreation/conservation	0.01	0.01		0

[1] For the Wellesley, Brunswick Middle and Brunswick Upper catchments the diffuse TP leaching factors and export rates were doubled

3.3 Point source export rates

The diffuse sources' leaching rates were deduced by comparing observed TN and TP loads in streams (calculated from concentration and flow data) with loads estimated by CMSS. The leaching rates were estimated to be about 5 per cent for nitrogen, and 7 per cent for phosphorus on low PRI soils and 1 per cent on high PRI soils. The phosphorus leaching rates for the Wellesley, Brunswick Middle and Brunswick Upper catchments were approximately double those of other catchments, either as a result of more intensive land uses or greater mobilisation of nutrients due to the irrigation inflows.

A similar methodology was used to estimate the amount of nutrient pollution from point sources, although it was impossible to carry out a 'calibration' procedure because the emissions from point sources are an order of magnitude less than the emissions from diffuse sources. For most point sources there is little opportunity for nutrients to be attenuated between the source and the receiving waterbody due to their high concentrations, short travel times and the disposal methods. In many cases effluent from point sources is discharged directly to streams (such as Brunswick WWTP to Elvira Gully) or infiltrated to groundwater (such as Kemerton WWTP and some of the abattoirs). Septic-tank effluent is generally discharged to the soil profile below the root zone of the surrounding vegetation. Studies of the Swan Coastal Plain by Whelan and Barrow (1984a, 1984b) and Whelan et al. (1981) revealed little attenuation of septic-tank effluent occurred between its source and the receiving waters; whether groundwater, an adjacent stream, estuary or ocean.

The only point sources included in this study are septic tanks and WWTPs. For nitrogen outflows from septic tanks and WWTPs, it is assumed that 25 per cent leaches to receiving waterways from high PRI soils and 50 per cent from low PRI soils. For phosphorus, it is assumed that no leaching occurs from high PRI soils, but 25 per cent from low PRI soils. High PRI soils have a great ability to immobilise phosphorus (Gerriste 1996). The reduced nitrogen-leaching factor in high PRI soils is attributed to the greater water-holding capacity and lower hydraulic conductivity of these soils. However, these leaching factors are 'best guesses' and may underestimate the pollution from these sources.

4 Catchment modelling results

The CMSS export rates were derived by comparing CMSS loads with average annual TN and TP loads for the period 1998 to 2007, calculated from flow and concentration data at gauging sites. Thus the TN and TP average annual loads and loads per unit area quoted in this study are the averages for the period 1998 to 2007. Annual load is highly dependent on annual rainfall and flow. In the period 1998 to 2007, 1999 and 2005 had the highest rainfall and 2001 and 2006 the lowest rainfall. For the sites where loads were calculated, annual TN and TP loads were between two and seven times greater in the high rainfall years compared with the low rainfall years (see Appendix 2). As an example, the TN and TP loads for site 612032 are plotted against annual flow in Figure 4.1. They are also shown as a time series in Figure 4.2.

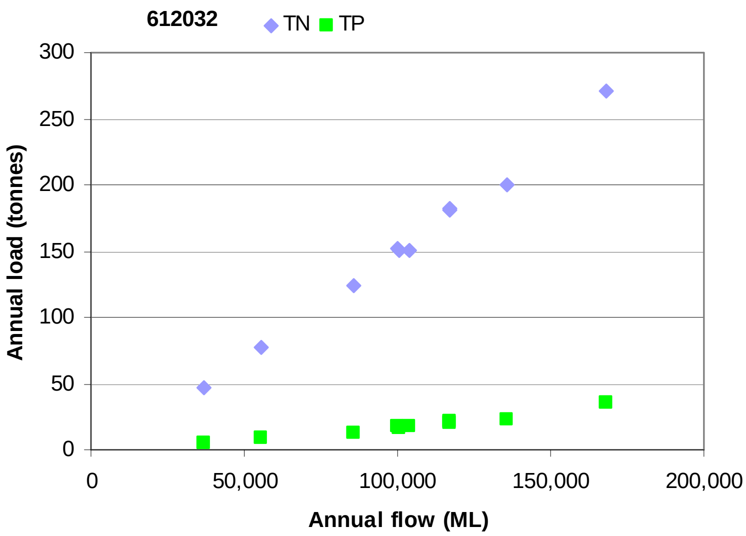


Figure 4.1 TN and TP loads as a function of flow for site 612032 (Brunswick River, Cross Farm) at the outlet of Brunswick Middle catchment.

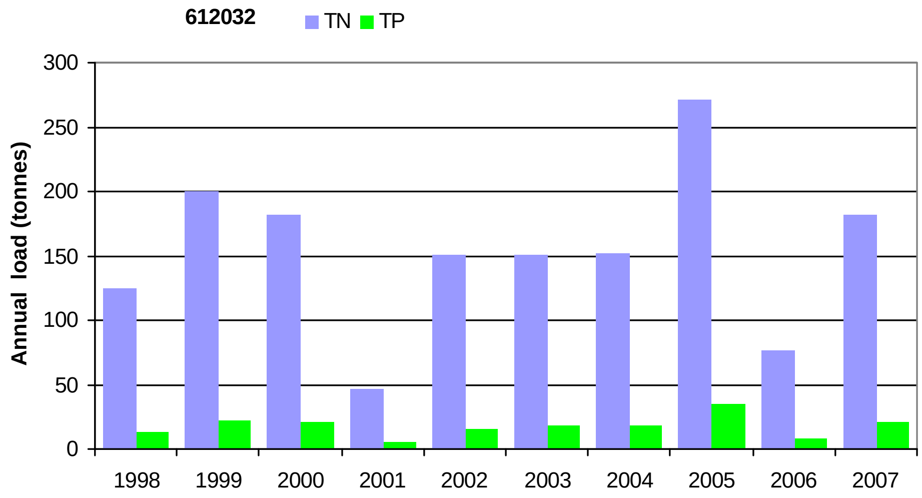


Figure 4.2 TN and TP loads for site 612032 (Brunswick River, Cross Farm) at the outlet of Brunswick Middle catchment.

4.1 Sources of nutrients

For reporting purposes the 30 diffuse land uses displayed in Table 2.1 have been grouped into the 12 categories listed in Table 4.1. The area of each of the land-use groups and their average annual TN and TP exports are listed in Table 4.2. These data are also displayed in Figure 4.3. Native vegetation constitutes 50 per cent of the catchment area but exports less than 1 per cent of nutrients to the waterways. The land use exporting the largest amounts of TN and TP to the waterways is ‘cattle for beef’, which is responsible for about 60 per cent of the TN and 48 per cent of the TP while occupying 31 per cent of the catchment area. ‘Cattle for dairy’ is much more intensive: exporting 19 per cent of the TN and 24 per cent of the TP from only 4 per cent of the catchment area. WWTPs and septic systems together contribute approximately 11 per cent of both TN and TP to the waterways. ‘Urban and public services’ contributes 3 per cent of the TN export and 4.2 per cent of the TP export from 2 per cent of the area, which is the second-most-polluting land use on a per area basis, after ‘cattle for dairy’. If all the urban contributions – namely ‘urban and public services’, ‘recreation’, WWTPs and septic tanks – are lumped together, then urban contributions are 15 per cent of TN and 17 per cent of TP. These contributions are from less than 2 per cent of the catchment area and are more intensive on a per area basis than dairying. ‘Horticulture, viticulture and plantation’ contribute 8 per cent of TP and about 3 per cent of TN.

Table 4.1 Land-use groups

Land use	Group
Cattle for beef Pasture for hay	Cattle for beef
Cattle for dairy	Cattle for dairy
Dam Waterbody Wetland	Water
Transport/access Utility	Tranport and utilities
Unused – cleared – grass	Vacant land
Recreation – grass Recreation – turf	Recreation
Recreation/conservation Unused – uncleared – trees/shrubs	Native vegetation
Manufacturing/processing Quarry/extraction	Industrial and mining
Horses Lifestyle block/hobby farm Rural residential/bush block	Lifestyle blocks
Abattoir Aquaculture Piggery	Intensive animal farming
Commercial Community facility – education Community facility – non-education Urban residential	Urban and public services
Annual horticulture Garden centre/nursery Perennial horticulture – trees Tree plantation Turf farm Viticulture	Horticulture, viticulture and plantation

Table 4.2 Area and average annual TN and TP exports for each land-use group

Group	Area		TN export		TP export	
	(ha)	%	(kg)	%	(kg)	%
Beef cattle	62 649	31	225 169	60	14 226	48
Cattle for dairy	8812	4	71 068	19	7230	24
Water	1715	1	0	0.0	0	0.0
Tranport and utilities	3436	2	0	0.0	262	0.9
Vacant land	4240	2	0	0.0	0	0.0
Recreation	414	0	3545	1.0	335	1.1
Native vegetation	101 281	50	1032	0.3	0	0.0
Industrial and mining	3117	2	0	0.0	0	0.0
Lifestyle blocks	4119	2	9902	2.7	520	1.7
Intensive animal farming	22	0	419	0.1	116	0.4
Urban and public services	3049	2	11 193	3.0	1259	4.2
Horticulture, viticulture and pla	9320	5	10 838	2.9	2376	8.0
WWTP			6913	1.9	655	2.2
Septic sytems			32 388	8.7	2781	9.3
Total	**202 173**	**100**	**372 464**	**100**	**29 760**	**100**

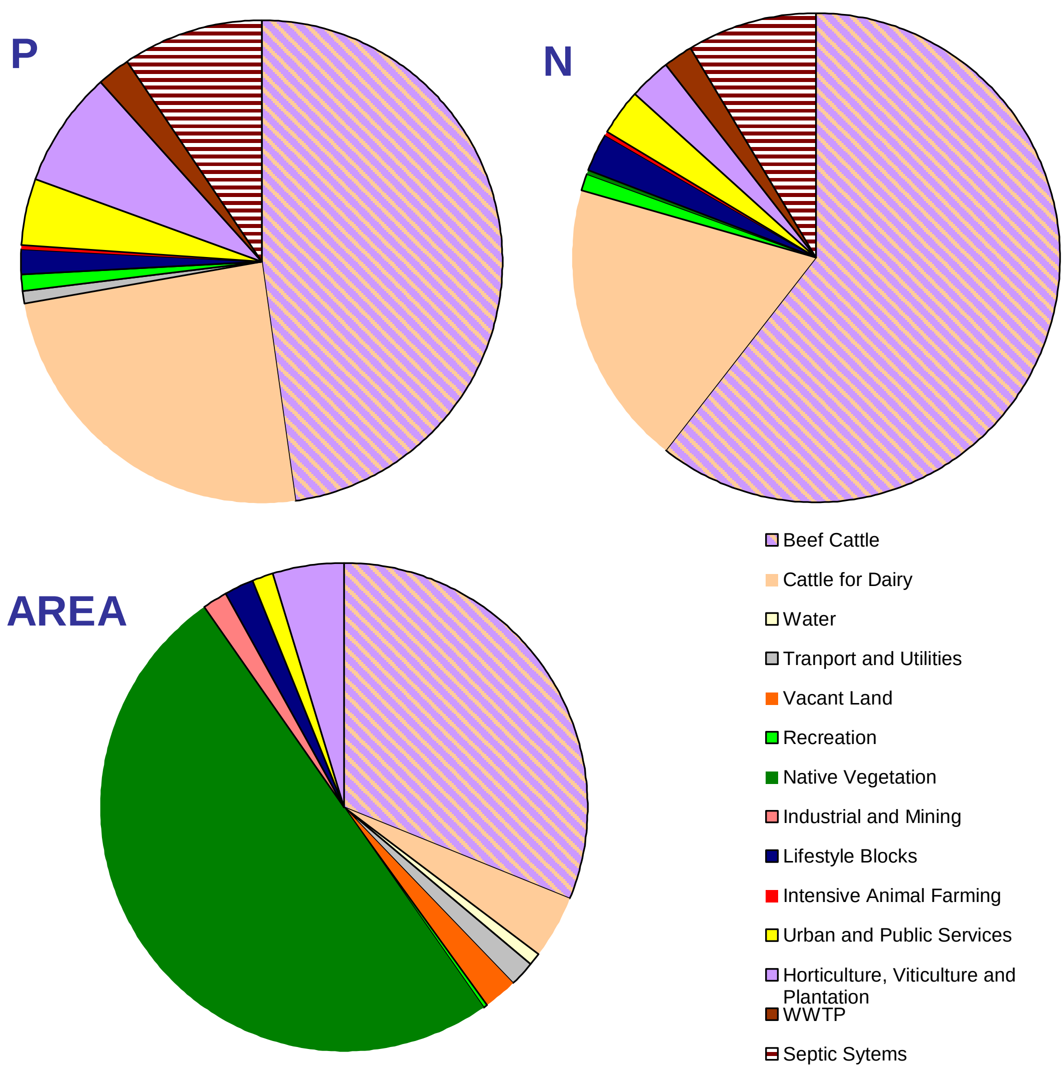


Figure 4.3 Areas, TN and TP exports for land-use groups

4.2 Nutrient loads from subcatchments

The catchment areas and estimated average annual TN and TP loads and loads per unit area for each of the subcatchments are listed in Table 4.3. The estimated average annual TN and TP loads to the Leschenault Estuary are approximately 359 and 29 tonnes respectively. The coastal catchments also emit 14 tonnes of TN and 1.4 tonnes of TP. The Wellesley catchment contributes the largest amounts of TN and TP even though it is only the fourth-largest catchment. In terms of TN export per unit area, the Wellesley catchment is surpassed by the catchments of Brunswick Lower, Collie Lower 1, Coast and Estuary which have relatively large areas of urban land uses. For TP export only the Brunswick Lower catchment has a greater load per unit area than the Wellesley. The urban and cattle-raising land uses are generally associated with excessive nitrogen pollution.

Table 4.3 Average annual TN and TP loads and loads per unit area from the Leschenault subcatchments estimated using the CMSS model

Catchment	Area (ha)	TN load (tonnes)	TN load per unit area (kg/ha)	TP load (tonnes)	TP load per unit area (kg/ha)
Brunswick Lower	1884	8	4.14	1.1	0.57
Brunswick Middle	9120	23	2.54	3.5	0.39
Brunswick Upper	20 899	12	0.55	0.8	0.04
Wellesley	20 834	72	3.43	8.1	0.39
Collie Lower 1	10 444	40	3.82	3.5	0.33
Collie Lower 2	14 667	14	0.93	0.5	0.03
Henty	4120	7	1.66	0.2	0.06
Ferguson	14 483	28	1.90	1.1	0.08
Preston Lower	14 845	37	2.49	4.1	0.28
Preston Middle	39 442	58	1.48	1.8	0.05
Preston Upper	31 136	27	0.88	0.9	0.03
Thomson	10 204	10	0.95	0.3	0.03
Coast	3590	14	3.77	1.4	0.39
Estuary	6503	25	3.79	2.4	0.37
Total	**202 173**	**372**	**1.84**	**30**	**0.15**

Figure 4.4 and Figure 4.5 display the average annual loads and loads per unit area for each subcatchment for TN and TP respectively. Figure 4.6 and Figure 4.7, which display the loads per unit area spatially, highlight the intensive land uses on the coastal plain adjacent to the inlet and ocean, as well as the Wellesley subcatchment. From this mapping it is clear that the worst water quality in the catchment is in the Wellesley, Brunswick and Lower Collie rivers and the coastal and inlet drains. This is confirmed by the concentration status for both TN and TP from the Department of Water monitoring sites – displayed in Figure 4.6 and Figure 4.7 respectively. The status classifications for the monitoring data are given in Figure 4.8.

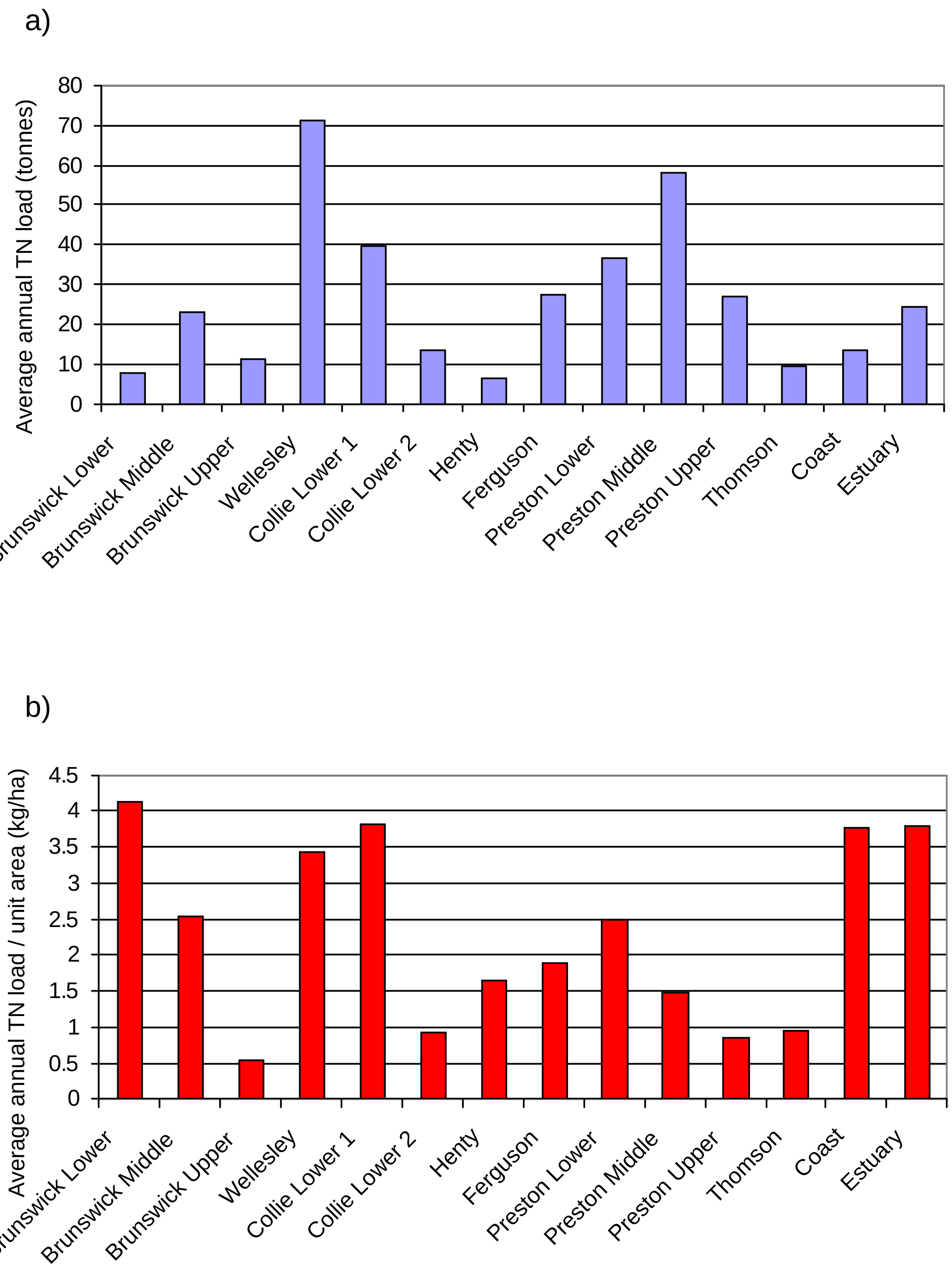


Figure 4.4 Average annual a) TN load (tonnes) and b) TN load per unit area (kg/ha) for the subcatchments of the Leschenault Estuary

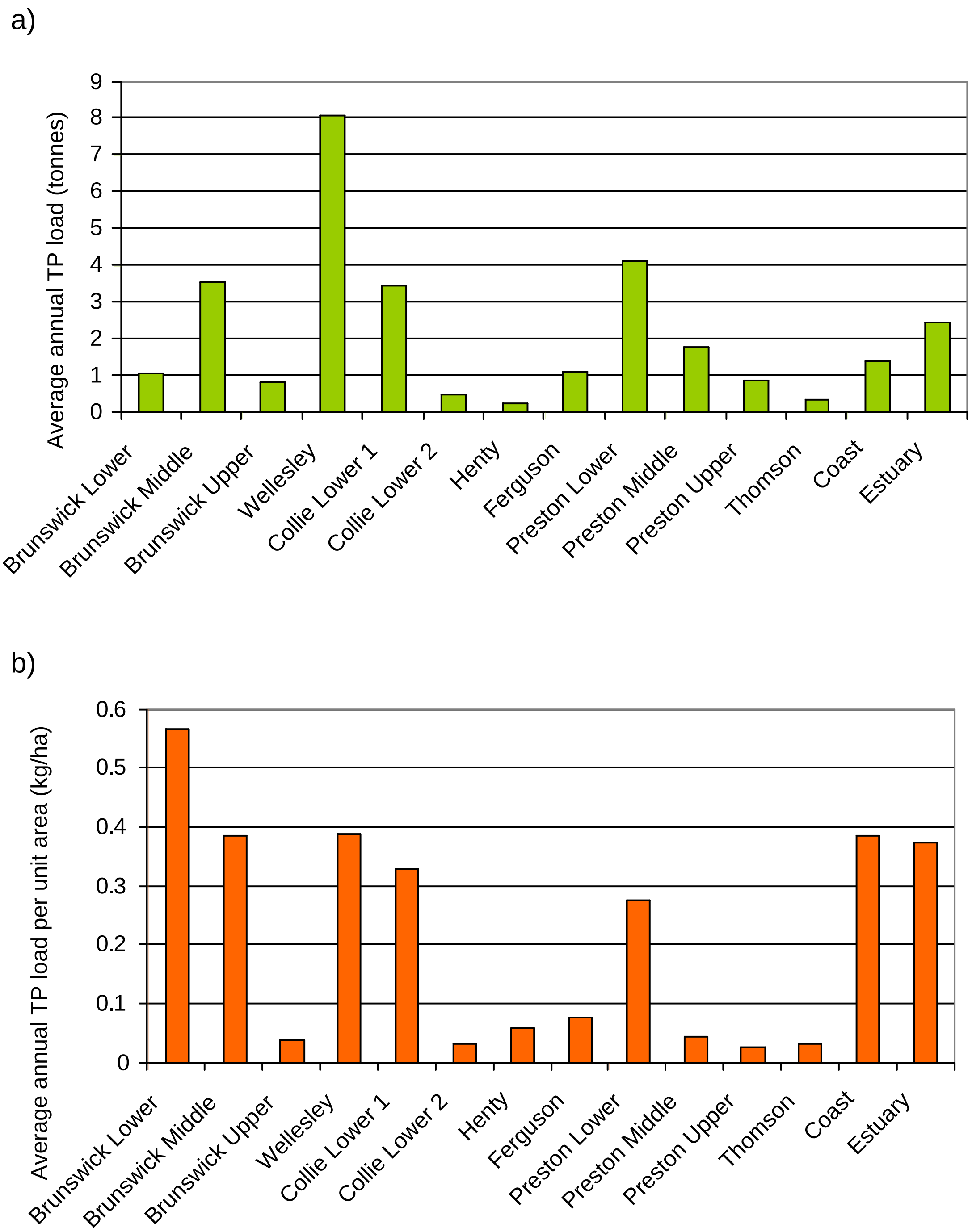


Figure 4.5 Average annual a) TP load (tonnes) and b) TP load per unit area (kg/ha) for the subcatchments of the Leschenault Estuary

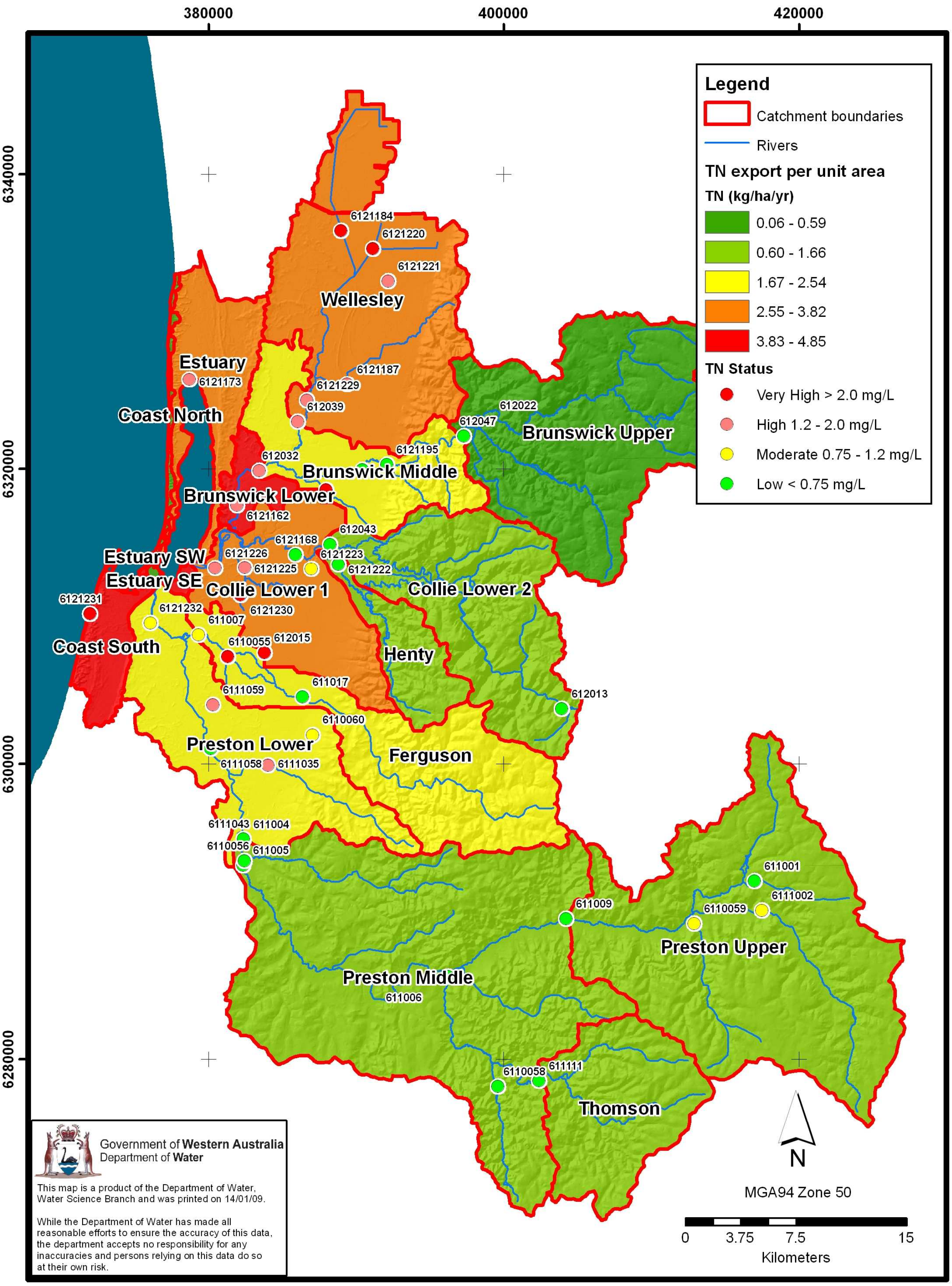


Figure 4.6 Average annual TN load per catchment area

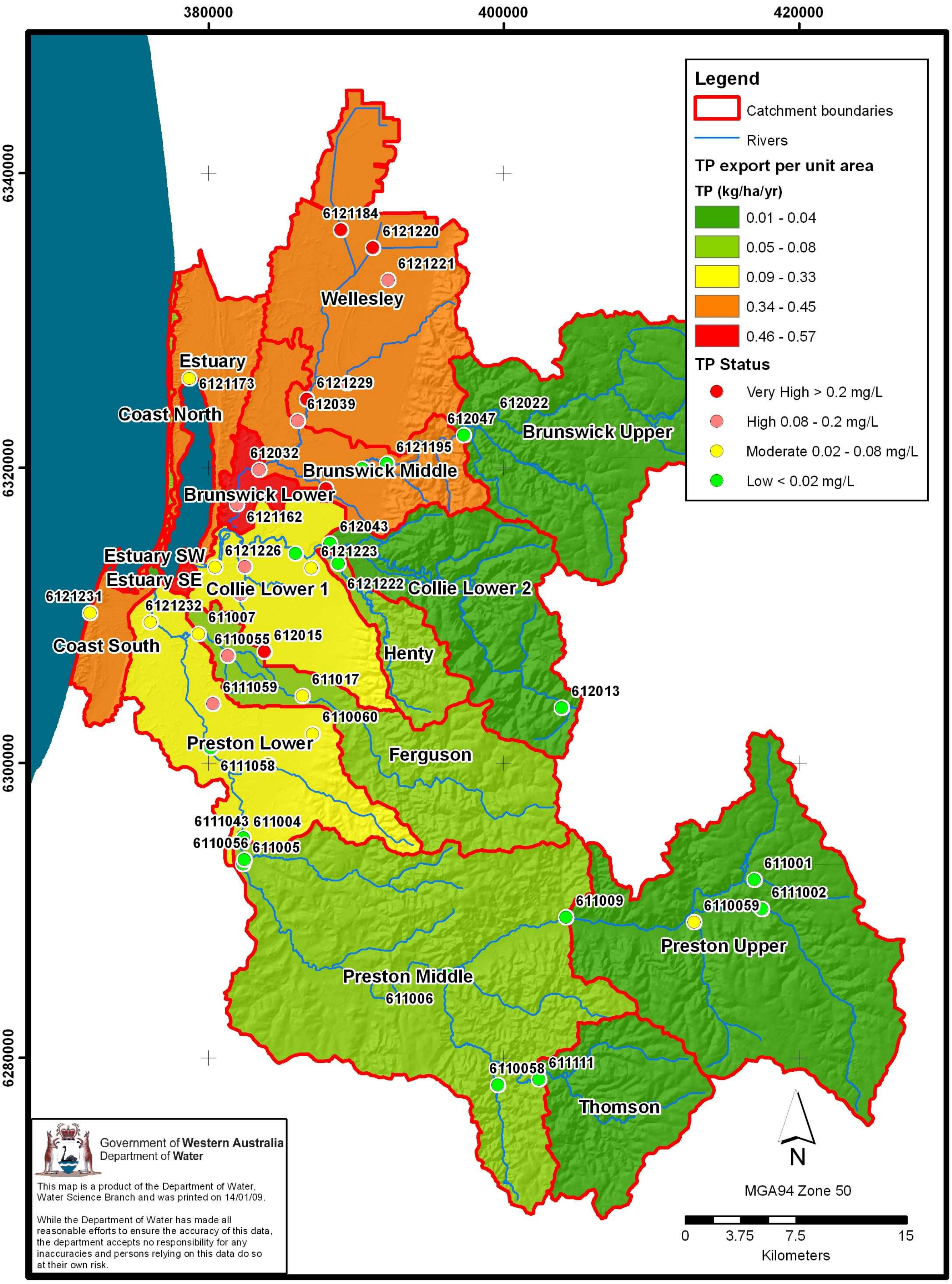


Figure 4.7 Average annual TP load per catchment area

TN	Status	TP
>2.0 mg/L	Very High	>0.2 mg/L
1.2–2.0 mg/L	High	0.08–0.2 mg/L
0.75–1.2 mg/L	Moderate	0.02–0.08 mg/L
<0.75 mg/L	Low	<0.02 mg/L

Figure 4.8 Status classification for three-year median TN and TP concentrations

5 Scenario modelling

The scenarios modelled in this study are listed in Table 5.1. They can be grouped into four categories for use in the following discussions:

- removal of septic tanks and WWTPs
- fertiliser management
- soil amendment
- intensification of dairies, horticulture and viticulture.

There are several other scenarios of interest to the Leschenault Catchment Council, but they have not been included in this study either because of time constraints or the CMSS model's limitations. These factors are discussed in Section 7 and will be included in the catchment modelling undertaken in 2009.

Table 5.1 Scenarios modelled by CMSS for the Leschenault catchment

Scenarios	Implemenatation
Septic tank management	Remove all septic tanks
WWTP management	Remove all WWTP effluent from catchment
Fertiliser Action Plan implementation	30% reduction in P leaching on Swan Coastal Plain
Fertiliser reduction	50% reduction of N fertilisation in urban, rural and urban + rural
Soil amendment	Increase soil PRI
Changes in land use	Intensification of dairies, horticulture and viticulture

CMSS models the potential impacts on TN and TP export to the waterways for the various scenarios. The practicalities and costs of land-use and management changes have not been included in this analysis.

5.1 Removal of septic tanks and WWTPs

There are five WWTPs in the Leschenault catchment, as shown in Figure 2.7 and Table 2.3, with an estimated total average annual nutrient output of 15 tonnes of TN and 3.1 tonnes of TP. There are septic tanks in all subcatchments, but the greatest concentrations are at Australind in the Estuary catchment and Bunbury in Coast South (Figure 2.7). The estimated annual loads from septic tanks are 74 tonnes of TN and 15 tonnes of TP (Table 2.5). The assumptions behind the CMSS leaching rates for effluent from septic tanks and WWTPs to receiving waterways were discussed in Section 3.

The effect of removing WWTPs and septics is displayed in Table 5.2 and Figure 5.1. Removing the WWTPs causes little change except in the Estuary subcatchment, where the Kemerton WWTP contributes about one-quarter of the TN and one-fifth of the TP load. Considering the whole catchment, the removal of the WWTPs decreases the TN load from 372 to 366 tonnes (2 per cent) and the TP load from 30 to 29 tonnes (2 per cent).

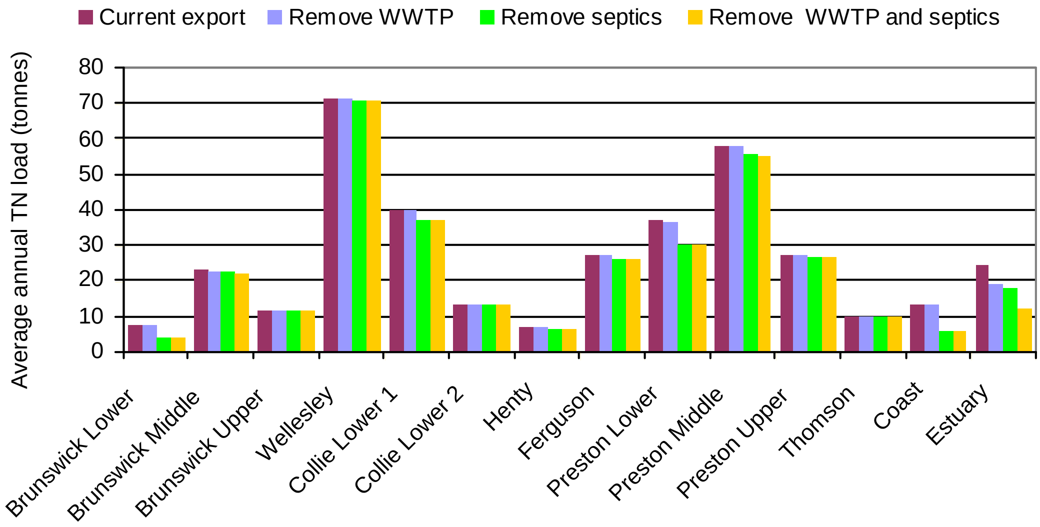
Removal of septic tanks for the whole catchment reduces the TN load from 372 to 340 tonnes (9 per cent) and the TP load from 30 to 27 tonnes (9 per cent) – provided the increased WWTP loads are disposed of appropriately. Removal of both WWTPs and septic tanks reduces the TN load to 333 tonnes (11 per cent reduction) and the TP load to 26 tonnes (12 per cent reduction). However, the removal of septic tanks and WWTPs has a large impact in the Coast and Estuary catchments (which include Bunbury and Australind) with TN loads decreasing by about 55 and 50 per cent and TP loads by 53 and 44 per cent respectively. The impact of the removal of septics can also be seen in the Brunswick Lower (TN decrease of 45 per cent; TP decrease of 33 per cent) and Preston Lower catchments (TN and TP decreases of 18 per cent), both of which also have large areas of residential land use.

Catchment	TN catchment loads						
	Current export	Remove WWTP		Remove septics		Remove WWTP and septics	
	(tonnes)	(tonnes)	% reduction	(tonnes)	% reduction	(tonnes)	% reduction
Brunswick Lower	8	8	0	4	45	4	45
Brunswick Middle	23	23	3	23	2	22	5
Brunswick Upper	12	12	0	12	0	12	0
Wellesley	72	72	0	71	1	71	1
Collie Lower 1	40	40	0	37	7	37	7
Collie Lower 2	14	14	0	13	1	13	1
Henty	7	7	0	7	1	7	1
Ferguson	28	28	0	26	4	26	4
Preston Lower	37	37	1	30	18	30	18
Preston Middle	58	58	1	56	5	55	5
Preston Upper	27	27	0	27	2	27	2
Thomson	10	10	0	10	0	10	0
Coast	14	14	0	6	55	6	55
Estuary	25	19	22	18	27	12	50
Total	**372**	**366**	**1.9**	**340**	**9**	**333**	**11**

Catchment	TP catchment loads						
	Current export	Remove WWTP		Remove septics		Remove WWTP and septics	
	(tonnes)	(tonnes)	% reduction	(tonnes)	% reduction	(tonnes)	% reduction
Brunswick Lower	1.1	1.1	0	0.7	33	0.7	33
Brunswick Middle	3.5	3.4	4	3.5	1	3.3	5
Brunswick Upper	0.8	0.8	0	0.8	0	0.8	0
Wellesley	8.1	8.1	0	8.0	1	8.0	1
Collie Lower 1	3.5	3.5	0	3.2	8	3.2	8
Collie Lower 2	0.5	0.5	4	0.5	0	0.5	4
Henty	0.2	0.2	0	0.2	0	0.2	0
Ferguson	1.1	1.1	0	1.1	0	1.1	0
Preston Lower	4.1	4.0	2	3.5	16	3.4	18
Preston Middle	1.8	1.8	0	1.8	0	1.8	0
Preston Upper	0.9	0.9	0	0.9	0	0.9	0
Thomson	0.3	0.3	0	0.3	0	0.3	0
Coast	1.4	1.4	0	0.6	53	0.6	53
Estuary	2.4	2.0	16	1.8	28	1.4	44
Total	**30**	**29**	**2.2**	**27**	**9**	**26**	**12**

Table 5.2 Current and predicted TN and TP loads in the Leschenault catchment, with and without WWTPs and septic tanks

a)



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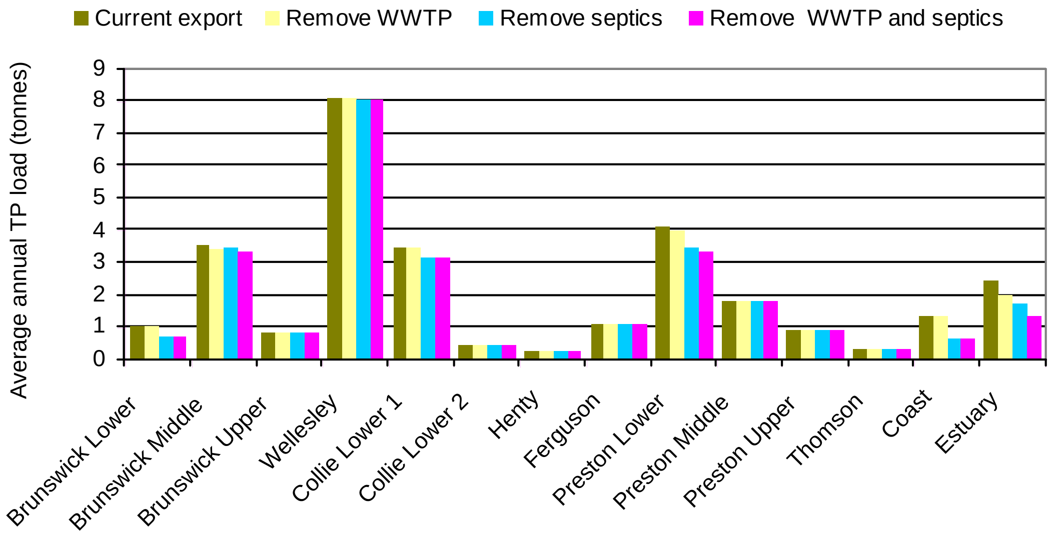

Figure 5.1 The predicted changes in a) average annual TN and b) average annual TP load due to the removal of WWTPs and septic tanks from the Leschenault catchment

5.2 Fertiliser management

For phosphorus, the impact of changes in fertilisation practices that are expected following implementation of the *Fertiliser action plan* (JGFWP 2007) are modelled. For nitrogen, a 50 per cent reduction in the fertiliser application rate was modelled. This percentage reduction was selected to demonstrate possible gains as a result of nitrogen fertiliser management.

5.2.1 Implementation of the *Fertiliser action plan*

The *Fertiliser action plan* has been invoked to reduce leaching of phosphorus from fertilisers to waterways. The plan aims to phase out the use of highly water-soluble phosphorus fertilisers on the low PRI soils of the coastal plain (McPharlin et al. 1990). The water-soluble phosphorus fertilisers (80 to 100 per cent soluble) will be replaced by fertilisers with low water solubility (40 per cent or less), such as Lime Reverted Super or 'Red Mud' coated superphosphate. The plan's implementation zone includes the Scott Coastal Plain and the Swan Coastal Plain from the Leeuwin-Naturaliste Ridge at Dunsborough to the Moore River catchment boundary in the north. In the Leschenault catchment this includes the subcatchments of Coastal, Estuary, Wellesley, Brunswick Middle, Collie Lower 1 and Preston Lower. Requests for continued use of highly water-soluble phosphorus fertilisers will be determined through a consultation process; and will need to be accompanied by a nutrient management plan that demonstrates low environmental risk from phosphorus application and loss, and that no low water-soluble fertiliser is an acceptable replacement. Although the details of the *Fertiliser action plan* are still to be finalised, it is proposed that fertiliser management will occur through the Fertiliser Industry Federation of Australia's *Fertcare* program. The *Fertcare* program will also provide guidance on nitrogen fertilisation.

The *Fertiliser action plan* will mandate maximum highly water-soluble phosphorus content of non-bulk (bagged) fertilisers for urban use to be 1 per cent for lawn fertilisers and 2.5 per cent for general garden fertilisers. These will be the only changes that result from the plan in urban areas.

In 2006 the Department of Water's Water Science branch surveyed nutrient application in urban areas. Nutrient application rates for urban areas with different locations, ages and densities were derived from the data supplied by the approximately 12 000 respondents. The median phosphorus fertiliser application rate in urban residential areas is 20 kg/ha/year. If the phosphorus content of bagged fertilisers is reduced to 1 per cent for lawn fertilisers and 2.5 per cent for garden fertilisers, and gardeners apply the same products (with the reduced phosphorus content) in the same quantities (mass) as previously, the median phosphorus fertiliser application rate will reduce by about 30 per cent.

An unexpected result of the urban nutrient survey was the large amount of organic fertiliser being applied. The *Fertiliser action plan*, as it stands, has no influence on the use of organic fertilisers in urban areas.

DAFWA has been the lead agency for this initiative and its research indicates that the phosphorus fertilisation requirement will decrease by approximately 30 per cent. Furthermore, plant uptake will increase by about 10 per cent (Summers et al. 2000) because the fertiliser will reside in the soil profile for longer due to its reduced solubility (Summers 2008, pers. comm.). DAFWA estimates the impact of this initiative will be a 30 per cent reduction in phosphorus leaching on a catchment scale.

CMSS models implementation of the *Fertiliser action plan* as a 30 per cent reduction in phosphorus leaching in the coastal plain catchments of Coastal, Estuary, Wellesley, Brunswick Middle, Collie Lower 1 and Preston Lower from both low and high PRI soils. The plan's impact is modelled in three ways:

1) Implementation in urban areas.
2) Implementation in rural areas.
3) Implementation in rural and urban areas.

Table 5.3 and Figure 5.2 display the results of the *Fertiliser action plan*'s implementation. In the rural areas, the plan's implementation will reduce TP export by about 18 per cent; whereas in urban areas, total TP export will decrease by about 2 per cent. In some catchments the percentage reductions from the plan's implementation in urban areas are greater, depending on the percentage of urban land use. For instance the expected reduction in phosphorus export from the Coastal catchment is 10 per cent after the plan's implementation in urban areas. The catchment with the greatest potential reduction in phosphorus export following the plan's implementation is the Wellesley (30 per cent).

On a whole-of-catchment basis, implementation of the *Fertiliser action plan* has the potential to decrease the phosphorus export to the waterways by 20 per cent. This is particularly significant because the phosphorus fertilisation changes have only been made in 32 per cent of the catchment (five subcatchments; 65 337 ha). Clearly the *Fertiliser action plan* has a role to play in reducing fertiliser leaching to the catchment's waterways.

Table 5.3 Application of Fertiliser action plan in the Leschenault catchment a) in rural areas only, b) in urban areas only, and c) in both rural and urban areas

Catchment	TP export (tonnes)						
	Current	a) rural		b) urban		c) rural + urban	
	export	Export	% Reduction	Export	% Reduction	Export	% Reduction
Brunswick Lower	1.1	0.9	12	1.0	6	0.9	19
Brunswick Middle	3.5	2.6	28	3.5	0	2.5	28
Brunswick Upper	0.8	0.8	0	0.8	0	0.8	0
Wellesley	8.1	5.7	30	8.1	0	5.7	30
Collie Lower 1	3.5	2.6	26	3.4	2	2.5	27
Collie Lower 2	0.5	0.5	0	0.5	0	0.5	0
Henty	0.2	0.2	0	0.2	0	0.2	0
Ferguson	1.1	1.1	0	1.1	0	1.1	0
Preston Lower	4.1	3.3	21	4.0	2	3.2	23
Preston Middle	1.8	1.8	0	1.8	0	1.8	0
Preston Upper	0.9	0.9	0	0.9	0	0.9	0
Thomson	0.3	0.3	0	0.3	0	0.3	0
Coast	1.4	1.3	3	1.3	10	1.2	13
Estuary	2.4	2.3	4	2.3	4	2.2	7
Total	**30**	**24**	**18**	**29**	**2**	**24**	**20**

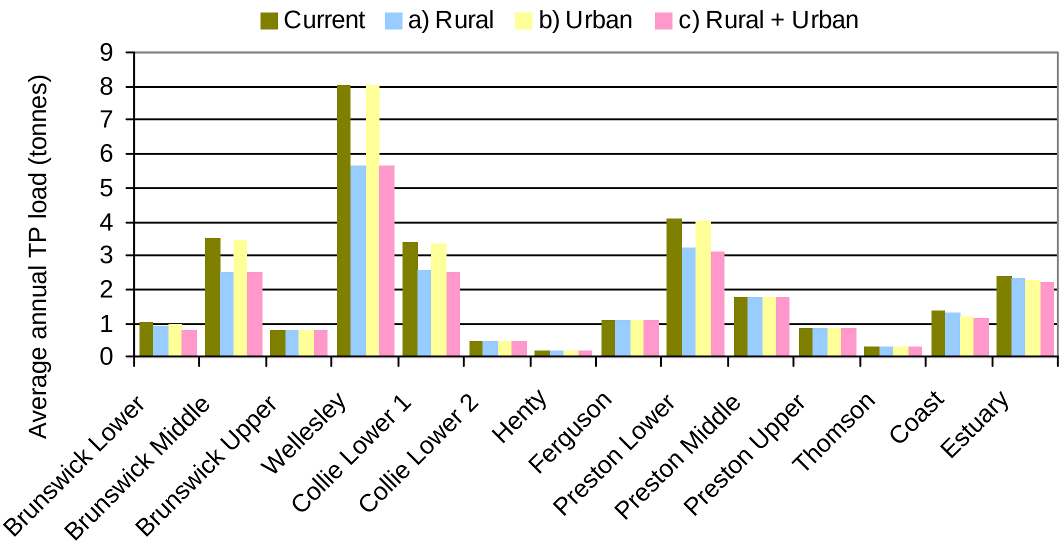

Figure 5.2 Implementation of the Fertiliser action plan in a) rural only, b) urban only, and c) in both rural and urban

5.2.2 Reduction in nitrogen fertiliser application

This scenario has been invoked to determine the possible impact of controlling nitrogen fertiliser application rates. Implementation involves a 50 per cent reduction in nitrogen fertilisation in all areas of the catchment. However, some rural land uses, such as dairy and beef cattle, have large nitrogen inputs from fixation by leguminous pasture. Nitrogen input from fertilisation is a small proportion of inputs in these land uses. Some research has also demonstrated that leguminous pasture compensates for insufficient fertilisation by increasing fixation. Thus decreased nitrogen fertilisation will not necessarily proportionally decrease nitrogen leaching from pastures. Table 5.4 contains the land uses affected by nitrogen fertilisation reductions, and the percentage of their nitrogen inputs that comes from applied fertiliser. Table 5.5 and Figure 5.3 display the expected changes in nitrogen export.

On a whole-of-catchment basis, a 50 per cent reduction in nitrogen fertiliser application to rural areas reduces the TN export to the estuary and ocean by 6 per cent, from 372 tonnes to 350 tonnes. This small reduction is a result of the large areas of beef and dairy cattle farming in the catchment and the large proportion of their nitrogen inputs that is from fixation. This highlights the difficulty in tackling nitrogen pollution ‘at source’ in rural land uses.

A 50 per cent reduction in nitrogen fertiliser application in urban areas reduces the total catchment export by 2 per cent. This is a reflection of the fact that urban land uses only occupy 2 per cent of the catchment. The percentage reductions in TN export from the catchments with the greatest areas of urban land use – Brunswick Lower, Coast and Estuary – are 9, 18 and 6 per cent respectively.

Table 5.4 Land uses affected by nitrogen fertiliser reductions

Land use	Percentage of N input from fertilisation
Urban land use:	
Urban residential	100
Commercial	100
Community facility – educatio	100
Community facility – non-educ	100
Recreation – turf	100
Recreation – grass	100
Rural land use:	100
Horses	2
Lifestyle block/hobby farm	2
Pasture for hay	20
Cattle for dairy	31
Cattle for beef	4.5
Turf farm	100
Viticulture	100
Tree plantation	100
Perennial horticulture – trees	100
Garden centre/nursery	100
Annual horticulture	100

Table 5.5 Impact of 50 per cent reduction in nitrogen fertiliser application in a) rural only, b) urban only, and c) in both rural and urban

Catchment	TN export (tonnes)						
	Current export	a) rural		b) urban		c) rural + urban	
		Export	% Change	Export	% Change	Export	% Change
Brunswick Lower	7.8	7.6	2	7.1	9	6.9	11
Brunswick Middle	23.2	21.6	7	23.0	1	21.5	7
Brunswick Upper	11.6	10.7	8	11.6	0	10.7	8
Wellesley	71.5	65.2	9	71.5	0	65.2	9
Collie Lower 1	39.9	37.3	7	39.3	1	36.8	8
Collie Lower 2	13.6	13.0	4	13.5	0	12.9	5
Henty	6.8	6.5	4	6.8	0	6.5	4
Ferguson	27.6	25.7	7	27.5	0	25.7	7
Preston Lower	37.0	35.7	3	36.0	3	34.7	6
Preston Middle	58.3	55.8	4	57.6	1	55.3	5
Preston Upper	27.3	25.9	5	27.2	0	25.9	5
Thomson	9.7	9.1	6	9.7	0	9.1	6
Coast	13.5	13.5	0	11.0	18	11.0	19
Estuary	24.7	22.0	11	23.1	6	20.9	15
Total	**372**	**350**	**6**	**365**	**2**	**343**	**8**

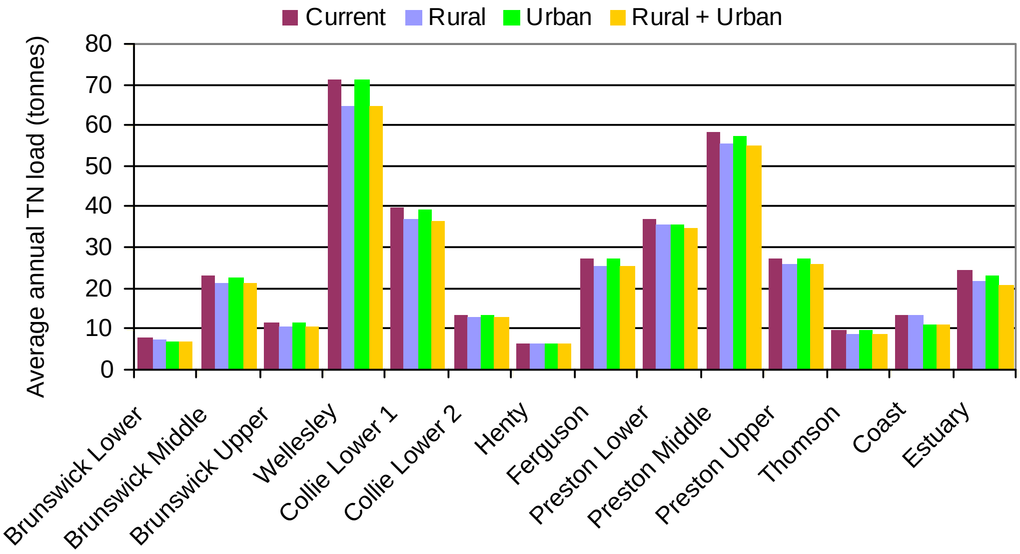

Figure 5.3 Application of 50 per cent nitrogen fertiliser reduction in a) rural only, b) urban only, and c) in both rural and urban

5.3 Soil amendment

This scenario looks at the decreases in phosphorus export that might be achieved by applying soil amendment to low PRI (<5) soils. Soil amendment is only applied to the agricultural land uses that are listed in Table 5.6, as it would be impossible to implement this strategy in established urban areas. Two levels of implementation are modelled: amendment of all low PRI soils, and amendment of half the low PRI soils. The underlying assumption of this action is that the amended soils behave in the same manner as the high PRI soils.

Laboratory and field trials of soil amendment have also indicated an associated increase in the water-holding capacity of soils, a decrease in the fertilisation requirement and an increase in plant productivity. These added benefits have not been modelled, but it should be noted that soil amendment may also decrease the nitrogen export when applied to poor sandy soils (Summers 1999).

Table 5.6 Agricultural land uses on which soil amendment is applied

Land use
Annual horticulture
Cattle for beef
Cattle for dairy
Garden centre/nursery
Horses
Pasture for hay
Perennial horticulture – trees
Piggery
Tree plantation
Turf farm
Viticulture

Table 5.7 and Figure 5.4 display the results of applying soil amendment. Application on all the low PRI soils in the catchment reduces the TP load to the estuary and coast from 30 to 18 tonnes, a decrease of about 40 per cent; while application to half the low PRI soils reduces the TP load by about 20 per cent. The catchments most affected by this management action would be Brunswick Middle, Wellesley, Collie Lower 1 and Preston Lower, where application of soil amendment to half the low PRI soils has the potential to reduce the phosphorus export from these catchments by 24 to 29 per cent. Clearly this is a management action that should be considered in strategic locations.

Table 5.7 Changes in TP export due to application of soil amendment

Catchment	TP export (tonnes)				
	Current export	Amend all low PRI soils	% Reduction	Amend half of low PRI soils	% Reduction
Brunswick Lower	1.1	0.66	39	0.86	19
Brunswick Middle	3.5	1.50	58	2.52	29
Brunswick Upper	0.8	0.82	0	0.82	0
Wellesley	8.1	4.18	48	6.13	24
Collie Lower 1	3.5	1.47	57	2.46	29
Collie Lower 2	0.5	0.43	13	0.46	7
Henty	0.2	0.21	14	0.22	7
Ferguson	1.1	0.80	27	0.95	14
Preston Lower	4.1	1.77	57	2.95	29
Preston Middle	1.8	1.74	3	1.77	2
Preston Upper	0.9	0.89	0	0.89	0
Thomson	0.3	0.34	0	0.34	0
Coast	1.4	1.22	12	1.30	6
Estuary	2.4	2.25	7	2.34	4
Total	**30**	**18**	**39**	**24**	**19**

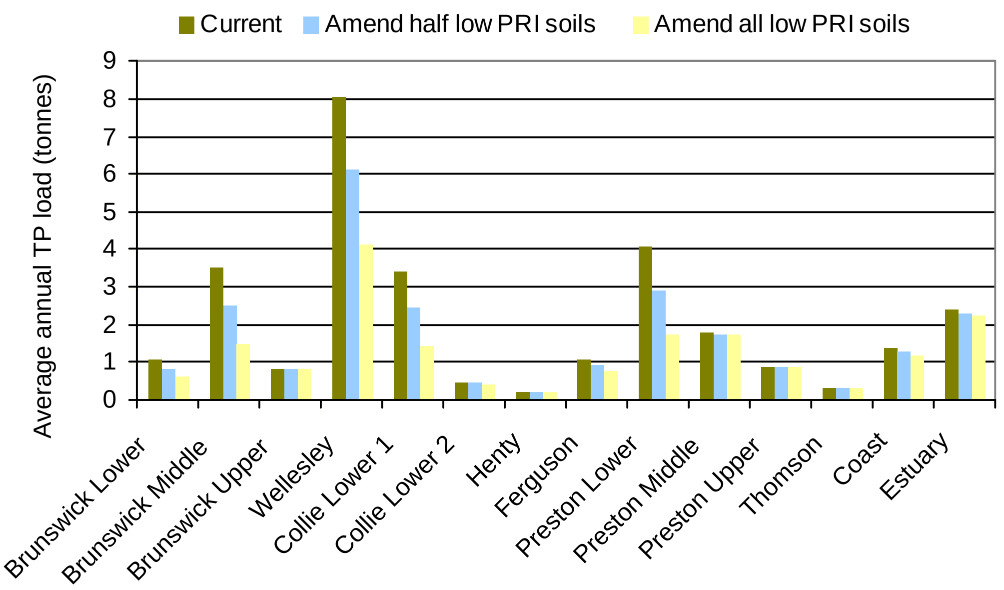

Figure 5.4 Changes in TP export due to application of soil amendment to low PRI soils

5.4 Intensification of dairies, horticulture and viticulture

In this scenario it was assumed that land uses did not change, but that areas designated as ‘cattle for dairy’, ‘horticulture’ and ‘viticulture’ intensified their practices by 50 per cent. (In the case of ‘cattle for dairy’, this means that nitrogen fixation was also increased.) Thus, the annual TN and TP export rates were multiplied by 1.5. Table 5.8 and Figure 5.5 display the expected changes in average annual nutrient exports for each of the subcatchments.

Table 5.8 Estimated average annual TN and TP export for each catchment following intensification of dairying, horticulture and viticulture land uses

Catchment	TN export (tonnes)			TP export (tonnes)		
	Current	Intensified land uses	% increase	Current	Intensified land uses	% increase
Brunswick Lower	8	8	5	1.1	1.1	7
Brunswick Middle	23	27	15	3.5	4.2	18
Brunswick Upper	12	13	8	0.8	0.9	7
Wellesley	72	89	25	8.1	10.1	25
Collie Lower 1	40	46	16	3.5	4.0	15
Collie Lower 2	14	14	3	0.5	0.5	4
Henty	7	7	5	0.2	0.3	9
Ferguson	28	32	14	1.1	1.2	13
Preston Lower	37	39	6	4.1	4.3	4
Preston Middle	58	59	0.8	1.8	1.9	5
Preston Upper	27	27	0.5	0.9	0.9	3
Thomson	10	10	0.4	0.3	0.4	2
Coast	14	14	0	1.4	1.4	0
Estuary	25	27	8	2.4	2.8	15
Total	**372**	**411**	**10**	**30**	**34**	**14**

The intensification of dairy farming, horticulture and viticulture increases the annual TN export to the waterways by 10 per cent, from 372 to 411 tonnes. The greatest change occurs in the Wellesley catchment, which increases its nitrogen export by 25 per cent. This is because of the large areas of dairy farming in this catchment (21 per cent of the catchment). The Brunswick Middle, Collie Lower 1 and Ferguson catchments display increases in TN export of 15, 16 and 14 per cent respectively, also mainly due to the large areas of dairy farming in these catchments. The catchments close to the estuary, with the exception of Estuary, display little change in their nitrogen exports due to the small areas of dairy farming, horticulture and viticulture within them. The increases in Estuary are due to the intensification of the horticultural region to the north of the estuary (568 ha), which drains to the estuary through Parkfield Drain.

The average annual TP export to the waterways increases by 14 per cent, from 30 to 34 tonnes. The increases in phosphorus export mirror those for nitrogen, with the exception of catchments with low PRI soils where the percentage increases are greater. This is most apparent in the Estuary catchment, where the increase in TP export is 15 per cent compared with an 8 per cent increase for TN export.

All increases in nutrient loads from the Wellesley catchment are of concern because of the current poor water quality emanating from this catchment. Site 612039 (Wellesley River, Juegenup) has 'high' status for both TN and TP median concentrations. The Brunswick and Lower Collie catchments also have poor water quality in their lower reaches, as shown in Figure 4.6 and Figure 4.7. The Ferguson River (611007) currently has moderate status for both TN and TP and intensified land use would have an adverse impact. The Parkfield Drain currently has 'high' TN status and 'moderate' TP status; intensification of horticulture would most likely cause the TN and TP status for this drain to change to 'very high' and 'high' respectively.

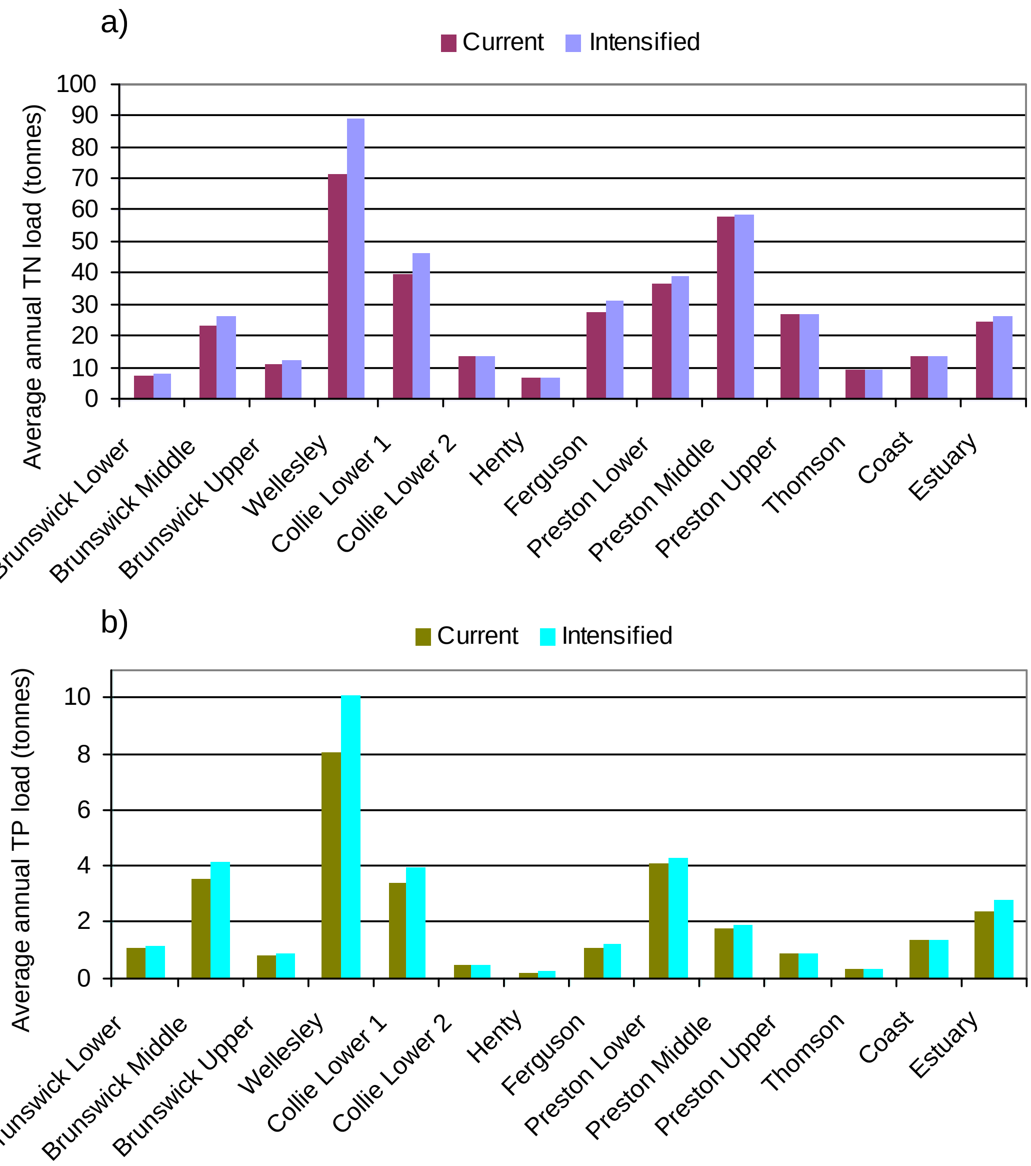

Figure 5.5 Changes in average annual a) TN and b) TP export due to intensification of dairy farming, horticulture and viticulture

6 Future modelling

The CMSS model provides estimations of the current average annual TN and TP loads for the period 1998 to 2007 to the waterways and estuary. It also provides estimations of expected changes in average annual loads following some land-use changes and management actions. However, CMSS is limited by its steady-state nature and the fact that it is not linked to a hydrological model.

In 2009 the Leschenault flow model developed by Marillier and Hall in 2008 will be further enhanced and used to drive a more sophisticated nutrient model. This will enable scenario modelling of climate change, examination of the impact of extreme weather events and seasonal decomposition of nutrient inflows to the estuary. Estimation of seasonal nutrient inflows is important to determine the impact of point sources and irrigation return flows on the streams and estuary in the dry season when algal growth is at its greatest.

The flow modelling of the Leschenault catchment (Marillier et al. 2009) used LIDAR elevation data on the Swan Coastal Plain (collected by the Department of Water in 2008) to define and validate stream lines and catchment boundaries. These catchment boundaries will be further refined and ground-truthed, and then used to define subcatchments for the future modelling.

The nutrient model to be implemented in 2009 will (most likely) be WaterCAST (the Water and Contaminant Analysis and Simulation Tool) <http://www.toolkit.net.au/watercast> which is part of the eWater CRC Catchment Modelling Toolkit. Developed from eWater's existing model 'E2', the WaterCAST platform models the amounts of water and materials flowing across a catchment and into receiving waters. A key feature of WaterCAST is its flexibility: a model can be constructed by selecting appropriate component models from available options in the Catchment Modelling Toolkit, and linking them in the WaterCAST platform. The hydrological driver will be the current flow model with some further refinement, which may be described as a monthly Zhang-Hall model (Zhang 2005; Hall 2009, pers. comm.) coded in TIME and calibrated against available gauges. This hydrological driver will be developed by the modelling team at the Department of Water's Water Science branch. The pollutants TN and TP will be modelled using a similar methodology to E2, which assigns dry-weather and event-mean concentrations to land uses, and then predicts waterway concentrations by flow-weighted averaging of nutrient yields from the various land uses. WaterCAST also provides various runoff-routing and in-channel processing options, and is suitable for modelling future land use, riparian and hydrological scenarios.

Table 6.1 contains a list of possible scenarios to be modelled, as discussed with the Leschenault Catchment Council in March 2009. The data requirement for implementation of the scenarios is quite onerous and is discussed briefly below.

Table 6.1 Possible scenarios to be modelled by WaterCast

Scenario	Implemenatation
Urban expansion	With soil amendment, without soil amendment.
Changes in land use	Intensification of dairies and horticulture.
Dairy effluent management	Model dairies with current effluent management and proposed improvements.
Point source management	Requires point source mapping and estimations of flow, TN and TP outputs from each point source. Model point source removal.
Riparian management	Estimate changes following riparian zone management, and estimate area of riparian zone required to make significant change to exports.
Climate change	Examine changes to river inflows to estuary with various climate change scenarios

Urban expansion

Spatial data showing potential urban expansion areas is readily available. However, in Western Australia the effectiveness of various urban best-management practices designed to reduce nutrient pollution is unknown. This means that the modelling predicts the changes to nutrient export that would result from ‘conventional’ urban development. This is thought to be the worst-case scenario.

Changes in land use – intensification of dairies and horticulture

This is easily modelled if the required changes are specified.

Dairy effluent management

For each dairy the required data includes the number of cows, the current effluent management practices and the proposed effluent management practices.

Point source management

All the nutrient point sources within the catchment need to be mapped and nutrient outputs and disposal methods known.

Riparian management

All areas of riparian zone management need to be located. The management actions need to be specified, including fencing, stock exclusion or revegetation. The effectiveness of riparian zone management in Western Australia is still being researched, with different results apparent in different locations. The modelling approach is to specify exactly the underlying assumptions, so that if these change, the modelling can be easily updated.

Climate change

To estimate future climate change, the Intergovernmental Panel on Climate Change (IPCC 2000) prepared 40 greenhouse gas and sulfate aerosol emission scenarios for the 21st century that combine a variety of assumptions about demographic, economic and technological driving forces likely to influence such emissions in the future. The two climate change scenarios that are generally modelled are:

- **B1 scenario:** The population 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. This is an optimistic scenario.

- **A2 scenario:** The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge slowly, leading to steadily increasing population and per capita economic growth. Technological changes are more fragmented and slower than in other scenarios. The A2 scenario is the highest emission option (pessimistic scenario) with continued high rates of greenhouse gas emissions that reach 1.7 times current levels by 2090.

To model these scenarios the estimated future rainfall and evaporation data for the catchment are required, and will be sourced from the Bureau of Meteorology or CSIRO, or generated by the Water Science branch's modelling team. Both scenarios will be modelled for a preliminary assessment of the impact of climate change on the inflows to Leschenault Inlet.

7 Concluding discussion

The average annual export of nutrients to the waterways draining to the Leschenault Inlet for the period 1998 to 2007 is estimated to be 359 tonnes of TN and 29 tonnes of TP. The Coastal catchment that drains directly to the ocean also emits 14 tonnes of TN and 1.4 tonnes of TP.

The main sources of nutrients are from 'beef cattle' (60 per cent of TN; 48 per cent of TP) and 'cattle for dairy' (19 per cent of TN; 24 per cent of TP). The point sources of septic tanks and wastewater treatment plants (WWTPs) contribute 11 per cent of both the TN and TP. Urban sources (excluding the septic tank and WWTP emissions, and the 'recreation' land uses) contribute 3 per cent of TN and 4.2 per cent of TP. Horticulture, viticulture and tree plantations contribute 3 per cent of TN and 8 per cent of TP. There are other land uses in the catchment that are just as intensive, or more intensive than dairy farming and urban uses on a load per unit area basis. However, because of their relatively small area and the whole-of-catchment modelling, they have not emerged as issues. From a catchment management perspective, land uses with high fertilisation rates and/or high stocking rates should always be sited and managed appropriately. In the Leschenault catchment these land uses include 'piggery', 'turf farms', 'recreation – turf and grass'.

Modelling was conducted on 14 subcatchments. The subcatchment with the greatest nutrient loads is the Wellesley – even though it is only the fourth largest subcatchment. This is because of intensive land uses (21 per cent of the area is devoted to dairy farming), poor soils and large amounts of irrigation. The catchments with the greatest loads per unit area besides the Wellesley are Estuary and Coast (due to urban and horticultural contributions) and Brunswick Middle, Brunswick Lower and Collie Lower 1 (due to poor soils, and beef and dairy cattle). The horticultural area north of the inlet, which drains to the inlet through Parkfield Drain, is only small but contributes significant loads.

The areas that CMSS modelling identified as having high nutrient contributions per unit area aligned well with sites that have observed poor water quality.

Management actions modelled included the removal of septic tanks and WWTPs, fertiliser management and the application of soil amendment. Figure 7.1 and Figure 7.2 display the estimated TN and TP loads for the whole catchment for the various management scenarios.

The removal of septic tanks and appropriate effluent disposal from Kemerton WWTP has the potential to significantly reduce nutrient export from all catchments that contain portions of Australind and Bunbury. The subcatchments Coast, Estuary, Brunswick Lower and Preston Lower have predicted TN reductions of 50, 50, 45 and 18 per cent respectively and predicted TP reductions of 53, 44, 33 and 18 per cent respectively.

On a whole-of-catchment basis, implementation of the *Fertiliser action plan* has the potential to decrease the phosphorus export to the waterways by 20 per cent. This is significant because phosphorus fertilisation changes have only been made in five subcatchments, which constitute 65 337 ha or 32 per cent of the catchment. This demonstrates that the

Fertiliser action plan has an important role to play in the reduction of fertiliser leaching to the catchment's waterways.

If soil amendment were applied to half of the agricultural land uses on low phosphorus-retention index (PRI) soils, the TP load to the estuary would reduce from 30 to 24 tonnes – a decrease of about 20 per cent. The catchments most affected by this management action would be Brunswick Middle, Wellesley, Collie Lower 1 and Preston Lower, where application of soil amendment to half of the low PRI soils could potentially reduce phosphorus export by 24 to 29 per cent. As such, this management action should be considered in strategic locations.

A scenario to examine how the intensification of dairy farming, horticulture and viticulture would impact on the catchment was modelled by increasing the fertilisation (and nitrogen fixation) rates on existing properties by 50 per cent. The greatest impacts are from the intensification of dairy farming (because this covers a much greater area than horticulture and viticulture). On a whole-of-catchment basis, the intensification of these land uses would result in a 10 per cent increase in TN export (from 372 to 411 tonnes) and a 14 per cent increase in TP export (from 30 to 34 tonnes), as displayed in Figure 7.1 and Figure 7.2.

The impact of this intensification would be greatest in the Wellesley catchment, which has 21 per cent of its area under dairy farming (potentially leads to a 25 per cent increase in both TN and TP export). The expected increases in the Brunswick Middle, Collie Lower 1 and Ferguson catchments are 15, 16 and 14 per cent for TN export respectively and 18, 15 and 13 per cent for TP export respectively (mainly due to dairy farming). The Estuary catchment also displays potential increases of 8 per cent for TN and 15 per cent for TP export, due to the intensification of the horticultural region to the north of the estuary which drains to the estuary through Parkfield Drain.

All the areas subject to intensification under this scenario already have poor water quality because of the current land uses. Increased nutrient loads would therefore exacerbate the existing problems.

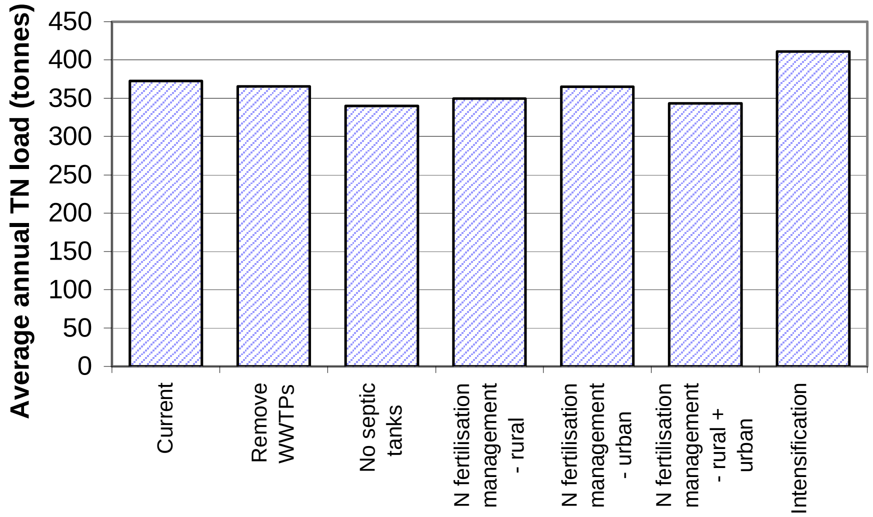

Figure 7.1 Estimated total TN loads from the Leschenault catchment for current land uses and the management scenarios – removal of WWTPs, removal of septic tanks, nitrogen fertilisation management in rural and urban areas, and intensification of dairy farming, horticulture and viticulture

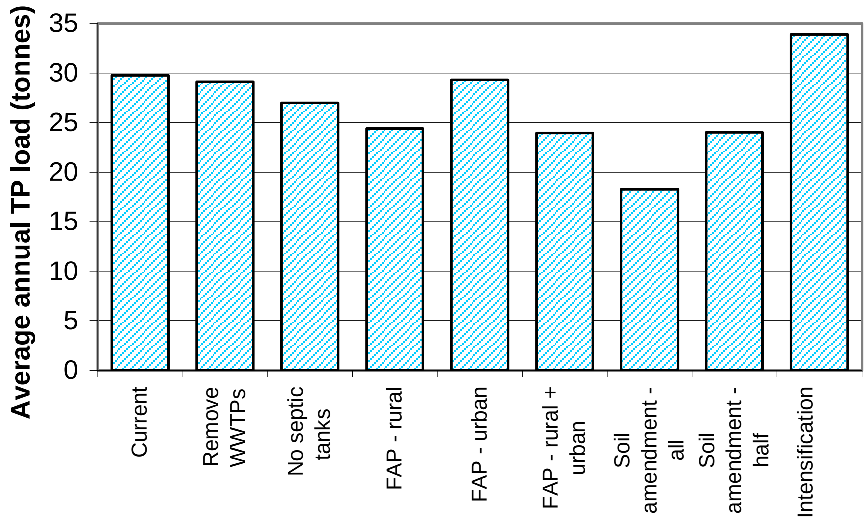

Figure 7.2 Estimated total TP loads from the Leschenault catchment for current land uses and the management scenarios – removal of WWTPs, removal of septic tanks, implementation of the Fertiliser action plan *in rural and urban areas, application of soil amendment to low PRI soils, and intensification of dairy farming, horticulture and viticulture*

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Appendix 1: Land-use areas (ha) in the Leschenault subcatchments

Land use	Subcatchment															Total land use area (ha)
	Brunswick Lower	Brunswick Middle	Brunswick Upper	Coast North	Coast South	Collie Lower 1	Collie Lower 2	Estuary	Ferguson	Henty	Preston Lower	Preston Middle	Preston Upper	Thomson	Wellesley	
Abattoir	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8
Annual horticulture	0	4	0	0	0	0	7	568	0	0	0	86	1	10	4	679
Aquaculture	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Cattle for beef	480	3946	2393	0	259	6285	3130	1104	4625	1513	5920	12 770	6744	2457	9653	61 281
Cattle for dairy	102	874	228	0	0	1596	95	1	968	60	524	0	0	0	4362	8812
Commercial	0	14	0	0	129	6	0	10	0	0	19	11	0	0	0	188
Community facility – non-education	23	3	0	0	81	17	0	3	0	0	56	16	0	0	0	199
Dam	5	24	94	0	1	31	18	30	89	58	62	485	200	55	50	1204
Garden centre/nursery	0	0	0	0	0	0	0	0	0	0	1	17	0	0	0	18
Horses	0	0	0	0	0	49	0	0	100	19	82	54	0	0	140	444
Lifestyle block/hobby farm	130	93	17	1	71	157	265	187	402	206	802	786	113	2	130	3360
Manufacturing/processing	1	66	773	0	121	27	0	84	95	0	362	0	0	0	0	1529
Pasture for hay	0	0	1	0	0	0	27	71	2	0	5	1086	148	12	15	1368
Perennial horticulture – trees	0	0	0	0	0	0	15	0	17	2	0	122	84	5	6	251
Piggery	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	12
Quarry/extraction	30	36	760	0	0	176	13	23	13	2	174	55	4	0	303	1588
Recreation – grass	4	15	0	0	184	14	0	6	4	0	69	22	3	0	0	322
Recreation – turf	0	0	0	5	0	8	0	60	0	0	0	20	0	0	0	92
Recreation/conservation	559	3042	14 515	524	667	1208	10 233	3005	6943	2040	5012	20 855	21 190	6412	4808	101 013
Rural residential/bush block	7	24	0	0	20	0	0	150	0	0	0	62	0	0	51	315
Transport/access	122	173	161	5	462	355	133	298	329	72	692	332	47	17	135	3334
Tree plantation	2	327	1426	0	0	56	581	47	577	6	329	1127	1830	1116	144	7570
Turf farm	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	7
Unused – cleared – grass	74	417	523	6	49	193	120	99	201	13	301	1019	527	117	581	4240
Unused – uncleared – trees/shrubs	1	4	0	0	19	10	4	119	11	0	21	0	0	0	80	268
Urban residential	319	50	3	12	889	220	13	510	14	12	380	212	13	0	15	2662
Utility	7	6	0	0	36	9	4	31	0	0	7	1	0	0	0	102
Viticulture	0	1	4	0	0	4	10	0	94	115	12	293	233	0	32	796
Waterbody	7	0	0	0	19	23	0	0	0	0	0	0	0	0	0	50
Wetland	9	1	0	0	32	0	0	80	0	0	15	0	0	0	326	461
Total subcatchment area (ha)	**1884**	**9120**	**20 899**	**553**	**3038**	**10 444**	**14 667**	**6503**	**14 483**	**4120**	**14 845**	**39 442**	**31 136**	**10 204**	**20 834**	**202 173**

Appendix 2: Annual TN and TP loads at flow gauges

TN and TP loads at flow sites in the Wellesley, Brunswick and Lower Collie catchments:

612032 Brunswick River, Cross Farm

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1992	169 063	268	32
1993	136 601	203	23
1994	107 801	155	18
1995	158 640	263	33
1996	240 536	436	58
1997	94 499	128	14
1998	85 732	124	13
1999	135 914	200	22
2000	117 164	182	21
2001	36 714	47	4.6
2002	100 332	151	16
2003	103 692	151	18
2004	99 744	152	18
2005	168 254	271	35
2006	55 396	77	8.3
2007	117 053	181	21
Average (1998–2007)	**101 999**	**154**	**18**

612039 Wellesley River, Juegenup

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1992	83 557		**22**
1993	59 152		**13**
1994	52 416		**11**
1995	67 124		**17**
1996	98 517		**26**
1997	64 692		**15**
1998	50 089	102	**12**
1999	72 343	151	**18**
2000	68 332	154	**18**
2001	19 149	33	**4**
2002	53 710	115	**13**
2003	54 273	113	**14**
2004	52 993	113	**13**
2005	83 051	183	**21**
2006	26 952	53	**6**
2007	62 650	140	**17**
Average (1998–2007)	**54 354**	**116**	**14**

612043 Collie River, Rose Road

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1997	71 095	40	2.11
1998	43 405	26	0.89
1999	105 496	63	2.10
2000	95 295	59	1.92
2001	31 684	17	0.53
2002	44 950	25	1.00
2003	36 544	20	0.69
2004	39 336	22	0.70
2005	77 153	43	1.46
2006	23 207	12	0.38
2007	52 111	29	0.94
Average (1998–2007)	**54 918**	**32**	**1.1**

612013 Collie River, Wellington Flume

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1998	75 687	37	0.34
1999	134 025	59	0.46
2000	121 935	57	0.46
2001	79 305	39	0.35
2002	64 179	32	0.29
2003	64 778	32	0.30
2004	65 543	33	0.30
2005	88 645	41	0.35
2006	54 170	27	0.26
2007	74 177	37	0.34
Average (1998–2007)	**82 244**	**40**	**0.34**

612047 Brunswick River, Beela

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
2001	15 405	7	
2002	33 267	19	0.7
2003	38 037	21	0.9
2004	44 915	27	1.2
2005	75 817	46	2.3
2006	22 915	12	0.5
2007	48 259	32	1.5
Average (2001–2007)	**39 802**	**24**	**1.2**

TN and TP loads at flow sites in the Ferguson and Preston catchments:

611004 Preston River, Boyanup Bridge

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1998	66 817	63	1.8
1999	146 247	155	4.7
2000	110 892	121	3.7
2001	14 268	8	0.3
2002	67 777	63	1.8
2003	71 666	66	2.0
2004	68 351	63	1.9
2005	104 142	98	3.4
2006	28 087	23	0.7
2007	77 279	76	2.3
Average (1998–2007)	**75 553**	**74**	**2.3**

611009/6111046* Preston River, Lowden Road Bridge

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
2000	26 794	34	0.59
2001	3956	2.1	0.04
2002	16 463	16	0.27
2003	20 650	23	0.40
2004	21 893	25	0.43
2005	34 325	41	0.70
2006	11 578	11	0.19
2007	28 820	35	0.60
Average (2000–2007)	**20 560**	**24**	**0.40**

**Sites 611009 and 6111046 are co-located*

611007 Ferguson River, SW Hwy Ferguson

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1992	47 597	67	5.0
1993	37 158	55	3.6
1994	28 158	37	2.0
1995	28 684	41	2.6
1996	52 363	87	6.8
1997	22 226	27	1.3
1998	10 335	11	0.4
1999	12 953	15	0.7
2000	35 050	55	4.1
2001	11 864	12	0.5
2002	18 967	25	1.2
2003	17 659	21	1.1
2004	23 530	32	1.8
2005	30 656	45	3.5
2006	15 189	22	1.7
2007	29 126	46	3.4
Average (1998–2007)	**20 533**	**28**	**1.8**

611111 Thomson Brook, Woodperry Homestread

Year	Annual flow (ML)	Annual TN load (tonnes)	Annual TP load (tonnes)
1997	9657	10	*
1998	6906	7.5	*
1999	17 615	21	*
2000	19 546	27	*
2001	1424	1.1	*
2002	8666	10	0.20
2003	7583	8.0	0.18
2004	6314	6.6	0.14
2005	10 991	12	0.29
2006	2848	3.0	0.07
2007	7948	8.6	0.20
Average (1998–2007)	8984	10	**0.18**

**TP 1996–2001 LOR = 0.4 mg/L*

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