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

Peel Coastal groundwater allocation plan methods report

Background information and description of the methods used to set allocation limits for aquifers in the Peel Coastal groundwater allocation plan

October 2015

Securing Western Australia's water future

Peel Coastal groundwater allocation plan

Methods report

Background information and description of the methods used to set allocation limits for aquifers in the *Peel Coastal groundwater allocation plan*

Securing Western Australia's water future

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What is this report?

This report explains how the Department of Water developed the allocation limits for each of the 14 groundwater resources covered by the *Peel Coastal groundwater allocation plan* (Department of Water 2015a). This companion document to the allocation plan provides further detail on the hydrogeological, environmental, cultural and social information available for the aquifers of the plan area, and on the decision-making process.

The allocation plan details the allocation limits, water licensing arrangements and resource monitoring specific to the plan area.

What does this report include?

This report is split into three main chapters which follow the department's water allocation planning process for plan development set out in *Water allocation planning in Western Australia: a guide to our process* (Department of Water 2011):

- Chapter 2 – Stage A: describes the information used in refining the precision of the allocation limits, particularly our current understanding of the groundwater resource, including current use of water and future demands.
- Chapter 3 – Stage B: outlines how we set the management and resource objectives and the methodology for making the allocation limit decisions.
- Chapter 4 – Stage C: describes the role of policy and licence conditions in local resource management and the broader water management approach to support the use of the allocation limits in the plan.

The following reports also supported the planning process and provide key reference material for groundwater management in and adjacent to the plan area:

- *Peel Coastal groundwater area: Groundwater-dependent ecosystems report*, (Department of Water 2015b)
- *Rockingham-Stakehill groundwater management plan* (Department of Water 2007a)
- *South West groundwater areas allocation plan* (Department of Water 2009a)
- *Draft Perth-Peel Regional water plan 2010-2030* (Department of Water 2009b)
- *Murray groundwater allocation plan* (Department of Water 2012).

Further information on the plan area can be obtained by contacting the Kwinana Peel regional office, or from the technical documents listed in the references section of this report

1 Introduction

This report explains how the Department of Water developed the allocation limits for each of the 14 groundwater resources included in the *Peel Coastal groundwater allocation plan* (Department of Water 2015a).

This report is designed to be read in conjunction with the *Peel Coastal groundwater allocation plan* (Department of Water 2015a). The References section of this document list further reading available on the plan area.

1.1 Peel Coastal plan area

The plan area extends along the Swan Coastal Plain from the northern surrounds of Mandurah (approximately 70 km south of Perth) to Myalup (Figure 1) and covers approximately 380 km². Most of the plan area is within the local government boundaries of the City of Mandurah and the Shire of Waroona.

The Peel Coastal plan area consists of seven subareas (see Figure 1):

- Coastal
- Colburra Downs
- Falcon
- Island Point
- Lake Clifton
- Mandurah
- Whitehills

Allocation plans have been developed for the areas adjacent to the Peel Coastal plan area. These include the Murray, Rockingham-Stakehill and South West groundwater allocation plans (Figure 1).

Figure 1: Peel Coastal groundwater allocation plan area

1.2 Our process for allocation planning and resource management

The *Peel Coastal groundwater allocation plan* (Department of Water 2015a) was developed using the department's process for water allocation plans: *Water allocation planning in Western Australia: a guide to our process* (Department of Water 2011) (Figure 2).

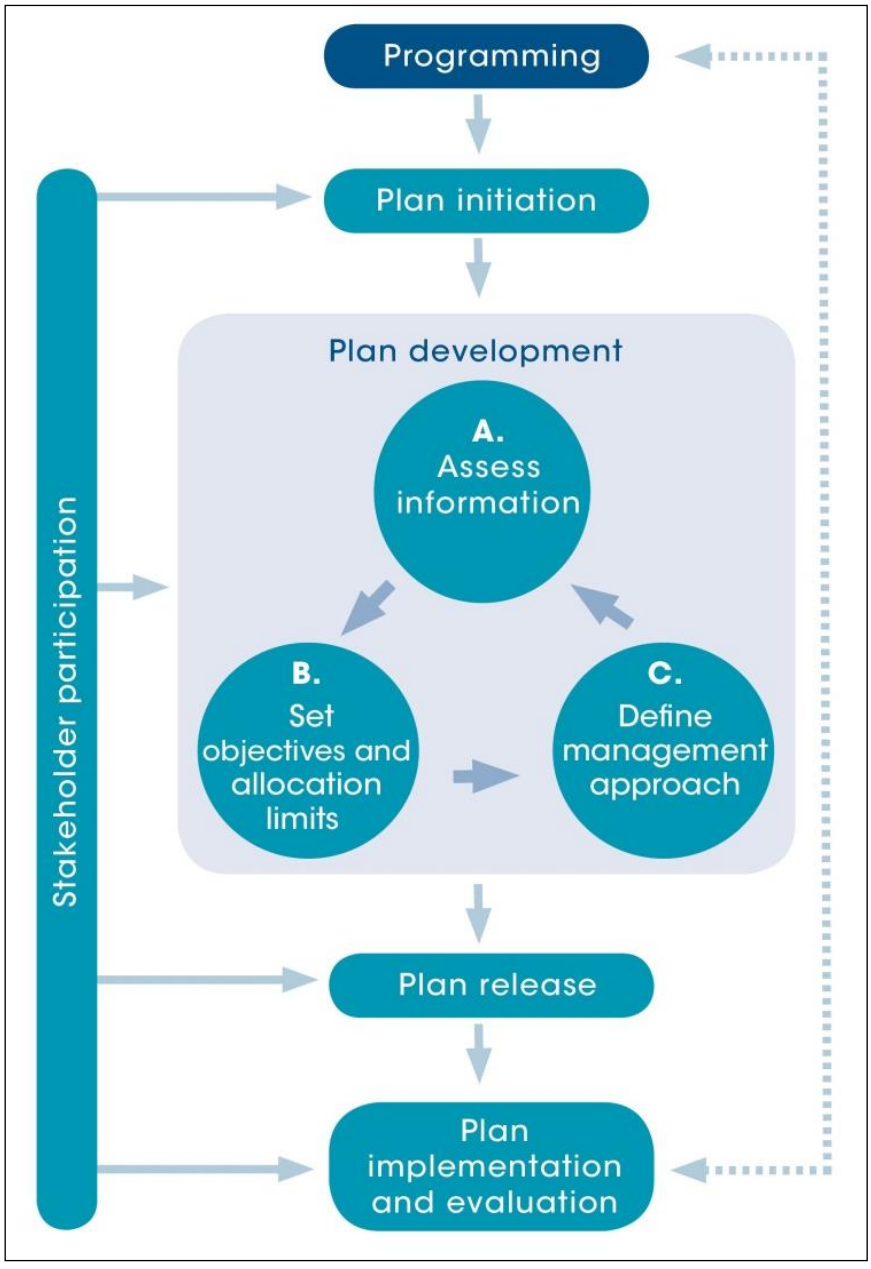


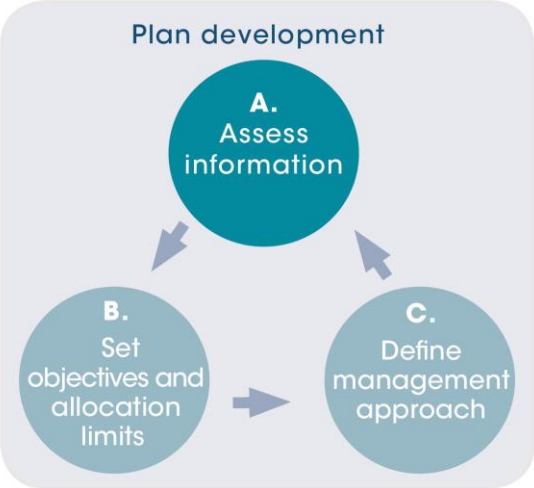
Figure 2: The Department of Water's standard water allocation planning process (Department of Water 2011)

This report is set out to follow the three stages of plan development and provides the information and methodology used to complete each stage (see Table 1). Each stage corresponds to a chapter in this report:

Table 1: Report alignment with the allocation planning process

Chapter 2 - Stage A: *Investigate and assess the water resource*	• Assess the area's hydrogeology (sections 2.1-2.5) • Consider the ecological, economic and social values (sections 2.6 and 2.7) • Assess the level of water use and future water demands (Section 2.8)
Chapter 3 - Stage B: *Set management objectives and allocation limits for the resource*	• Set resource objectives (Section 3.1) • Consider allocation options (Section 3.2) • Set allocation limits (Section 3.2)
Chapter 4 - Stage C: *Define the management approach for the resource*	• Identify the water licensing approach to meet plan outcomes and objectives (Section 4.1) • Identify any specific local licensing policies required other than state-wide policies (Section 4.2) • Develop a monitoring and evaluation process to monitor performance against specific resource objectives (sections 4.3 and 4.4)

2 Part A: Assessing information



In Part A of the allocation planning process, we assess:

- the hydrogeology of the resource
- how much water needs to be left in the system (environmental water)
- current water use and future demand for groundwater.

This information is used to set objectives, allocation limits and define the water licensing approach for the plan area.

Key points from this section:

- The key groundwater resources in the plan area are the freshwater lens of the Superficial aquifer, and the marginal to brackish component of the Leederville aquifer.
- The drying climate experienced in the south-west of Western Australia since the 1980s has reduced groundwater recharge in the plan area. This trend is projected to continue.
- Groundwater resources and their dependent values are at risk from movement of the seawater interface, acid sulphate soils, declines in water levels and reductions in freshwater through flow.
- There are high-value environmental features in the plan area which are groundwater-dependent, such as Lake Clifton (Ramsar) and the Peel-Yalgorup wetland chain.
- Future land planning does not indicate significant change in water demand up to 2030.

2.1 Understanding the water resource

There are three aquifers present in the plan area. In order of increasing depth, these are the Superficial and Leederville aquifers, and the Cattamarra Coal Measures. The resource boundaries for the Superficial and Leederville aquifers are shown in Figure 3 and their properties are summarised in Table 2.

The Cattamarra Coal Measures also exist in the plan area, however due to their salinity (brackish to saline), depth (>290m) and subsequent low demand are not covered here or in the allocation plan.

Table 2: Aquifer descriptions for the Peel Coastal plan area

Aquifer	Description
Superficial	• Extends across whole plan area (regional formations). • Shallow, unconfined aquifer, that is easily accessible. • Thin lens of fresh water floats above saline water. • Freshwater recharge is primarily through direct rainfall infiltration. • The thin, freshwater lens is high susceptible to saline intrusion from the ocean, estuary and underlying water. • Generally this aquifer is in hydraulic connection with the underlying Leederville aquifer, except where the confining Osborne Formation is present and forms an aquiclude. • Formations include Tamala Limestone, Safety Bay Sands and Bassendean Sand (known collectively as the Superficial aquifer). • Supports groundwater-dependent ecosystems through access to the watertable or freshwater throughflow.
Leederville	• Major regional confined aquifer which extends outside the Peel Coastal plan area. • Recharge conditions vary, due to localised hydrogeology. • Freshwater leakage generally occurs from the overlying Superficial aquifer, and in some areas aquifer throughflow occurs. • In the Falcon subarea the abstraction in the Leederville aquifer is believed to induce saline recharge from the Peel Inlet. • In the Colburra Downs subarea recharge throughflow is likely to be from the adjoining Murray groundwater area. • The aquifer is vulnerable to saline intrusion in most subareas.

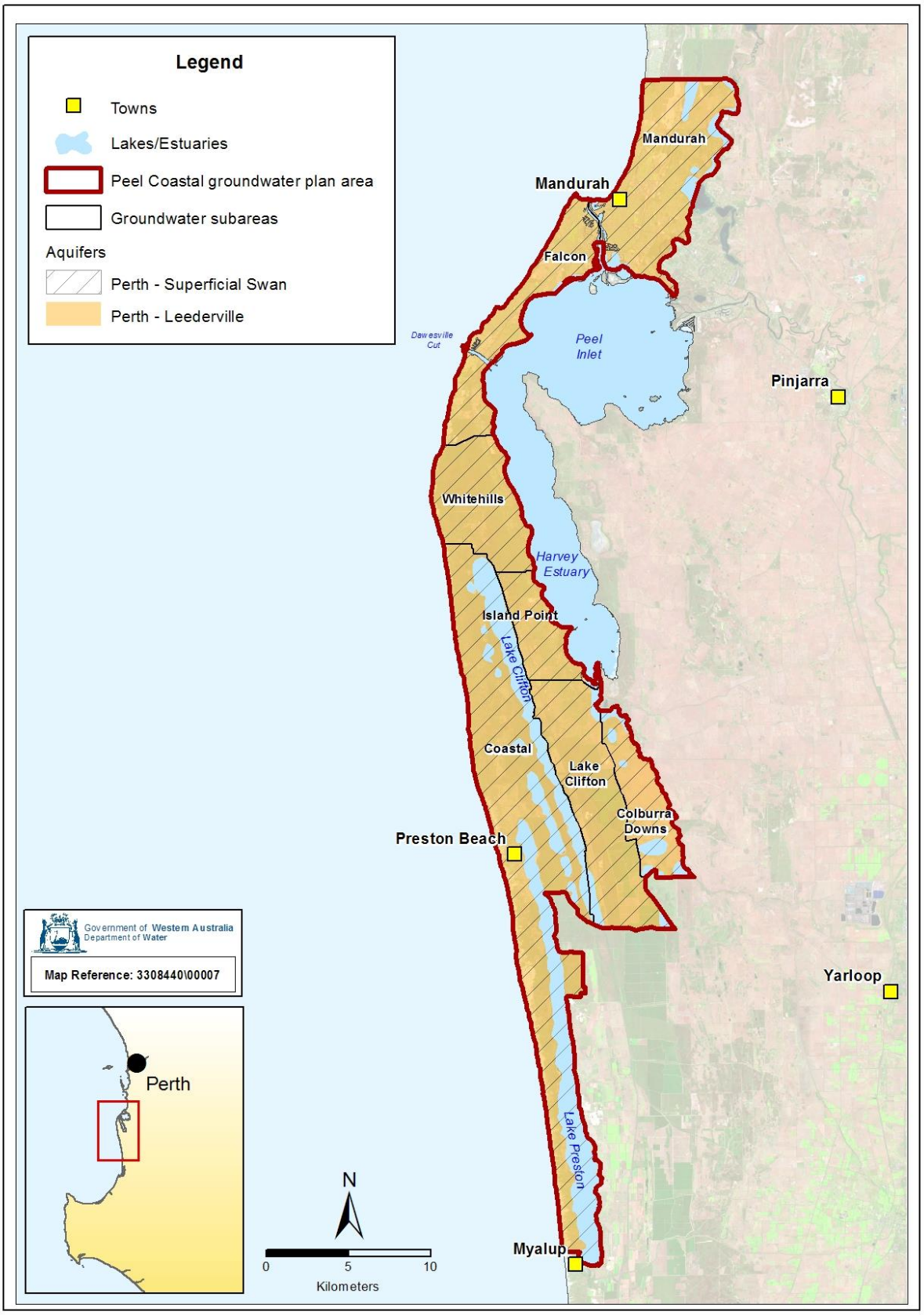


Figure 3: Peel Coastal plan area subarea boundaries and resource shapes

Conceptual hydrogeology of the Superficial aquifer

The Superficial aquifer is an unconfined, stratigraphically complex, multilayered aquifer consisting mainly of porous Tamala Limestone which is generally in hydraulic connection with the underlying Leederville aquifer. It occurs at shallow depths with a maximum saturated thickness of 25 m.

The Superficial aquifer forms a significant and extensively exploited aquifer. It occurs at shallow depth and is readily available. Individual bore yields range from 500-2000 kL/day in the Bassendean Sand formation to more than 5000 kL/day in the karstic Tamala Limestone formation.

The conceptual hydrogeology for the Superficial aquifer is generally consistent across the subareas, consisting of a layer of fresh water overlying denser, saline water, with the weight of the fresh water depressing the underlying saline groundwater. As this freshwater layer is reduced (e.g. by pumping or reduced recharge), its weight is reduced and the underlying saline water rises. This has the effect of buffering the overall water level in the bore and makes monitoring water levels an unreliable means of monitoring the health of the resource. As a result of this, the resource is also at risk of saline upconing when over-abstraction occurs at a local scale.

Figures 4 and 5 illustrate local groundwater recharge and flow paths for the Superficial aquifer in the plan area.

The Superficial aquifer supports groundwater-dependent ecosystems such as lakes, wetlands, terrestrial vegetation and rare Thrombolite communities. These ecosystems rely on either access to the watertable or freshwater throughflow and discharge. For more information on groundwater-dependent ecosystems in the plan area, see Section 2.6 or refer to the *Peel Coastal plan area: Groundwater-dependent ecosystems report* (Department of Water 2015).

Groundwater flow and discharge

Groundwater flow in the Superficial is complex in the plan area (Figure 5). Groundwater discharges to low-lying areas (groundwater sinks) from local groundwater mounds and divides (e.g. Lake Clifton and Lake Preston). Groundwater also flows towards the Indian Ocean, the Peel Inlet and the Harvey Estuary, and the Serpentine and Harvey rivers. In addition, discharge occurs through evaporation, transpiration and leakage to underlying aquifers.

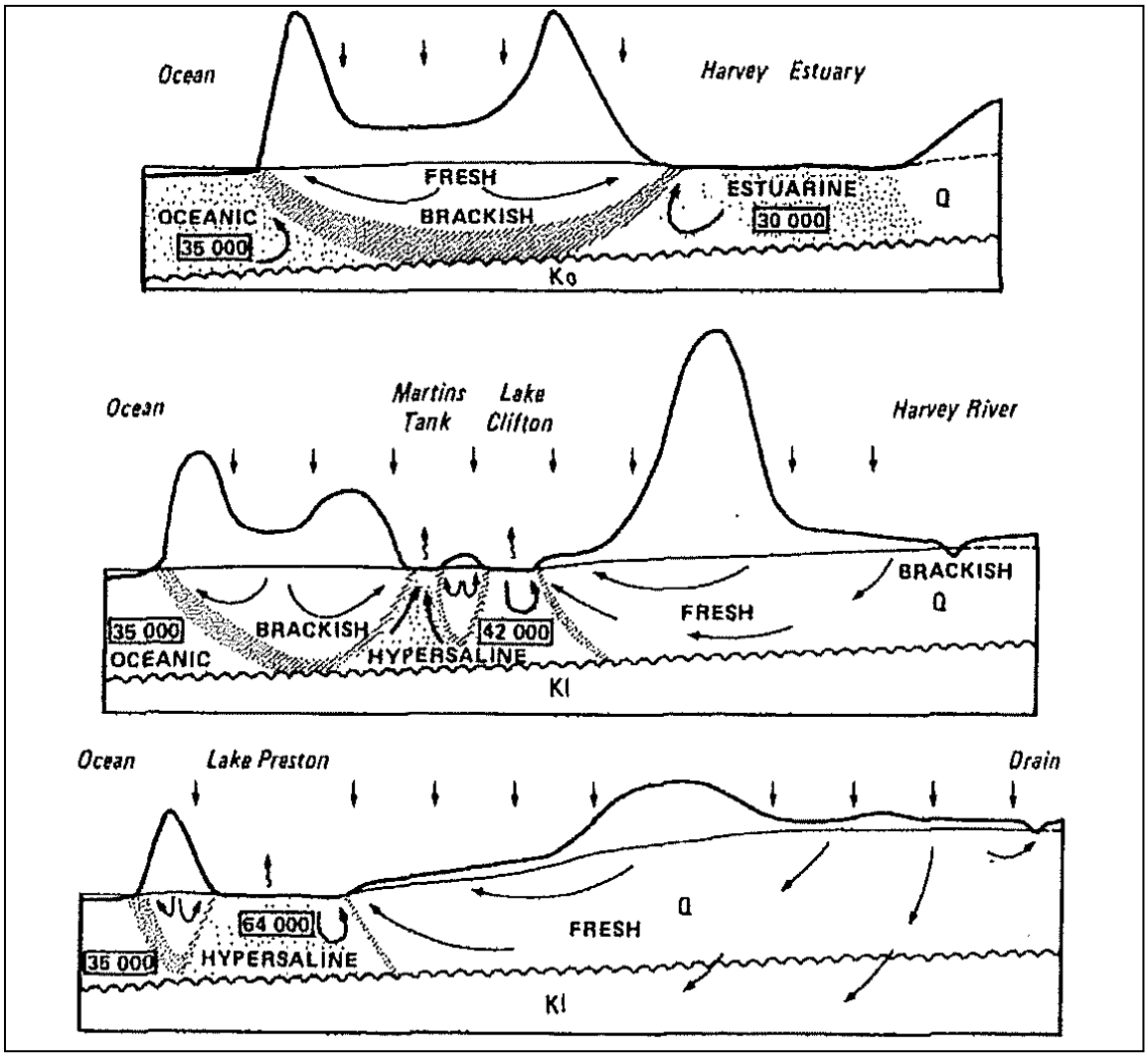


Figure 4: Groundwater recharge, discharge and throughflow in the Superficial aquifer (after Commander 1988)

Recharge

The Superficial aquifer is recharged directly by rainfall, with a large proportion of infiltration lost to evapotranspiration (CSIRO 2009). Recharge rates vary across the plan area as a result of variation in lithology, vegetation, depth to watertable and topographic gradient. Groundwater recharge is highest in sparsely vegetated coastal dunes and where the land has been cleared for agriculture. Groundwater recharge is lowest in dense Eucalyptus woodlands (e.g. Tuart forest).

Inflow to the Superficial aquifer occurs locally by upward leakage from the underlying Leederville aquifer along the coast where there are increasing hydraulic heads with depth and no confining beds between the Superficial and Leederville aquifers.

Figure 5: Geomorphology and Superficial aquifer flow system

The Water Corporation infiltrates treated wastewater into the Superficial aquifer at three wastewater treatment plants (WWTPs) in the plan area: Gordon Road WWTP in the Mandurah subarea, Halls Head WWTP in the Falcon subarea and Caddadup WWTP in the Falcon subarea. This recharge supports some localised abstraction, as well as preventing seawater intrusion in the Falcon subarea.

Groundwater quality

The salinity of groundwater in the Superficial aquifer ranges from less than 250 mg/L to 64 000 mg/L adjacent to Lake Preston. Fresh water is found overlying deeper saline groundwater (this stratification happens due to differences in density).

Saline groundwater occurs in the lower part of the Superficial aquifer across a large part of the plan area and some discharge areas (Figure 4). Hypersaline groundwater is found adjacent to and below Lake Preston.

The coastal lakes are groundwater sinks and are commonly saline to hypersaline due to evaporative concentration of dissolved salts. However, rainfall and groundwater throughflow contribute some fresh water to the system.

Conceptual hydrogeology of the Leederville aquifer

The Leederville aquifer is a major, regionally confined aquifer, with a thickness of about 140 m in the Mandurah subarea and up to 180 m south of Lake Clifton. It extends outside of the plan area. The Leederville aquifer forms a significant groundwater resource with bore yields of up to 1500 kL/day.

It is a multilayered, groundwater flow system consisting of interbedded sandstone, siltstone and shale. In some subareas, a sandy, green marker bed divides the Leederville aquifer. Above this marker bed, water quality is marginal. Below the marker bed, the groundwater is marginal to brackish, and its salinity increases with depth. This is due to the influence of the Peel Inlet and Harvey Estuary.

Current abstraction from the Leederville aquifer is relatively small compared to the Superficial aquifer. Groundwater abstraction should be managed carefully to prevent any lateral movement of saline water and upconing of the deeper saline groundwater.

Groundwater flow

Groundwater in the Leederville aquifer flows westerly and eventually discharges offshore into the Indian Ocean. Onshore, some groundwater in the Leederville aquifer discharges into the Superficial aquifer where the Kardinya Shale Member is absent and where there is increasing head with depth and upward hydraulic gradients.

Recharge

The Leederville aquifer is mainly recharged at the foot of the Darling Range, outside the plan area, where it is in direct hydraulic contact and connection with the Superficial aquifer and where there is downward hydraulic gradient.

There is limited data available on the hydrogeology and groundwater recharge mechanisms of the Leederville aquifer in the plan area. Recent drilling indicates that the geology is quite variable. The results of drilling carried out in 2012 by the Department of Water are expected to further improve our knowledge of the Leederville aquifer in the plan area. An interpretation of the results is expected to be published in 2016.

Where the groundwater recharge intake areas for the Leederville aquifer are overlain by the Peel Inlet and Harvey Estuary, recharge into the existing freshwater resource is saline. The time frame for the resulting decline in water quality is unknown and will need to be managed carefully.

Groundwater quality

The salinity of water drawn from most production bores in the Leederville aquifer is greater than 1000 mg/L TDS. The salinity of the Leederville aquifer increases with depth. Salinity is lowest in the shallower sections of the Leederville aquifer where recharge occurs. Where the aquifer lies beneath the Peel Inlet and Harvey Estuary, salinity is increasing.

Resource and subarea boundaries

Both the Superficial and Leederville aquifers exist across the entire plan area. Subarea boundaries separate the aquifer into individual resources for licensing purposes and reflect groundwater flow systems as discretely as possible to allow area-specific management strategies.

Further detail on the hydrogeology of the plan area may be found in:

- *Groundwater yields in south-west Western Australia: A report to the Australian Government from the CSIRO South West Western Australia sustainable yields project* (CSIRO 2009)
- *Hydrogeology and groundwater resources of the Perth region, Western Australia* (Davidson 1995)
- *REG75- A tool for estimating mean annual flow for the South West of Western Australia* (Department of Water 2007b)
- *Climate change, water demand and water availability scenarios to 2030: Perth-Peel water plan background paper* (Department of Water 2009c).

2.2 Aquifer trends

Groundwater monitoring and measurement data is available from 29 departmental bores across the Peel Coastal plan area (Figure 6). The majority of the monitoring bores are screened in the Superficial aquifer. Assessment of the water level trends from groundwater hydrographs is a key consideration in setting allocation limits.

Groundwater trends in the Superficial aquifer

Analysis of the hydrographs shows that groundwater levels experienced a small, long-term decline in most subareas. The decline is generally less than 1 m over the last 30 years. Exceptions to this trend in individual hydrographs can be explained by local factors such as relatively high abstraction, infiltration of treated wastewater into the watertable or buffering from the close proximity to both the Indian Ocean and the Peel Inlet. Coastal buffering suppresses any large response in groundwater levels to abstraction or rainfall declines.

Individual trends for the different resources are described in Table 7 in Section 3.2. Links to our *Water Information Reporting* website are also provided.

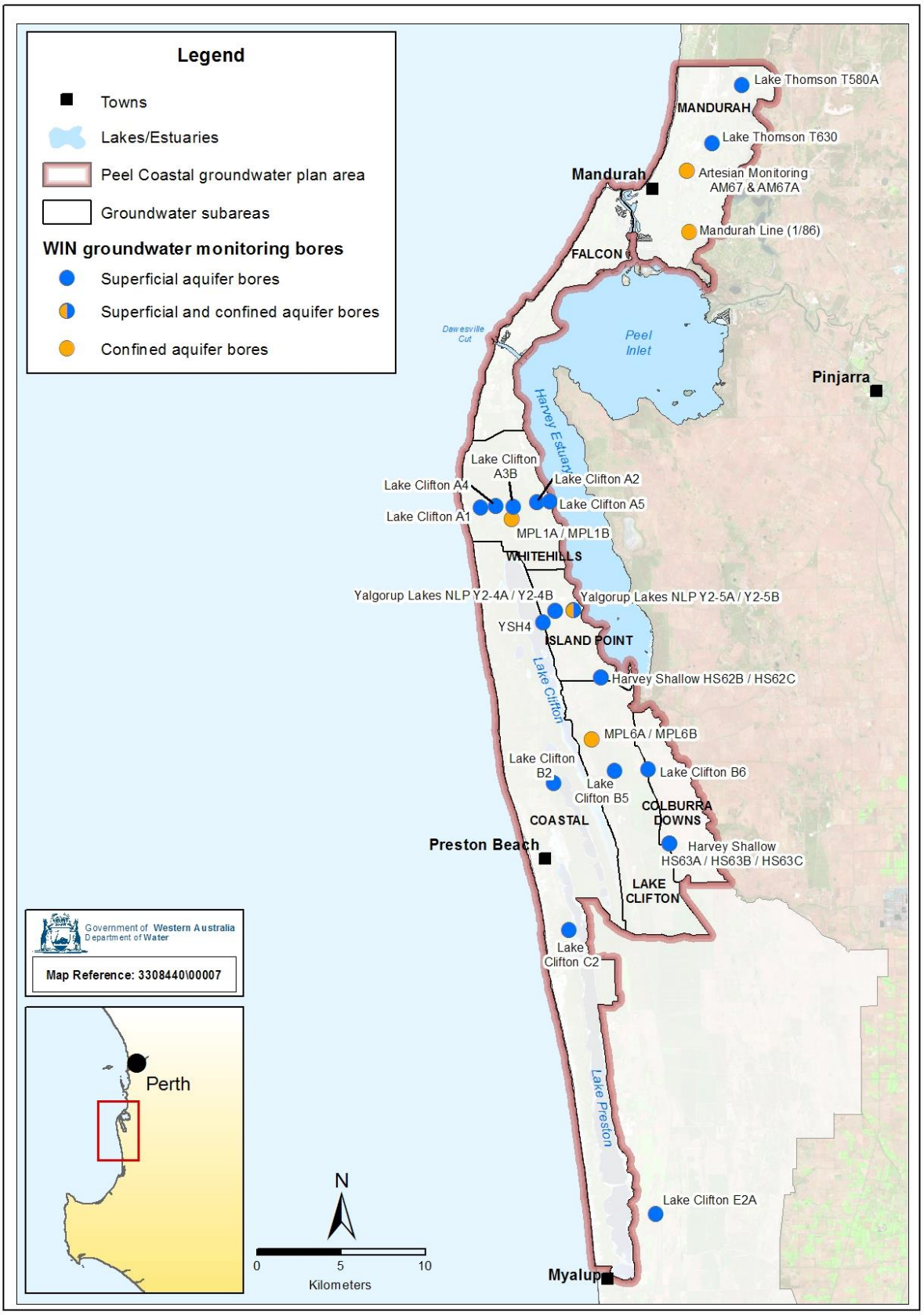


Figure 6: Monitoring bores in the Peel Coastal plan area

Groundwater trends in the confined aquifers

There is limited evidence to assess pressure-head trends in the Leederville aquifer across the entire plan area. However, there are a small number of bores in the Mandurah subarea that indicate that trends follow the regional declining pressure-heads observed across the Swan Coastal Plain (search for monitoring site AM67A (Ref no. 61415005) at http://wir.water.wa.gov.au. This is likely to be a result of groundwater abstraction and reduced recharge, not just in the plan area but from recharge zones to the east.

No long-term monitoring data was available at the time of plan development for the Leederville aquifer south of Mandurah.

In 2012, two new monitoring bores were installed in the Island Point and Whitehills subareas as part of the department's State Groundwater Investigation Program to address the limited information available. Data from these bores will improve our knowledge of the southern Leederville aquifer. The *Murray-Peel Groundwater Investigation Bore Completion Report* is in preparation and due for publishing in 2016 by the Department of Water.

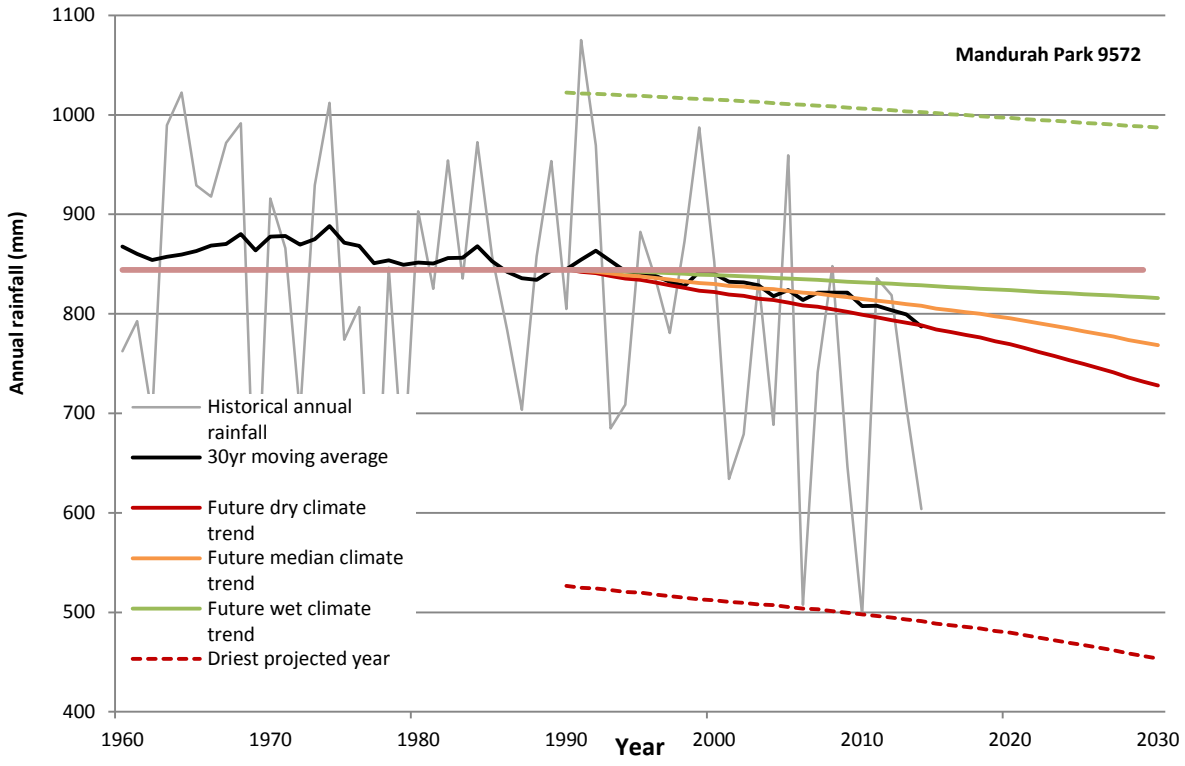
2.3 Climate and rainfall

We have continued to observe significant reductions in rainfall across the southwest of Western Australia since the mid-1970s. This is affecting surface water run-off and groundwater recharge and means that it is a critical factor in our water planning. It is likely that the climate will continue to dry over the life of the plan.

We use the most update-to-date climate modelling from the Intergovernmental Panel on Climate Change to project future rainfall across the state (Department of Water, 2015c).

The department's projections (Figure 7) indicate that by 2020 the long-term average annual rainfall for Mandurah, which was 845 mm/yr over the baseline period of 1961 to 1990, will decline by 2.5, 5.8 and 8.9 per cent under a wet, mid and dry scenario respectively, and by 2030 by 3.4, 9 and 13.6 per cent.

The climate has been particularly dry over the last decade. It is characterised by declines in both mean annual and autumn-winter rainfall, with an associated decline in the number of rainfall events per year that result in significant runoff, and also a rise in average annual temperature (Charles et al. 2010).



The future scenarios are calculated relative to a 1961-1990 baseline, so the climate trends are plotted using 1990 as the starting year.

Figure 7: Historical rainfall and projected rainfall for wet, mid and dry scenarios at the Bureau of Meteorology site Mandurah Park 9572

Effect of reduced rainfall on aquifer recharge

Reduced rainfall makes a significant difference to groundwater recharge and water levels in the plan area. In addition to affecting the amount of water we are able to make available for licensing into the future, reduced recharge has and will continue to increase the risks of:

- movement of the seawater interface
- exposure of acid-sulfate soils
- declines in water levels support wetlands and vegetation
- reductions in freshwater through flow that support thrombolite communities.

Hydrographs from the Superficial aquifer in the plan area indicate that the decline in rainfall experienced since the mid-1970s has significantly contributed to the slow, gradual declines in groundwater levels.

A hydrograph from the Coastal subarea is presented below (Lake Clifton B2, ref. no. 61319130; Figure 8). This bore is located in an area with minimal abstraction and the midline, around which seasonal variation in water level occurs, drops approximately 0.3 m over approximately 18 years.

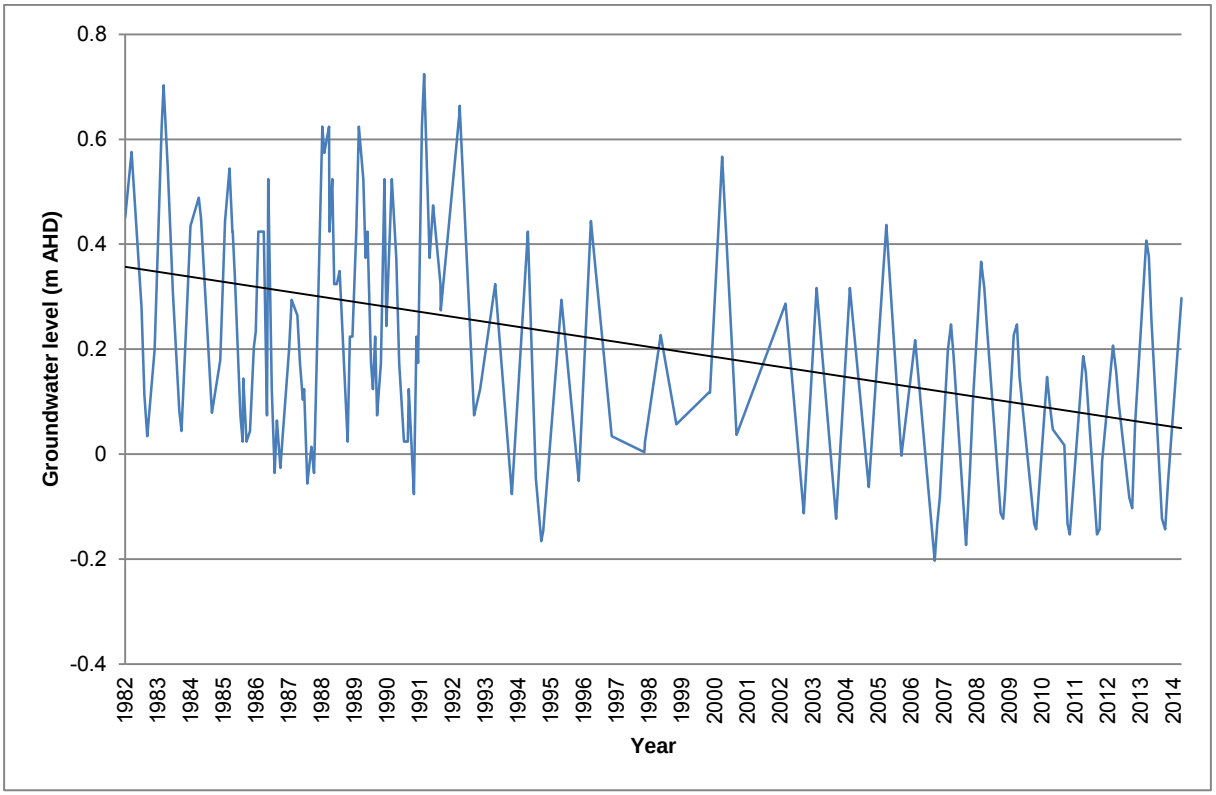


Figure 8: Groundwater hydrograph for Lake Clifton B2 (Ref. no. 61319130) in the Coastal subarea 1979-2014

Accounting for drying climate in our allocation decisions

Accounting for the continued decline in future rainfall when we set allocation limits helps to ensure an ongoing reliable groundwater supply for water users and minimises the risks to the environment. Section 3.2 describes in detail how we did this.

We will also continue to monitor how the drying climate is affecting groundwater resources through the monitoring and plan evaluation program outlined in the plan. Where necessary we will adapt our management over time.

2.4 Calculating aquifer recharge

Historical groundwater data in the plan area is limited and made our assessment of recharge volumes and a sustainable yield difficult. A number of recharge estimation methods were trialled, however no approach could be applied consistently across the whole plan area. Similarly, due to the inconsistent spread of data, application of a numerical groundwater model for the purposes of recharge and yield calculations was not seen as practical or beneficial given the monitoring information available.

To deliver an effective result, we used a risk-based approach for setting allocation limits. Further explanation of why and how this was carried out is outlined in Section 3.2.

2.5 Water to remain in the aquifers

When setting allocation limits, we ensure that water remains in the aquifer to protect the long-term viability of the aquifer for use and to support groundwater-dependent ecosystems.

In the plan area there are risks from over-abstraction to water levels, as well as water quality. Over time, water quality (particularly in the Superficial aquifer) is likely to pose a greater risk to users and groundwater dependent ecosystems. This is because although water levels will be held relatively stable by the proximity to the ocean and the estuary, water quality can still change dramatically through landward movement of the seawater interface and localised saline upconing.

Seawater interface

The seawater interface is the boundary between the fresh water throughflow of the aquifer and the denser, saline water of the ocean (Figure 9). Over-abstraction from areas near the coast and declining rainfall and recharge will increase the draw of saline water into the freshwater aquifer.

Over-abstraction and declining rainfall and recharge will also cause landward movement of the saline waters from the Peel-Harvey Estuary.

This risk of this occurring is considered in the process to set allocation limits described in Section 3.2.

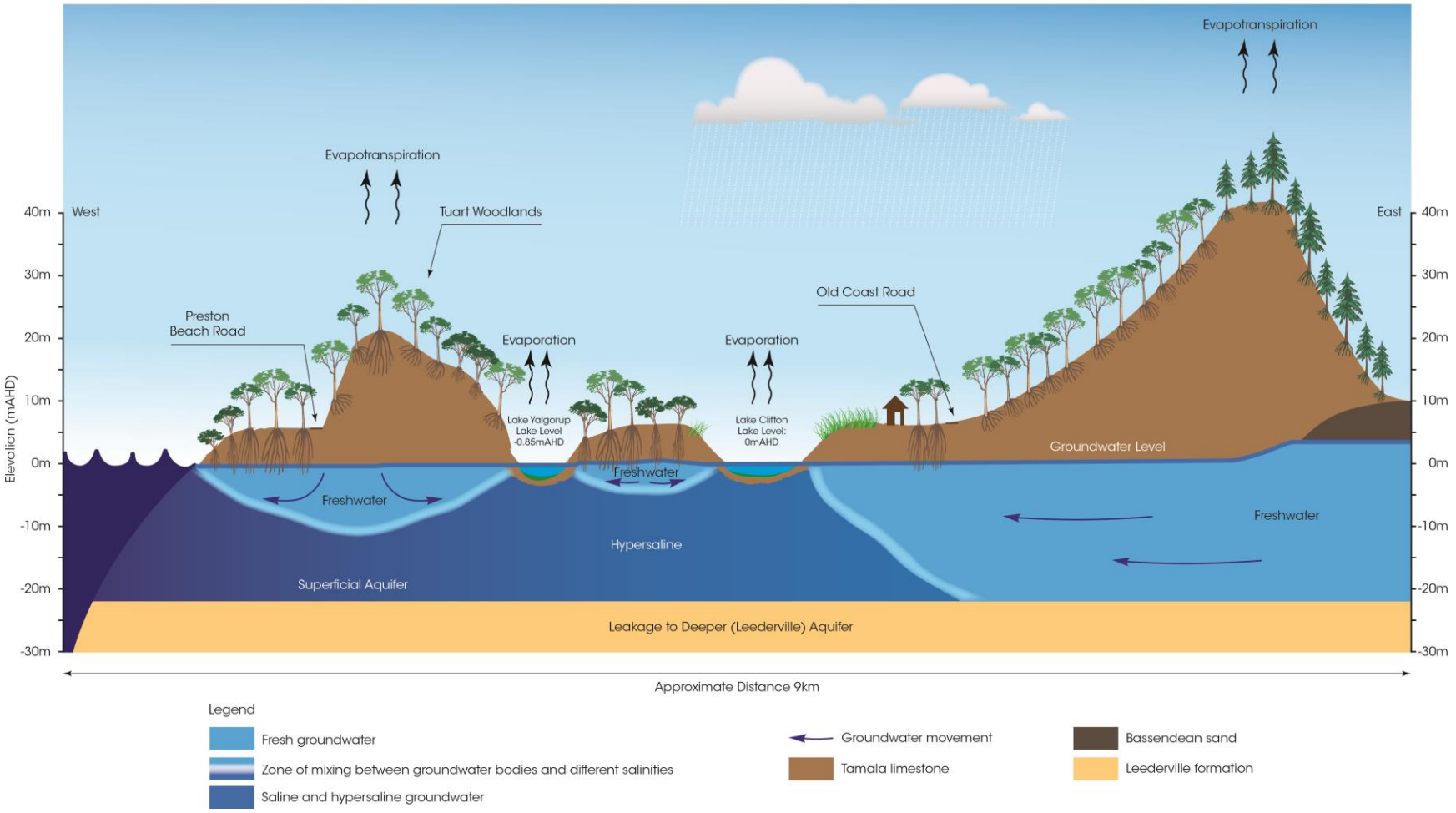


Figure 9: Schematic diagram of saltwater intrusion

Saline upconing

In the plan area there are unique areas of coastal hydrogeology where the freshwater portion of the Superficial aquifer is underlain by saline water. Localised intrusion from underlying saline water up through the aquifer can occur if abstraction is too high.

We considered the risk of saline upconing occurring when setting allocation limits, but more importantly when outlining how water is abstracted locally. Local licensing policies relating to the spacing and rate of abstraction are outlined in Section 4.3 of the plan.

Groundwater-dependent ecosystems

In administering the *Rights in Water and Irrigation Act 1914*, the Department of Water provides for both the sustainable use and development of water resources, and the protection of ecosystems associated with water resources.

Under the *Environmental water provisions policy for Western Australia* (Water and Rivers Commission 2000), we commit to undertake allocation planning in a way that protects key groundwater-dependent environmental values, given they are vulnerable to changes in the quantity or quality of groundwater.

Many of the natural values in the plan area are dependent on groundwater – lakes, wetlands and priority terrestrial vegetation complexes that are situated on or near shallow groundwater, or rely on groundwater discharge (Figure 10). Many of the vegetation complexes of the area are now of regional significance, given widespread clearing on the Swan Coastal Plain.

The Yalgorup National Park and the Ramsar-listed Peel-Yalgorup wetland system cover a large portion of the plan area. These are regionally and internationally significant natural features and make up one of the largest coastal reserves in Western Australia.

Because of the reserves, the plan area supports a diverse range of flora and fauna species including a number of regionally, nationally and internationally threatened species. Of these, the living thromobolite community found in Lake Clifton is of particular importance.

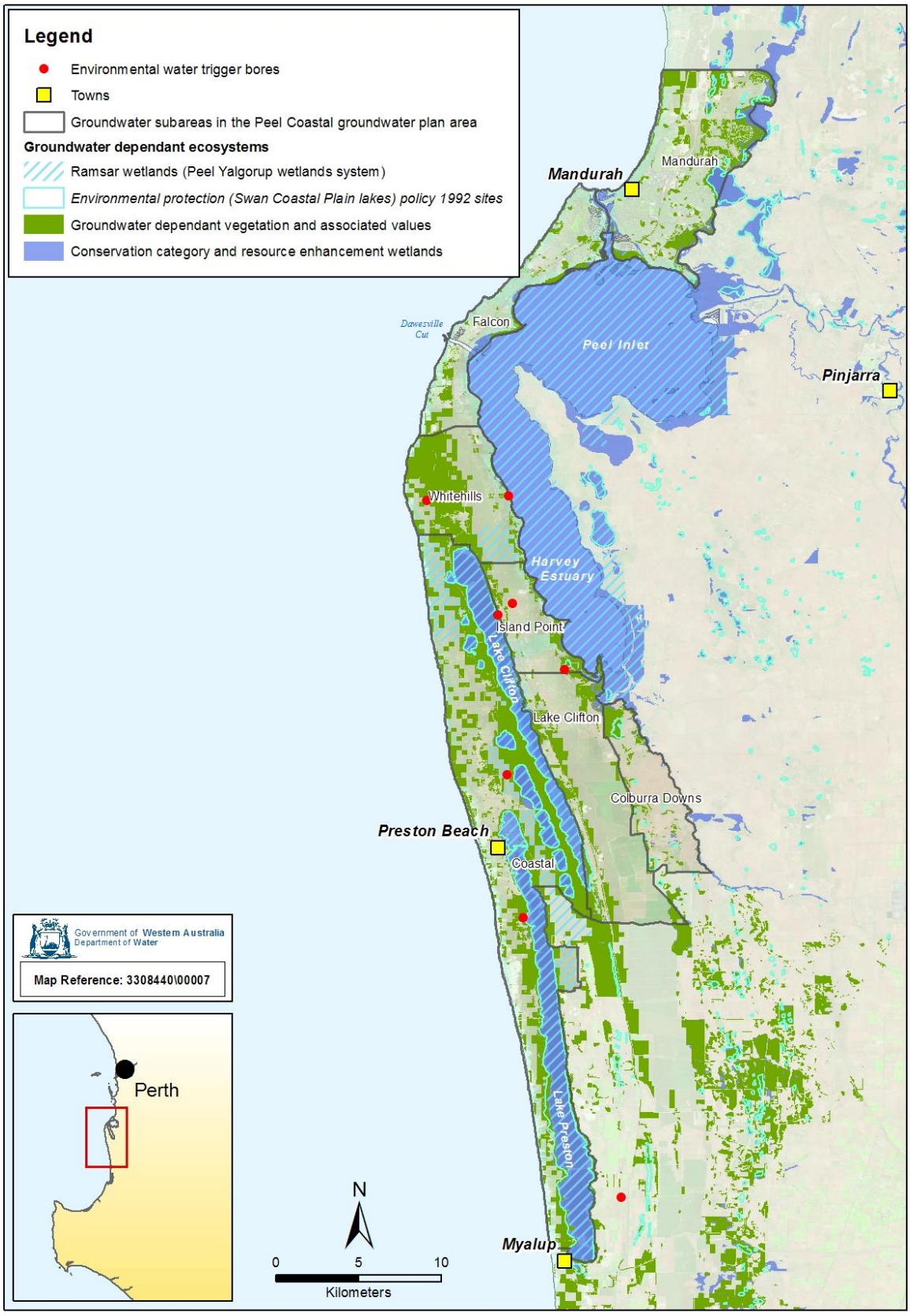


Figure 10 Groundwater-dependent ecosystems of the Peel Coastal plan area

Environmental assessment

Peel Coastal groundwater allocation plan: Groundwater-dependent ecosystems report (Department of Water 2015b) describes the biophysical setting of the Peel Coastal plan area, and the ecological values of each subarea.

The report assesses information on groundwater-dependent ecosystems by:

- mapping areas of potential groundwater dependence
- identifying environmental values likely to be associated with the Superficial aquifer based on their occurrence on shallow groundwater
- establishing the significance of those values at local, state and national levels.

In the report we combined vegetation and wetland mapping with depth-to-groundwater data to identify sites where groundwater-dependent ecosystems occur. The mapping shows where groundwater-dependent ecosystems rely on the Superficial aquifer and sites where groundwater is discharged into the lakes.

We used the information in this report to assess the risks to groundwater-dependent ecosystems from abstraction, to set allocation limits and to develop local licensing policies.

Further information on groundwater-dependent ecosystems in the Peel Coastal plan area can be found in:

- *Swan Coastal Plain South Draft Management Plan* (Department of Parks and Wildlife 2014)
- *Environmental Protection Authority Bulletin 864 - Final Criteria for Environmental Acceptability for Land Use proposals within the Catchment of Lake Clifton* (Environmental Protection Authority 1997).

Minimum groundwater reference levels

We describe ecological water requirements, in the form of minimum groundwater reference levels, for selected sites in the plan area (Table 3). These levels allowed us to assess the risks to groundwater-dependent ecosystems associated with abstraction and to set allocation limits. They will also form the basis of an adaptive monitoring and management framework. It is expected that ecosystems can tolerate some change to average minimums but still remain at a low level of risk.

The reference levels were developed by selecting representative sites using wetland and vegetation mapping, and analysis of aerial photography which showed the wetlands of high conservation value and areas of terrestrial vegetation.

Generic ecological water requirements, in the form of maximum drawdown and rate of change criteria, were then established for each site. We used long-term groundwater monitoring data and published information on vegetation response to groundwater drawdown to develop these minimum levels.

We have identified that some additional work is required to ensure that reference levels and our monitoring program are effective in managing the groundwater

resource (see actions 3 and 4 in Table 4 of the plan). This applies to sites at Lake Clifton, Lake Preston and Martin's Tank that require groundwater discharge to maintain Thrombolite communities. In these instances, water quality monitoring and criteria will need to be put in place. Monitoring groundwater levels alone in these instances will not be sufficient because as mentioned previously water quality may change significantly without any change in water levels.

Table 3: Reference groundwater levels for monitoring sites in the Peel Coastal plan area

Resource objective	Subarea	Monitoring bore	Ecological value	Reference groundwater levels
Groundwater levels are sufficient to minimise risks to groundwater-dependant ecosystems	Mandurah	T630 61410026	Remnant groundwater-dependent vegetation	Groundwater level above 0.13 m AHD
	Island Point	YSH4 61319530	Riparian vegetation	Currently collecting data for determination of level
		HS62C 61330103	Riparian vegetation and Environmental protection policy wetland	Groundwater level above 0.01 m AHD
	Coastal	Lake Clifton C2 61319137	Riparian vegetation	Groundwater level above −0.45 m AHD
		Lake Clifton B2 61319130	Riparian vegetation	Groundwater level above −0.26 m AHD
Maintain sufficient groundwater discharge into Lake Clifton, Lake Preston and Martin's Tank	Island Point	Y2-4B 61319508	Throughflow to Lake Clifton	Groundwater level above −0.05 m AHD
		YSH4 61319530	Discharge into Lake Clifton	Baseline
	Coastal	Lake Clifton C2 61319137	Discharge into Martin's Tank Lake	Groundwater level above −0.45 m AHD
		Lake Clifton B2 61319130	Discharge into Lake Preston	Groundwater level above −0.26 m AHD

Our commitment to ongoing monitoring and evaluation of these values is presented in Chapter 5 of the plan.

2.6 Social and cultural water values

The *Environmental water provisions policy for Western Australia* (Water and Rivers Commission 2000) identifies the following as the social values that require consideration in planning:

- Aboriginal cultural values
- Australian heritage values
- recreational and tourism pursuits
- landscape and aesthetic aspects
- educational and scientific aspects.

Social values relate to water found in its natural place, not water consumed for social benefit (Beckwith 2009).

Although specific studies to describe or quantify the social values associated with groundwater were not completed as part of developing the plan, some clear assumptions can be made. Wetlands and natural areas found in the plan area – in particular those associated with Yalgorup National Park and other conservation reserves – provide valuable tourism assets, prized recreational areas, and sites of both Aboriginal cultural and Australian heritage significance (Department of Water 2009b, Department of Parks and Wildlife 2014).

Given that most of these are dependent on groundwater, ensuring that we regulate and manage abstraction appropriately will deliver significant social and cultural outcomes.

2.7 Demand for water

We take into account both current and future demand for groundwater when setting allocation limits. Section 3.2 describes how we did this in the plan area.

Current groundwater use

Land use in the northern part of the plan area – in and around Mandurah – is primarily urban, with groundwater used to irrigate public open space, sporting grounds and domestic gardens. Groundwater use in the south supports small-scale agriculture, horticulture, plantations and domestic gardens. The volume of licensed water used by different land uses is summarised in Table 4.

Household potable water supplies in Mandurah and surrounding areas are provided by Water Corporation's Integrated Water Supply Scheme. Water for the scheme comes from a combination of surface water dams, groundwater from outside of the plan area, desalination and recycled water. A small volume of groundwater (20 000 kL/yr) is licensed to Water Corporation from the Leederville aquifer in the Coastal subarea to supply drinking water to Preston Beach.

Water use across the plan area is highest in the Mandurah and Falcon subareas with licensed entitlements totalling ~4 698 000 kL/yr accounting for 87 per cent of the total licensed entitlements of the plan area (5 389 175 kL/yr). The remaining five subareas total 711 000 kL/yr in licensed entitlements.

Stock, garden and domestic bore use (exempt from licensing) is also particularly high in this plan area (5 379 000 kL/yr), accounting for almost half of all groundwater use. Exempt use includes backyard garden bores for urban blocks, as well as traditional stock and domestic allocations for larger 'lifestyle lots' and properties south of Falcon which do not have access to scheme water supply. Table 5 identifies the estimated volume of exempt use in each Superficial resource. The method used for calculating these estimates is presented in Appendix A.

Table 4: Total licensed water entitlements categorised by use in the Peel Coastal plan area (Superficial and Leederville aquifers) July 2014

Usage category	Total licensed entitlement volume (kL/yr)	Percentage of total entitlement volume (%)
Agriculture	858 700	16
Public drinking water scheme supply (reserve)	20 000	0.4
Licensed stock and domestic	125 130	2
Commercial and institutional	205 563	4
Industry and power generation	44 300	1
Parks, gardens and recreation	4 155 482	77
TOTAL	**5 389 175**	**100**

Table 5: Exempt domestic use estimates for the Peel Coastal plan area (Superficial aquifer)

Subarea	Estimated exempt use (kL/yr)
Mandurah	2 628 000
Falcon	1 667 000
Whitehills	243 000
Island Point	283 000
Lake Clifton	355 000
Coastal	133 000
Colburra Downs	70 000
TOTAL	**5 379 000**

Future groundwater use

The *Peel Coastal groundwater allocation plan* (Department of Water 2015) aligns water allocation planning with land use planning to ensure that future water needs are able to be met, while also protecting the resource and its dependent values.

We used the following planning documents to estimate likely future groundwater use:

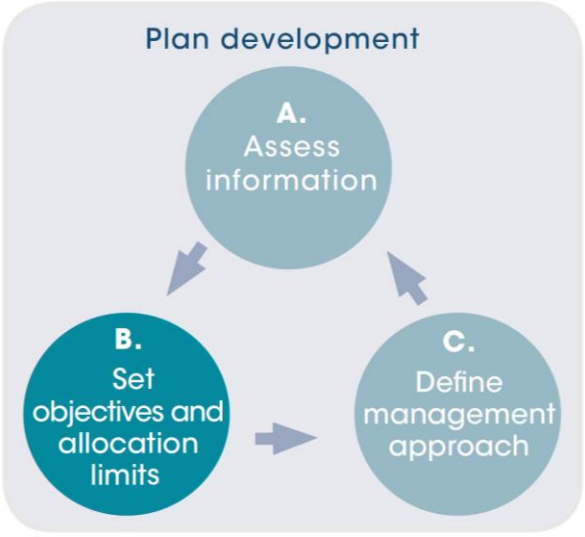
- *Directions 2031 and beyond* (Western Australian Planning Commission 2010)
- *Outer metropolitan Perth and Peel sub-regional strategy* (draft) (Western Australian Planning Commission and Department of Planning 2010)

Overall, groundwater needs for the plan area are not expected to increase significantly over the next 10 years. An estimated 268 ha of new urban areas have been identified in the plan area. Most of this is in the Mandurah and Dawesville areas. We have projected that water needs for public open space in these areas will be approximately 200 000 kL/yr.

Local structure plans for the area indicate some rezoning of rural areas south of Mandurah, but a substantial increase in groundwater requirement is not anticipated. The draft *Southern Mandurah Rural Structure plan* (City of Mandurah 2013) indicates that it is likely that exempt-from-licensing groundwater demand may increase by approximately 47 000 kL/yr.

Section 3.2 describes how we considered these estimates of future use when setting allocation limits.

3 Part B: Setting plan objectives and allocation limits



In Part B of the allocation planning process we:

- set objectives for our management of the area
- outline the methodology selected
- assess allocation options
- decide allocation limits.

Key points for this section:

- We developed measurable resource objectives to achieve the plan outcomes, which are to:
  - support the water needs of current and future land uses in the Peel Region
  - protect valuable ecosystems dependent on groundwater, including those of the Peel–Yalgorup wetland system, from any adverse effects of groundwater abstraction
  - encourage water trading and the use of alternative water sources.
- A risk-based approach was used to set allocation limits and consider the needs of competing consumptive use and in-situ demands for water in a drying climate.
- In setting the allocation limits we used the following to inform our decisions:
  - our understanding of groundwater-dependent ecosystems, significant environmental assets and social values
  - trends in groundwater levels and assessment of the risk of taking more, less or the same volume of water
  - current licensed and exempt-from-licensing water use
  - future demand for water based on land use planning
  - stakeholder feedback.

3.1 Setting objectives

In administering the *Rights in Water and Irrigation Act 1914*, the Department of Water provides for both the sustainable use and development of water resources, and the protection of ecosystems associated with water resources.

The process of setting allocation limits, developing licensing approaches and policies, and setting up our monitoring and evaluation program are guided by the outcomes and resource objectives described below. They will also continue to inform our management as we implement the plan.

Outcomes

We aim to support achievement of the plan outcomes by implementing the water resource management described in the plan. The outcomes for the *Peel Coastal groundwater allocation plan* are to:

- support the water needs of current and future land uses in the Peel Region
- protect valuable ecosystems dependent on groundwater, including those of the Peel-Yalgorup wetland system, from impacts of abstraction
- encourage water trading and the use of alternative water sources.

Resource objectives

To support the plan outcomes, our management is directed towards meeting specific water resource objectives. Water resource objectives must be measurable and relate directly to maintaining, increasing, improving, restoring, reducing or decreasing surface water flow, groundwater levels or water quality. They are measurable, so that progress against them can be assessed during regular plan evaluations.

Resource objectives for the plan area and the factors considered in setting them are summarised in Table 6.

Table 6: Developing the resource objectives and water management framework for the Peel Coastal plan area

Resource objective	Main factors considered in developing the resource objective
1. Abstraction does not cause the seawater interface to move inland	Preventing significant seawater intrusion into the aquifer as a result of abstraction will contribute to maintaining the reliability of freshwater supply for existing users and the environment. Groundwater users and any groundwater-dependent ecosystems located along the coast are likely to be adversely impacted if the seawater interface moves further inland. There is some natural saltwater intrusion expected associated with declining rainfall and groundwater recharge climate, however the trend is slow.
2. Saltwater up-coning does not affect other users	Preventing local saltwater upconing as a result of abstraction will contribute to maintaining the reliability of freshwater supply for existing users, their neighbours and the environment. If the freshwater portion of the aquifers becomes saline it will limit what the resource can be used for into the future and adversely affect groundwater-dependent ecosystems.
3. Groundwater levels are sufficient to minimise risks to groundwater-dependant ecosystems	The Peel Coastal plan area contains many highly valued ecosystems that depend on groundwater. The department is responsible for minimising the risk to groundwater-dependent ecosystems, where abstraction occurs. We expect that groundwater-dependent ecosystems will undergo natural changes over time as a result of declining rainfall and this may include changes to groundwater levels in the Superficial aquifer. However, we aim to minimise this risk through our allocation limits, licensing and ongoing monitoring and evaluation.
4. Fresh groundwater discharge into Lake Clifton, Lake Preston and Martin's Tank is sufficient to minimise further risk to dependent ecological values	Lake Clifton, Lake Preston and Martin's Tank are all highly valued environmental assets which require annual fresh groundwater discharge to maintain their ecological state (see *Peel Coastal groundwater allocation plan: Groundwater-dependent ecosystems report,* Department of Water 2015b for more information). Freshwater discharge is particularly important for Thrombolite communities. We expect that groundwater-dependent ecosystems will undergo natural changes over time as a result of declining rainfall and this may include changes to how much freshwater is discharged at these sites. We aim to minimise this risk in how we manage groundwater in the plan area.

3.2 Setting allocation limits

What is an allocation limit?

An allocation limit is the annual volume of water set aside from a water resource for consumptive use. Allocation limits are the main tool that the Department of Water uses to ensure sustainable take and security of supply at the resource scale. The limit does not include water allocated to remain in the aquifer.

The allocation limit decision represents a balance between current and future groundwater use, and the amount of water that needs to be retained in the aquifer for environmental and resource-protection purposes.

Selecting the best method to set allocation limits

Due to the relatively low use of groundwater (compared to other areas of the state) the department does not have an extensive monitoring program across the plan area. As a result, the high level of data needed to support quantitative methods for setting allocation limits, such as a numerical model, was not available.

Additionally, the risks that are evident from the drying climate across the whole of the south-west of the state, suggest that an update to allocation limits in the plan area could not be postponed until more information was available. Additional work would have delayed the plan and delayed the actions we have now taken.

Therefore, as in other areas of the state with limited monitoring data, we used a risk-based approach to set allocation limits. This typically involves understanding how water use (current and future) could impact on the resource and determining whether more or less water can be allocated while still achieving the plan's outcomes and objectives.

How we set allocation limits in the Superficial aquifer

Allocation limits have generally been set at the current level of use (current entitlements plus the estimate of exempt-from-licensing use) for Superficial resources in the plan area. There are two exceptions; Colburra Downs and Island Point. In Colburra Downs there are no licence entitlements, so the allocation limit has been set at the estimated level of exempt use. In Island Point, there may be some small future increase in exempt use as a result of subdivisions, so we have added an additional 45 600 kL/yr to current entitlements and estimated exempt use to set the allocation limit.

The key factors that support the decision to set allocation limits at the current level of use in the Superficial resources are outlined below:

1. Our assessment of current and future groundwater level trends shows that there is a slow decline across the plan area that will continue with the drying climate. This means that allowing additional water to be allocated would increase the risk of not meeting the plan's outcomes and resource objectives.

2. The unique coastal geography of the plan area, in particular its proximity to both the ocean and estuarine environments, means that the groundwater resources are extremely susceptible to declines in water quality from saline intrusion and upconing. Allowing additional water to be allocated would put further pressure on maintaining water quality. The drying climate means that there is already a long-term risk of the seawater interface and saline water from the estuary moving landward and reducing water quality.
3. The high-value environmental, social and cultural assets in the area, namely Yalgorup National Park, the Peel-Yalgorup wetland system and the rare Thrombolite communities of Lake Clifton, are susceptible to reductions in both water level and water quality. These are already under threat from urbanisation, climate change and the changes we have already observed to the groundwater resource. Allowing additional water to be allocated would put additional risk on already stressed systems that are highly valued and deliver significant community benefits.

   With likely continued declines in rainfall and recharge, allowing the allocation of additional water would place an unacceptable level of risk on these values. Table 7 below includes an indication of localised risk to significant environmental values.
4. The ability of future water use, primarily for irrigating public open space, to be met by alternatives sources, instead of through additional groundwater entitlements was a major consideration when setting allocation limits. Although local groundwater is typically the lowest cost option for public open space, the department expects future water needs to be met by:
   a. Trading or transferring from existing users or reaching agreement to use an existing entitlement.
   b. Alternative water sources such as treated wastewater, sub-surface drainage or managed aquifer recharge.

   Setting allocations limits at the level of current use is critical as a signal/incentive for water users to investigate and drive improvements in efficiency and to develop alternative water sources. Given that there are already examples of treated wastewater being used in Mandurah (Gordon Road, Caddadup and Halls Head wastewater treatment plants infiltrate around 5 GL of treated wastewater per year) and that volumes available in the future are likely to increase, this is a reasonable option. We will work with proponents to explore and facilitate all alternative water source options.

We also considered the option of reducing entitlements below current use in order to reduce risks to water levels, water quality and groundwater-dependent ecosystems. This was not considered a reasonable approach at this time given the current reliance on groundwater in the area. This may be reconsidered in the future if there is clear evidence of increasing impacts to users or groundwater-dependent values from declining water levels or water quality, and if alternative sources are accessible.

Table 7 below provides the rationale for the allocation limit decision in each individual Superficial resource.

Table 7: Allocation limits for the Superficial aquifer (by subarea) in the Peel Coastal plan area

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Mandurah - Superficial	5 000 000	4 653 729	**1. Groundwater trend assessment** • Measurement data (hydrographs) indicate a slow, decline (less than 1 m) in water levels over the last 30 years (search for Lake Thomson T581 (Ref no. 61410048) and T580A (Ref no. 61410723) at http://wir.water.wa.gov.au). • Trend likely to continue due to continued declines in rainfall but may be buffered by proximity to the coast. • Localised increases in water levels due to wastewater infiltration. • Groundwater levels well above reference groundwater levels (Figure 17, Department of Water 2015b).
			2. Current and future use • Most water is used for public open space. • High domestic exempt use (exempt use was previously not accounted for). • Structure plans indicate some land use change. Public open space may require up to 200 000 kL/yr for future developments.
			3. Allocation limit decision Reduced to entitlements plus exempt estimates. • Current level of allocation poses an acceptable risk to groundwater-dependent ecosystems in the Mandurah subarea. Any further groundwater abstraction would increase the risk of decline in water quality from seawater intrusion and potentially impact existing users (such as high value public open space and domestic/garden supplies). • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge. • Significant opportunities for alternative sources to meet future water needs, potentially utilising Water Corporation's Gordon Road wastewater treatment plant.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Falcon – Superficial	1 800 000	2 321 923	**1. Groundwater trend assessment** • No water level measurement data was available for the Falcon subarea, however we have assumed groundwater level conditions are similar to those experienced in the Mandurah area because of the similarities in abstraction volumes and land use. • Trend likely to continue due to continued abstraction and declines in rainfall but may be buffered by location between the coast and the estuary.
			2. Current and future use • Most water is used for public open space. • High domestic exempt use (exempt use was previously not accounted for). • Structure plans indicate the subarea is mostly developed, and that there will be little or no change in land use and water demand.
			3. Allocation limit decision Reduced to current entitlements plus exempt estimates. • No future demand increase and further groundwater abstraction would significantly increase the risk of decline in water quality from seawater intrusion due to the location of this subarea between the ocean and the estuary. Reductions in water quality would likely impact existing users (high value public open space). • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge. • Significant opportunities for alternative sources to meet future water needs, potentially utilising the Water Corporation's Halls Head and Caddadup wastewater treatment plants.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Whitehills – Superficial	200 000	335 909	**1. Groundwater trend assessment** • Groundwater hydrographs indicate that water levels are generally stable over the last 30 years (search for Lake Clifton A5 (Ref No. 61319128) at http://wir.water.wa.gov.au) likely to be due to the location between the estuary and the ocean and the very low use.
			2. Current and future use • Mostly undeveloped area with some small urban/rural areas to the east. • Yalgorup National Park contains valuable natural assets that are groundwater-dependent. • Structure plans for the subarea do not indicate significant land use change or significant amounts of further development, indicating that demand for water is unlikely to change.
			3. Allocation limit decision Set at current entitlements plus exempt estimates. • Limited access to alternative sources available at this time but future increases in demand unlikely. • Water quality already under increasing risk from projected declines in rainfall and recharge. • Current stable groundwater level trends pose minimal local risk to groundwater-dependent vegetation in Yalgorup National Park.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Island Point – Superficial	1 600 000	568 375	**1. Groundwater trend assessment** • Groundwater hydrographs indicate a slow decline (less than 1 m) in water levels over the last 30 years particularly in the southern parts of the subarea (search for Harvey Shallow NS62B (Ref No. 61330102) at http://wir.water.wa.gov.au). • Water levels are more stable in the north of the subarea due to the location between the estuary and the ocean (search for Harvey Shallow NS62B (Ref No. 61330102) at http://wir.water.wa.gov.au). • Trend likely to continue due to continued declines in rainfall but may be buffered by location between the coast and the estuary. • Water levels have fallen below reference levels (for groundwater-dependent ecosystems and groundwater throughflow) in low rainfall years only. Average water levels are above reference levels.
			2. Current and future use • Generally undeveloped with some semi-rural properties with some small urban development (on estuary side of subarea). • Relatively high exempt use (exempt use was previously not accounted). • City of Mandurah's *Draft Southern Structure plan* proposed some future rezoning of semi-rural blocks with an estimated additional exempt water use component of 45 600 kL/yr.
			3. Allocation limit decision Reduced to current entitlements plus current and future exempt estimates. • Drying climate poses a risk to high-value groundwater-dependent ecosystems to the west and downstream of groundwater flow of the subarea, including vegetation and wetlands in Yalgorup National Park and Thrombolite communities in Lake Clifton. • Minor additional future demand, but limited access to alternative sources available at this time. • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Lake Clifton – Superficial	3 000 000	661 440	**1. Groundwater trend assessment** • Groundwater hydrographs indicate a decline in water levels of less than 1 m over the last 30 years (search for Harvey Shallow HS63B (Ref No. 61319133) at http://wir.water.wa.gov.au). • Trend likely to continue due to continued declines in rainfall.
			2. Current and future use • Small-scale agriculture and horticulture with licensed use. • Relatively high exempt use (exempt use was previously not accounted for). • Some pine plantations present. • Structure plans for the subarea do not indicate land use change, indicating that demand for water is unlikely to increase.
			3. Allocation limit decision Reduce to current entitlements plus exempt estimates. • Drying climate poses a risk to high-value groundwater-dependent ecosystems to the west and downstream of groundwater flow in the subarea. This includes vegetation and wetlands in Yalgorup National Park and Thrombolite communities in Lake Clifton. The location of Superficial aquifer monitoring in this subarea limited our ability to set groundwater reference levels and quantify the risks. • No additional future demand and limited access to alternative sources available at this time. • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Coastal – Superficial	4 100 000	192 550	**1. Groundwater trend assessment** • The hydrographs indicate a slight decline in groundwater levels (less than 1 m) over last 30 years (search for Lake Clifton B2 (Ref No. 61319130) at http://wir.water.wa.gov.au). • Trend likely to continue due to continued declines in rainfall but may be buffered by proximity to coast. • Water levels have only fallen below groundwater reference levels (for groundwater-dependent ecosystems and groundwater throughflow) in low rainfall years only. Average water levels are well above the reference levels.
			2. Current and future use • Mostly undeveloped area with some small urban/rural areas to the east. • Yalgorup National Park contains valuable natural assets that are groundwater-dependent. • Preston Beach townsite (but doesn't access the Superficial resource). • No expectation of land development other than the Preston Beach townsite. The demand for water in the townsite will be supplied from outside the subarea (scheme water).
			3. Allocation limit decision Reduce to current entitlements plus exempt estimates. • Drying climate poses a risk to groundwater-dependent ecosystems in the Yalgorup National Park as well as to water quality from landward movement of seawater. • No additional future demand. • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge.

Resource (subarea and aquifer)	Previous allocation limit (kL)	New allocation limit (kL)	Risk assessment and allocation limit decision
Colburra Downs – Superficial	1 600 000	70 000	**1. Groundwater trend assessment** • Hydrographs indicate a slow steady decline of less than 1 m in groundwater levels (search for Harvey Shallow HS63A (Ref no. 61330104) at http://wir.water.wa.gov.au). • Trend likely to continue due to continued declines in rainfall and possible regional abstraction influence. • Water quality is poorer than elsewhere in the plan area with increased risk of saline upconing.
			2. Current and future use • There are no licensed entitlements, or demand, in this subarea, the allocation limit reflects only exempt use estimates. • Structure plans for the subarea do not indicate any future development.
			3. Allocation limit decision Reduce to estimates of exempt use • No future demand. • Water levels and water quality already under increasing risk from projected declines in rainfall and recharge.
Total	**17 300 000**	**8 803 926**	

NOTE: Applications received before 8 July 2014 are considered current land use and are included in the allocation limits of the Peel Coastal plan area. When we receive applications after 8 July 2014 within fully allocated aquifers, we formally contact proponents to let them know that water is not available and it is likely that their application will be refused.

How we set allocation limits in the Leederville aquifer

As with the Superficial resources, allocation limits for Leederville resources in the Mandurah, Falcon and Coastal subareas have been set at the current level of use (note that there is no exempt use from the Leederville aquifer in the plan area).

The key factors in setting allocation limits in these three Leederville resources are outlined below:

1. Despite there being limited local monitoring information in the Leederville aquifer, it can be inferred from available data and regional information that pressure-heads are falling at a significant rate, in most cases more dramatically than in the Superficial aquifer. Additional abstraction would increase the risk of seawater intrusion into the aquifer and likely impact on its existing users.
2. Recharge to the Leederville aquifer is mostly from the Superficial aquifer and additional abstraction would also impact on water levels, water quality and high-value groundwater-dependent ecosystems in the Superficial aquifer.
3. In the Falcon subarea, the Leederville aquifer is recharged with saline estuarine water from the Peel Inlet. This means that the freshwater resource is non-renewable. Additional abstraction of the fresh water from this resource would directly impact on current users. In addition to the allocation limit being set at the current level of use, when a licence is relinquished or cancelled the associated volumes of water will not be made available.
4. As described for the Superficial aquifer, potential new water demands in the Mandurah and Falcon subareas are primarily for public open space and can reasonably be met via trading, transfers, agreement with existing users and the use of alternative sources such as treated wastewater.

For the remaining Leederville resources, allocation limits have been set at zero as there is no current use and no future demand identified through land use planning processes.

Table 8 summarises allocation limits for Leederville resources in the plan area.

Table 8: Allocation limits for the Leederville aquifer (by subarea) in the Peel Coastal plan area

Subarea	Previous allocation limit (kL)	New allocation limit *(current use)* (kL)	Risk based approach to allocation limit
Mandurah	1 000 000	802 100	Set at current entitlements • Some Department of Water groundwater level monitoring. • No salinity monitoring. • Limited licensee monitoring data. • Limited information available on impacts of abstraction. • Risks of saline intrusion and impacts to current license entitlements.
Falcon	2 200 000	1 606 420	Set at current entitlements • No Department of Water monitoring data. • Limited licensee monitoring data. • Recharged from estuary. • Risks of saline intrusion and impacts to current license entitlements. • Non-renewable resource.
Island Point	10 000	0	Set a 0 kL • No current demand and unlikely to be future demand • No monitoring data. • Risk of saline intrusion.
Whitehills	110 000	0	Set a 0 kL • No current demand and unlikely to be future demand • Limited Department of Water monitoring data. • Risk of saline intrusion.

Subarea	Previous allocation limit (kL)	New allocation limit *(current use)* (kL)	Risk based approach to allocation limit
Lake Clifton	10 000	0	Set a 0 kL • No current demand and unlikely to be future demand. • Limited Department of Water monitoring data. • Risk of saline intrusion.
Coastal	100 000	20 000	Set at current entitlements • Allocation is licensed to the Water Corporation for the Preston Beach public water supply. • Limited licensee monitoring data. • Risk of saline intrusion and potential impacts to lake system.
Colburra Downs	10 000	0	Set a 0 kL • No current demand and unlikely to be future demand. • No monitoring data. • Risk of saline intrusion.
TOTAL	**3 440 000**	**2 430 020**	

Summary of allocation limits decisions

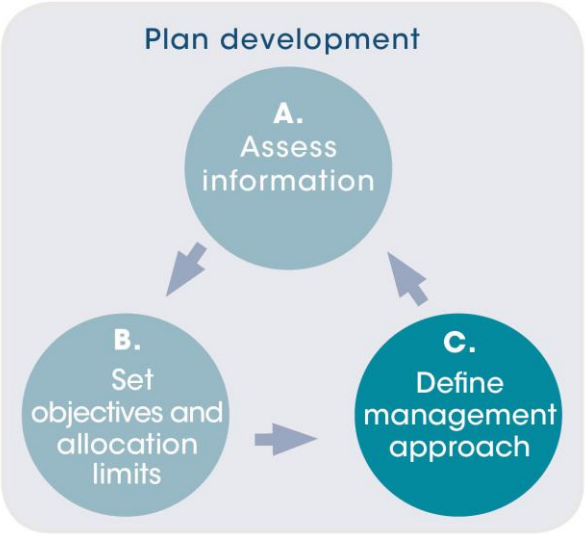
The decision-making process outlined above has resulted in allocation limits being reduced by a total of approximately 9.5 GL/yr in the Peel Coastal plan area. As explained, this is primarily due to the fact that current allocation limits were set in 1989 when climate change was not a major consideration (Water Authority 1989).

Importantly these allocation limit decisions will trigger improved water use efficiency measures, encourage trading and promote investment in alternative water source options.

Why have some allocation limits increased?

Allocation limits for the Whitehills and Falcon Superficial resources increased when compared to the previous allocation limits because we have included exempt use estimates in the allocation limit for the first time. This does not make more water available for use but instead ensures we have accounted for all current use.

4 Part C: Defining the management approach



In Part C of the allocation planning process, we define the management approach in meeting the outcomes and objectives of the plan.

Much of this information is adequately explained in chapters 4, 5 and 6 of the allocation plan, so only a summary is presented here.

Key points from this section:

- The department has put in place a suite of management arrangements that complement our allocation limit decisions.
- The water licensing approach described in Chapter 4 will ensure there are improvements to water use efficiency, will facilitate water trading and result in the progressive development of alternative water sources.
- The local licensing rules set out in Chapter 4 of the plan are designed to:
  - protect the integrity of the resource and the groundwater-dependent environment, where this may be impacted upon by licensed abstraction
  - prevent licensees from impacting upon each other's ability to take groundwater in accordance with a licence.
- The monitoring and evaluation programs detailed in chapters 5 and 6 of the plan have been developed to support adaptive management of groundwater resources in the plan area.

4.1 Water licensing in the plan area

A water licence issued under the provisions of the *Rights in Water and Irrigation Act 1914* provides legal and secure access to water. Water allocation plans set out how we will assess licence applications, set licence conditions and manage licences on an ongoing basis. By doing this, allocation plans provide clear guidance to proponents and provide justification for our decisions.

Chapter 4 of the allocation plan outlines our water licensing approach and local licensing policies.

Water licensing approach

The water licensing approach described in Section 4.2 of the allocation plan focuses primarily on how proponents can meet their water demands in fully allocated resources. Given that allocation limits have been set at the current level of use, there is no additional groundwater available for licensing.

As a result, we have provided positions on the following issues in the plan:

- Water use efficiency – improving how water is used is one way that proponents may be able to access additional water. It may also make water available for trading.
- Water trading and transfer – we will apply *Operational policy 5.13: Water entitlement transactions for Western Australia* (Department of Water 2010).
- Alternative water sources – given that no additional groundwater is available into the future, we are committed to working with proponents to identify potential alternative sources as part of implementing the plan and meeting future demand projections.

  The department recommends the use of our *Guideline for the approval of non-drinking water systems in Western Australia: Urban Developments* to provide information about considerations and approvals for possible alternative water sources.

  For potential managed aquifer recharge projects we have developed *Operational policy 1.01: Managed aquifer recharge in Western Australia* to provide information on the considerations and licensing requirements of these schemes.

Local licensing policies

Local licensing policies outlined in Section 4.3 of the plan are required to address resource management issues where they are not addressed by state-wide policy. They are designed to help us achieve the outcomes and resource objectives in the plan.

As there is no additional water available in the plan area, local licensing policies will be applied if water does become available through the relinquishment of licensed volumes, from departmental recouping activities, when a licence is renewed or if monitoring of the water resource indicates there is a need to amend a licence.

Table 9 describes the intent of each local licensing policy.

Table 9: The intent of the local licensing policies

Local licensing policy	Intent of local licensing policy
Licence assessment: Assessing the impacts of a proposal on groundwater-dependent environmental values and water quality	The intent of this policy is to identify any potential impacts to the environment or the groundwater resource through the assessment phase of the licensing process. Identifying the potential impacts early ensures that they are adequately considered and addressed before a licence is issued (where water is available). Before we can assess the impacts of the proposal, the proponent will need to clearly demonstrate how they will prevent or manage the effect of their proposal on: a) significant wetlands b) acid-sulfate soils c) local saltwater upconing d) the landward movement of the seawater interface. Each proponent will be provided with direction on what we require to complete our assessment of the licence application by the regional office. The department applies a consistent approach to assessing the potential impacts of a licence application on groundwater-dependent ecosystems across the state. Further details on assessing groundwater-dependent ecosystems in the Peel Coastal plan area can be found in the *Peel Coastal plan area: Groundwater-dependent ecosystems report* (Department of Water 2015b).
Managing impacts: • Managing impacts on groundwater-dependent environmental values • Managing impacts on water quality • Licences requiring operating strategies • Amending licences if impacts on groundwater-dependent environmental values or water quality are observed	The intent of these policies is to minimise and prevent impacts for existing and new licences. Existing groundwater abstraction that could impact on groundwater-dependent ecosystems and/or groundwater quality may be amended by the department. Amendments may include: • relocation of production bores, including new or replacement bores • change to the rate of abstraction (volume drawn over time) • requirements to install and measure groundwater levels in local monitoring bores • requirements to sample and measure water quality • restricted abstraction (e.g. timing, rate of abstraction) • relocation of production bores • requirement to install and measure groundwater levels in local monitoring bores to identify if the changes to abstraction or location of the draw was effective. Any proposal to amend a licence will be discussed with the licensee and follow the standard process applied by the department across the state.

Local licensing policy	Intent of local licensing policy
Metering: Requirements for metering	Meters are the most accurate tool for measuring the volume of water abstracted from a bore. The additional metering requirements for this policy are designed to understand use in urban areas, particularly linking local groundwater use with groundwater levels (cumulative impacts on the resource). The additional need for a meter on a bore abstracting from the Leederville aquifer in the Falcon subarea is to track the amount of groundwater abstracted in this non-renewable resource. If too much is abstracted then the resource is likely to become saline.

4.2 Monitoring and evaluation program

Through monitoring groundwater resources, we will understand how the aquifers perform over time in response to abstraction and changes in groundwater recharge. This will help us assess how well the allocation limits, licensing approach and local licensing policies described above are helping us to meet the plan's outcomes and resource objectives.

Critically, it will inform our adaptive management approach in the plan area.

Chapter 5 of the plan details the monitoring we will carry out and the performance indicators we will use to assess how well we are meeting the specific resource objectives of the plan. The monitoring program will also be important in understanding how the declining rainfall is affecting groundwater resources, and how ecological values are responding.

As we have noted in this document and the plan itself, some improvements need to be made to the monitoring program, particularly to include appropriate water quality monitoring. We will be actioning this as part of implementing the plan (refer to Table 4 in Chapter 6 for a list of actions to implement the plan).

Chapter 6 outlines how we will implement and evaluate the plan. Evaluation is part of the department's adaptive management approach and assists us to continually improve our management of water resources. It is applied to all allocation plans across the state.

We will regularly evaluate whether the plan outcomes and resource objectives are being delivered through implementation of the plan, and make this information publicly available in evaluation statements at least every three years.

Appendix A - Determining the volume of water to be set aside for exempt stock and domestic use

The allocation limit is the volume of water set aside for use, including use that is exempt from licensing. Water available for licensing is determined by subtracting the estimated volume of water taken for exempt purposes from the allocation limit.

Groundwater abstraction is exempt from licensing if the bore and its use complies with the current by-laws and exemption orders under the *Rights in Water and Irrigation Act 1914* and the *Water Agencies (Powers) Act 1984*. This includes water used for:

- stock[1], domestic and garden use[2]
- firefighting
- short-term dewatering[3]
- monitoring purposes.

In the Peel Coastal plan area, exempt use is generally for stock, domestic and garden use from the watertable aquifer. As this water is required on a continual basis it must be accounted for in portioning available groundwater for allocation. All other exempt uses are not continuously required and do not need to be accounted for on a permanent basis.

Information used to estimate exempt use

Exempt water use in the Peel Coastal plan area was estimated using the following information:

- Cadastral information including lot zoning, size, tenure and number of blocks obtained from the departments' GIS database, supplied by the Department for Planning.
- Departmental knowledge of exempt water use in the area.
- Recent departmental investigations into the incidence of bores and their water use in the Perth metropolitan area.
- Water use factors for domestic bore use sourced from *Strategic policy 2.03 – managing unlicensed groundwater use* (Department of Water 2009d).

[1] To water cattle or other stock, other than those being raised under intensive conditions (see Section 21 (4) of the *Rights in Water and Irrigation Act 1914* for the definition of intensive)

[2] Lawn or garden that does not exceed 0.2 ha (2000 m^2)

[3] Refer to definitions of exempt dewatering within the *Rights in Water and Irrigation Exemption (Section 26C) (Dewatering) Order 2010*

- Comparison with licensed water use in the Peel Coastal plan area where a proportion of the use on the licence is assigned as stock, domestic and/or garden purposes.
- Scheme water supply locations.

Assumptions

Estimating exempt use (stock, domestic and garden use) requires several assumptions when calculating the volume of water required to account for this use. The assumptions used were:

- All exempt use is abstracted from the Superficial aquifer (watertable aquifer).
- All exempt use that is not taken from the Superficial aquifer is licensed.
- Eligible exempt users are found only on freehold, privately held residential land.
- Exempt users in subareas subject to watering restrictions will comply with the three-day per week watering roster.
- Exempt users in predominantly residential subareas will use water in a similar way to users of backyard bores in the Perth metropolitan area.
- The information gathered to estimate exempt use is a snapshot in time, and does not take into account any predicted increase or decrease in exempt use across the plan area.
- Any future refinements to the allocation limits will need to undertake additional investigations into exempt use to identify and account for any changes.

The assumptions used to determine the estimated exempt use in the Peel Coastal plan area for each land planning type is described in Table A1 below. The values presented in Table A1 are taken from *Strategic policy 2.03 – managing unlicensed groundwater use,* with amendments listed as marked.

Table A1: Estimated water use by cadastral block size in the Peel Coastal plan area

Category	Land size (m^2)	Estimated water use (kL/yr)	Estimated incidence of bore use (%)
Small urban blocks	Under 500	405^ or 800	5
Large urban blocks	500-999	405^ or 800	25*
Semi-rural properties	1000-5000	1000	50
Rural holdings	Over 5000	1500#	80

^ 405 kL/yr is the amount specified by the domestic bore metering project, which varies from the previously specified amount of 800 kL/yr, following the introduction of watering day restrictions. The subareas of Mandurah, Falcon and Whitehills were estimated using the 405 kL/yr figure, where the remainder utilised the 800 kL/yr estimate as they are outside the restriction zone.

* Bore incidence was altered from the previous figure of 30 per cent, following the 2011 Perth-Mandurah region domestic bore review (Stone, unpublished) which indicates that in recent years the rate of domestic bore ownership in urban premises dropped, resulting in a new estimate of 25 per cent.

Incorporates a component for internal household requirements (150 kL), as these properties do not access scheme water. This volume also is sufficient to water approximately 2000 m^2 of lawns and gardens and supply small amounts of stock water. This also assumes that rainwater tanks are not used for in-house purposes.

Methodology

To determine the estimated volume of exempt use the following steps were taken:

Steps	Notes
1. Collect data on the number of blocks, block size, zoning, land use and tenure for each subarea in the plan area. Filter data by subarea.	Exempt use was allocated only to freehold, privately held land for residential purposes. Properties held by commercial interests or public bodies, as well as vacant land for domestic purposes, were removed. Properties identified as strata or triplex/quadruplex were also removed from the database as these were unlikely to have individual garden bores. Duplex premises remain within the 'small urban blocks' category.
2. Determine the volume of licensed entitlements for each subarea where use on the licence was assigned as stock, domestic, fire fighting or garden purposes, and cross check with the rural estimate in Table A1.	The average exempt use figure was determined by reviewing existing licenses that contained a stock and domestic proportion[4] compared with the estimate of exempt use for rural premises in *Strategic policy 2.03*. The average use for stock and domestic purposes by licensed users in the plan area was 2096 kL/yr. Where stock, garden and domestic entitlements are included on a licence the property was removed from the subarea estimate calculations in Table A2 to avoid double-counting. The number of licensed premises and the total of the licensed stock, garden and domestic entitlements in a subarea is listed in Table A4.

[4] A licensing example is where an agricultural user's licence also contains a stock and domestic proportion, for a domestic dwelling present on the same property.

Steps	Notes
3. Apply the assumptions from Table A1 to the data collected from step 1 and 2 (see tables A2 and A3).	An estimate of 405 kL/yr per bore was adopted for the small and large urban blocks in the Mandurah, Falcon and Whitehills subareas. The original 800 kL/yr/bore set in *Strategic policy 2.03* was reduced to factor in the influence of restrictions on domestic bore watering to three days a week, and publicity on responsible bore use. For the remaining subareas the 800 kL/yr/bore estimate was retained as they are outside of the Perth to Mandurah watering restriction zone. The original *Strategic policy 2.03* estimate of 1000 kL/yr/bore for semi-rural blocks under 0.5 ha was retained for all subareas as scheme water supply is restricted in some subareas, particularly for larger block sizes. Users of groundwater for stock and domestic use are likely to be exempt from watering restrictions where scheme water availability is restricted. A map of piped scheme water locations was used to identify that the subareas of Island Point and Coastal, although partly covered by the restriction zone, are highly likely to be supplied by exempt use as there is no scheme connection available. The small and large urban blocks in the Whitehills subarea are largely connected to scheme so the 405 kL/yr estimate was used in this area as it is in the restriction zone.

4. Round the calculated estimate of exempt use to the nearest 1000 kL/yr to get the final estimated volume of exempt use.
5. Confirm with licensing staff that the estimates provided are robust and correlate with local knowledge of stock and domestic use.

Calculations

Table A2: Calculating the estimated volume of exempt use in the Peel Coastal plan area

Subarea	Block type	Number of blocks*	Estimated percentage of blocks with exempt bores (%)	Indicative use (kL/yr)	Estimated volume of stock and domestic use (kL/yr)
Island point	Small urban	0	5	800	0
	Large urban	0	25	800	0
	Semi-rural	1	50	1000	500
	Rural	235*	80	1500	282 000
	Subtotal				*282 500*
Whitehills	Small urban	0	5	405	0
	Large urban	104	25	405	10 530
	Semi-rural	101	50	1000	50 500
	Rural	152*	80	1500	182 400
	Subtotal				*243 430*
Lake Clifton	Small urban	0	5	800	0
	Large urban	0	25	800	0
	Semi-rural	0	50	1000	0
	Rural	296*	80	1500	355 200
	Subtotal				*355 200*
Falcon	Small urban	322	5	405	6 520
	Large urban	6511	25	405	659 239
	Semi-rural	1875	50	1000	937 500
	Rural	53*	80	1500	63 600
	Subtotal				*1 666 859*

Subarea	Block type	Number of blocks*	Estimated percentage of blocks with exempt bores (%)	Indicative use (kL/yr)	Estimated volume of stock and domestic use (kL/yr)
Mandurah	Small urban	807.66^	5	405	16 355
	Large urban	10 873.8^	25	405	1 100 972
	Semi-rural	1857	50	1000	928 500
	Rural	485*	80	1500	582 000
	Subtotal				*2 627 827*
Coastal	Small urban	0	5	800	0
	Large urban	264	25	800	52 800
	Semi-rural	16	50	1000	8000
	Rural	60*	80	1500	72 000
	Subtotal				*132 800*
Colburra Downs	Small urban	1	5	800	40
	Large urban	2	25	800	400
	Semi-rural	3	50	1000	1 500
	Rural	57	80	1500	68 400
	Subtotal				*70 340*
Peel Coastal plan area total:					**5 378 956**

*See Table A4 below for the number of properties removed from the rural calculations in this table, due to premises being already licensed for stock, garden and domestic use. These are removed to avoid double-counting of stock, garden and domestic use,

^Mandurah subarea, due to its size and number of cadastral listings, was calculated differently to the other subareas. As listings in the small and large urban categories are listed multiple times because of the number of owners of each property, and Falcon subarea also showed this duplication with approximately 37 per cent of listings duplicated in these categories. As a result we filtered the data from Mandurah subarea with the same percentage of duplicate properties from Falcon subarea (37 per cent) and removed them from the database.

Table A3: Final estimate volume of exempt use for Peel Coastal plan area

Subarea	Final estimated volume of exempt use (kL/yr*)
Island Point	283 000
Whitehills	243 000
Lake Clifton	355 000
Falcon	1 667 000
Mandurah	2 628 000
Coastal	133 000
Colburra Downs	70 000
TOTAL	**5 379 000**

Table A4: Groundwater licensees with stock, garden and domestic component on their licence, by subarea*

Subarea	Number of properties with licensed^ stock, garden and domestic use in the Superficial aquifer	Volume licensed for stock, garden and domestic use in the Superficial aquifer (kL/yr^)
Island Point	12	18 050
Whitehills	5	9 500
Lake Clifton	16	42 830
Falcon	2	2 500
Mandurah	6	16 000
Coastal	3	2 050
Colburra Downs	0	0
TOTAL	**44**	**90 930**

* Licences that contain a stock, domestic and garden usage component within their groundwater licence.

^ Licensed use for the Peel Coastal plan area was collected from the department's licensing database. These figures were correct as at 11 January 2012.

Glossary

The terms that are used the most in reference to water resource management of the Peel Coastal plan area are listed below.

Abstraction	Withdrawal of water from any surface water or groundwater source of supply.
Allocation limit	Annual volume of water set aside for use from a water resource.
Consumptive use	Water used for consumptive purposes considered as a private benefit including irrigation, industry, urban and stock and domestic use.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	The water regime needed to maintain the current ecological values (including assets, functions and processes) of water-dependent ecosystems consistent with the objectives of an ecological water requirements study.
Environmental protection policy wetlands	Wetlands deemed to be of high conservation value under the *Environmental Protection Act (1986)*.
Fit-for-purpose water	Water that is of suitable quality for the intended end purpose. It implies that the quality is not higher than needed.
Groundwater area	The boundaries proclaimed under the *Rights in Water and Irrigation Act 1914* and used for water allocation planning and management.
Groundwater-dependent ecosystem	An ecosystem that is at least partially dependent on groundwater for its existence and health.
Groundwater-dependent social value	An in-situ quality, attribute or use associated with a groundwater resource (or dependent on a groundwater resource) that is important for public benefit, welfare, state or health.
Licence (or licensed entitlement)	A formal permit which entitles the licence holder to take water from a watercourse, wetland or underground source under the *Rights in Water and Irrigation Act 1914.*

Ramsar-listed wetland	Wetlands recognised as internationally significant and registered on the list of Convention of Wetlands of Importance (Ramsar 1971).
Reference groundwater level	A groundwater level that triggers management actions or responses to be implemented so that the risk of abstraction having an adverse effect on the water resource and dependent values is reduced.
Reliability	The frequency with which a water licence holder can obtain their full licensed volume.
Seawater or saltwater intrusion	The inland or up-gradient intrusion of salt water into a layer of fresh groundwater, from the sea or from the edges of the aquifer.
Saltwater upconing	The upward movement of saline water caused from excessive pumping, affecting fresh groundwater resources above.
Subarea	A subdivision, within a surface or groundwater area, defined to better manage water allocation. Subarea boundaries are not proclaimed and can therefore be amended without being gazetted.
Water reserve	An area proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* or *Country Areas Water Supply Act 1947* to protect water used for public drinking water supply.

Shortened forms

AHD	Australian height datum
CSIRO	Commonwealth Scientific and Industrial Research Organisation
TDS	Total dissolved solids

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 Megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 Gigalitre	(GL)

References

Barr, AD 2003, *Investigation of the Water Balance of Lake Clifton*. Client report to the Western Australian Department of Conservation and Land Management January 2003, CSIRO

Beckwith, JA 2009, *The social values of South West water resources*, Beckwith Environmental Planning, Perth.

Charles SP, Silberstein R, Teng J, Fu G, Hodgson G, Gabrovsek C, Crute J, Chiew FHS, Smith IN, Kirono DGC, Bathols JM, Li LT, Yang A, Donohue RJ, Marvanek SP, McVicar TR, Van Niel TG and Cai W, 2010, *Climate analyses for south-west Western Australia;* a report to the Australian Government from the CSIRO South-West Western Australia Sustainable Yields Project, CSIRO, n.p.

City of Mandurah 2013, *Southern Mandurah Rural Structure plan (draft)*, City of Mandurah, Western Australia.

Commander DP 1988, *Geology and hydrogeology of the Superficial formations and coastal lakes between Harvey and Leschenault Inlets (Lake Clifton Project),* Geological Survey Western Australia, Professional Papers, Report 23, Geological Survey of Western Australia, Perth

CSIRO 2009, *Groundwater yields in south-west Western Australia, A report to the Australian Government from the CSIRO South West Western Australia sustainable yields project,* CSIRO Water for a Healthy Country Flagship, n.p.

Davidson WA 1995, *Hydrogeology and groundwater resources of the Perth region,* Geological Survey of Western Australia, Perth, Western Australia.

Department of Parks and Wildlife 2014, *Swan Coastal Plain South draft management plan 2014*, Government of Western Australia, Perth.

Department of Planning and Western Australian Planning Commission 2010*, Outer metropolitan Perth and Peel sub-regional strategy* (Draft), Government of Western Australia, Perth.

Department of Water 2005, *State groundwater investigation,* Government of Western Australia, Perth, viewed 25 May 2015, http://www.water.wa.gov.au/planning-for-the-future/finding-water/groundwater-investigations/state-groundwater-investigation-program

——2007a, *Rockingham-Stakehill groundwater management plan*, Government of Western Australia, Perth.

——2007b, *REG75- A tool for estimating mean annual flow for the South West of Western Australia*, Government of Western Australia, Perth.

——2009a, *South West groundwater areas allocation plan*, Government of Western Australia, Perth.

——2009b, *Draft Perth-Peel Regional water plan 2010-2030*, Government of Western Australia, Perth.

——2009c, *Climate change, water demand and water availability scenarios to 2030: Perth-Peel water plan background paper*, Government of Western Australia, Perth.

——2011, *Water allocation planning in Western Australia: a guide to our process*, Government of Western Australia, Perth.

——2012, *Murray groundwater allocation plan*, Government of Western Australia, Perth.

——2015a, *Peel Coastal groundwater allocation plan*, Government of Western Australia, Perth

——2015b, *Peel Coastal plan area: Groundwater-dependent ecosystems report*, Government of Western Australia, Perth.

——2015c, *Selection of future climate projections for Western Australia*, Water Science Technical Series, report no. 72, Government of Western Australia, Perth.

——in prep., *Murray-Peel Groundwater Investigation Bore Completion Report*, a draft report currently in preparation, Hydrogeological record series, Government of Western Australia, Perth.

Environmental Protection Authority 1997, *EPA Bulletin 864 - Final Criteria for Environmental Acceptability for Land Use proposals within the Catchment of Lake Clifton,* Government of Western Australia, Perth.

Johnson, S.L., Commander, D. P., O'Boy, C.A. and Lindsay, R. P., 2005, *Groundwater investigation program in Western Australia (2005 to 2020)*, Department of Environment, Hydrogeological Record Series, Report HG10, Perth.

Ramsar 1971, Ramsar Convention on Wetlands, Ramsar, Iran.

Stone, R., 2011, *Perth-Mandurah region domestic bore review*, Unpublished report for the Department of Water, Perth.

Water and Rivers Commission 2000, *Environmental water provisions policy for Western Australia,* Government of Western Australia, Perth.

Water Authority 1989, *South West Coastal groundwater area groundwater management review,* report no. WG 84, Government of Western Australia, Perth.

Western Australian Planning Commission 2010, *Directions 2031 and beyond*, Government of Western Australia, Perth.

Western Australian Planning Commission and Department of Planning 2010*, Outer metropolitan Perth and Peel sub-regional strategy* (draft), Government of Western Australia, Perth.

Legislation

Government of Western Australia 1914, *Rights in Water and Irrigation Act 1914*, Western Australia, Perth.

——1914, *Rights in Water and Irrigation Exemption (Dewatering) (section 26C) Order 2010,* Western Australia, Perth.

Policy

Department of Water 2009d, *Strategic policy 2.03 – managing unlicensed groundwater use*, Government of Western Australia, Perth.

——2010, *Operational policy 5.13 Water entitlement transactions for Western Australia*, DWPF 5.13, Department of Water, Perth.

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