Government of **Western Australia**
Department of **Water and Environmental Regulation**

Exmouth groundwater subareas allocation limits review

Background information and methods to revise allocation limits for the Exmouth Peninsula

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Acknowledgement of Country

The Department of Water and Environmental Regulation acknowledges the Traditional Owners and custodians of the Exmouth Peninsula and their deep and continuing connection to the land and waters on which we all rely.

We pay our respects to Elders past, present and emerging, and to all members of the Aboriginal communities in the area and their cultures. We acknowledge that the Traditional Owners have been custodians of Country for countless generations and that water is integral to life.

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Summary

In this report, the Department of Water and Environmental Regulation (the department) reviews and updates the groundwater allocation limits for the Exmouth Peninsula, last set in the *Exmouth groundwater subareas allocation plan* (Exmouth plan) (WRC 1999). The review includes updated water allocation limits and guidance to support sustainable groundwater use and environmental outcomes. We will consider the information in this report, together with the Exmouth plan, to make licensing decisions in the Exmouth groundwater subareas.

The department's technical work has underpinned this review, using existing or updated knowledge and a new airborne electromagnetic (AEM) survey. See Part A for a summary of this work and more details in the appendices. We have also released a supporting report – *The importance of water to the Exmouth Peninsula's environmental, heritage and social values* (DWER 2025) – which describes the peninsula's groundwater-dependent values, focusing on those listed for protection under legislation, policy and environmental guidance.

This report will inform Water Corporation's current water source planning to meet existing and future demand for the Exmouth town water supply scheme. Water Corporation is assessing two options for additional groundwater: southwards expansion of its borefield, and seawater desalination. A new source will need to account for future climate conditions to ensure a secure water supply. The department will continue to work with Water Corporation to find a sustainable solution.

This review and the supporting values report (DWER 2025) will inform our advice to the Minister for Environment's Exmouth Gulf Taskforce, and help the taskforce shape recommendations to enhance protections for the Cape Range Subterranean Waterways. The review also responds to Nganhurra Thanardi Garrbu Aboriginal Corporation's (NTGAC) concerns about abstraction and climate change pressures on the Cape Range Subterranean Waterways.

What this allocation limits report includes

This report summarises how the department considered local information to update the Exmouth groundwater allocation limits, including:

- future climate projections, consistent with the *Guide to future climate projections for water management in Western Australia* (DWER 2024)
- new hydrogeological information, including a jointly commissioned AEM survey with Water Corporation
- revised estimates of groundwater recharge to the Cape Range Limestone aquifer
- ecological, cultural, heritage and social values related to groundwater
- management objectives and principles in the Exmouth plan and specific water resource objectives

- the amount of groundwater that should remain in the aquifer to support groundwater-dependent values.

This report has three main parts, each starting with a summary page of key points:

Part A – Assessing information: describes the information used to review and set the allocation limits – the hydrogeological, ecological, cultural, heritage, social and community information that underpinned our decisions.

Part B – Setting objectives and allocation limits: sets out water resource objectives for both environmental and water use outcomes, our method for assessing future climate implications, and how we determined the updated water allocation limits.

Part C – Management approach: outlines our considerations for local water management to support allocation limit decisions and manage any risks to water users, the water resource and dependent values.

The expected outcomes from this review

The allocation limit decisions and review outcomes include the following:

- Allocation limits have changed for both the Cape Range Limestone and saline resources across the plan area (Table 1).
- The revised allocation limits reflect updated considerations of the hydrogeology, groundwater-dependent values, water use and the potential impacts of future climate.
- The Badjirrajirra and Exmouth Saltflats subareas replace Exmouth South to reflect new understandings and support better management of the resources.
- No further water is available for licensing from the Cape Range Limestone resource in the Exmouth Town and Exmouth Central subareas, where the town water supply borefield is located.
- A public water supply reserve is set aside in the Badjirrajirra subarea (Cape Range Limestone resource) to support the investigation of future scheme water supply options.
- Water is available for general licensing from the Cape Range Limestone resource in the Badjirrajirra and Exmouth Saltflats subareas, along with limited volumes in the Exmouth North and Exmouth West subareas.
- Allocation limits have changed to ‘not set’ for the saline resource because of the uncertainty around setting allocation limits for this resource and the unique habitat that saline groundwater provides for subterranean fauna. Licence applications can still be made for these resources and will be assessed on a case-by-case basis.
- No changes to the volume of water allocated under existing groundwater licences.
- Updated accounting of the Department of Defence’s groundwater demands in the Exmouth North and Exmouth Saltflats subareas (exempt from licensing).

- The review informs our discussions with Traditional Owners about their aspirations for future commercial water use.
- New local guidance for assessing licences in the saline resource, managing saline upconing in Cape Range Limestone resource, and managing risks to groundwater-dependent values around town water supply scheme bores.
- Guidance is provided to support engagement with native title holders in considering the potential impacts of water licences on cultural values.

Table 1 Previous and revised allocation limits for the groundwater resources of the Exmouth Peninsula (see Chapter 8 for allocation limit components)

Water resource		Previous allocation limit kL/year	Revised allocation limit kL/year
Subarea	**Aquifer**		
Exmouth North	Cape Range Limestone	200,000	215,400
Exmouth Town		300,000	300,000
Exmouth Central		1,000,000	872,748
Badjirrajirra		4,700,000*	1,320,050
Exmouth Saltflats			744,150
Exmouth West		50,000	50,000
Total Cape Range Limestone		**6,250,000**	**3,502,348**
Exmouth North	Saline resource	500,000	Not set**
Exmouth Town		400,000	Not set**
Exmouth Central		4,000,000	Not set**
Badjirrajirra		500,000*	Not set**
Exmouth Saltflats			Not set**
Exmouth West		1,000,000	Not set**
Total saline resource		**6,400,000**	**Not set**

*As part of this review, the Exmouth South subarea is split into the new Badjirrajirra and Exmouth Saltflats subareas for both the Cape Range Limestone and saline resources (**Figure 1**).

** Licence applications can still be made for these resources and will be assessed by the department on a case-by-case basis.

1 Introduction

In this report, the Department of Water and Environmental Regulation (the department) reviews and updates the groundwater allocation limits across the Exmouth Peninsula (also known as the North West Cape). The revised allocation limits replace those set for the Cape Range Limestone aquifer in the *Exmouth groundwater subareas allocation plan* (Exmouth plan) (WRC 1999) (see Section 1.2) and those subsequently set for the fresh and saline resources. This report explains why we updated these allocation limits and the method we used.

1.1 Plan area

The Exmouth plan covers the Exmouth Peninsula in Western Australia's (WA's) Mid West – Gascoyne region, 1,260 km north of Perth (Figure 1). The plan area sits within the Shire of Exmouth and includes the Exmouth township, which has a residential population of about 3,000 people (2021 Census[1]).

The Exmouth Peninsula juts into the Indian Ocean in a northerly orientation. It extends 96 km north to south and is 21 km wide. Cape Range is the dominant land feature, which runs down the centre of the peninsula, with coastal plains on either side. Cape Range reaches a maximum elevation of about 315 m above sea level.

The Exmouth Peninsula remains largely uncleared because of its remoteness and limited fresh surface water. It includes the Cape Range National Park, which is part of the Ningaloo Coast World Heritage Area. The fringing coral reefs of Nyinggulu (Ningaloo) Reef are present to the west and north of the peninsula, while the shallow Exmouth Gulf borders the east. These natural features are highly valued and attract thousands of visitors each year.

Fresh groundwater from the karstic Cape Range Limestone aquifer is the major water resource in the Exmouth plan area. It is used to supply drinking water to the Exmouth township, as well as water for public amenities, domestic gardens (garden bores), tourism, defence, aquaculture and industrial uses. Saline groundwater is used for aquaculture, dust suppression and desalination purposes.

Groundwater subareas and resources

The Exmouth Peninsula is proclaimed as part of the Gascoyne groundwater area under WA's *Rights in Water and Irrigation Act 1914.* This means that users must have a water licence to legally take groundwater (see Section 1.2 and Chapter 5).

The department uses subareas to divide proclaimed plan and subregional areas into smaller areas for water management purposes. The Exmouth plan originally divided the plan area into five groundwater subareas. There are now six subareas as a result of this review.

[1] 2021 Census QuickStats, Exmouth LGA, Australian Bureau of Statistics, 2021 Exmouth, Census All persons QuickStats, accessed May 2024.

The original five subareas were based on the concentrated use and need for careful management in the Exmouth North, Exmouth Town and Exmouth Central subareas; low water use in the Exmouth South subarea; and restricted land use in the Exmouth West subarea (mostly national park). The Exmouth South subarea is now replaced by two new subareas – Badjirrajirra and Exmouth Saltflats (Figure 1). The names of these new subareas reflect the water features of Badjirrajirra Creek north of Learmonth, and the coastal mangroves and salt flats of the Exmouth Gulf.

Dividing the Exmouth South subarea into two new subareas has enabled us to better consider the local hydrogeology, water demands and groundwater-dependent values of each area in reviewing and setting allocation limits:

- **Badjirrajirra subarea** – This area has a similar hydrogeology and prospective borefield area to that of the Exmouth Central subarea. It aligns with groundwater being considered as an alternative water source option for expanding the town water supply scheme.
- **Exmouth Saltflats subarea** – This area is less prospective than Badjirrajirra because it has a thinner fresh groundwater resource, with the seawater interface being further inland. There is low existing and future demand and arguably more significant ecological and cultural assets than to the north (Badjirrajirra).

We set allocation limits and license water for each water resource (the aquifer or water source within a subarea). For management and licensing purposes we have divided the main aquifer into two resources in each subarea (explained further in Chapter 3 and throughout the report):

- The Cape Range Limestone resource is the freshwater portion of the aquifer within each subarea, which supplies water for the town of Exmouth and its surrounding industries.
- The saline resource is the saline portion of the aquifer within each subarea, which has been targeted to supply water for aquaculture, dust suppression and desalination purposes.

The Birdrong Sandstone aquifer is situated more than 1 km below ground and is unlikely to be targeted for use. The aquifer is not a resource covered in this review but is explained further in Chapter 3.

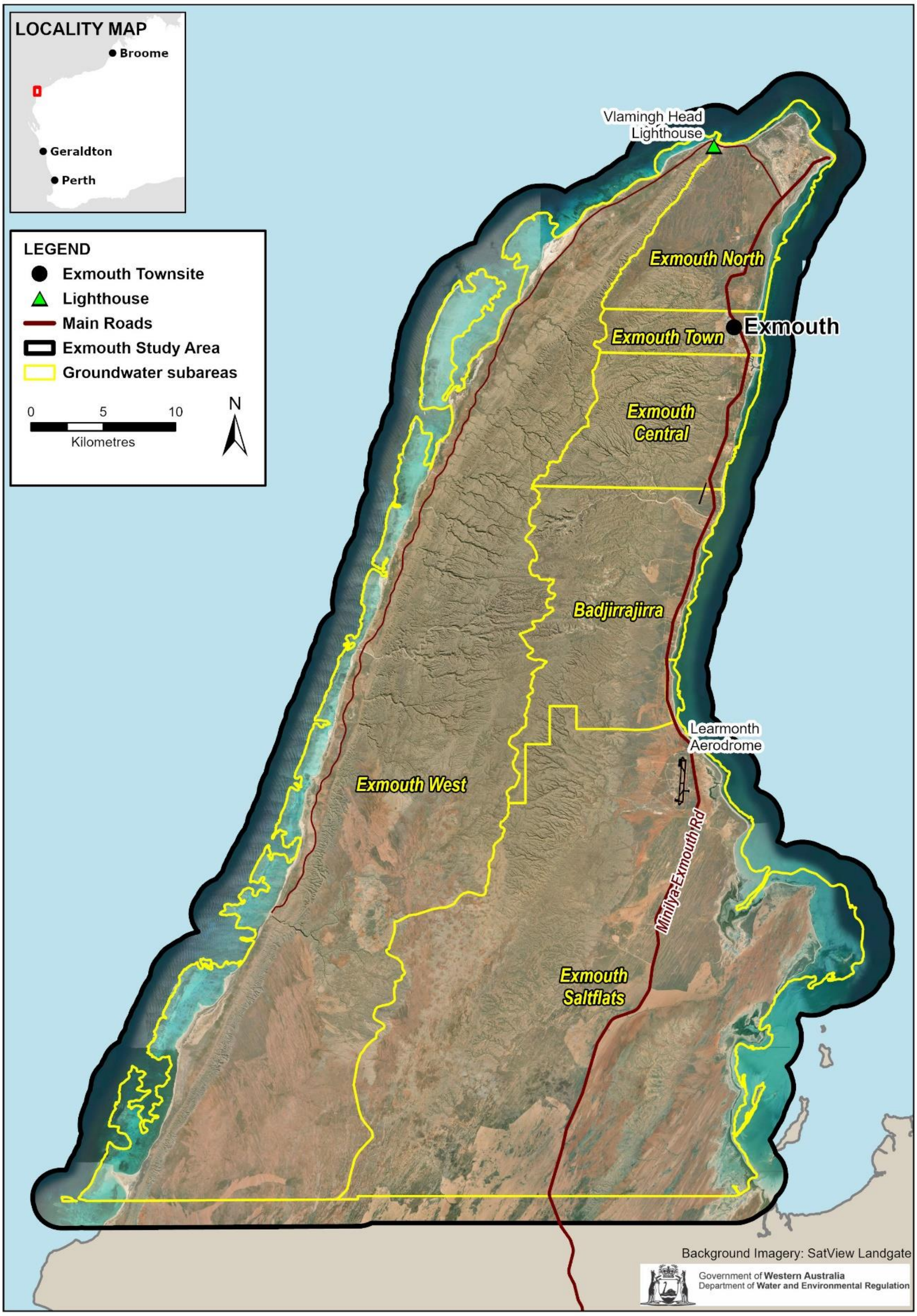

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Figure 1 Subareas in the Exmouth plan area, including Badjirrajirra and Exmouth Saltflats which replace the previous Exmouth South subarea

1.2 Water allocation planning for the Exmouth Peninsula

The department supports WA's community, economy and environment by managing and regulating the state's environment and water resources. Water licensing and water allocation planning are important processes for managing the state's water resources.

A water licence or permit is the regulatory instrument under the *Rights in Water and Irrigation Act 1914* that entitles a licensee to take water (the licensed entitlement) from a water resource in accordance with the specified terms, conditions and restrictions. Decisions on each licence or permit application are made consistent with legislative provisions, statewide policy and water allocation plans (where present).

The former Waters and Rivers Commission (now Department of Water and Environmental Regulation) released the Exmouth plan in 1999. The Exmouth plan (WRC 1999) is the first and only water allocation plan that has been developed for managing the Exmouth groundwater resources. The plan was designed to manage the take and use of groundwater across the Exmouth subareas, and included allocation limits.

1.3 Water allocation limits

A water allocation limit is an annual volume of water set aside for use from a water resource and accounts for water that is both licensed and exempt from licensing. The department uses allocation limits to sustainably manage water resources. Allocation limits are set at a water resource scale, and do not provide an amount of water available at any one location. Water availability at a specific location is considered through the water licensing and assessment process.

When setting allocation limits, we consider the best available information. If this information is limited and high levels of uncertainty exist, we apply a precautionary approach (such as in the Exmouth plan area). We also consider the water that needs to stay in the environment to maintain the water resource and support groundwater-dependent values. This water remains in the resource and is not included in the allocation limit (i.e. it is not available for allocation or abstraction). This process is set out in Section 8.

We divide an allocation limit into different components to help us account for different water uses and administer water licensing (Figure 2). Allocation limit components in WA may include:

- water that is available for general licensing
- water that is licensed for public water supply (such as for the Exmouth township)
- water that is exempt from licensing under the *Rights in Water and Irrigation Act 1914* (see Section 5.1)

- water that is reserved for future public water supply
- water that is held in reserve for the economic benefit of Aboriginal people (referred to as an Aboriginal Water Reserve).

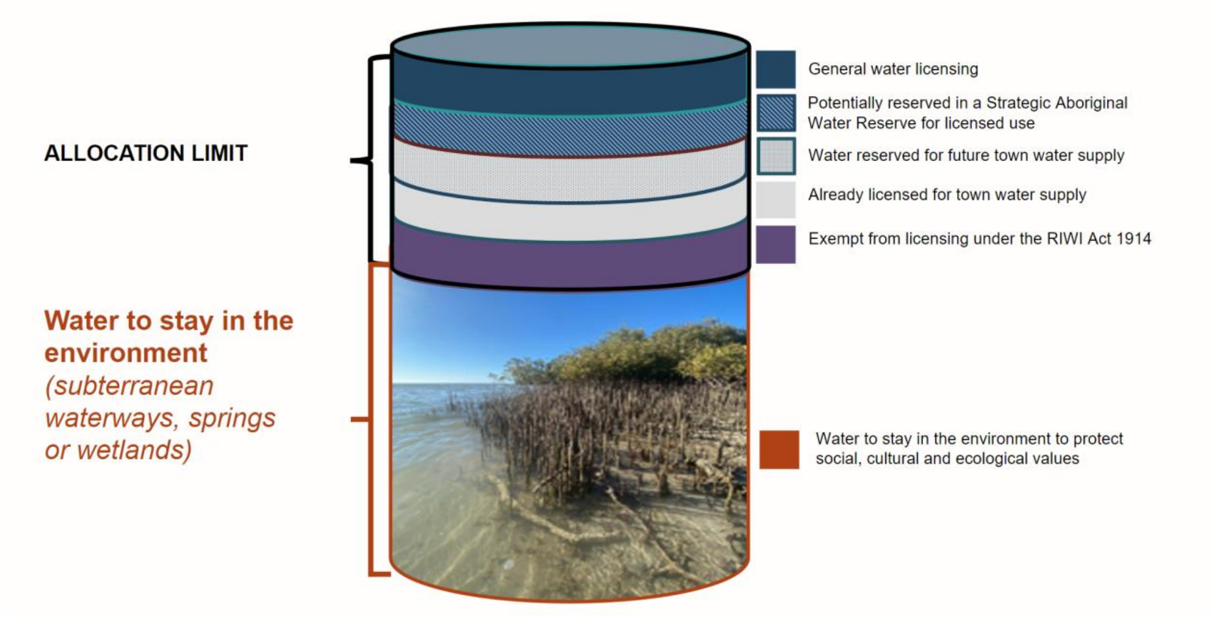

Figure 2 Water allocation limit components for water licensing and accounting purposes in WA, separate to the water that stays in the environment (not to scale or representative of Exmouth limits)

Previous allocation limits and estimates

In general, previous allocation limits for the Cape Range Limestone aquifer were set based on the estimated average throughflow (the average volume of groundwater flowing to the coast each year from rainfall recharging the aquifer).

Forth (1972 and 1973) first calculated recharge and a sustainable yield for the Cape Range Limestone aquifer to inform development of the borefield for the Exmouth town water supply. These works calculated throughflow at the borefield from an average annual rainfall of 254 mm and a recharge rate of 10 per cent across an area of 54.4 km^2 (the area upgradient of the borefield). This resulted in an estimated throughflow of 1,350,000 kL per year across the 8 km length of the borefield, or 168,750 kL/km.

The Exmouth plan (WRC 1999) used Forth's estimates and assumed a similar throughflow of 170,000 kL/km of coastline, and set the allocation limits at 60 per cent of the estimated throughflow in each subarea. The remaining 40 per cent of throughflow was allocated to stay in the aquifer to maintain the seawater interface and groundwater-dependent ecosystems.

At the time the Exmouth plan was developed, groundwater taken from small domestic, garden and stock bores required a licence. Since then, the Rights in Water and Irrigation Act 1914 Exemption (Section 26C) Order 2011 has come into effect, which made these small bores exempt from licensing. The licensed volumes that became exempt were then accounted for as an exempt component within the allocation limit.

The Exmouth plan does not refer to the saline resource. We created allocation limits for the saline resource in 2017 to support proponent interest in onshore seawater abstraction for aquaculture. In setting the allocation limits, we considered the expected interest from proponents – at volumes considered to pose a low risk of inland movement of the seawater interface.

1.4 Allocation limits review process

Our approach to this review of the Exmouth plan's allocation limits follows the guidance set out in *Water allocation planning in Western Australia: a guide to our process* (DoW 2011). This guide provides a consistent and transparent process for water allocation planning for sustainably managing water resources.

We have structured this report to align with this planning model (Figure 3):

- Part A describes the information used to develop and set the allocation limits.
- Part B sets out water resource objectives and our method for developing and deciding on the water allocation limits.
- Part C describes considerations for our adaptive management approach to water allocation and licensing.

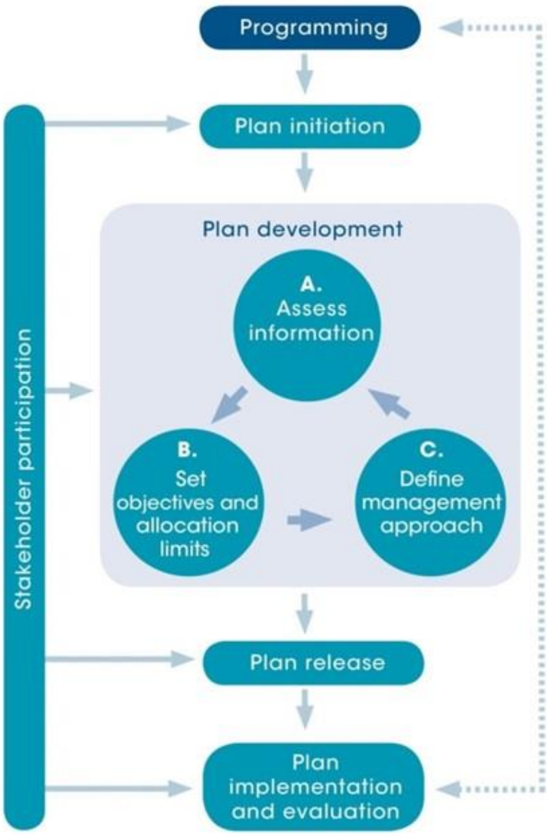

Figure 3 The water allocation planning model we use in WA

Stakeholder interests and consultation

This review will inform our advice to the Minister for Environment's Exmouth Gulf Taskforce, and help the taskforce shape recommendations to enhance protections for the Cape Range Subterranean Waterways. The taskforce, established in July 2022, is the State Government's key coordinating body for providing strategic advice on environmental protection and integrated management options for the Exmouth Gulf in partnership with Traditional Owners. We presented on the technical aspects and progress of the review to the taskforce throughout 2023 and 2024. In 2025 the taskforce will provide its final advice to the Minister for the Environment on management options, as well as its strategic recommendations.

The Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC) is the registered native title body corporate for the Baiyungu and Yinnigurrura People, the Traditional Owners of Nyinggulu (Ningaloo), Warnangura (Cape Range) and the Exmouth Gulf. In November 2022, NTGAC asked us to prioritise review of the Exmouth plan because of concerns about abstraction and climate change pressures on the Cape Range Subterranean Waterways. We have presented to the NTGAC Board on the process and outcomes of the allocation limits review. The Board expressed interest in establishing Aboriginal water reserves for the Exmouth resources where water remains available.

Water Corporation manages the Exmouth town water supply scheme and has obligations under Ministerial Statement 459 to manage impacts to stygofauna and report on performance compliance. The existing borefield includes 34 production bores and extends for 10 km. It is designed and operated to abstract water at low flow rates to mitigate saline intrusion and maintain conditions to support stygofauna habitat across the borefield. With the scheme often operating at close to capacity, groundwater from the current scheme will not meet anticipated medium- to long-term demand, with up to a further 1 GL per year required.

We have consulted with Water Corporation on the review process and outcomes. Water Corporation is using information from this process to inform its water source development planning for Exmouth's public water supply. We will continue to work with Water Corporation as it assesses the options for future supply, focusing on those that are sustainable and adequately consider future climate conditions.

The Department of Defence uses groundwater to supply the Learmonth Airbase and Harold E. Holt facilities, which are exempt from licensing but which the allocation limits take account of. The Department of Defence has confirmed that its current estimated unlicensed use will continue to meet short-term groundwater needs (which we have incorporated into this review).

Part A – Assessing information

In Part A of this review, we report on:

- past rainfall trends and future climate change impacts on the resource
- new hydrogeological information for the plan area
- how water in the environment supports ecological, cultural, heritage and social values
- current groundwater use and developing demands for water.

The details in Part A inform the setting of objectives and allocation limits in Part B.

Key points from Part A

- For management and licensing purposes, the main aquifer is defined as two resources in each subarea: the Cape Range Limestone resource (fresh to marginal water) and the saline resource (brackish to saline water).
- Most bores take water from the Cape Range Limestone aquifer on the coastal plain where a freshwater lens is underlain by brackish to saline water. As the freshwater lens can be quite thin close to the coast, it is very susceptible to saline upconing, which has occurred in the past.
- Historical records show that rainfall has remained relatively stable across the Exmouth North, Exmouth Town and Exmouth Central subareas (assessed at the rainfall stations that best represent climate for these subareas).
- Historical records show a drying trend in the Exmouth Saltflats subarea. Both the Learmonth Airport (BoM station 5007) and Exmouth Gulf (BoM station 5004) rainfall stations show long-term declines in average annual rainfall. Learmonth Airport also indicates an increase in annual average temperature and potential evapotranspiration.
- Both fresh and saline groundwater support the unique ecology of the Cape Range Subterranean Waterways. Groundwater discharge at the coast may also support the nearshore marine values of Ningaloo and the Exmouth Gulf.
- We have calculated groundwater recharge assuming 15 per cent of annual rainfall.
- We have redefined groundwater recharge areas based on the outcomes of an airborne electromagnetic (AEM) survey.
- Historically, water quality has been the main management issue – with freshwater abstraction prone to saline upconing in the aquifer. Groundwater levels stay relatively stable due to the high transmissivity of the limestone.

2 Climate

The Exmouth Peninsula's climate is semi-arid, with hot summers and milder winters. There is a high natural variability in rainfall, both monthly and annually. The wet season extends from January to July, with rainfall coming from tropical cyclones in the north (January to March) and low-pressure systems extending from the south (May to July). Monthly average rainfall, temperature and evaporation varies greatly throughout the year (Figure 4).

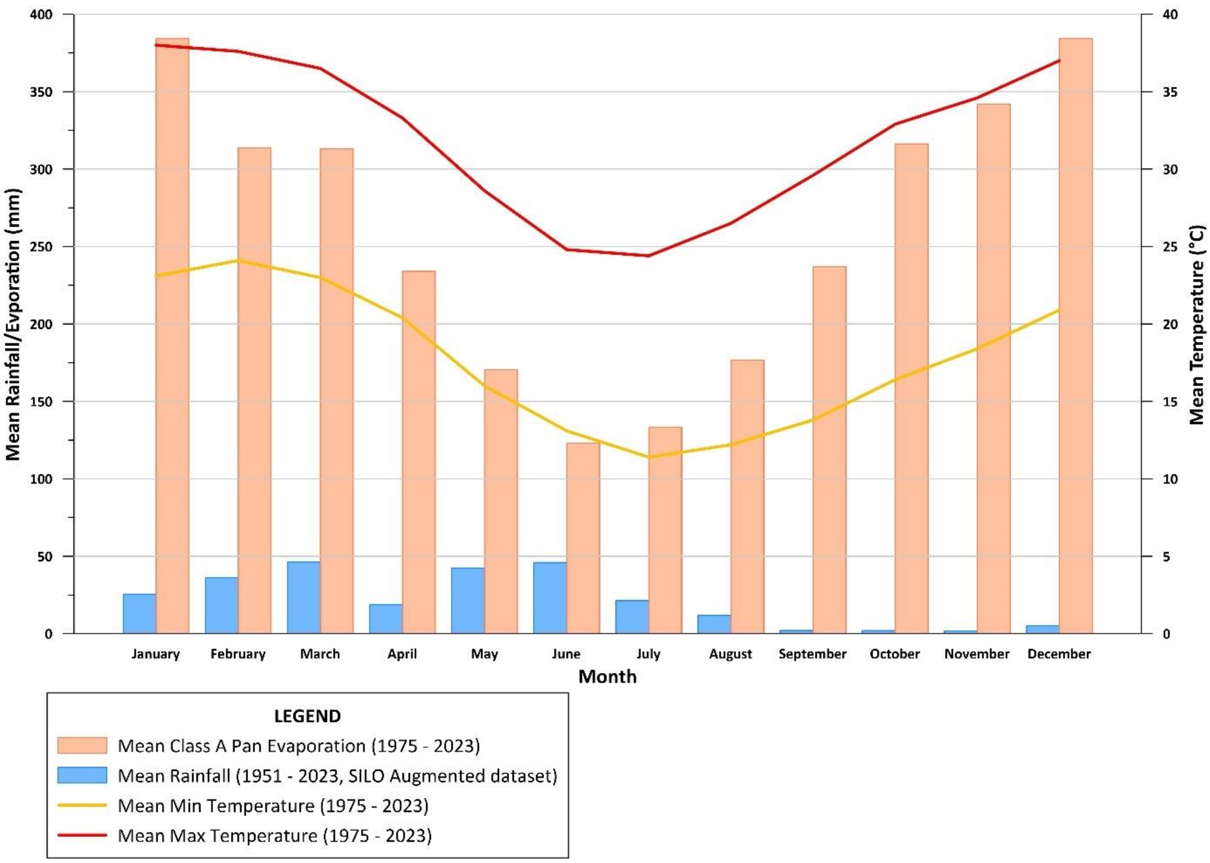

Figure 4 Monthly climate statistics from Learmonth Airport weather station (BoM station #5007)

Rainfall also varies across the peninsula, affected by the location and elevation of Cape Range. The Exmouth Saltflats subarea, and to a lesser extent the Badjirrajirra subarea, are rain-shadowed by Cape Range. These subareas have a lower average and median annual rainfall than the other subareas (Table 2) and more frequent occurrences of low rainfall years (Table 3).

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Figure 5 Bureau of Meteorology weather stations and climate reference locations

2.1 Historical climate

To assess the Exmouth Peninsula's historical climate, we looked at the climate data collected from three Bureau of Meteorology weather stations that are representative of the Exmouth subareas (Table 2 and Figure 5).

By comparing the long-term average annual rainfall from each weather station against the 20-year moving average, we see that historically the Exmouth Peninsula has undergone slightly wetter and slightly drier periods:

- Exmouth Town station shows no long-term drying or wetting trend, with the recent 20-year average rainfall close to the long-term average rainfall (Table 2 and Figure 6).
- Learmonth and Exmouth Gulf stations both show long-term drying trends, with 6.4 and 17.1 per cent less rainfall for the recent 20-year average than the long-term average respectively (Table 2, Figure 7 and Figure 8).

Table 2 Bureau of Meteorology weather stations used to assess historical rainfall changes for each subarea

Subarea	Bureau weather station#	Long-term rainfall record*	Long-term average annual rainfall	Recent average annual rainfall (2003–23)	Change in average annual rainfall
Exmouth North Exmouth Town Exmouth Central	Exmouth Town 5051	1968 to 2023	272 mm	269 mm	-1%
Badjirrajirra Exmouth West	Learmonth 5007	1951 to 2023	257 mm	241 mm	-6%
Exmouth Saltflats	Exmouth Gulf 5004	1915 to 2023	256 mm	212 mm	-17%

* Incomplete datasets have been augmented with Queensland's Government SILO point data (SILO | LongPaddock | Queensland Government).

Historical rainfall data collected before 1998 has not been quality controlled for any of these weather stations.

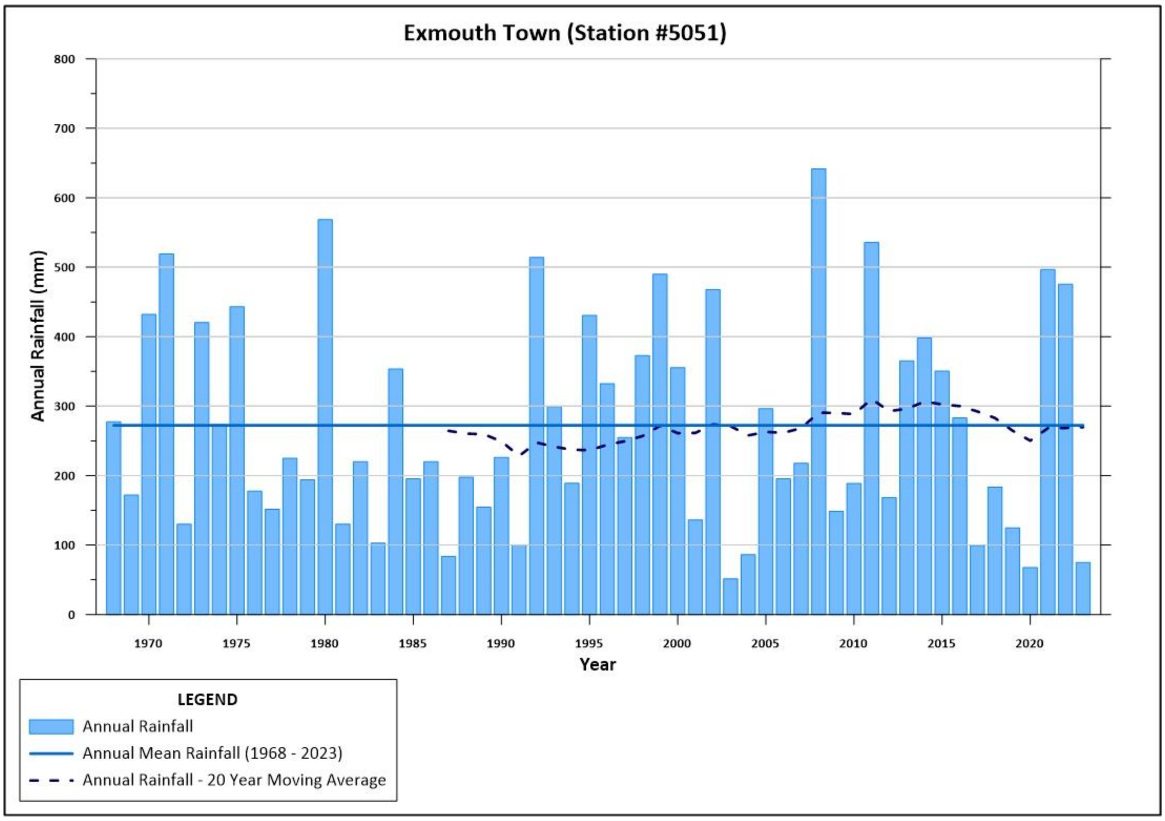

Figure 6 Annual rainfall at Exmouth Town (BoM station 5051)

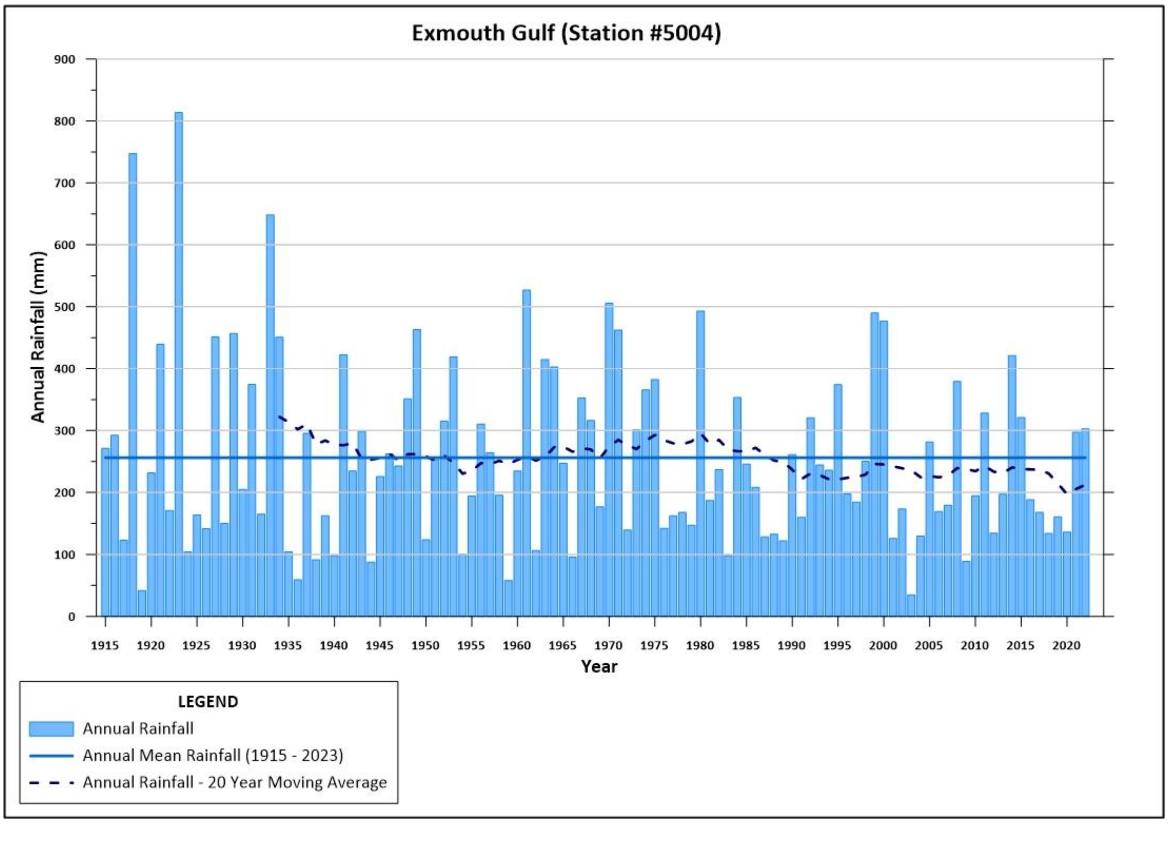

Figure 7 Annual rainfall at Exmouth Gulf (BoM station 5004)

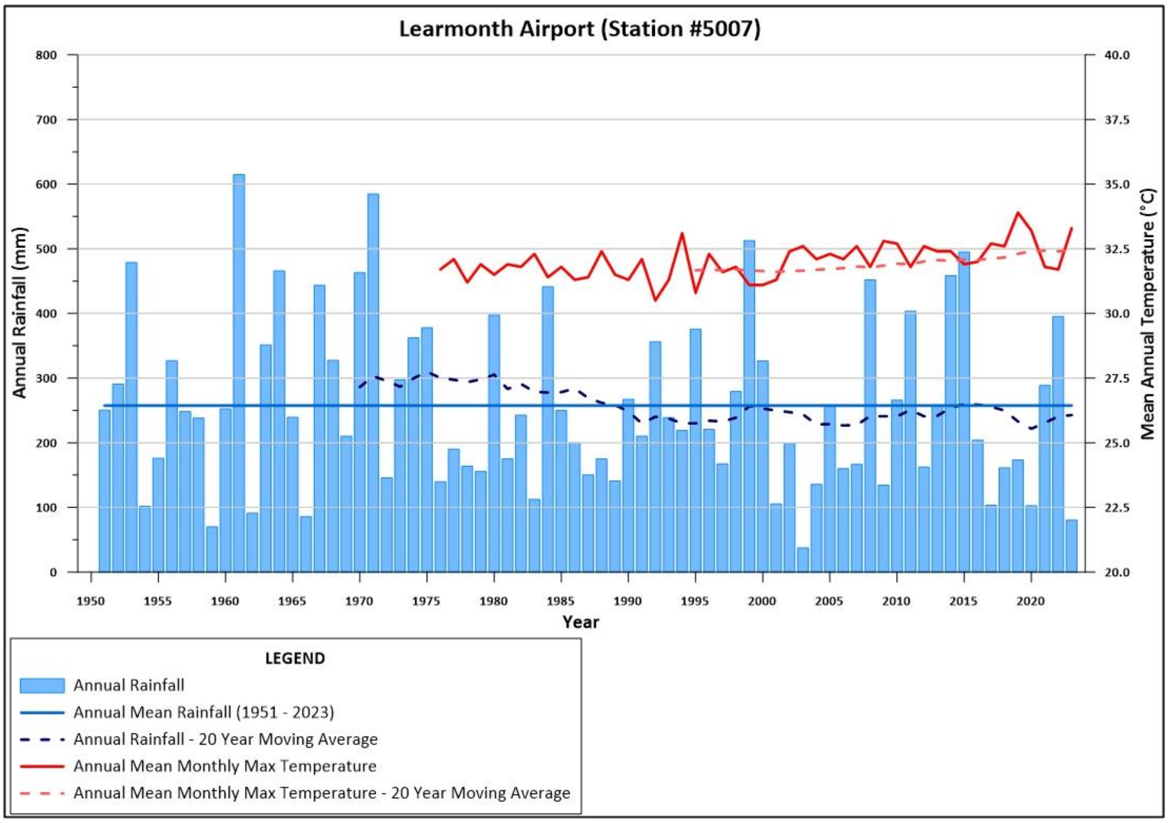

Figure 8 Annual rainfall and average monthly maximum temperate at Learmonth Airport (BoM station 5007)

Temperature data within the Exmouth Peninsula is recorded at the Learmonth weather station (Figure 8). Historical annual average maximum temperature data has shown an increasing trend since 2001. Consequently, potential evaporation would also have been increasing. However, as the system is very water limited year-round (evaporation far exceeds rainfall, Figure 4), and there are few surface water features and minimal groundwater use by vegetation, the rise in temperature is unlikely to have a significant overall impact on the water balance.

2.2 Future climate change and potential impacts

The department has updated the guidelines on how to use future climate projections for water management as part of a State Government initiative delivering up-to-date climate science resources for WA's water community (DWER 2024).

For this review, we followed the guideline and used future climate projections from the National Hydrological Projections (NHP) that the Bureau of Meteorology released in 2022 (BoM 2022a). These projections provide water resource managers with local-scale climate data from 32 projected climate futures to use in decision-making.

The department has summarised the range of projections for WA (DWER 2021). In the Rangelands natural resource management region, which includes the Exmouth Peninsula, DWER (2021) indicates there may be:

- increased rainfall variability and an increase in the length of low rainfall periods

- increased, decreased or unchanged wet season rainfall patterns
- an increase in temperature and evapotranspiration.

Of these, an increase in the length of low rainfall periods is likely to be the largest risk to the Exmouth groundwater resources to consider and manage. Annual rainfall in 2019 and 2020 was well below average, which correlated with increased salinity levels in Water Corporation's production bores (Section 3.3). This suggests that water quality in the Cape Range Limestone aquifer would not be resilient to an increase in the length of low rainfall periods under the current abstraction pattern for the town water supply borefield.

An increase or decrease in the wet season rainfall pattern is considered a smaller risk in this system. This is because the high transmissivity of the limestone units causes rainfall recharge to flow through to the ocean relatively quickly and water levels remain relatively stable. Similarly, as mentioned above, a potential increase in evapotranspiration is a smaller risk because it is a small proportion of the water balance.

2.3 Low rainfall periods or consecutive 'dry' years

To consider the impact of possible increases in the length of low rainfall periods, we looked at the historical occurrence of consecutive 'dry years' for each weather station (Table 3). We defined a 'dry year' as one when the annual rainfall was below the third decile of annual rainfalls from a reference period. This definition comes from *Victoria's water in a changing climate – insights from the Victorian Water and Climate Initiative* (DELWP 2020).

We used the reference period of 1976 to 2005 – the same period used for the *Rangelands National Hydrological Projections assessment report* (BoM 2022a) – as this best represents the current hydroclimate conditions on a regional scale.

Table 3 Historical dry year rainfall (calculated from the reference period) and occurrences of consecutive dry years (recorded across the full rainfall record)

Subarea	Bureau weather station (period of record)	Dry year rainfall (1976–2005 reference period)	Historical occurrence of consecutive dry years (over the period of record)	
			Number of occurrences	Maximum length
Exmouth North Exmouth Town Exmouth Central	Exmouth Town 5051 (1968–2023)	171 mm or less	2	Two years
Badjirrajirra Exmouth West	Learmonth 5007 (1951–2023)	163 mm or less	3	Two years
Exmouth Saltflats	Exmouth Gulf 5004 (1915–2023)	156 mm or less	5	Three years

3 Understanding the groundwater system

3.1 Hydrogeology

The groundwater system of the Exmouth Peninsula, including Cape Range and the coastal plain, comprises calcareous sediments (Figure 9). The unconfined Cape Range Limestone aquifer is the major source in the Exmouth plan area, which includes both fresh and saline water resources (see Section 1.1 and below).

See Appendix A Geological and hydrogeological information for further details, including more about the airborne electromagnetic (AEM) survey that we commissioned in partnership with Water Corporation.

Cape Range Limestone resource

The Cape Range Limestone resource is the freshwater portion (fresh to marginal) of the Cape Range Limestone aquifer within each subarea. Towards the coast it is present as a thinner lens of fresh groundwater overlying seawater (Figure 9 and Figure 10). As such, it is susceptible to the upward migration of saline water if bores are screened too deep or pumping rates are too high.

The Cape Range Limestone aquifer has variable but generally high hydraulic conductivity (water flows easily and rapidly) as it has extensive and well-developed karstic features (Forth 1973). Historical groundwater abstraction has primarily been from the fresh groundwater resource on the coastal plain, where bore yields are maintained at low rates (<2 L/s) because of the risk of upconing of more saline groundwater. Typical total dissolved solids (TDS) concentrations of groundwater from these resources are 600 to 1,500 mg/L (fresh to marginal water quality/salinity). Bores located within the Exmouth township typically yield more marginal water due to the limited lens thickness on the coastal plain.

The aquifer is recharged through direct rainfall infiltration, with high-intensity rainfall events likely causing concentrated infiltration along drainage lines, which have connectivity to shallow karstic features. The hydraulic gradient of the aquifer is low because of the high transmissivity of the limestone. Consequently, the watertable is relatively flat and the depth to watertable increases markedly with surface elevation, with depths of more than 250 m below ground level at the top of the range.

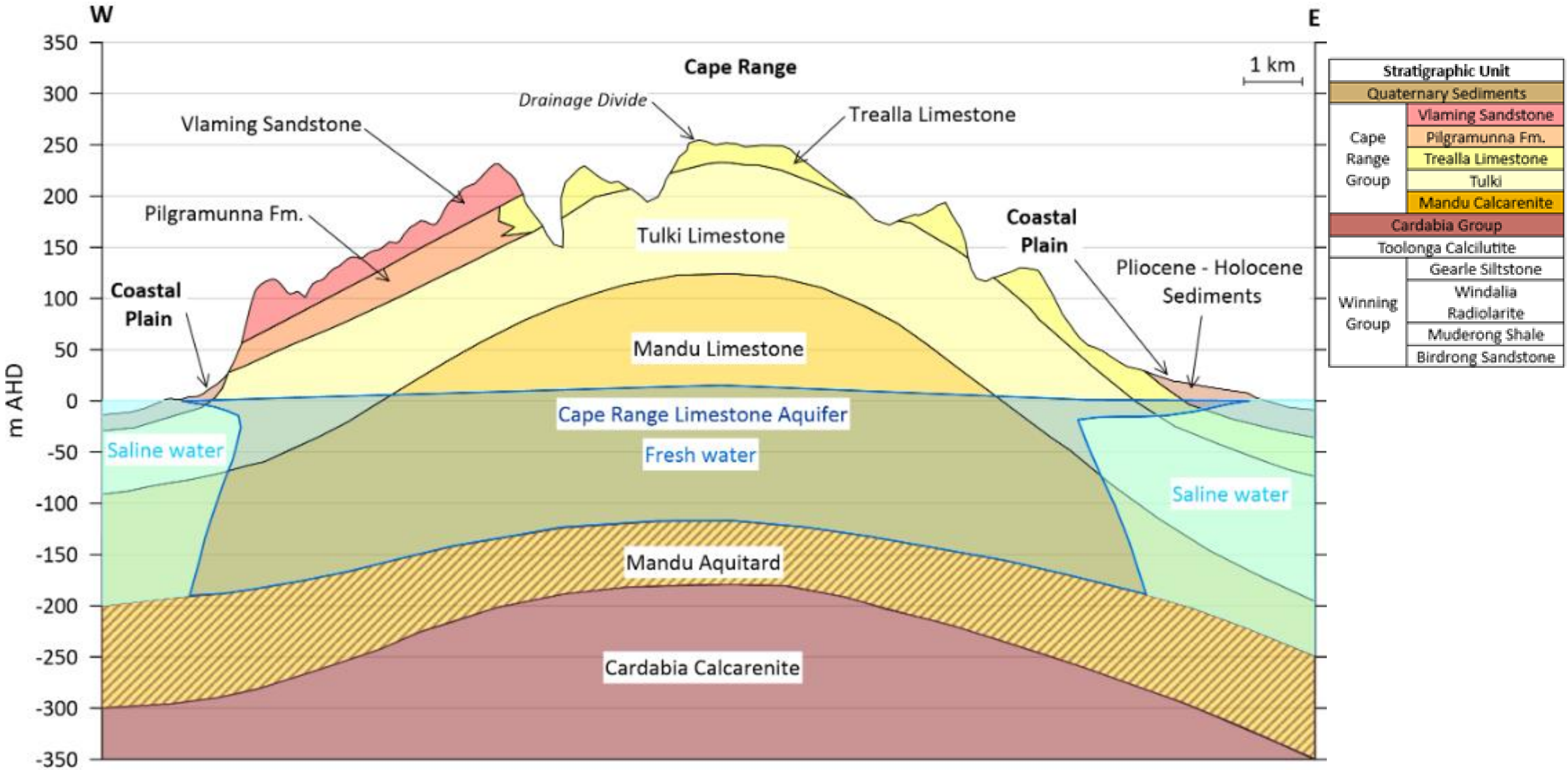

Figure 9 Conceptual cross-section of the Exmouth Peninsula's aquifer system showing a west (left) to east (right) transect through the Cape Range and coastal plains

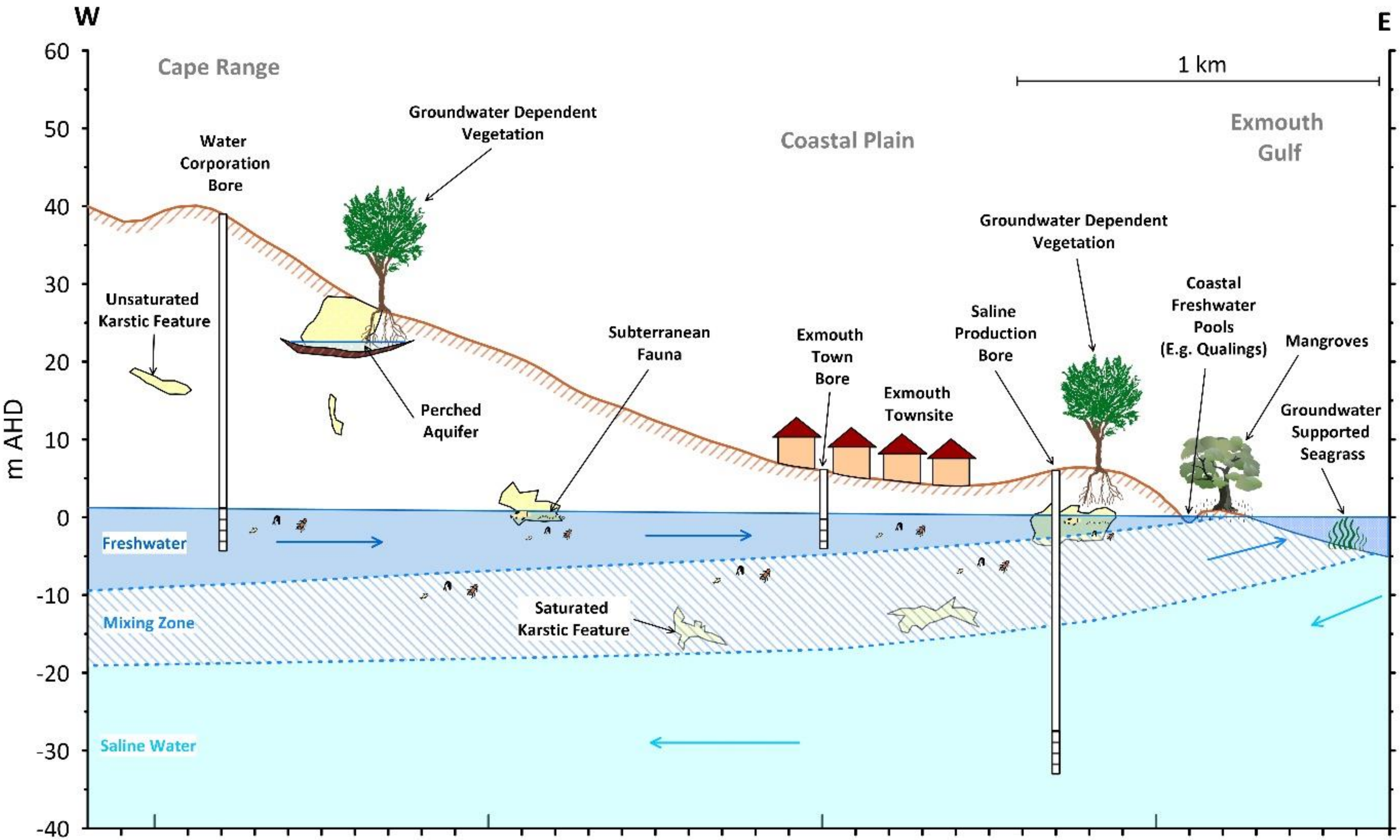

Figure 10 Conceptual hydrogeological cross-section showing how groundwater, water use, and groundwater-dependent ecosystems interact on the peninsula's eastern side (the west coast of Exmouth Gulf)

Saline resource

The saline resource is the part of the unconfined aquifer in each subarea to which sea water has naturally intruded (Figure 9). Extending inland from the coast, ocean water intrudes into the aquifer as a body of denser, saline water, sitting on the base of the permeable upper Mandu Limestone and beneath the fresh water of the Cape Range Limestone resource.

A broad mixing zone, known as the seawater interface, occurs where the fresh water and sea water meet (Figure 10). Here, groundwater salinity transitions from fresh to saline. The department considers the mixing zone to be:

- part of the saline resource
- the zone of brackish-to-saline groundwater quality in the unconfined aquifer.

We have conceptualised the shape of the seawater interface (Figure 9) based on new data from the AEM survey jointly commissioned with Water Corporation. See Appendix A for more information on the shape and AEM survey and the inset in Figure 11 for an example cross-section.

The maximum inland extent and thickness of the seawater intrusion varies, largely in relation to the hydraulic characteristics of the local strata. The position of the seawater interface changes over time and is influenced by seasonal variability in groundwater recharge and throughflow, and sea level and tidal fluctuations.

Birdrong Sandstone aquifer

The Birdrong Sandstone aquifer is a regional aquifer that extends beyond the plan area (over about 50,000 km^2 in total). Within the Exmouth plan area, it is confined by several stratigraphic units and found at depths of more than 1,000 m. While it can produce relatively large yields, water quality is poorer than in the Cape Range Limestone aquifer and generally varies from brackish to saline (DoW 2007).

We did not consider the Birdrong Sandstone aquifer in this review. Because of the depth and water quality of this aquifer, it is not likely to be used as a groundwater resource on the Exmouth Peninsula. However, outside the Exmouth plan area the aquifer is prospective and licensed for consumptive use. The regional Birdrong Sandstone aquifer is managed and licensed in accordance with the department’s *Carnarvon Artesian Basin water management plan* (DoW 2007).

3.2 Groundwater recharge estimations

This section summarises the previous and updated methods we used to estimate groundwater recharge, including the assumptions that inform this review. See Appendix B Revised groundwater recharge rate for further information about our groundwater recharge estimates.

Forth (1973) provided the previous estimates of groundwater recharge, which were calculated using both Darcy’s Law and sodium chloride content methodologies.

These methods respectively estimated that the groundwater recharge at the town water supply borefield was 9.8 and 8.9 per cent of an average annual rainfall of 254 mm. Subsequently, a recharge rate of 10 per cent of average annual rainfall was used to estimate groundwater recharge volumes and inform water availability (Section 1.3).

Updated groundwater recharge rate

We have updated the estimated groundwater recharge rates for the Cape Range Limestone aquifer, informed by new data collected since the original calculations by Forth (1973).

Using the chloride mass balance method, we calculated the average annual groundwater recharge rates from six Water Corporation bores located to the west (inland) of the seawater interface. The estimated groundwater recharge rates ranged from 7 to 28 per cent of the long-term (1968–2023) average annual rainfall measured at the Exmouth Town station (Table 2 and Appendix B). The variation in estimated recharge rates across the bores is likely due to spatial differences; for example, high recharge rates are generally observed along or near drainage lines. Furthermore, a study by Water Corporation in 2020 estimated the groundwater recharge rates at the borefield were between 16 and 20 per cent of the annual rainfall.

The groundwater recharge estimates in the plan area have a high level of uncertainty because of:

- the limited spatial and temporal range of available data
- the broad range in groundwater recharge estimates
- a significant difference between the recharge estimates calculated for this review (7–28 per cent) and the 10 per cent previously calculated by Forth (1972).

In the context of this uncertainty, we adopted a groundwater recharge rate of 15 per cent of average annual rainfall, which is a 50 per cent increase on the previous rate. This updated rate is within the full range of estimates and conservative enough to account for the identified uncertainties. The 15 per cent rate is also considered consistent with the principles and objectives for the plan area (Chapter 6), and appropriate given the deficiencies identified in the previous approach for estimating groundwater recharge (see Appendix B). We have used the 15 per cent rate in our estimates of recharge to the Cape Range Limestone aquifer under several possible future climates (see Section 8.1).

Updated groundwater recharge area

The department reviewed the method underpinning the allocation limits in the Exmouth plan and found that the previous approach calculated throughflow based on the recharge area upgradient of the town water supply borefield (Forth 1973) (Section 1.3), rather than the whole subarea. Subsequent allocation limits set in the Exmouth plan assumed the same throughflow without accounting for the greater area contributing to recharge.

As the recharge area contributing to throughflow was underestimated and the allocation limits were set as a proportion of throughflow, the allocation limits were much smaller than they would have been if the entire recharge area had been considered for each water resource.

The department jointly funded an AEM survey with Water Corporation, which was conducted in 2023 (Southern Geoscience 2024, unpublished). We used the results of the AEM to define the recharge area of the Cape Range Limestone and saline resources. See Appendix A Geological and hydrogeological information for further information on the AEM survey.

Conductivity maps produced using the AEM data show that the freshwater lens is absent or of very limited thickness along the coastline (Figure 11). Although the aquifer would receive rainfall recharge in these areas, it does not contribute any recharge to the freshwater resource. As such, we have excluded these coastal areas from the recharge area calculations for the freshwater resource. We defined the recharge area as the area across which fresh water is present at 0 m AHD (Figure 11; Figure A2 in Appendix A).

Table 4 Updated groundwater recharge area for the freshwater resource in each subarea, based on the presence of fresh water at 0 m AHD

Subarea	Recharge area (m^2) (fresh at 0m AHD)	Area excluded (m^2) (fresh water absent at 0m AHD)
Exmouth North	34,854,677	83,740,842
Exmouth Town	32,720,038	2,401,290
Exmouth Central	108,775,242	2,969,045
Badjirrajirra	187,242,083	6,600,989
Exmouth West	553,762,845	275,318,864
Exmouth Saltflats	551,529,534	235,423,949

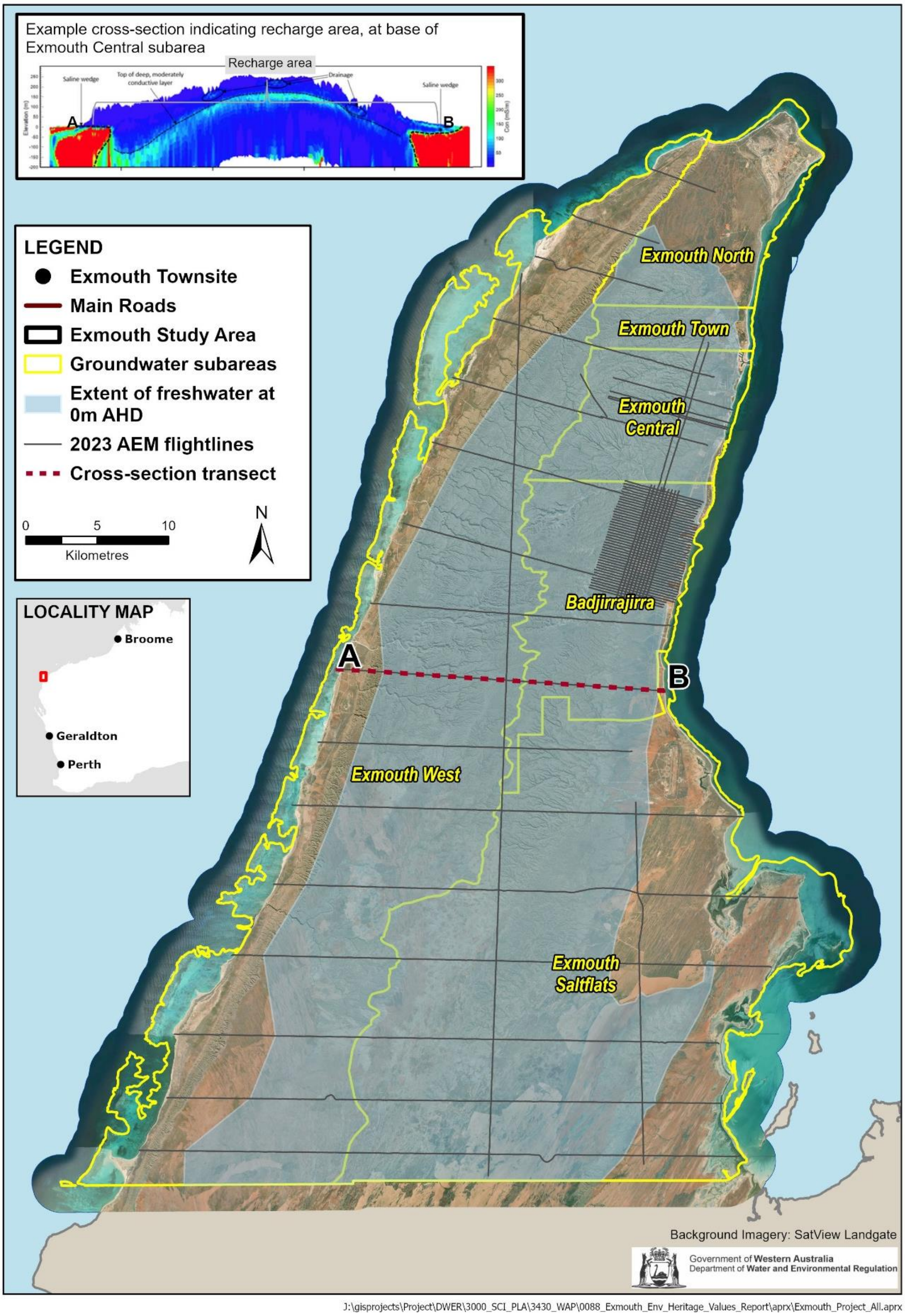

Figure 11 Recharge area of the freshwater resource (at 0 m AHD, shaded blue) and example cross-section A-B (inset of AEM line 300801) showing the conductivity profile and 0 m AHD interface boundary

3.3 Impacts of groundwater abstraction

Exmouth town water supply scheme

Water Corporation is licensed to take water from the Cape Range Limestone resource in the Exmouth Town and Exmouth Central subareas. Groundwater is taken from its borefield to supply the Exmouth town water supply scheme. The borefield was constructed in several stages and consists of 34 equipped production bores distributed over 10 km along a north–south transect.

To ensure impacts are detected and managed, Water Corporation regularly measures groundwater level and quality from the production bores and 26 monitoring bores designated for either seawater interface (SWIM bores), stygofauna habitat (SHM bores) and/or watertable (WT bores) monitoring. Groundwater level and water quality data has been collected from these bores regularly since 1989 (and from bores constructed thereafter).

Based on data from Water Corporation's bores, there have been no significant abstraction impacts on groundwater levels or the position of the seawater interface in the Cape Range Limestone aquifer.

Some temporary salinity-level increases have been observed in the production bores, often correlating with increased abstraction rates. An AEM survey undertaken in 2016 also shows an area of shallow water with high electrical conductivity around some of Water Corporation's production bores in the Exmouth Central subarea (Figure 12).

Higher salinity levels have not been observed in the nearby monitoring bores. This suggests the salinity increases at the production bores are localised and due to abstraction, regardless of climate factors. No change in the salinity and thickness of the freshwater lens has been observed in the SWIM or SHM bores. A comparison of the 2016 and 2023 AEM surveys does not indicate any significant inland movement in the position of the seawater interface.

It is therefore likely that the salinity increases in the production bores are caused by upward migration or upconing of saline water from the underlying mixing zone. Since salinity changes are spatially restricted to the immediate area around the production bores, this can generally be managed by reducing the abstraction rates at the affected individual bores until the salinity levels return to background levels.

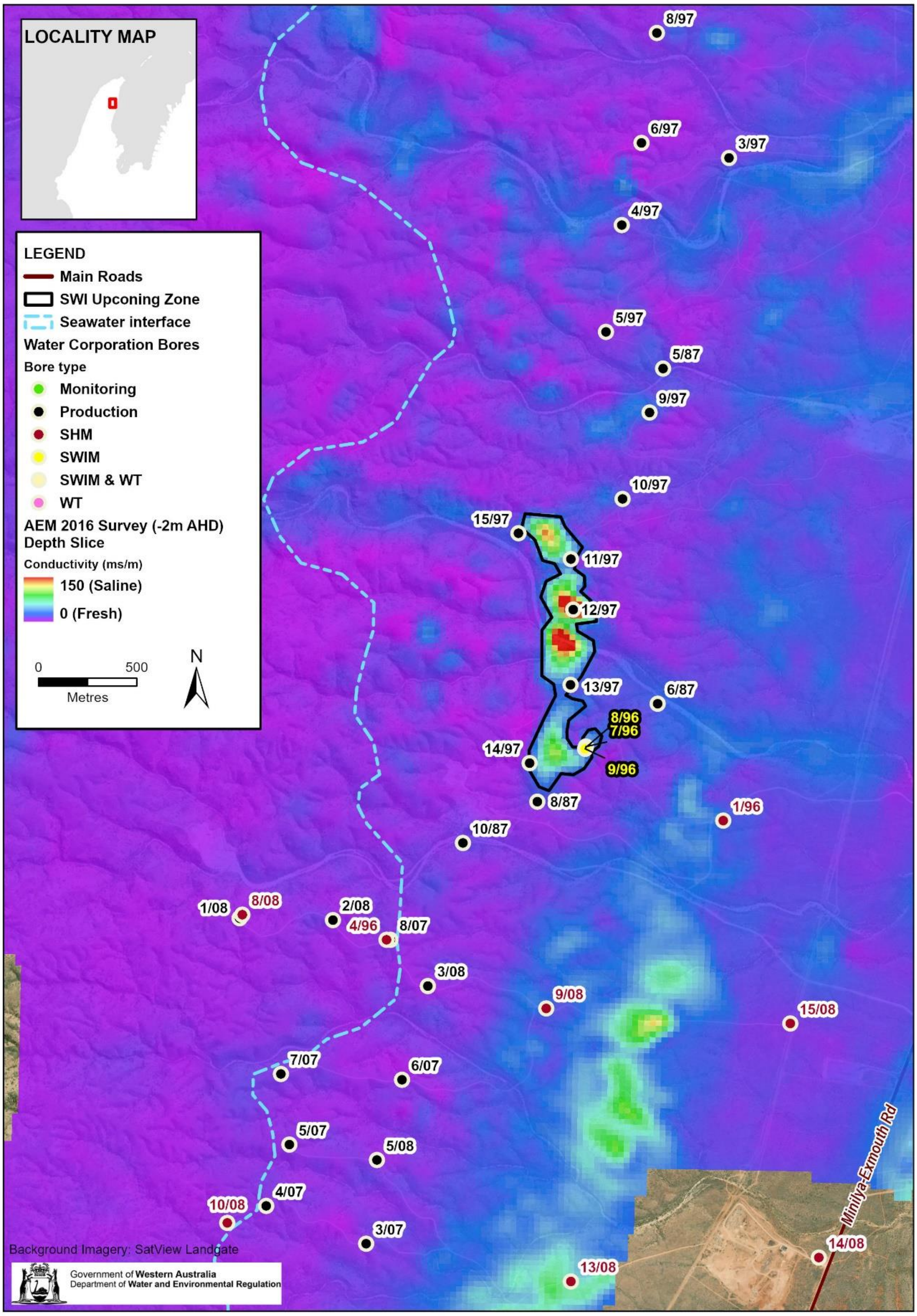

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Figure 12 Conductivity map using AEM data from 2016 shows localised saltwater upconing at the time of survey (yellow to red, immediately adjacent to affected bores) in Water Corporation's borefield (black outlined area)

Impact of abstraction combined with periods of consecutive dry years

We looked at historical occurrences of periods of consecutive dry years (Section 2.3) to determine if an increase in these, combined with abstraction, was a risk to the water resource or water supply. Consecutive dry years were recorded during 2003 to 2004 and 2019 to 2020 at the weather station closest to the Water Corporation borefield (Exmouth Town, BoM station 5051).

During 2019 to 2020, roughly half (47 per cent) of the production bores demonstrated increased salinity from saline upconing – as a result of abstraction combined with low recharge to the aquifer (Table 5). At the time, the average salinity increase in these bores was 300 mg/L TDS, with about a third of production bores (11 out of 34) measuring above 1,000 mg/L TDS (brackish) (Figure 13).

Table 5 Salinity trends in Water Corporation bores during the dry period 2019–20

Bore type	Salinity response in Water Corporation bores during 2019–20			
	Decrease	Stable	Increase	Inconclusive or no data
Monitoring bores (26 total)	1	8	1	16
Production bores (34 total)	2	10	16	6

These salinity increases indicate that extended periods of low rainfall could compromise the current borefield's capacity to supply the amount of water that has been taken historically. This situation would likely be exacerbated if climate change presents a future with longer periods of consecutive dry years, which some climate models are projecting (see Sections 2.2 and 7.1). The aquifer's susceptibility to impacts from climate change means that the take of groundwater needs to be monitored and proactively managed, especially during extended dry periods. It also demonstrates the need to develop an additional water source to ensure the Exmouth town water supply scheme can meet the growing demand for water and provide a secure, sustainable supply that adequately considers future climate changes.

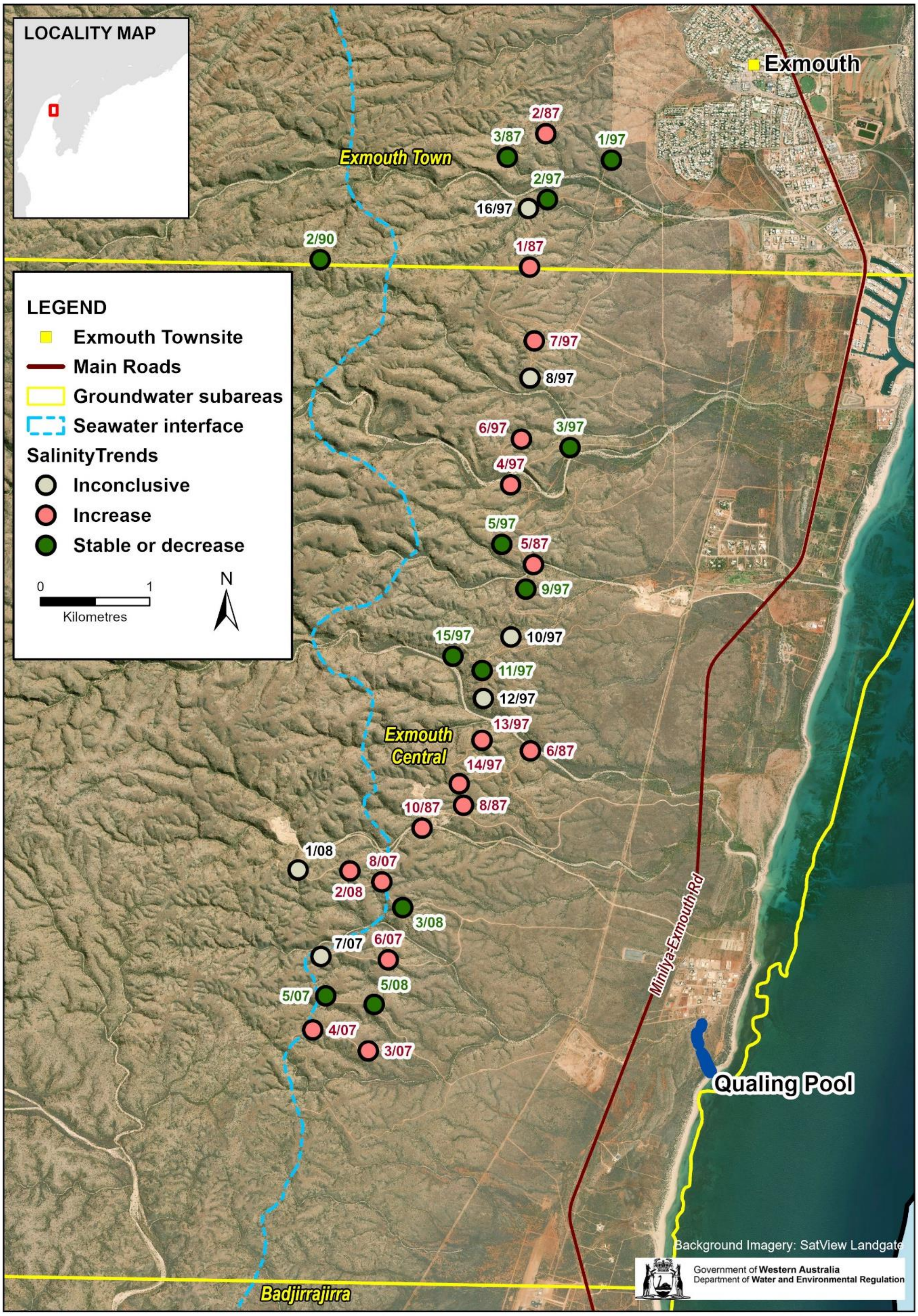

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Figure 13 Salinity trends in Water Corporation production bores 2019–20

Other water users

Closer to the coast, in the Exmouth township area (Figure 1), the freshwater lens is thinner and self-supply water users and garden bore owners have periodically observed increasing salinity levels in their bores. Our predecessor departments (Water and Rivers Commission and Department of Water) sampled bore water quality during the 1990s and 2000s and found that high salinity was common for bores located on the coastal plain. Up to 81 per cent of the bores tested had salinity above 2,500 mg/L TDS (Figure 14), averaging about two out of three bores in the 1990s and about one out of three bores in the 2000s.

These high salinity levels were likely caused either by excessively high pump rates (causing localised upconing of the deeper saline groundwater) or by the bores being screened too deep (into the mixing zone or the saline intrusion) (WRC 1999). Over time, irrigation efficiency and a better understanding of the need for low-flow-rate pumping has contributed to the reduced incidence of salinisation for self-supply bore users.

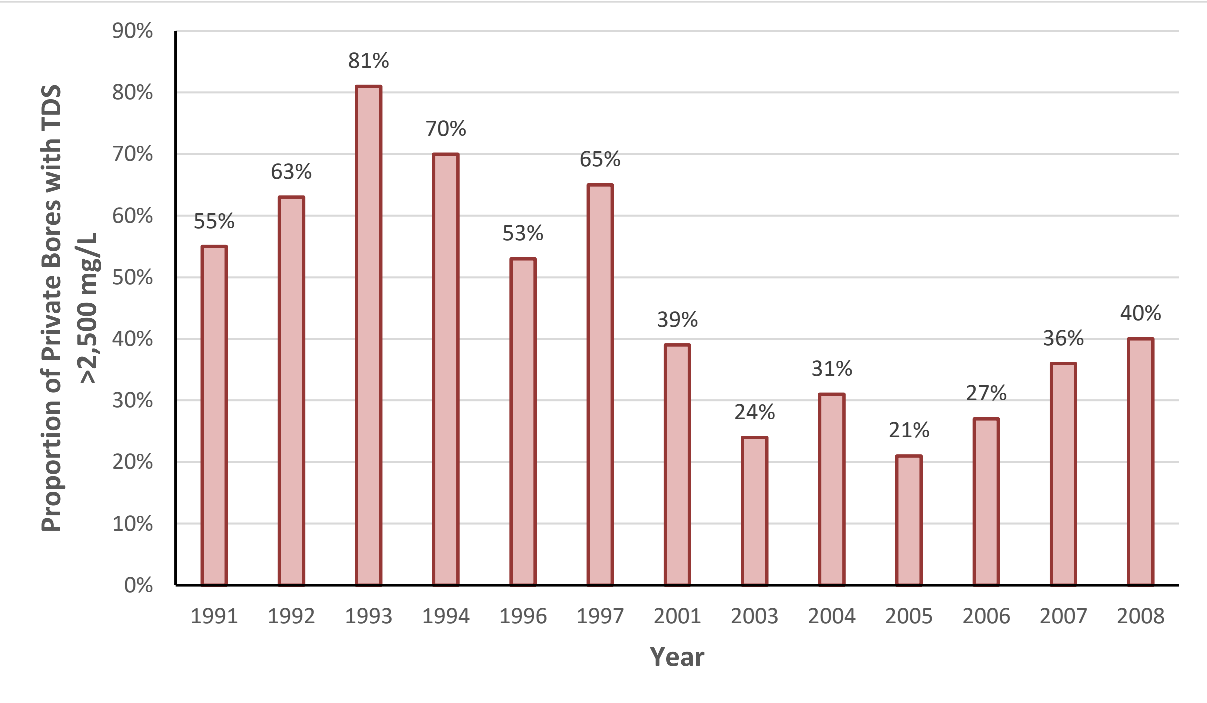

Figure 14 High salinity levels in bores with small licences or exempt from licensing, from sampling in the 1990s and 2000s

4 Groundwater-dependent values

This chapter summarises the key ecological, cultural, heritage and social values of the Exmouth plan area that depend on groundwater to some extent.

The department completed a desktop assessment and limited field surveys to prepare the report *The importance of water to the Exmouth Peninsula's environmental, heritage and social values* (DWER 2025). The report describes the values associated with the peninsula which are listed under legislation, policy and guidance. It also considers the:

- ecological values of water-dependent ecosystems and the current understanding of how they are supported by groundwater
- registered cultural values including cultural and heritage places that relate to water
- social values of tourism, commercial fishing, recreation and research that relate to water.

We used the values report to set the water resource objectives (Chapter 6) and assess the risks of abstraction when determining the water allocation limits (Chapter 8).

4.1 Groundwater-dependent ecological values

The Cape Range Limestone aquifer supports a range of groundwater-dependent ecosystem types:

- subterranean and aquifer ecosystems (freshwater and mixing zone)
- wetland ecosystems (creeklines and pools)
- nearshore marine ecosystems (mangroves, seagrass communities)
- springs
- terrestrial vegetation.

The Cape Range Subterranean Waterways

The Exmouth Peninsula has unique groundwater-dependent subterranean waterway ecosystems. These subterranean systems occur in karst features within the Cape Range Limestone aquifer (Figure 15) along the coastal plain and foothills of the plan area.

DCCEEW (2023a) describes the Cape Range Subterranean Waterways as unique because they:

- Support threatened species listed under WA's *Wildlife Conservation Act 1950* and the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

- Meet two Ramsar criteria for possible listing as a wetland of international importance (Jaensch & Watkins 1999), given the system is the only one of its type (apart from Barrow Island) in arid north-western Australia.
- Are the only wetlands listed principally for subterranean aquatic fauna values in the *Directory of important wetlands in Australia* (DIWA) (Environment Australia 2001).
- Support a rich, entirely endemic (local) subterranean community mostly of relictual marine (Tethys Sea) fauna:
  a) Many species share similarities with those from similar habitats in the Caribbean and Canary Islands.
  b) The fauna includes the only southern hemisphere representatives of entire classes, orders, families and genera of crustaceans.

See below for more details on the subterranean and aquifer ecosystems and fauna.

Figure 15 Water-dependent environmental values, including the highly valued groundwater-dependent Cape Range Subterranean Waterway wetlands (DIWA) and threatened ecological communities

Subterranean and aquifer ecosystems

Subterranean and aquifer ecosystems support an array of fauna that spend their entire lives below the Earth's surface. Although most species are macroinvertebrates, the blind gudgeon (*Milyeringa veritasi*) and blind cave eel (*Ophisternon candidum*) are also found in the waterways (Humphreys 1999).

The fauna belongs to two groups:

- stygofauna – aquatic and living in groundwater
- troglofauna – air breathing and living in voids and caves above the watertable, dependent on the humid conditions in these habitats caused by proximity to groundwater (Tomlinson & Boulton 2010) or rainfall recharge from the surface (Bennelongia 2021).

Much of the stygofauna is present in the mixing zone of the aquifer – where fresh and saline groundwater meet and diffuse into each other (Figure 10). Maintenance of water quality, natural hydrological regimes and the mixing zone within the subterranean waterways is particularly important for the conservation of stygofauna and groundwater-dependent troglofauna (DEC 2010).

Bundera Sinkhole is an example of where the mixing zone is providing important habitat. The sinkhole is listed under the EPBC Act as a critically endangered threatened ecological community (TEC), as well as being a DIWA wetland. The sinkhole supports two species of fauna listed as threatened and vulnerable under WA's *Biodiversity Conservation Act 2016* (BC Act) and the EPBC Act respectively.

The Camerons Cave Troglobiotic Community (Figure 15) is another TEC listed under the BC Act. This community contains a unique assemblage of troglofauna, of which at least eight species are only found in this cave and are likely dependent on the humidity from groundwater at the base of the cave. Parts of the cave extend below the watertable, believed to be the unconfined Cape Range Limestone aquifer (DEC 2012).

Wetlands and waterways

In addition to the subterranean waterways, the peninsula supports a few persistent and ephemeral creeks and wetlands. Yardie Creek is the main surface water feature on the Exmouth Peninsula and the only permanent, groundwater-fed watercourse (Allen 1993; DEC 2010) (Figure 15). Yardie Creek supports populations of emergent aquatic flora that occur a considerable distance away from their normal ranges.

Qualing Pool, in the Exmouth Central subarea near the mouth of an unnamed creek (Figure 15), is made up of a series of pools that are also considered permanent and groundwater-fed (Allen 1993). The creek and pools likely represent significant spiritual, cultural and historical heritage values for the NTGAC Traditional Owners (Oceanwise 2022).

Nearshore marine environment

A cluster of submarine springs, offshore at Mangrove Bay, is thought to discharge fresh water into the marine environment (Collins & Stevens 2010). This submarine groundwater discharge likely plays a vital role in maintaining the diversity and richness of nearshore and marine ecosystems, including mangroves and seagrass communities, which in turn support the area's diverse marine ecology (Figure 10).

The locations and volume of fresh water discharging into the Ningaloo Marine Park and Exmouth Gulf from surface flows and groundwater discharge is not yet established. However, groundwater discharge into the marine environment provides both fresh water and nutrients for seagrass, mangrove and saltflat communities (Pollino et al. 2018) and likely supports marine productivity and the unique biodiversity of the Exmouth nearshore environment.

The role of groundwater discharge into nearshore marine habitats is a growing field of study in Australia and around the world. The department has investigation programs underway in other areas of the state, such as the coastline between Eighty Mile Beach and Roebuck Bay in northern WA (La Grange groundwater investigation).

From research to date, there is increasing evidence that freshwater inputs, such as groundwater, rain and/or river flow are important for above-ground growth in mangroves and that the trees use this water in preference to saline water (Green & Short 2003; Hayes et al. 2018). An extensive area of mangroves has been mapped in Gales Bay and the Bay of Rest in the Exmouth Saltflats subarea (Figure 16) (DWER 2025). Smaller areas of mangroves are known in the Exmouth West subarea, including in the Mangrove Sanctuary zone at Mangrove Bay (Figure 16).

Saline coastal flats (salt flats) can support cyanobacterial mats, which are made up of microbial cyanobacterial communities. Carbon and nutrient exchange with the marine environment occurs at high tides or through groundwater flows (DWER 2025).

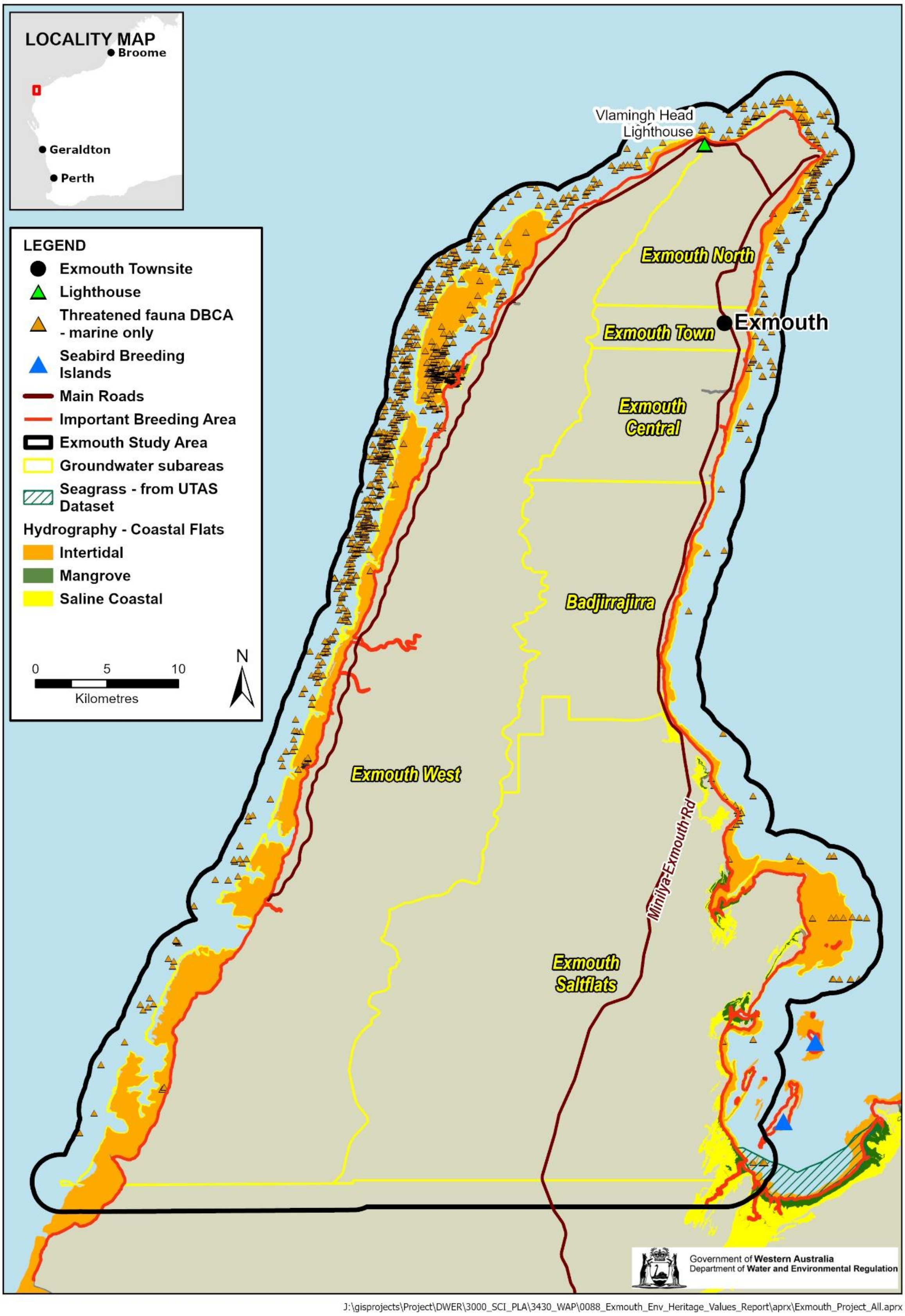

Figure 16 Marine ecosystem values potentially supported by groundwater discharge

Springs

In arid and semi-arid environments, springs are critically important sources of water supporting terrestrial fauna, and aquatic and riparian habitat. Springs are often important places to Traditional Owners and are a source of water for pastoralists.

Springs were known to occur on the boundary of the Tulki/Mandu Limestones in the creek within Shothole Canyon and in the headwaters of Yardie Creek. The Shothole Canyon spring was described as *"…a freshwater spring…emerging at the contact between the lower impermeable part of the Mandu Formation and the upper friable chalky strata. The spring is perennial... flows for several hundred metres and then disappears…*" (Forth 1972).

Fresh to brackish springs were known to occur near the coastline (Forth 1972 and 1973) and a cluster of submarine springs has been observed offshore at Mangrove Bay, discharging fresh water into the marine environment (Collins & Stevens 2010). Forth (1972) also mapped two soaks and a gnamma hole in the Mowbowra Creek area. It was noted that Mowbowra bore/well to the south of the gnamma holes supported stygofauna before it was decommissioned and filled in (Oceanwise 2022; Brooks 2015).

Terrestrial groundwater-dependent vegetation

Limited occurrences of *Eucalyptus camaldulensis* (river red gum), *Ficus brachypoda*, (rock fig) and the BC Act-listed priority-four Millstream fan palm (*Livistona alfredii*) have been observed or noted across the Exmouth Peninsula (Forth 1972; Oceanwise 2022; Collins & Stevens 2010; Humphreys et al. 1990). These species are likely to be accessing fresh groundwater.

4.2 Cultural values of groundwater

Traditional Owners have custodial responsibilities for land and waters in the Exmouth region. The Gnulli native title claim was determined in December 2019 and gave recognition to the Baiyungu, Yinnigurrura and/or Thalanyji people over a 71,354 km^2 area of the Mid West – Gascoyne region, including the Exmouth Peninsula.

Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC) and Yinggarda Aboriginal Corporation are the prescribed bodies corporate under the *Native Title Act 1993* (Cth) that hold the native title rights and interests on trust for the native title holders across this region. NTGAC is the prescribed body corporate for the Baiyungu and Yinnigurrura[2] area that includes Ningaloo and Exmouth Gulf.

The people represented by NTGAC have a deep cultural connection with water and there are cultural sites across the Exmouth Peninsula. Under traditional lore (law), the Baiyungu and Yinnigurrura people have responsibilities to care for Country and

[2] Also spelt 'Yinikurtira'. In the native title determination, the native title holders are referred to as the Baiyungu and Thalanyji people; however, NTGAC has advised Baiyungu and Yinnigurrura is more culturally appropriate (Exmouth Gulf Taskforce, 2023).

keep culture strong. The cultural heritage, spiritual and religious values of the Exmouth Peninsula and its surrounding environment are of paramount importance to the Traditional Owners.

Cultural sites that exist due to the presence of groundwater are considered groundwater-dependent cultural values. They include the Baiyungu, Yinnigurrura, Yinggarda and Thalanyji dreaming stories and subterranean waterways – referred to here as freshwater cultural values.

An understanding of where freshwater cultural values occur in the Exmouth Peninsula and how they are connected to, and rely on, groundwater is an important consideration in water allocation planning. Aboriginal heritage values that depend on groundwater are discussed below.

4.3 Groundwater-dependent heritage values

The Exmouth Peninsula is internationally recognised for its outstanding natural heritage values, which are supported by the connections between fresh and salt water systems. The Ningaloo Coast, which runs along the Exmouth Peninsula's western side, was listed as a World Heritage site in 2011. Covering 7,050 km^2 of marine and terrestrial environments, the site includes one of the longest nearshore reefs in the world (DEWHA 2010). The marine area supports numerous listed marine mammals, fish and reptiles, including humpback whales, coastal dolphins, dugongs and marine reptiles (including turtles and sea snakes). The nearshore marine ecosystems are believed to be supported by fresh groundwater discharging along the coast (Sutton & Shaw 2021; Collins & Stevens 2010).

The Ningaloo Coast was listed as a national heritage site in 2010. The 8,000 km^2 site includes a marine area of about 5,500 km^2, incorporating the Ningaloo Marine Park and the state-managed Muiron Islands Marine Management Area.

Aboriginal heritage places listed under the *Aboriginal Heritage Act 1972*

All Aboriginal heritage sites in WA are protected by law, regardless of whether they are a registered site. Information about how the Aboriginal heritage laws regulate the protection, conservation and preservation of Aboriginal heritage can be found online at Find Aboriginal cultural heritage in WA.[3]

Close to 100 sites are registered under the *Aboriginal Heritage Act 1972* in the Exmouth plan area. All listed sites in Exmouth are located within the Warnangura (Cape Range) cultural precinct, which covers 3,000 km^2 of the peninsula (Figure 17). Sites may be of ceremonial or mythological significance; recognised as a water source; or contain artefacts, middens, engravings, caves and rock shelters (e.g. Mandu Mandu, Yardie Creek, Sandy Point).

[3] The Find Aboriginal cultural heritage in WA is a webpage of the WA Department of Planning, Lands and Heritage and includes the ACHIS map viewer.

European heritage places

Four European heritage sites are listed under the *Western Australian Heritage Act 2018* in the Exmouth plan area. All are associated with the Vlamingh Head lighthouse, which was a significant feature of the peninsula’s north-west coast for 50 years until 1967. Numerous other sites are listed for local heritage value, including Charles Knife Road and Wapet Jetty. None of the European heritage values are groundwater related.

4.4 Groundwater-dependent social values

The Exmouth Peninsula makes up a large portion of the Ningaloo Coast World Heritage Area. This includes the Ningaloo Marine Park (state and Commonwealth waters), Cape Range National Park, Jurabi and Bundegi coastal parks, and areas of unallocated crown and defence land.

In addition to cultural and heritage values, there are social values and other public benefits that depend on the presence of water in the environment. Some of these are outlined below.

Recreation and tourism

The natural beauty, ecological significance and low levels of development of the Ningaloo Coast and wider Exmouth Peninsula make it a unique place: a ‘jewel in the ocean’ (Deloitte 2020). The area attracts growing numbers of tourists each year.

Fishing off the beach at the Qualing and Mowbowra creek mouths is particularly popular, and the nearshore environment is likely to be directly supported by groundwater inputs. Boat tours of Yardie Creek are also popular and only possible due to the persistent pools found in the gorge.

Educational and scientific values

The Exmouth Peninsula is the subject of significant and ongoing scientific and educational work. The Western Australian Speleological Group Inc. surveys and studies many of the cave ecosystems that support stygofauna.

Landscape and aesthetics

The area also holds intrinsic (non-use) value. This is likely to include knowing that people can experience Ningaloo Reef and its environs (corals, mangroves, creeks and other wetlands) now and in the future, and valuing it simply because it exists.

The groundwater-dependent ecosystems are also valued for the ecosystem services they provide. These include nutrient cycling (salt flats), habitat provision (creeks, aquifers, reefs) and coastal protection (mangroves).

The peninsula’s landscape and aesthetic values are a major tourism drawcard. The pristine nature of the marine environment and places such as Yardie Creek and Shothole Canyon could be considered groundwater-dependent to some extent.

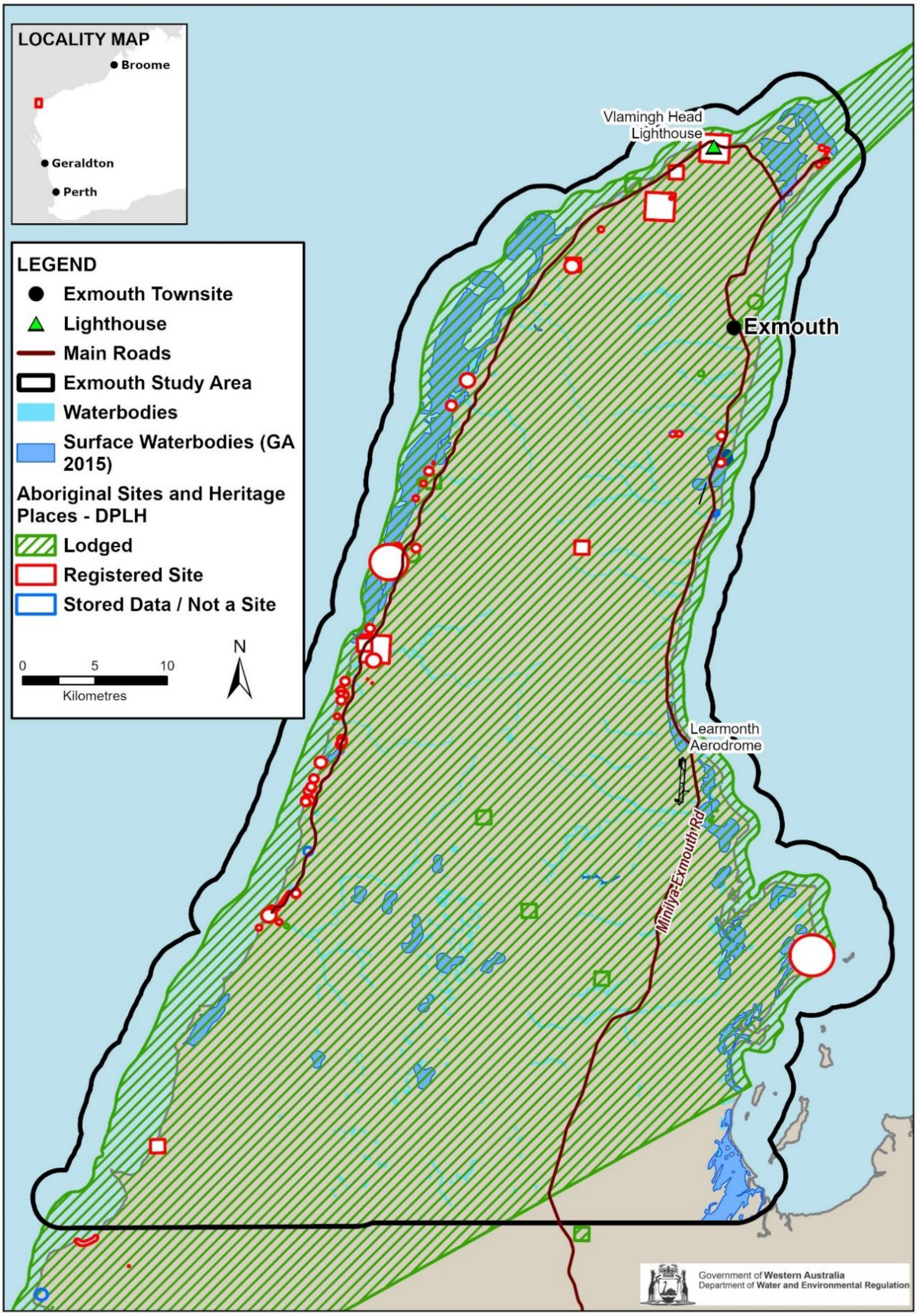

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Figure 17 Warnangura (Cape Range) cultural precinct (green hashed area) and registered Aboriginal heritage places in the Exmouth plan area (as of April 2024)

5 Groundwater use and demand

This chapter describes how groundwater is used in the Exmouth plan area and outlines the anticipated future water demand. Water licensing under the *Rights in Water and Irrigation Act 1914* is an important process for preventing and managing local risks and impacts from constructing bores and taking groundwater. See Section 3.3 to understand the impacts of abstraction in the Exmouth plan area, and Part C for abstraction management information.

5.1 Current and historical water abstraction

Fresh groundwater from the Cape Range Limestone aquifer is the primary water source for water use across the Exmouth Peninsula. About 1.6 gigalitres of groundwater per year (GL/year) is licensed for abstraction from the aquifer, for both the Exmouth town water supply scheme and a small number of self-supply licensees (13 licensed water users[4]).

The Exmouth town water supply scheme provides water for a residential population of nearly 3,000 people, although tourist visitation can cause numbers to swell at different times of the year. Scheme supply makes up almost two-thirds of fresh groundwater licensed on the peninsula, followed by uses exempt from licensing, at just over 20 per cent (Figure 18). Self-supply licences for fresh groundwater are located both in town and around the peninsula to supply local commerce, tourism, industry, green parks and ovals, and premises that are not connected to scheme water (Figure 18 and Figure 20).

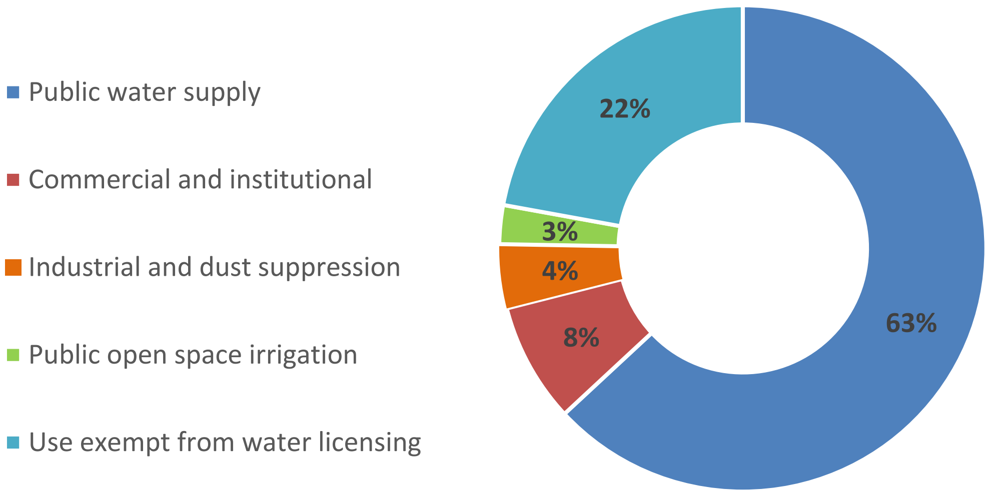

Figure 18 Fresh groundwater use from the Cape Range Limestone aquifer is mostly licensed for public water supply (as of September 2024)

[4] Licensing information current as of September 2024.

Interest in saline groundwater has increased during the past decade, and is licensed for aquaculture, dust suppression and desalination for other purposes (Figure 19 and Figure 20). About six water licensees draw a total of 2 GL/year from the saline resource.

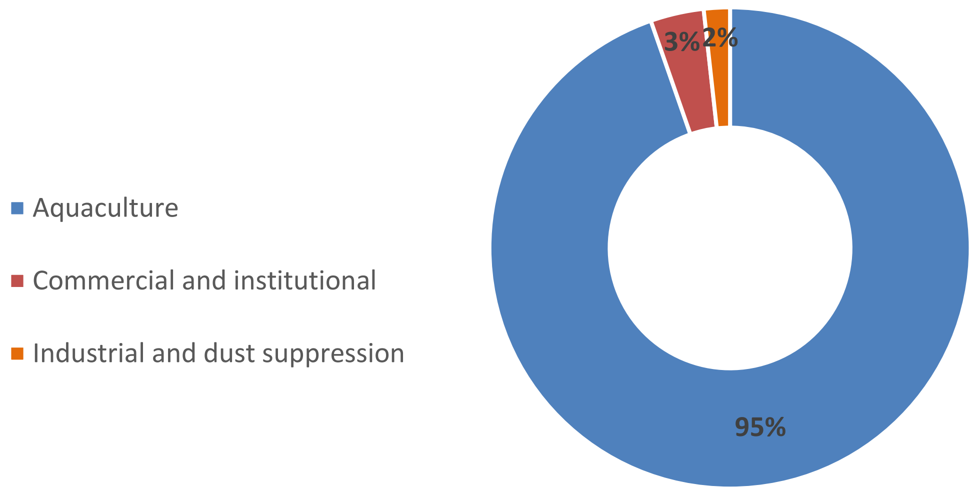

Figure 19 Groundwater licensed from the saline resource (as of September 2024)

[5] Licensing information as of September 2024.

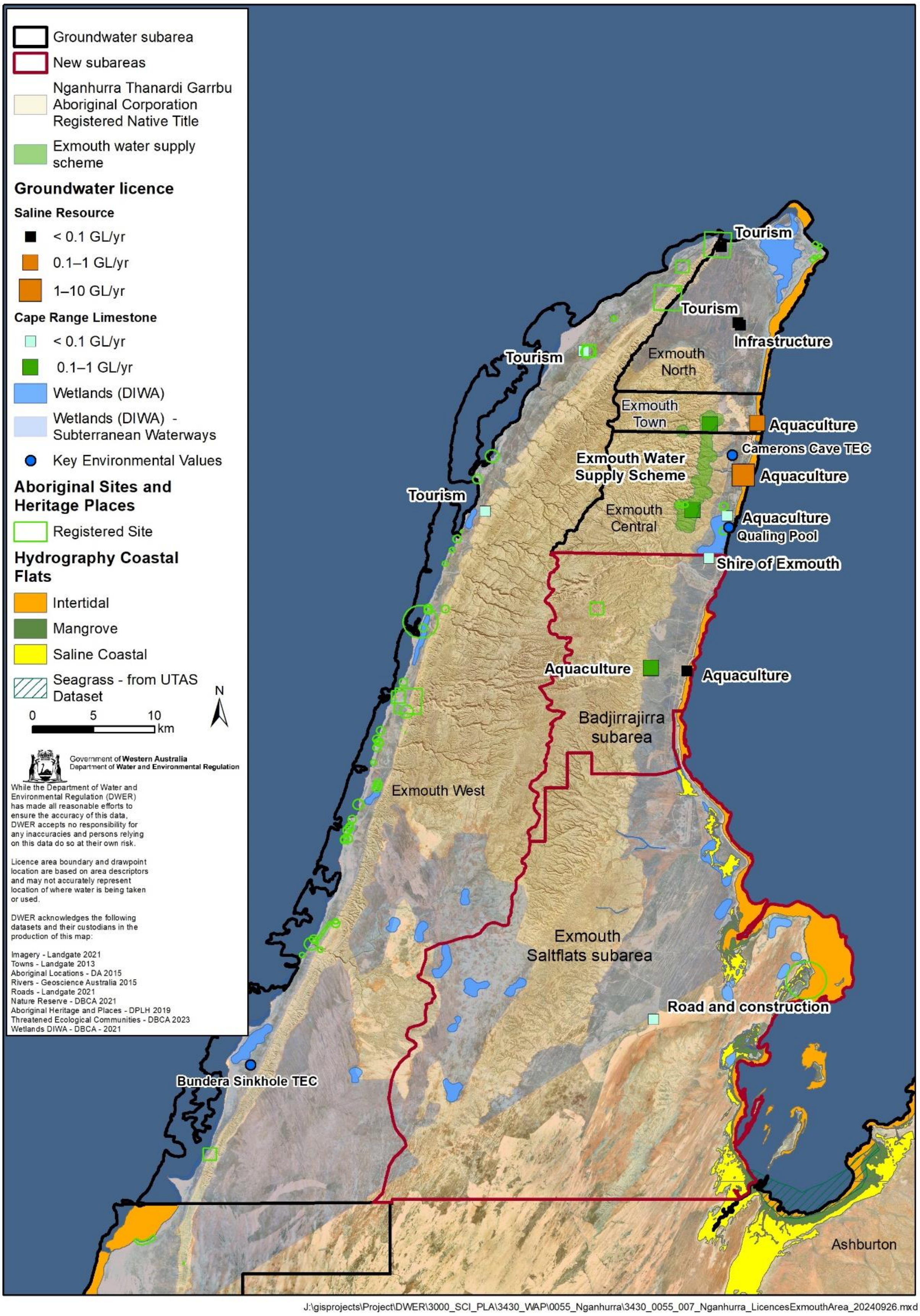

Figure 20 Licensed groundwater use in relation to water-related environmental features and values across the Exmouth subareas

Exmouth town water supply scheme

Water Corporation manages and operates the Exmouth town water supply scheme borefield, located in the Exmouth Town and Exmouth Central subareas (Figure 20), in accordance with two groundwater licences for a total of 1,032,000 kL/year. Abstraction for town water supply has increased as the town of Exmouth has grown, along with an increase in tourist visitation rates. The Exmouth borefield was last expanded following Assessment 921 by the Environmental Protection Authority in 1997 (EPA 1997).

Annual demand from the borefield is now approaching total licensed entitlements. In early 2023, Water Corporation began a review of future water supply options to meet projected demand, in combination with demand reduction strategies.

Groundwater abstraction exempt from licensing

Domestic garden bores, bores for non-intensive stock watering, and bores supplying Department of Defence lands access shallow, fresh groundwater from the Cape Range Limestone resource. These uses are exempt from licensing[6], and so we estimate the volume of exempt use and account for it as a component within the allocation limit.

The previous allocation limits set in the Exmouth plan did not include exempt use components because these were established in 2010 when the exemption order[7] came into place (Section 1.3). At the time of the 2010 exemption, there were 46 domestic bore users licensed in the Exmouth Town subarea, 17 in Exmouth Central and one in Exmouth South. We subsequently cancelled these licences, and accounted for the water use in an exempt use component of the allocation limits.

Domestic garden bores

Although domestic garden bores individually consume a negligible amount from the shallow aquifer, cumulative abstraction in a condensed setting (such as around the Exmouth township) needs to be considered, particularly because the Cape Range Limestone resource is already highly allocated in the Exmouth Town and Exmouth Central subareas.

Garden bores have been popular in Exmouth for irrigating domestic lawns and gardens since the township was developed. A 2016 phone survey on garden bore use by Research Solutions indicated that garden bores remained common and continued to be installed in new developments in Exmouth, despite the difficulties

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[6] Groundwater abstracted by Commonwealth government agencies is exempt from licensing under the *Rights in Water and Irrigation Act 1914* (WA). In Exmouth, this includes use by the Department of Defence bases at the Harold E. Holt facility and Learmonth Airbase. The Department of Defence manages its groundwater abstraction and communicates progress with the Department of Water and Environmental Regulation under a memorandum of understanding.

[7] Since the plan was released, the Rights in Water and Irrigation Act 1914 Exemption (Section 26C) Order 2011 came into effect, removing the need for small domestic, garden and stock watering bores to be licensed. Groundwater use meeting the definition for exemption is accounted for in an exempt component within the allocation limit of a water resource.

associated with installing bores in this remote location and the low water quality at the coast.

We account for groundwater used by garden bores in an exempt component of the allocation limit for each freshwater resource. Exempt components for the Exmouth Town and Exmouth Central subareas were not updated in this review and consist of the total volume of cancelled licence entitlements for domestic water purposes at the time the exemption order came into place in 2011. Further surveys would inform our understanding of changes in use patterns as the Exmouth community grows.

Native title activities

Section 211 of the *Native Title Act 1993* (Cth) gives native title holders the right to exercise their native title rights (to hunt, fish, gather and carry out cultural or spiritual activities for the purpose of satisfying their personal, domestic or non-commercial communal needs) without requiring a water licence. The taking of water for these practices has not been estimated but is considered to involve relatively low volumes. We acknowledge that this water has always been taken and will continue to be.

Water for non-intensive livestock production

Water for non-intensive livestock production and stock held in stock yards for short periods is exempt from licensing under the Rights in Water and Irrigation Exemption (Section 26C) Order 2010 when it is abstracted from an unconfined watertable aquifer.

The Exmouth Gulf Station pastoral lease extends across the Exmouth Saltflats and Badjirrajirra subareas. Watering points for livestock, supplied through small low-yielding bores in the unconfined aquifer, are distributed across the station.

To estimate the average annual stock water needed for the station, we assumed a carrying capacity and average stock water demand consistent with advice and published information from the Department of Primary Industries and Regional Development (Future Beef 2011).

We calculated that the station’s average need for stock water is 33,375 kL/year. This groundwater requirement is split between the Badjirrajirra and Exmouth Saltflats subareas, based on land area within the subarea boundaries, and rounded to 2,000 kL/year and 31,350 kL/year respectively.

5.2 Meeting future demand

Population statistics and strategic direction for the area is detailed in the Shire of Exmouth’s *2023–2033 Strategic community and corporate business plan* (Shire of Exmouth 2022). Exmouth’s residential population grew by 13 per cent between 2016 and 2021 – reflected in an increase in scheme water connection requests to Water Corporation. Tourist numbers to Exmouth have also increased – more visitors are now coming in the summer and shoulder months, whereas previously visitor patterns were seasonal (four to five months over the cooler winter season).

This review has adjusted groundwater availability in line with our improved understanding of the Cape Range Limestone aquifer and environmental water needs, and in consideration of climate change. We are working with Water Corporation to manage ongoing demand for public water supply for the Exmouth township while protecting groundwater-dependent ecosystems. Existing and future developments should optimise the groundwater available through water sensitive design and efficient irrigation practices.

Meeting future demand will make it necessary to improve water use efficiency (both among scheme users and self-supply licensees and domestic bore users) and use sources other than groundwater. For example, the Exmouth Shire and Water Corporation operate a water reuse scheme which treats wastewater from the Exmouth Water Resource Recovery Facility (wastewater treatment plant) to irrigate ovals, the Exmouth golf course and surrounds. Wastewater facilities are regulated under WA's *Environmental Protection Act 1986.*

Water Corporation, under the State Government's 2024 Smart Meter project, has also upgraded water connection meters in Exmouth to 'smart' meters, which allow for faster identification of hidden leaks. This will reduce water wastage, improve efficiency and help meet more immediate demand shortfalls in the Exmouth Town and Exmouth Central subareas.

As discussed, Water Corporation is exploring two options to meet Exmouth's future water needs: southwards expansion of its borefield, and seawater desalination. We will continue to work with Water Corporation as it assesses options to find a sustainable solution that adequately considers future climate change.

For advice about groundwater availability and licensing in the Exmouth area, contact one of our Mid West – Gascoyne regional offices. For information on scheme supply and efficiency incentives for Exmouth, contact Water Corporation or search the Water Corporation website for initiatives in Exmouth.

Part B – Setting objectives and allocation limits

In Part B of this review, we define the:

- water resource objectives
- how we assessed future climate
- the risk assessment process behind the allocation limit options
- our allocation limit decisions for the Exmouth subareas.

These steps use the key information gathered, analysed and set out in Part A of this report.

Key decisions from Part B

- We have set water resource objectives in addition to the Exmouth plan objectives (WRC 1999). These have guided our allocation limit decisions.
- We used a dry climate scenario, with an increased number and length of consecutive dry year periods, for our water balance calculations to account for a possible drier future climate.
- In the Exmouth West and Exmouth Saltflats subareas, the allocation limit decisions prioritise the protection of groundwater-dependent values.
- In the Exmouth Town and Exmouth Central subareas, the allocation limit decisions recognise the importance of maintaining the existing, licensed public water supply. This requires adaptive management to manage risks to groundwater-dependent values (see Part C) and means no water is available for additional general licensing or public water supply.
- Water is available for licensing from the freshwater resource in the new Badjirrajirra and Exmouth Saltflats subareas. Water Corporation is investigating both groundwater expansion into the Badjirrajirra subarea and local seawater desalination as new water source options. We have set aside 0.5 GL as a public water supply reserve in the Badjirrajirra – Cape Range Limestone resource while the investigation continues.
- Our decisions mean there are no changes to water allocations for existing groundwater licences.
- We have changed the allocation limits for the saline resource in all subareas to ‘not set’ because of the uncertainty around setting them and the unique habitat saline groundwater provides for subterranean fauna. We will manage water available for licensing and local risks and impacts through individual, site-specific licence assessments (see Part C).
- We will continue discussions with NTGAC on water aspirations for future economic development. Any future potential Aboriginal water reserves would come from the remaining water available for general licensing.

6 Setting objectives

As part of this review, the department reviewed the objectives in the Exmouth plan (WRC 1999) and developed specific water resource objectives. We used these new objectives to assess allocation limit options and make decisions during the review process. We will also use the objectives to evaluate the success of our water management in the future.

6.1 Objectives of the Exmouth plan

The Exmouth plan established policies and principles for the sustainable allocation of groundwater resources across the plan area. The plan includes water management objectives and principles to guide groundwater allocation and licensing. These management objectives and principles are still relevant, and we used these as a guide to set specific water resource objectives for the allocation limits review (Section 6.2).

The Exmouth plan's objectives focus on ensuring that we:

- recognise and protect the environmental values of groundwater
- protect the beneficial uses of groundwater for present and future generations
- support sustainable groundwater abstraction for the long-term security of the freshwater resource in the region
- ensure, where possible, reasonable security of supply to existing water users
- promote allocation of available groundwater for the most benefit to the community
- encourage efficient water use.

The water allocation and licensing principles aim to ensure groundwater is:

- used efficiently to conserve water, especially by large water users
- licensed equitably, for both long-term water use and the environment
- managed according to:
  - ecologically sustainable development and biodiversity protection principles in relevant state and national agreements
  - the best-practice management principles of being precautionary to prevent environmental degradation, ensuring intergenerational equity, and preserving biological diversity and ecological sustainability.

6.2 Water resource objectives

A water resource objective is a measurable statement that is designed to assist with achieving the objects and principles of the *Rights in Water and Irrigation Act 1914*. Water resource objectives are set for specific water resource/s and guide how we want water resources to respond to our management.

Consistent with the plan's management objectives and principles, we set water resource objectives with both environmental and water use outcomes in mind (Table 6). The first two water resource objectives are set for environmental outcomes. These recognise the need to protect and manage impacts on the unique, recognised and important ecological, cultural and social values of the Exmouth Peninsula that depend on groundwater (Chapter 4).

Table 6 Water resource objectives set in this review for environmental and water use outcomes across the Exmouth plan area

Water resource objectives	Applicable resources and subareas	Outcome focus
1. The current groundwater regime (level, flow[1] and quality) is maintained to support groundwater-dependent values and the resource.	Cape Range Limestone and saline resources in: • Exmouth Town • Exmouth Central • Exmouth North.	Environmental outcomes
2. The natural groundwater regime (level, flow[1] and quality) is maintained to protect groundwater-dependent values and the resource.	Cape Range Limestone and saline resources in: • Exmouth West • Badjirrajirra • Exmouth Saltflats.	
3. **The groundwater regime (level and quality) is maintained to support a sufficient and sustainable supply of fresh groundwater for use.**	Cape Range Limestone resource in all subareas.	Water use outcomes

[1] Flow relates to groundwater throughflow required to maintain the location of the seawater interface to protect stygofauna habitat, and to maintain the water quality of nearshore freshwater seeps and submarine springs.

The third objective is to ensure water use outcomes. It recognises that groundwater is essential for water supplies in the Exmouth plan area (Chapter 5), including for:

- water uses exempt from licensing, including domestic and garden use, stock watering, relevant native title purposes and emergency firefighting (exempt uses)
- scheme supply (licensed and reserved) for drinking water and commercial enterprises in Exmouth
- irrigating green spaces and active sporting fields in Exmouth (licensed)
- industry, agriculture and new developments across the peninsula (licensed).

We also recognised the need to consider outcomes for future demand in setting objectives and reviewing water allocation limits. This includes considering water available for future public water supply and potentially for future Aboriginal water reserves (Section 8.1).

7 Accounting for future climate in allocation limits

We have used a climate storyline approach to determine the future climate scenarios to inform the allocation limits. The approach is consistent with the department's *Guide to future climate projections for water management in Western Australia* (DWER 2024).

The future climate guide and approach comprises three decision-making stages (Figure 21). The first stage – understand the water system and context – is covered in Part A of this report (particularly Chapters 2 and 3). The second stage – a future climate water assessment – is set out below (Chapter 7).

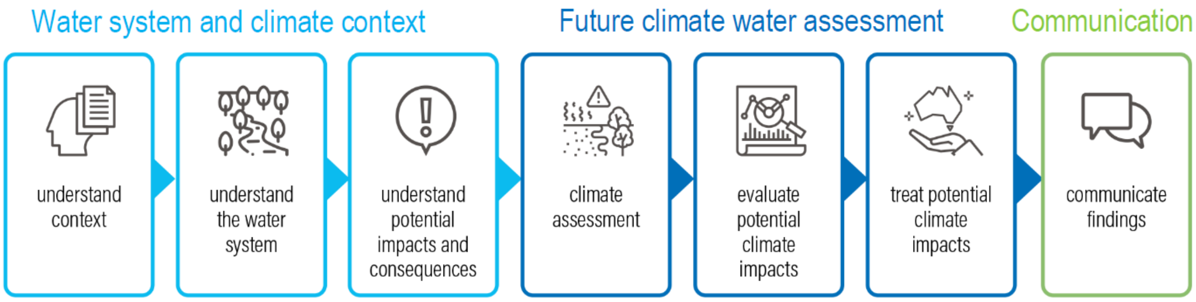


Figure 21 Climate storyline stages and steps for applying climate projection data in water resource planning and decision-making processes (DWER 2024)

7.1 Future climate assessment

We did a preliminary review of the Bureau of Meteorology's National Hydrological Projections (NHP) (BoM 2022a) gridded time-series dataset to consider the risk and consequences of climate change on the groundwater resources. The data was generated for the five climate reference locations aligning with the subareas, shown in Chapter 2 (Figure 5).

We assessed the climate projection data using a 30-year modelled period, centred on a planning horizon of 2040 (2025–54). This 30-year time-slice enabled comparison with the NHP 30-year reference period (1976–2005).

As discussed in Part A:

- longer periods of consecutive dry years are likely to be the largest risk to the Exmouth groundwater resources, which needs to be considered and managed
- we used the reference period to describe the historical regional hydroclimate and define a 'dry' year (explained in Section 2.3)
- an analysis of groundwater salinity data shows that groundwater quality declined (salinity levels increased in production bores) following the two consecutive dry years of 2019 and 2020 (see Section 3.3).

Longer periods of consecutive dry years are likely to be a limiting factor for meeting the water resource objectives, thus we focused on the projected changes to consecutive dry years in reviewing the NHP datasets.

Analysis of future climate projections and potential impacts

Our climate guidance (DWER 2024) recommends developing 'storylines' to consider the potential climate change impacts specific to local groundwater systems and to help decide how to choose and apply projections for an assessment. To best represent the projected changes to consecutive dry year periods across the Exmouth Peninsula, and its effect on groundwater resources, we developed five storylines to consider how a future climate may impact on water management in the plan area (see Appendix C). The storylines centred around the length of consecutive dry year periods either increasing, decreasing or remaining the same, with three storylines selected to represent an increase because of the large number of projections that fit the criteria.

We have graphed the historical rainfall for each subarea paired with the 32 NHP climate scenarios, and highlighted the five storyline scenarios, to demonstrate the potential variations in future climate across the peninsula. Figure 22 shows the results for the Exmouth Town and Central subareas. The graphs for Exmouth North, Exmouth West, Exmouth Saltflats and Badjirrajirra subareas are in Appendix C.

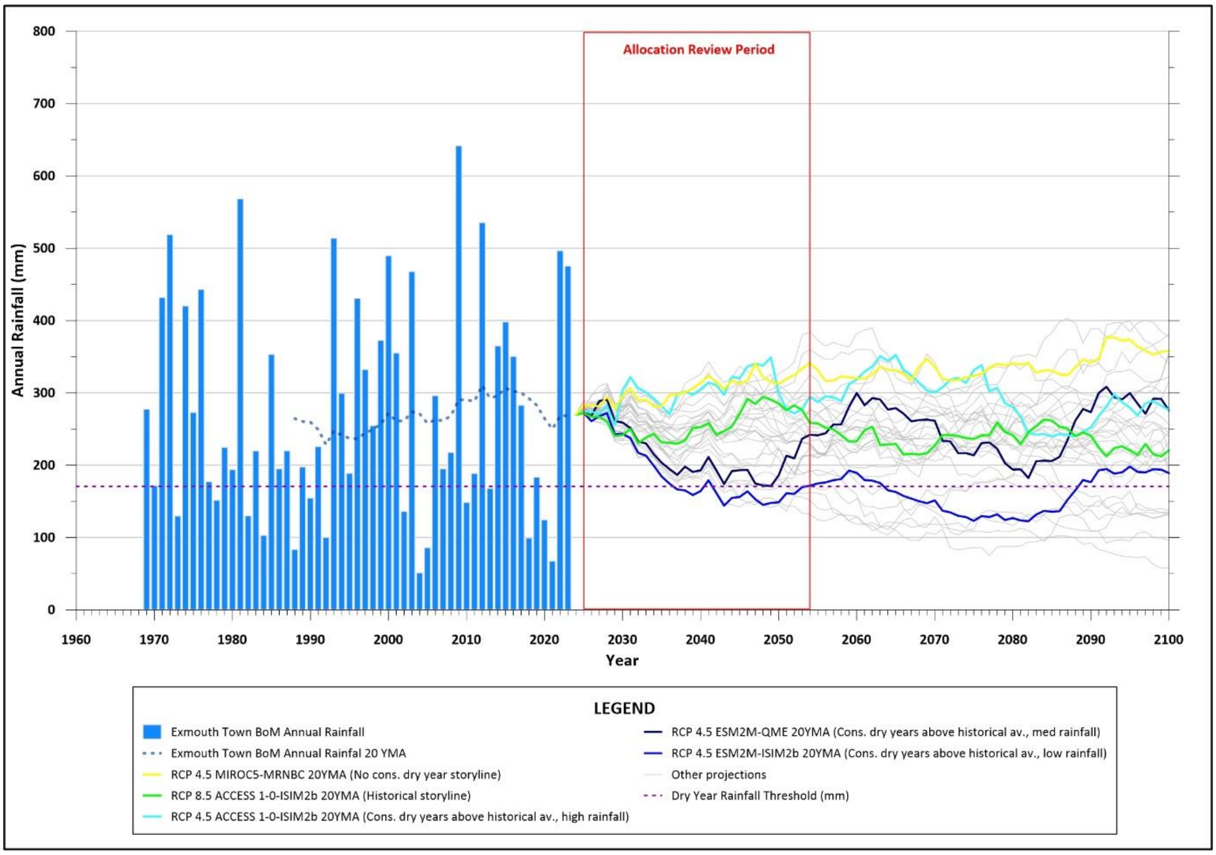


Figure 22 Exmouth Town/Central reference site – historical and projected rainfall (NHP 20-year moving averages), with storyline projections highlighted

We considered how each storyline might impact the water resource and objectives if the allocation limits were unchanged and current abstraction amounts continued. See Appendix C for more details about the storylines, selection criteria and related climate data and projections.

Future climate selections to inform setting allocation limits

Of the five storylines identified (Appendix C), we decided to use the following two storylines to inform the allocation limit review and decisions. We selected a singular projection for each storyline in each subarea (Table 7 below) based on a set of selection criteria (Appendix C).

Storyline 1c: A future climate with periods of three or more consecutive dry years

This storyline reflects a future climate that has longer periods of consecutive dry years compared with the historical climate. The projection selected for this storyline has a high number of consecutive dry years and a low average annual rainfall (Appendix C). Of the five storylines developed, storyline 1c represents the possible future climate with the highest risk of not achieving the plan and water resource objectives. This is supported by the increases in salinity observed in some production bores during the two consecutive dry years of 2019 to 2020, with salinity taking over 12 months to return to baseline levels in some of these bores.

Potential impacts under this storyline (Appendix C) involve a greater likelihood of the upconing of saline water into production and private bores and possible salinisation of ecological habitats. It is reasonable to plan for this situation because the majority of the 32 projections (between 19 and 21 projections per subarea) have at least one occurrence of three or more consecutive dry years in the 30-year period ahead (2025–54).

Given the high risk and potential impacts of this future climate, we considered it appropriate to include this storyline in decision-making.

Storyline 2: A future climate with consecutive dry years similar to the historical climate

This storyline reflects a future climate similar to the historical climate in that two consecutive dry years would sometimes occur, but not three or more consecutive dry years. Under this storyline, we would expect localised, short-term upconing of saline water into production bores during periods of two consecutive dry years unless the current abstraction regimes were changed. To maintain current abstraction rates while still meeting environmental outcomes, Water Corporation would need to actively manage how water is taken from the current production bores.

The projection selected for this storyline in each subarea (Table 7) is generally near the mid-point within the range of NHP rainfall projections. Using this storyline in our review allows us to consider a future climate similar to the historical climate to assess different allocation limit options.

Table 7 Selected storylines, climate projections and projected average annual rainfall (2025–54) for each subarea used to calculate allocation limit options

Subarea	Storyline 1c: A future climate with periods of three or more consecutive dry years*		Storyline 2: A future climate with consecutive dry years similar to the historical climate	
	Projection	Average annual rainfall (mm)	Projection	Average annual rainfall (mm)
Exmouth North	RCP 4.5 ESM2M-ISIM2b	164.8	RCP 8.5 MIROC5-QME	307.4
Exmouth Town Exmouth Central	RCP 4.5 ESM2M-ISIM2b	162.9	RCP 8.5 ACCESS 1-0-ISIM2b	250.2
Exmouth West	RCP 4.5 ESM2M-ISIM2b	160.7	RCP 8.5 ACCESS 1-0-ISIM2b	248.0
Badjirrajirra	RCP 8.5 MIROC5-CCAM-ISIM2b	187.7	RCP 8.5 CNRM-QME	241.2
Exmouth Saltflats	RCP 8.5 MIROC5-CCAM-ISIM2b	179.9	RCP 8.5 MIROC5-QME	285.4

* The climate projection selected for storyline 1c in each subarea has a high number of consecutive dry years and a low average annual rainfall (Appendix C). The projections are from the Bureau of Meteorology's National Hydrological Projections (BoM 2022b).

8 Setting water allocation limits

The department sets water allocation limits that represent a balance between current and future groundwater use and how much water should remain in the aquifer to support groundwater-dependent values and the water resource. Allocation limits are a decision based on considering:

- the best-available information about the water resources, including hydrogeology, groundwater recharge and water quality
- the water required to stay in the environment to support groundwater-dependent values and the resources
- the consumptive uses of water, including short- to medium-term future demand.

8.1 Method for the Cape Range Limestone aquifer

When setting allocation limits, we consider the level of uncertainty and apply a precautionary approach when information is limited and high uncertainty exists. As water use increases, more detailed monitoring, technical understanding and planning can be applied, which may trigger a review of allocation limits.

To determine allocation limit options for the Cape Range Limestone aquifer, we used the approach described in *Groundwater risk-based allocation planning* (DoW 2011). This risk-based approach makes the best use of available information in data-poor areas and guides setting a proportion of recharge for allocation. This approach is considered appropriate for the Cape Range Limestone aquifer because of the limited hydrogeological data available outside of the Exmouth Town and Exmouth Central subareas. In addition, little is known about the water requirements and interactions between groundwater and important dependent ecosystems including the Cape Range Subterranean Waterways and nearshore marine environment.

This risk-based process works through four steps, outlined below.

Step 1: Calculate annual groundwater recharge

The Cape Range Limestone resource is recharged primarily during rainfall events and from subsequent intermittent surface water flows. There is minimal throughflow into the subareas and outflow is mainly through discharge into the ocean.

For each subarea, we calculated the annual groundwater recharge for the two selected storylines using the following equation:

$$\text{Estimated annual groundwater recharge (GL)} = \frac{A \times B \times C}{1000}$$

Where:

A = the area (km^2) of the aquifer which is fresh at 0m AHD (Table 4)
B = the projected average annual rainfall (mm) between 2025 and 2054 (Table 7)
C = the groundwater recharge rate set at 15 per cent (Section 3.2)

Step 2: Assign a risk rating and develop allocation limit options as a proportion of recharge

To determine how much recharge can potentially be allocated for use, we assigned ratings of high, medium or low to in situ risk and development risk (see Appendix E Subarea risk assessments).

In situ risks are the risks to aquifer properties and to ecological, social and cultural values that may arise from groundwater abstraction. We especially considered:

- the sensitivity of the aquifer properties to impacts from abstraction (such as water quality changes from saline upconing)
- the significance of groundwater-dependent values, and their sensitivity to abstraction (such as maintaining water quality to protect subterranean fauna and groundwater discharge to springs).

Development risks are the risks to productive use that may arise if water is not abstracted. These were informed by considering:

- the local and wider economic risks of limiting groundwater availability for consumptive use
- the availability of alternative options to meet future development.

Once we assigned the risk ratings, we then used a risk matrix (Table 8) to convert the risks into an allocation option as a proportion of groundwater recharge.

Table 8 Risk-based matrix for determining allocation limit options as a proportion of groundwater recharge (DoW 2011)

		Risk-based allocation limit options as a proportion of groundwater recharge		
In situ risk: the risk to the aquifer and ecological, social and cultural values that may arise from groundwater abstraction.	*High*	5%	25%	50%
	Medium	25%	50%	60%
	Low	50%	60%	70%
		Low	*Medium*	*High*
		Development risk: the risk to productive use that may arise if water is not abstracted.		

We assigned a high risk to in situ values for all subareas (Table 9). This aligns with the observed sensitivity of the aquifer to saline upconing in response to abstraction, and with the significance of groundwater-dependent values and their high sensitivity to changes in groundwater quality or groundwater level.

We assigned two development risk ratings (high and medium) to the Exmouth Town and Exmouth Central subareas, which gave us two allocation limit options to consider for each of these subareas (Table 9). We considered that a high development risk rating aligned with these subareas because they are nearing full allocation and use, primarily to meet demand for public water supply. This demand will be ongoing to support future growth in the area. We also considered that a medium development risk was appropriate because other water source options are available and being investigated to meet future demand ([Exmouth water source planning – Water Corporation]).

We also assigned two development risk ratings (medium and low) to the Exmouth North, Badjirrajirra and Exmouth Saltflats subareas, which gave us two allocation limit options to consider (Table 9). We felt that a medium development risk aligned with the potential to make water available to meet future demand, including water for public water supply and commercial use, as well as for Aboriginal water reserves. Assigning a low development risk allowed us to assess if we could protect the environment while still meeting water use outcomes.

For Exmouth West, we assigned a low development risk to align with minimal demand for water and likely minimal support for commercial development in the subarea (Table 9). This is because the Exmouth West subarea covers the Cape Range National Park and is entirely within the Ningaloo national heritage area. The existing allocation limit also remained as an option.

Table 9 Allocation limit options to consider for each subarea based on the risk-based matrix

Subarea	In situ risk	Development risk	Allocation limit options (percentage of recharge)
Exmouth Central	High	Medium	25%
	High	High	50%
Exmouth Town	High	Medium	25%
	High	High	50%
Exmouth North	High	Medium	25%
	High	Low	5%
Badjirrajirra	High	Medium	25%
	High	Low	5%
Exmouth Saltflats	High	Medium	25%
	High	Low	5%
Exmouth West	High	Low	5%
	–	–	Existing allocation limit

The outcomes from Step 1 and 2 above are shown in Appendix D Values used to calculate allocation limit options and understand decisions.

Step 3: Assess allocation limit options against objectives

We then assessed whether each of the allocation limit options, calculated using projected rainfall for climate storyline 1c, would meet the objectives set for each of the resources (Table 10). In particular, we looked at whether the options supported environmental and water use outcomes if a future climate with longer consecutive dry periods were to eventuate.

Table 10 Assessment of allocation limit options against environmental and water use outcomes under storyline 1c (green is met and red is not met)

Subarea	In situ risk	Development risk	Percentage of recharge for allocation	Allocation limit options (kL/year)	Current licensed entitlements and exempt use (kL/year)	Does the allocation option meet the water resource objectives in Chapter 6?					
						Environmental outcomes (objectives 1 and 2)	Water use outcomes (objective 3: maintain groundwater quality and quantity to support a sufficient and sustainable supply of fresh groundwater for use)				
							Exempt use	Public water supply	General licensing	Future public water supply reserve	Potential for Aboriginal water reserve
Water resource objective 1: maintain the current groundwater regime to support values and the resource											
Exmouth Central	High	Medium	25%	664,889	872,748*	✓	✓	✗	✓	✗	-
	High	High	50%	1,329,777		✗	✓	✓	✓	✓	-
Exmouth Town	High	Medium	25%	200,001	299,450*	✓	✓	✗	✓	✗	-
	High	High	50%	400,002		✗	✓	✓	✓	✓	-
Exmouth North	High	Medium	25%	215,402	188,000	✓	✓	-	✓	-	-
	High	Low	5%	43,080		✓	✗	-	✓	-	-
Water resource objective 2: maintain the natural groundwater regime to protect values and the resource											
Badjirrajirra	High	Medium	25%	1,320,057	102,000	✓	✓	-	✓	✓	✓
	High	Low	5%	264,011		✓	✓	-	✓	✗	✗
Exmouth Saltflats	High	Medium	25%	3,720,756	251,350	✓	✓	-	✓	-	✓
	High	Low	5%	744,151		✓	✓	-	✓	-	✓
Exmouth West	High	Low	5%	667,423	33,800	✓	✓	-	✓	-	-
	Existing allocation limit			50,000		✓	✓	-	✓	-	-

* After assessing these options for Exmouth Central and Exmouth Town, we also considered the volume of current licensed entitlements and exempt use and existing allocation limits as further options (see step 4).

In Exmouth West and Exmouth Saltflats, both allocation limit options met all water resource objectives and environmental and water use outcomes. In this instance, we selected the option which allocated the lowest proportion of recharge for use (see Table 10 and Appendix D), keeping the largest proportion of recharge in the aquifer. This is because it presents the best option for meeting the water resource objective to maintain natural regimes to protect the groundwater-dependent values.

For Badjirrajirra and Exmouth North, the allocation limit option allocating a higher proportion of recharge for use (corresponding to a medium development risk) met all objectives and potential water use outcomes. The lower allocation limit option (corresponding to a low development risk) also met all objectives but did not support future water use outcomes.

In Exmouth Town and Exmouth Central, neither allocation limit option (medium or high development risk) could meet all the objectives and water use and environmental outcomes. In these instances, we determine which objective/s and outcome/s should be prioritised and balanced between the allocation limit options. We consider the volume for existing licensed entitlements and exempt use or allocation limits as further allocation limit options. This is further explained in Step 4.

We also calculated allocation limit options under storyline 2 (see Appendix D) to estimate and consider a sustainable yield under a future climate with occurrences of two consecutive dry years similar to the historical climate. We used this to further assess the existing volumes of licensed entitlements and exempt use and the range of plausible allocation limit options. This showed that under storyline 2, all water resource objectives, and environmental and water use outcomes, would be met under allocation limit options that allocated 25 per cent of recharge for use.

How much water should remain in the aquifer to maintain groundwater-dependent values

To understand how much water needs to stay in the aquifer to protect groundwater-dependent values, we assessed available monitoring and abstraction data to determine if current abstraction rates have impacted on groundwater-dependent habitat. That is, we sought to understand whether groundwater levels or quality had changed where it supports groundwater-dependent values.

In the Exmouth Town subarea – where abstraction amounts are high enough to assess impacts – monitoring data shows that under current abstraction rates, no observable impacts to groundwater levels or quality have occurred where groundwater supports groundwater-dependent habitat. We have seen some changes to water quality at production bores in the subarea, but these are localised and short term. Hence, we do not consider that the changes have impacted on groundwater-dependent habitat.

We also calculated groundwater recharge under the current climate for the Exmouth Town subarea using the equation in Step 1, using average annual rainfall for the NHP baseline period (1976–94). This shows that existing licensed entitlements and exempt use in the subarea are about 25 per cent of historical groundwater recharge, which means about 75 per cent of recharge stays in the aquifer.

Based on this, we have assumed that under storyline 1c, if we keep abstraction rates at or below about 25 per cent of the estimated groundwater recharge, we will be maintaining the current groundwater regime to support groundwater-dependent ecological, social and cultural values at a low level of risk. As such, allocating 25 per cent of recharge or less will meet the water resource objectives in the Exmouth Town, Exmouth Central and Exmouth North subareas.

To put this into context, CSIRO (2011) put forward, as a simple rule-of-thumb, that no more than 50–75 per cent of recharge should be abstracted from an aquifer without very careful assessment. Following this rule-of-thumb, it would allow for only 25–50 per cent of recharge to stay in the aquifer to support groundwater-dependent values.

Step 4: Set allocation limits

See Sections 8.2 and 8.3 for an explanation of the final allocation limits and components for the Cape Range Limestone and saline resources. The subsections below explain how we decided on these.

Exmouth Town and Exmouth Central subareas

From all the information explored, we can see that the Exmouth Town and Exmouth Central subareas have competing demands for groundwater:

- Groundwater use is established and ongoing, both for public water supply and commercial and domestic self-supply. The demand for water to support future growth in the area is increasing.
- Groundwater also supports significant ecological and cultural values such as subterranean fauna assemblages, Camerons Cave, Qualing Pool and known zones of nearshore groundwater discharge. Many of these values are highly dependent on groundwater and sensitive to any changes in water quality or level.

The allocation limit option of 25 per cent of recharge for use is the lower risk option for supporting environmental outcomes, which would mean keeping 75 per cent of groundwater recharge in the aquifer. However, this would reduce allocation limits, over-allocate the resource and not meet water use outcomes to maintain existing licensed drinking water supply nor support future public water supply (Table 10). We also considered that the other allocation limit option of 50 per cent of groundwater recharge for use was unacceptable because it would not meet environmental outcomes.

As both allocation options were unacceptable, we also considered a third option that met existing licensed entitlements and exempt use, but not future demand. This option would result in groundwater recharge of about 38 and 33 per cent being allocated for use in Exmouth Town and Exmouth Central respectively. This option would retain about 62 and 67 per cent of aquifer recharge in the respective subareas, not only to support environmental outcomes but also the existing licensed entitlements and exempt use. While this would mean that groundwater from the existing borefield was not available to meet future public water demand (Table 11), we consider that this development risk is acceptable because alternative water sources are available to meet such demand.

Note that the existing licensed entitlements and exempt use volumes are similar to a medium development risk scenario under a future climate similar to the historic climate (storyline 2) (see Appendix D). This indicates the third option is sustainable under a future climate similar to historical trends. However, if less rainfall is experienced into the future, there would be a greater need to adaptively manage water licences to avoid or minimise negative impacts on groundwater-dependent values.

Based on this, we decided to retain the allocation limit for Exmouth Town (no change) and reduce the allocation limit for Exmouth Central to the volume of existing licensed entitlements and exempt use (Table 11). These decisions balance the need to maintain existing water supply (existing public and private licensed entitlements and water use exempt from licensing) with the amount of water to be left in the aquifer to support groundwater-dependent values.

Table 11 Allocation limit decisions for the Exmouth Central and Exmouth Town subareas against environmental and water use outcomes under storyline 1c (green is met and red is not met)

Subarea	**Percentage of recharge for allocation**	**Allocation limit decision kL/year**	**Does the allocation option meet the objectives and outcomes in Chapter 6?**				
			Environmental outcomes (objective 1: maintain current groundwater regimes to support values and the resource)	**Water use outcomes** (objective 3: maintain groundwater quality and quantity to support a sufficient and sustainable supply of fresh groundwater for use)			
				Exempt use	**Public water supply**	**General licensing**	**Future public water reserve**
Exmouth Central	About 33%	872,748	✓ with adaptive management	✓	✓	✓	×
Exmouth Town	About 38%	300,000	✓ with adaptive management	✓	✓	✓	×

As the amount of water staying in the aquifer is less than the 75 per cent (i.e. below the assumed low risk level), these decisions do present an increased risk of impact on groundwater-dependent values and the aquifer under storyline 1c. This risk will need to be managed through licensing assessments and an improved monitoring and adaptive management approach (see Section 9.1).

These decisions also mean that groundwater in the Exmouth Town and Exmouth Central subareas cannot provide for the projected water demand for development of the Exmouth township. However, this aligns with Water Corporation's forward planning and investigation of other water source options for future public water supply. See Water Corporation for more information on water source planning in Exmouth.

Exmouth North subarea

In the Exmouth North subarea, the primary (and licence exempt) water user is the Department of Defence, which accesses the fresh groundwater resource for the Harold E. Holt base. Of the two options (Table 10), the allocation option of 5 per cent of recharge for use would maintain a natural groundwater regime for subterranean fauna habitat and groundwater discharge to the nearshore marine environment, but it might not provide sufficient water to meet the future needs of this user.

The second allocation option of 25 per cent of groundwater recharge for use meets both the water use and environmental outcomes (Table 10), maintaining 75 per cent of groundwater recharge in the aquifer to protect groundwater-dependent values at a low level of risk. The allocation limit encompasses current water demand for the Harold E. Holt base, while a small amount remains unallocated for future growth at the base or other general licensing needs.

Badjirrajirra subarea

There is low demand for water in the Badjirrajirra subarea, with only one commercial licence using water from the Cape Range Limestone and saline resources in the subarea. The groundwater regime supports the Cape Range Subterranean Waterways and subterranean fauna habitat, ephemeral wetlands, and groundwater discharge to the nearshore marine environment of the Exmouth Gulf.

This review prioritises a public water supply reserve in this resource to meet future water demand from Exmouth. To meet this water use outcome, the allocation limit has been set as 25 per cent of groundwater recharge, allowing for 75 per cent of groundwater recharge to remain in the aquifer to protect groundwater-dependent values at a low level of risk. While the lower allocation option would allow 95 per cent of groundwater recharge to remain in the aquifer to further protect the natural groundwater regime, it would not provide enough water to set a reserve for future growth in scheme demand, or for additional commercial water use closer to Exmouth.

If climate storyline 1c were to eventuate, there would be a higher risk of not meeting the environmental outcome for this subarea, which is to protect the natural groundwater regime. This would need to be managed through licensing assessments and implementation of an appropriate monitoring and adaptive management approach. Detailed licence assessments would be required to access the public water supply reserve – if groundwater expansion is chosen as the preferred water source to meet existing and future scheme demand.

Exmouth Saltflats subarea

In the Exmouth Saltflats subarea, the primary (licence exempt) water user is the Department of Defence. There is minimal projected growth in demand beyond what might be required to support the department’s Learmonth Airbase upgrade project.

The risk to the environment from abstraction is considered higher than for the other subareas because of the potentially higher proportion of offshore groundwater discharge supporting mangrove and nearshore marine habitats. The seawater intrusion in this subarea also extends further inland, which increases the potential for salinisation (seawater interface movement further onshore and upconing).

Both allocation limit options meet the water use and environmental outcomes (Table 10). However, based on the higher risk of abstraction negatively affecting the environment and the water resource, we decided to set the allocation limit at the lower option, with 5 per cent of groundwater recharge set aside for use and 95 per cent to remain in the aquifer to maintain the natural groundwater regime and protect groundwater-dependent values.

The allocated amount provides for current licensed entitlements, Department of Defence water needs for Learmonth Airbase, and exempt stock water requirements. There is also water available for any growth in demand from the Department of Defence to upgrade the airbase and for a potential Aboriginal water reserve.

Exmouth West subarea

Resource information for the Exmouth West subarea is limited and demand for further groundwater is low.

The Exmouth plan prioritised groundwater for the natural environment in this subarea and set the allocation limit at 50,000 kL/year to better account for existing licensed use. Under climate storyline 1c, the option to retain the allocation limit would account for about 1 per cent of groundwater recharge and retain about 99 per cent of groundwater recharge in the aquifer.

We decided to retain the allocation limit (no change) to enable us to meet the environmental and water use outcomes for this subarea (Table 10). This decision also recognises the knowledge gaps associated with how groundwater supports the Ningaloo Reef and other significant groundwater-dependent values of the area, and the absence of groundwater data and monitoring infrastructure on the peninsula’s western side (which would otherwise support risk management).

8.2 Allocation limit decisions for the Cape Range Limestone aquifer subareas

The allocation limits in Table 12 below replace the previous allocation limits for the Cape Range Limestone resource, including those set in the Exmouth plan (WRC 1999). We have based the allocation limits on the decisions explained in Step 4 of Section 8.1 above, and rounded to the nearest 50 kL where possible. The components of the allocation limits are explained below.

Table 12 Allocation limits, components and water available for licensing for the Cape Range Limestone resource of the Exmouth groundwater subareas and previous allocation limits

Water resource management subarea	Previous allocation limit kL/year	Reviewed allocation limit kL/year	Allocation limit components kL/year					Status of water availability for licensing
			Licensable		Unlicensed	Reserved water		
			General licensing	Public water supply	Exempt use	Public water supply reserve	Potential Aboriginal water reserve*	
Gascoyne groundwater area, Carnarvon – Cape Range Limestone aquifer								
Exmouth North	200,000	215,400	27,400	0	188,000	0	0	Yes
Exmouth Town	300,000	300,000	79,700	200,000	20,300	0	0	Very limited
Exmouth Central	1,000,000	872,748	8,898	832,000	31,850	0	0	No
Badjirrajirra	4,700,000 (previously Exmouth South subarea)	1,320,050	818,050	0	2,000	500,000	Potential	Yes
Exmouth Saltflats		744,150	512,800	0	231,350	0	Potential	Yes
Exmouth West	50,000	50,000	50,000	0	0	0	0	Yes[#]
TOTAL	**6,250,000**	**3,502,348**	**1,496,848**	**1,032,000**	**473,500**	**500,000**	**TBC**	

*No volumes are currently proposed for an Aboriginal water reserve.

^Status of water availability indicates whether water is available for further licensing from the general licensing component. ‘Yes’ means less than or equal to 70 per cent has been allocated, ‘limited’ means more than 70 per cent has been allocated, ‘very limited’ means more than 99 per cent has been allocated, and ‘no’ means that the resource is fully allocated.

#Limited access to land in this subarea, due to national park tenure.

Components of the allocation limit

We selected the allocation limit components relevant to the water needs in each subarea. Within the Exmouth subareas, we allocated water into components for general licensing, public water supply (in the Town and Central subareas) and exempt use.

We set the components as follows:

- The general licensing components are the remainder of the water available after accounting for public water supply and exempt use.
- The public water supply components remained the same.
- A new public water supply reserve in the Badjirrajirra subarea was established (see below).
- The exempt use components for the Badjirrajirra and Exmouth Saltflats subareas were reviewed (see Section 5.1) while the exempt use components for the other subareas remained the same.

Establishing a public water supply reserve for Exmouth

We have set aside a portion of the available groundwater in the Badjirrajirra subarea as a public water supply reserve. This provides for a future scheme water supply option and allows time for investigations and an investment decision about whether groundwater supply from this area is viable. The reserve volume is not available for general licensing purposes and only a public water service provider can access it.

We set this volume in consultation with Water Corporation. Both parties considered how much water was needed in the short to medium term to meet expected town growth and which could be sustainably drawn close to the existing borefield infrastructure. We will continue to work with Water Corporation as it assesses the options for future water, including southwards expansion of the borefield and seawater desalination), with a focus on options that are sustainable and adequately consider future climate changes.

8.3 Allocation limit decisions for the saline resources

Historically, the abstraction of brackish or saline groundwater has been considered a lower risk activity for groundwater-dependent values than the abstraction of fresh water. However, the Exmouth plan area’s saline resource provides unique habitat for subterranean fauna listed under state and federal environmental legislation.

We have decided to change the allocation limits for the Cape Range saline resource in each subarea to ‘not set’ (Table 13) as there is uncertainty around setting an allocation limit due to the natural movement of the seawater interface and ocean influences (see Section 3.1). This means that we will manage risks to the aquifer and groundwater-dependent values at a local, site-specific scale, through assessing groundwater licence applications on a case-by-case basis.

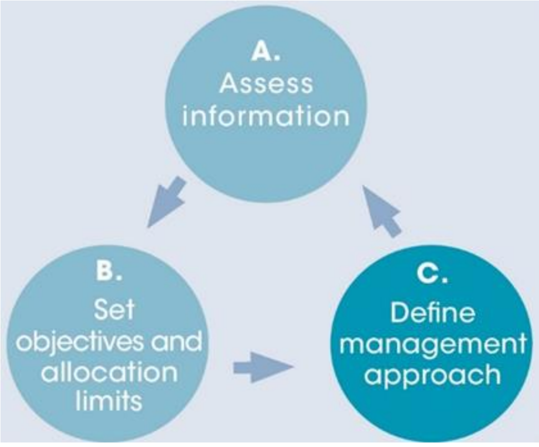
Table 13 Allocation limit changes for the saline resource of the Exmouth groundwater subareas and previous allocation limits

Water resource management subarea	Previous allocation limit kL/year	Current licensed entitlements kL/year as at Oct 2024	Reviewed allocation limit kL/year	Allocation limit components kL/year			Status of water availability for licensing
				Licensable		Unlicensed	
				General licensing	Public water supply	Exempt use	
Gascoyne, saline resource							
Exmouth North	500,000	77,220	Not set	Not set	0	0	Case-by-case assessment: detailed hydrogeological assessment required as part of a water licence application.
Exmouth Town	400,000	400,000	Not set	Not set	0	0	
Exmouth Central	4,000,000	1,500,000	Not set	Not set	0	0	
Badjirrajirra	500,000	30,000	Not set	Not set	0	0	
Exmouth Saltflats		0	Not set	Not set	0	0	
Exmouth West	1,000,000	0	Not set	Not set	0	0	
TOTAL	**6,400,000**	**2,007,220**	**Not set**	**Not set**	**0**	**0**	

Part C – Management approach

In Part C of this review, we outline our considerations for the management approach required to support allocation limit decisions and manage any risks to water users, the resource and dependent values. This includes considering approaches for:

- implementation
- water licensing
- monitoring, evaluating and reporting.



Key points from Part C

- We have defined a water licensing approach to:

  e) manage saline upconing for exempt and licensed water users

  f) assess licence requests for the saline resources, including stygofauna surveys.

- We will work with Water Corporation to progress delivery of potential water source options for scheme supply, as part of implementing the outcomes of this allocation limit review.
- We will work with Water Corporation to ensure management of potential risks to groundwater-dependent values from groundwater abstraction.
- We have provided guidance to help proponents engage with native title holders around the potential impacts of water licences on cultural values.

9 Implementation

This chapter sets out how the department intends to implement the allocation limits and manage the residual risks for meeting the water resource objectives in Chapter 6. This includes management approaches through the water licensing process and monitoring, evaluating and reporting on water resources (see Sections 1.2, 3.3 and 5.1 for further discussion).

9.1 Water licensing approach

We will continue to assess all water licences in the Exmouth plan area in accordance with the *Rights in Water and Irrigation Act 1914*, statewide policy and the plan's local licensing policies. The Exmouth plan includes general allocation policies (Chapter 8 of the plan), and general and local licensing policy tables for each subarea (Chapter 9 of the plan). These were established to manage local water resource issues that are not specifically addressed in the department's strategic, statewide or operational policies.

In reviewing the allocation limits, we identified issues that can be managed through the licensing process in order to meet the environmental and water use outcomes. To support the allocation limit decisions and manage any risks from water abstraction, the following guidance will be used in conjunction with the Exmouth plan to assess applications and to manage water licences in the plan area.

Please contact our Mid West – Gascoyne regional office for up-to-date information on water licensing and management in the Exmouth plan area.

Managing saline upconing in bores exempt from licensing

Groundwater abstraction that is exempt from licensing under the *Rights in Water and Irrigation Act 1914* must be taken from the shallow, unconfined groundwater aquifer and meet the conditions of the Rights in Water and Irrigation Act 1914 Exemption (Section 26C) Order 2011. Exempt purposes include groundwater for domestic garden irrigation (less than 2,000 m^2), as well as for household use, minor fire-fighting or non-intensive stock watering.

The use of garden and domestic bores is managed under the provisions of the Water Agencies (Water Use) By-Laws 2010 for specific zones around the state. Exmouth is covered by the sprinkler restrictions for the North Area 1 zone. Garden bore users in Exmouth can water once on any day, either before 9am or after 6pm. This timing avoids water wastage from high evaporation due to high daytime temperatures. Go to WA.gov.au under 'garden bore water restrictions' for more information.

In addition to the existing guidance and policies which apply to the Exmouth plan area, we recommend (to minimise salinisation of bore water from saline upconing) that exempt users who take water from the Cape Range Limestone resource should:

- use low-flow pumps with a pumping rate less than 0.3 L/sec
- pump for short periods, allowing bores time to rest

- regularly check the salinity of bore water to understand and manage abstraction impacts
- have a maximum bore depth of 4 m.

By following these recommendations, bore users will minimise the chance of drawing in the underlying saline water, especially close to the coastline.

For further information or advice on how to monitor salinity levels, bore users in Exmouth can contact our Mid West – Gascoyne region by email: midwestgascoyne@dwer.wa.gov.au

Managing saline upconing from licensed groundwater abstraction

We will use the following policy to guide licensing in the plan area (which replaces the policy for managing salinity under the general policy in Chapter 9 of the Exmouth plan).

We may ask licence applicants and licensees renewing their licence to set trigger levels or threshold criteria, and to implement monitoring of groundwater levels and/or water quality to maintain these parameters within the historical range.

Where water salinity is increasing above the local baseline level because of abstraction, we may ask that an operating strategy associated with a licence is updated to undertake that:

- the frequency of groundwater level and quality monitoring will be increased to monthly or as specified in the operating strategy
- when a salinity trigger level at a bore has been exceeded for three consecutive months, with consideration to peak demand, management actions will be implemented
- if required, modified pumping regimes will be implemented, which may include reducing or stopping pumping from affected bores until salinity levels stabilise (return to baseline levels)
- the department is notified within 10 working days on the management actions and implementation timeframes to rectify any impact/s identified.

Salinity thresholds will be set in individual operating strategies based on observed baseline salinity levels.

Assessing licence applications for the saline resource in the Exmouth plan area

The saline resource in each subarea is the naturally occurring seawater intrusion in the unconfined aquifer, which extends inland from the peninsula's coastline. The saline resource includes the 'mixing zone', which is the transitional zone between the freshwater lens and saline resource in the unconfined aquifer. See Section 3.1 for more information. The following is additional to existing guidance and policies that apply to the Exmouth plan area.

Applications to take saline water could impact on the seawater interface and present an increased risk to the groundwater-dependent habitat supported by the mixing zone. To be able to assess this risk, we may require a higher level of information or assessment than required under *Operational policy 5.12 – Hydrogeological reporting associated with a groundwater well licence* (DoW 2009).

Where there is potential for changes to water quality or the position of the seawater interface, or risks to groundwater-dependent values, we will request additional information that could include:

- the intake location and screen depth of a proposed production bore
- groundwater-dependent ecological values in the vicinity of the bore/s – this may include assessments for the presence of subterranean fauna[8]
- pumping plans, including optimisation plans (total abstraction, rate, duration, continuity and spread of draw)
- aquifer testing results
- modelled potential for movement of the seawater interface as a result of the proposed abstraction
- baseline groundwater monitoring (water level, water quality and/or geophysical logging)
- meter installation and bore construction details.

Managing risk to groundwater-dependent values in the Exmouth Central and Exmouth Town subareas

For the Exmouth Town and Exmouth Central subareas, where less than 75 per cent of groundwater recharge will remain in the environment, we are assuming a greater risk of impact to aquifer properties and groundwater-dependent values, which in turn will require a higher level of management. We will work with Water Corporation to ensure its management approach for the Exmouth town water supply scheme accounts for these circumstances. This might involve the development of a strategy which describes how it will manage abstraction during consecutive dry years to minimise the upconing of saline groundwater, while meeting customer demand.

As outlined in Part A, the upconing of saline water has been observed across Water Corporation's borefield in the Exmouth Town and Exmouth Central subareas. Given this, and the potential for longer periods of consecutive dry years, we may ask Water Corporation to:

- locate replacement or new production bores (to maintain current use) inland of the current borefield to reduce upconing of saline groundwater

[8] Further information is available in Technical guidance for subterranean fauna surveys for environmental impact assessment (2021), Figure 1, at epa.wa.gov.au.

- locate additional production bores to increase supply beyond the current borefield, either in Badjirrajirra or the saline resource (desalination) to meet future demand
- develop a responsive and adaptive monitoring and management approach across the scheme.

Guidance for engaging with native title holders on the potential impacts of water licences on cultural values

This section provides guidance to support the department, licensees and licence applicants in relation to how a groundwater licence may impact on cultural values. We consider the impact of the take and use of water on sites of cultural significance in our assessment of a water licence application as part of the considerations under Schedule 1, Division 2, clause 7(2) of the *Rights in Water and Irrigation Act 1914*.

In order to exercise decision-making functions under the Act, we may ask a licence applicant to provide information about the impact of their proposed activities on water-related cultural values and sites of cultural significance, as well as evidence that native title parties have been consulted about the proposal.

We recognise that the Baiyungu and Yinnigurrura (Yinigurdira) People are the custodians of their culture and cultural values and that their views are critical to understanding relevant impacts. Traditional Owners have knowledge about their sites of cultural significance which can inform our assessment of the risk of impacts from a water licence or permit application. Based on the cultural importance of water, we will assume that all freshwater places in the plan area are likely to have some cultural value, unless otherwise advised by the Traditional Custodians of that place.

For these reasons, applicants should engage with Traditional Owners to identify any relevant potential impacts, using a best-practice approach. Applicants in the plan area should contact the Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC) and have regard to their expectations and cultural protocols for engaging and consulting on a water licence or permit application.

When licence applicants engage with Traditional Owners (evidence of which may be requested) about cultural values and the potential impacts of a water licence, applicants are encouraged to consider the following guidance:

- Published information may not list all Aboriginal heritage or sites of cultural significance that the proposed activity may impact on. This is because not all Aboriginal heritage places or sites of cultural significance are recorded publicly.
- Engage early with the Traditional Owners on the water licence application. Proponents are advised to engage with Traditional Owners at the same time as contacting the department to allow for the necessary cultural studies to be identified and conducted along with the ecological and hydrogeological studies.
- Share appropriate information with Traditional Owners to enable them to make informed comment on the project in question.

- Give adequate time for Traditional Owners to consider information about the project and provide feedback. Early in the process, discuss how much time they may need. This may depend on the project's complexity and current capacity of the prescribed body corporation.
- Contact the native title holders before visiting sites to determine if access is restricted, ensure that protocols are followed, and ensure that cultural monitors are provided, if required.
- Undertake an initial cultural heritage assessment if requested by the native title holders (as per the *Aboriginal Heritage Act 1972)* and submit the completed assessment through Department of Planning, Lands and Heritage (which then comes to us as part of the licensing process).

The time required to engage with the relevant Traditional Owners can be factored into the licence assessment timeframe.

If comments received from Traditional Owners or the department's risk assessment indicates a medium or higher risk of impact to water-dependent cultural values and sites of cultural significance, then the applicant may need to show they have feasible means to reduce the risk of impact.

It is the applicant's responsibility to demonstrate that they can avoid impacts, or minimise the risk of impacts, on water-dependent cultural values and sites of cultural significance.

It is important that applicants ensure that any monitoring or management actions are culturally appropriate.

Guidance on engagement with Traditional Owners has been developed by other agencies and organisations which can serve as best-practice guides. For example, some guidance is provided in the *Interim engaging with First Nations people and communities on assessments and approvals under the Environmental Protection and Biodiversity Conservation Act 1999* (DCCEEW 2023b).

9.2 Monitoring

The department does not have a regional monitoring network in place across the Exmouth plan area, and our monitoring assets in the vicinity of the borefield area are not actively monitored. Instead, we obtain monitoring data through conditions set on water licences. In the plan area, most of this is collected by Water Corporation.

We may require certain licensees to conduct local area monitoring to detect and manage any impacts on the local environment from abstraction associated with the licensed water use activities. Monitoring requirements are established in operating strategies developed during the licence assessment process. Data collected by licensees is reported to the department in accordance with their operating strategies.

We will assess water resource monitoring data collected by water users and evaluate the aquifer's performance against the water resource objectives set in this review.

Our approach to allocation and management is adaptive and work will be ongoing in the plan area to refine how we monitor, report and license groundwater over time.

Monitoring under Ministerial conditions

Where development proposals are deemed to hold significant risk and be of public interest, these may be referred to Western Australia's Environmental Protection Authority (EPA) for assessment. The Minister for the Environment may impose specific conditions on a proponent, related to the taking of water, which are to be managed through the department or the EPA on an ongoing basis.

In Exmouth, the current Ministerial monitoring conditions in place are as follows:

- Water Corporation's borefield for the Exmouth town water supply scheme – conditions are specified in Ministerial Statement 459 and within Water Corporation's water resource management operating strategy for its two groundwater licences for public water supply.
- Ningaloo Lighthouse Holiday Park – conditions are specified in Ministerial Statement 1215 and managed through the licensee's inland water quality management plan, annual compliance assessment report, and a water resource management operating strategy associated with the water licence.

Licensees with Ministerial monitoring conditions in place provide updates to the EPA, as specified in their conditions. Monitoring requirements are also established in operating strategies developed during the licence assessment process and reported to the department in accordance with the operating strategy for the water licence/s.

9.3 Evaluations and future work

Looking forward, the department will periodically evaluate how the Exmouth plan is tracking against the water resource objectives and intended environmental and water use outcomes in Chapter 6 of this report. During plan evaluations, we will consider whether the plan is effective or a new plan is required, and whether we need to review or refine the allocation limits, licensing policy positions or the monitoring program (including whether additional monitoring bores are required). Outcomes from this work may be published in an evaluation statement.

In this review, we have set the water allocation limits based on an estimate of annual groundwater recharge to the Cape Range Limestone aquifer (Chapter 8) under a future climate scenario with longer consecutive dry periods. This estimate is based on the future climate scenario for storyline 1c, which we chose with consideration of the local vulnerabilities of the environment and water use to abstraction and climate change (Chapter 7 and Appendix C).

We will be able to observe any impacts from groundwater abstraction under the future climate through review of the monitoring and reporting undertaken by proponents. We will regularly review climate and rainfall data, along with aquifer trends, to identify if the allocation limits are continuing to meet the water resource objectives.

Further review of the water allocation limits, or management arrangements, may be triggered if future groundwater recharge conditions vary markedly from the climate projections we have used to set the revised allocation limits, or if monitoring indicates that impacts are occurring.

As mentioned in Chapter 8, we consider that the allocation limits for the Cape Range Limestone resource of the Exmouth Town and Exmouth Central subareas present a higher risk to the aquifer and groundwater-dependent values. This is because of the high level of existing water allocations and higher percentage of recharge abstracted from the aquifer to meet demand for public and local water supply (Chapter 8).

This was a balanced decision to meet water resource objectives for both water use and environmental outcomes. As part of implementing the outcomes of this review, we will continue to work with Water Corporation to manage the higher level of risk in the Exmouth Town and Central subareas and support investigations into potential water sources for alternative supply.

We will also continue to discuss Aboriginal water reserves with NTGAC and local stakeholders.

Appendices

Appendix A Geological and hydrogeological information

Investigations undertaken by Forth (1973), Martin (1990) and Allen (1993) provide the basis of our present understanding of the geology and hydrogeology of the Exmouth Peninsula. These investigations focused on identifying the primary hydraulic characteristics of the unconfined aquifer to support development of a borefield for public water supply.

Geology

The Exmouth Peninsula is situated within the Exmouth sub-basin of the Carnarvon Basin and is underlain by up to 10,000 m of Phanerozoic-aged sedimentary rocks, up to 541 million years old (Allen 1993). The area is tectonically complex and is dominated by anticlines that have surface expressions that correspond to the Cape, Rough and Giralia ranges (Wyrwoll et al. 1993). These anticlines have formed from the movement of underlying faults (from normal to reverse) that have been intermittently active since the Late Cretaceous (Allen 1993).

Sea level changes during the Pleistocene, coupled with the tectonic uplift, have resulted in the formation of the incised marine terraces on the western side of Cape Range, as well as the formation of sedimentary deposits on the coastal plain (Wyrwoll et al. 1993).

The shallow geology of Cape Range comprises Oligocene to Miocene (Tertiary) aged rocks of the Cape Range Group. Within the Exmouth sub-basin, this unit is composed of several discrete formations, including: the Vlaming Sandstone, Pilgramunna Formation, Trealla Limestone, Tulki Limestone and Mandu Limestone.

Of these formations, the Vlaming Sandstone and Pilgramunna Formation are generally absent from the area to the east of the Cape Range anticline (Figure 9). On the coastal plain, the Cape Range Group is unconformably overlain by younger Pliocene- to Holocene-aged sediments. The upper stratigraphy (to 700 m depth) of the peninsula as summarised by Allen (1993) is presented in Table A1.

Table A1 Generalised Exmouth stratigraphy

Age	Stratigraphy		Thickness (m)	Primary lithology	Comments
Holocene	Various minor units		<20	Eolian deposits, alluvium, colluvium, littoral deposits	Sediments preserved on marine terraces and coastal plain
Pleistocene	Bundera Calcarenite			Calcarenite and Calcirudite	
Pliocene	Exmouth Sandstone			Quartzose Calcarenite	
Unconformity					
Middle to Late Miocene	Cape Range Group	Vlaming Sandstone	65	Calcarenite: well sorted, medium grained, quartzose, eolian	Restricted to western side of Cape Range
Middle Miocene		Pilgra-munna Formation	25	Calcarenite: well sorted, quartzose, fine to very coarse grained with interbedded beds of packstone and boundstone	Lateral equivalent of the upper Trealla Limestone, mainly restricted to western side of Cape Range
		Trealla Limestone	20	Packstone/ grainstone: bioclastic fossiliferous, high carbonate content	Lateral equivalent of the Pilgramunna Formation, exposed in western and northern part of Cape Range
Early Miocene to Late Oligocene		Tulki Limestone	90	Packstone/ grainstone: foraminiferal marly packstone and grainstone	Lateral equivalent of upper Mandu Limestone, karstic features are well developed in this unit
		Mandu Limestone	280	Calcarenite/calcilutite /calcisiltite: chalky to marly, fossiliferous	Locally exposed in incised valleys between Exmouth and Learmonth
Unconformity					
Middle Eocene to Palaeocene	Cardabia Calcarenite		<200	Calcarenite/calcisiltite and greensand	Not exposed

The lithology of these units is mostly calcareous, with extensive karstic features having developed within the Pliocene–Holocene sediments, as well as in the Trealla, Tulki and upper parts of the Mandu Limestones (Cape Range Group).

The regional unconfined aquifer occurs within the Cape Range Group and the Pliocene–Holocene sediments on the coastal plain. These units, where saturated, are in hydraulic connection and form a contiguous aquifer. The aquifer is heterogeneous due to the varying degree of karstification of the units, as well as differences in primary porosity of the sediments (Allen 1993). The lower Mandu Formation is dominated by clay and silt sized particles (marl) and is interpreted to form a regional aquitard, impeding groundwater flow to/from the underlying Cardabia Calcarenite. The shallow hydrogeological setting of the peninsula is summarised below (Table A2).

Table A2 Hydrogeological setting of the Exmouth Peninsula (North West Cape)

<table>
<tr><th colspan="3">Stratigraphy</th><th>Hydrogeology</th><th>Characteristics</th><th>Water quality</th></tr>
<tr><td colspan="3">Various minor units</td><td rowspan="6">Unconfined aquifer</td><td rowspan="3">Overlies the Trealla Limestone on the coastal plain. Where saturated, it is hydraulically connected to the regional unconfined aquifer. Some karstic features</td><td rowspan="6">Fresh to saline. Freshwater/brackish lens overlying intruded seawater, generally 3 to 5 km from the coast. TDS concentrations of 600–800 mg/L from lens in Water Corporation borefield</td></tr>
<tr><td colspan="3">Bundera Calcarenite</td></tr>
<tr><td colspan="3">Exmouth Sandstone</td></tr>
<tr><td rowspan="4">Cape Range Group</td><td colspan="2">Trealla Limestone</td><td rowspan="3">Where saturated, these units form the primary thickness of the unconfined aquifer. Karstic features are well developed in the Trealla and Tulki Limestones</td></tr>
<tr><td colspan="2">Tulki Limestone</td></tr>
<tr><td rowspan="2">Mandu Limestone</td><td>Upper</td></tr>
<tr><td>Lower</td><td>Aquitard</td><td>Marly deeper strata of the Mandu Limestone</td><td></td></tr>
<tr><td colspan="3">Cardabia Calcarenite</td><td>Confined aquifer</td><td>Likely minor confined aquifer</td><td>Likely saline</td></tr>
</table>

The direction of groundwater flow is away from the central anticlinal axis of Cape Range towards the coastline, where it is possible that it discharges in discrete subsea springs and to a lesser extent in small onshore pools/springs such as Qualing Pool (Allen 1993). The hydraulic gradient of the aquifer is very low due to the high transmissivity of the limestone and, therefore, the watertable is relatively flat, with the depth to the watertable increasing markedly with surface elevation. The watertable is likely over 300 m below ground level at the topographic maxima of the range.

Recharge of the aquifer is inferred to occur by direct infiltration through the high permeability calcareous units, particularly after large rainfall events (Forth 1973). Areas of concentrated recharge are interpreted to occur where karstic features have surface expression (e.g. sink hole, cave openings), as well as along drainage lines (Allen 1993), which are likely aligned with areas of structural weakness in the underlying rock (faults, joints, poorly cemented strata).

Seawater intrudes the unconfined aquifer from the coastline of the peninsula and forms a body of saline water which is overlain by a freshwater lens. This is discussed further below.

Vegetation use of the freshwater aquifer is interpreted to mostly occur within 500 m of the coast (Forth 1973), where the depth to water is shallow enough to allow root access to the regional watertable (Figure 10). Therefore, evapotranspiration represents only minimal losses from the system (Allen 1993).

Ephemeral to semi-permanent perched aquifers are anecdotally known to occur throughout the peninsula, even at high elevations within Cape Range. Although not important in a water supply context, these aquifers are likely supporting subterranean fauna and groundwater-dependent vegetation communities (discussed in Chapter 4).

Confined aquifers with significant storage occur at depth, with the shallowest likely being in the Cardabia Calcarenite, which underlies the Mandu Limestone aquitard. However, due to the lack of recharge, flow within these aquifers is likely to be largely inactive and the groundwater quality saline.

Airborne electromagnetic survey

A high-density (150 m transect spacing) airborne electromagnetic (AEM) survey was conducted by Water Corporation across the Exmouth town water supply scheme borefield in 2016 (Figure A1). A further survey, jointly funded by Water Corporation and the department, was conducted in 2023 (Southern Geoscience 2024, unpublished). This more recent survey focused on the northern section of the new Badjirrajirra subarea due to interest in expansion of the scheme borefield. In this area, high-density transects (200 m spacing) were undertaken, with more widely spaced transects (5 km) flown over most of the remainder of the peninsula to learn more about the unconfined aquifer beyond the borefield area. The formation conductivity detected by these surveys delineates the approximate position of the seawater interface. The flight paths of these surveys are shown in Figure A1, with depth slices of the 2023 survey data at 0 m AHD and -100 m AHD provided in Figure A2 and Figure A3 respectively.

The regional watertable on the peninsula is estimated to have a maximum mounding height of 5 to 10 m AHD at the centre of Cape Range, tapering to sea level (0 m AHD) at the coast. Consequently, the 0 m AHD data slice is representative of electrical conductivity at or near the watertable surface throughout most of the peninsula.

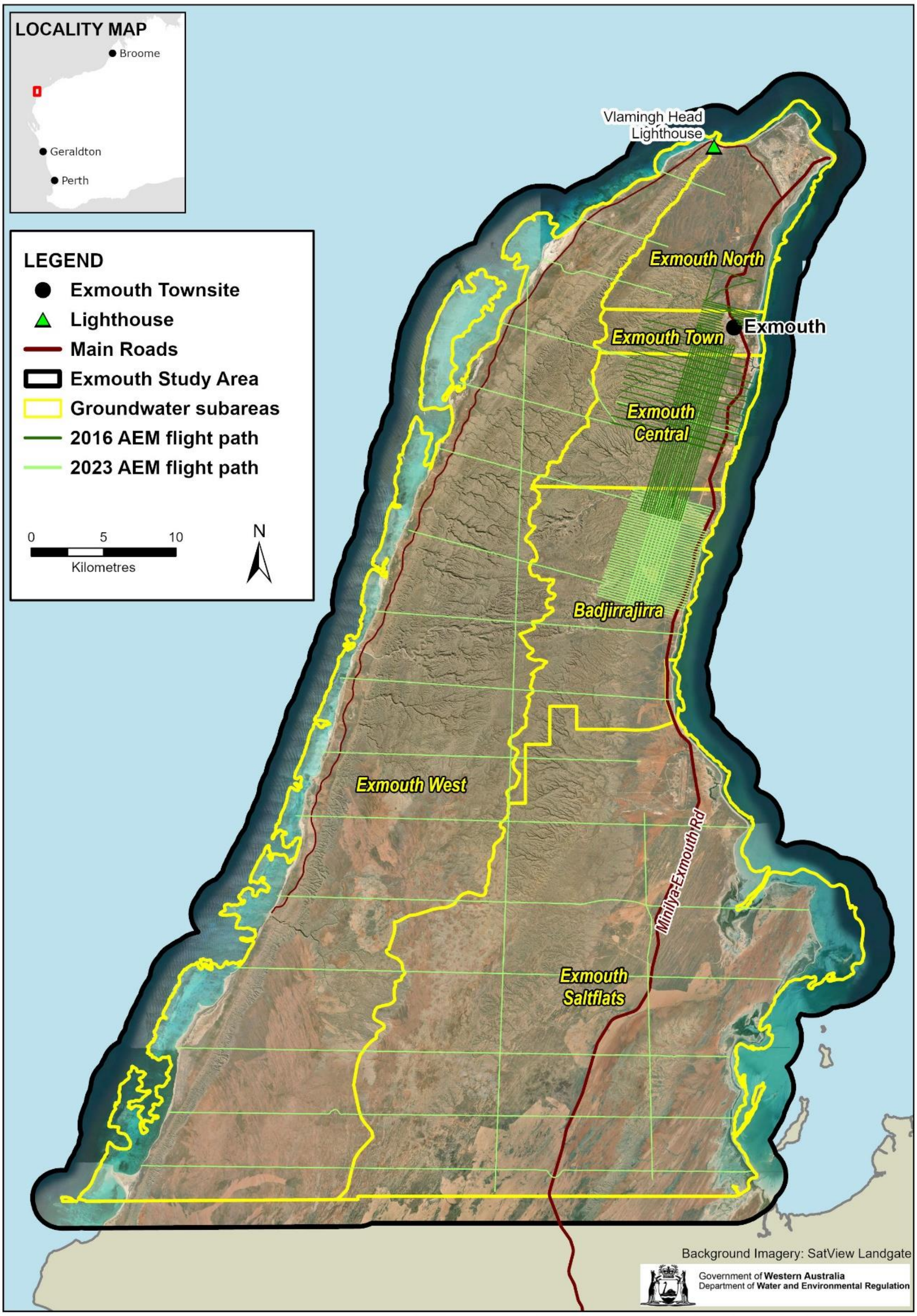


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Figure A1 Flight paths of AEM surveys in 2016 (dark green) and 2023 (light green)

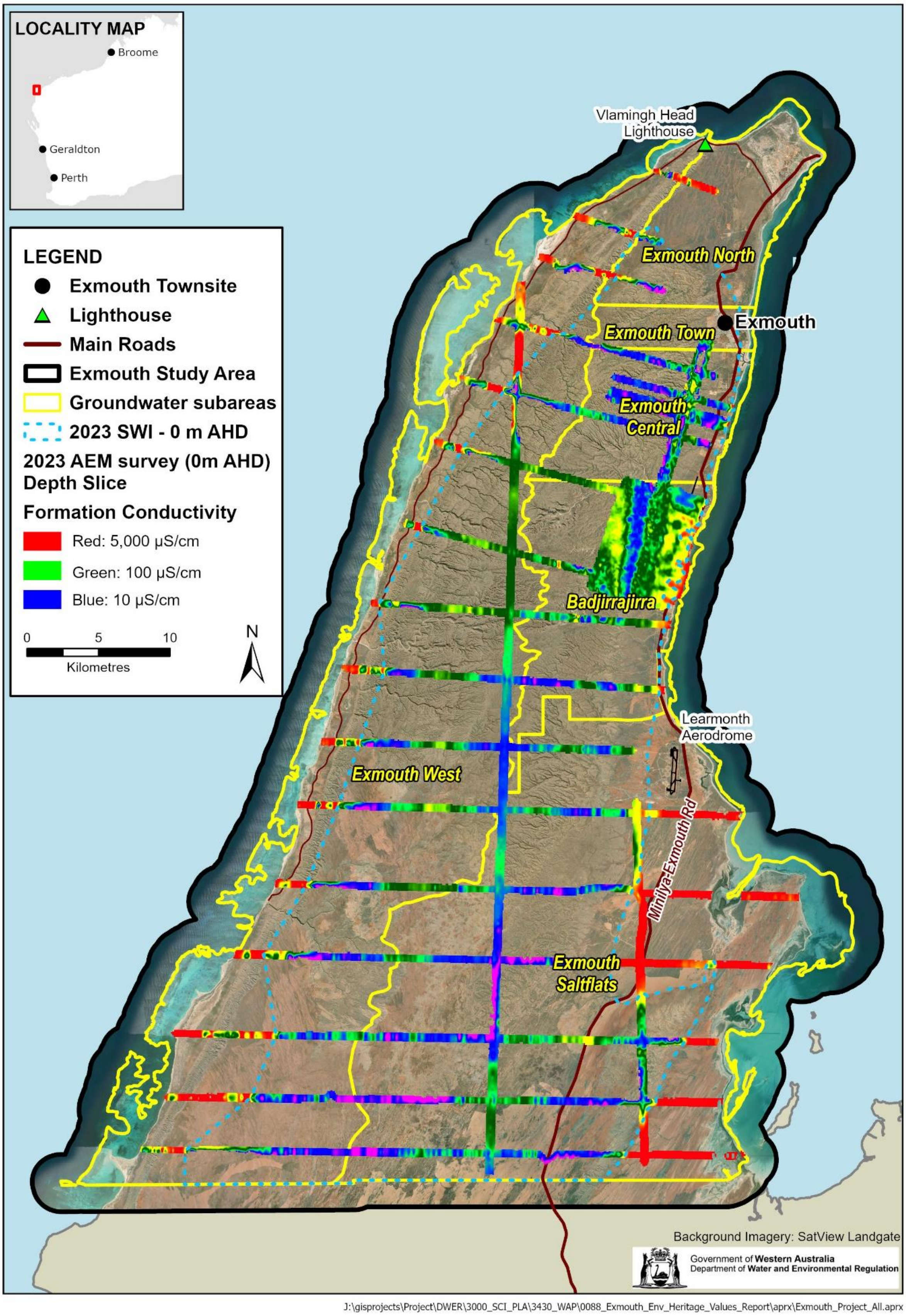

Figure A2 Formation conductivity at 0 m AHD along the flight paths of the AEM in 2023

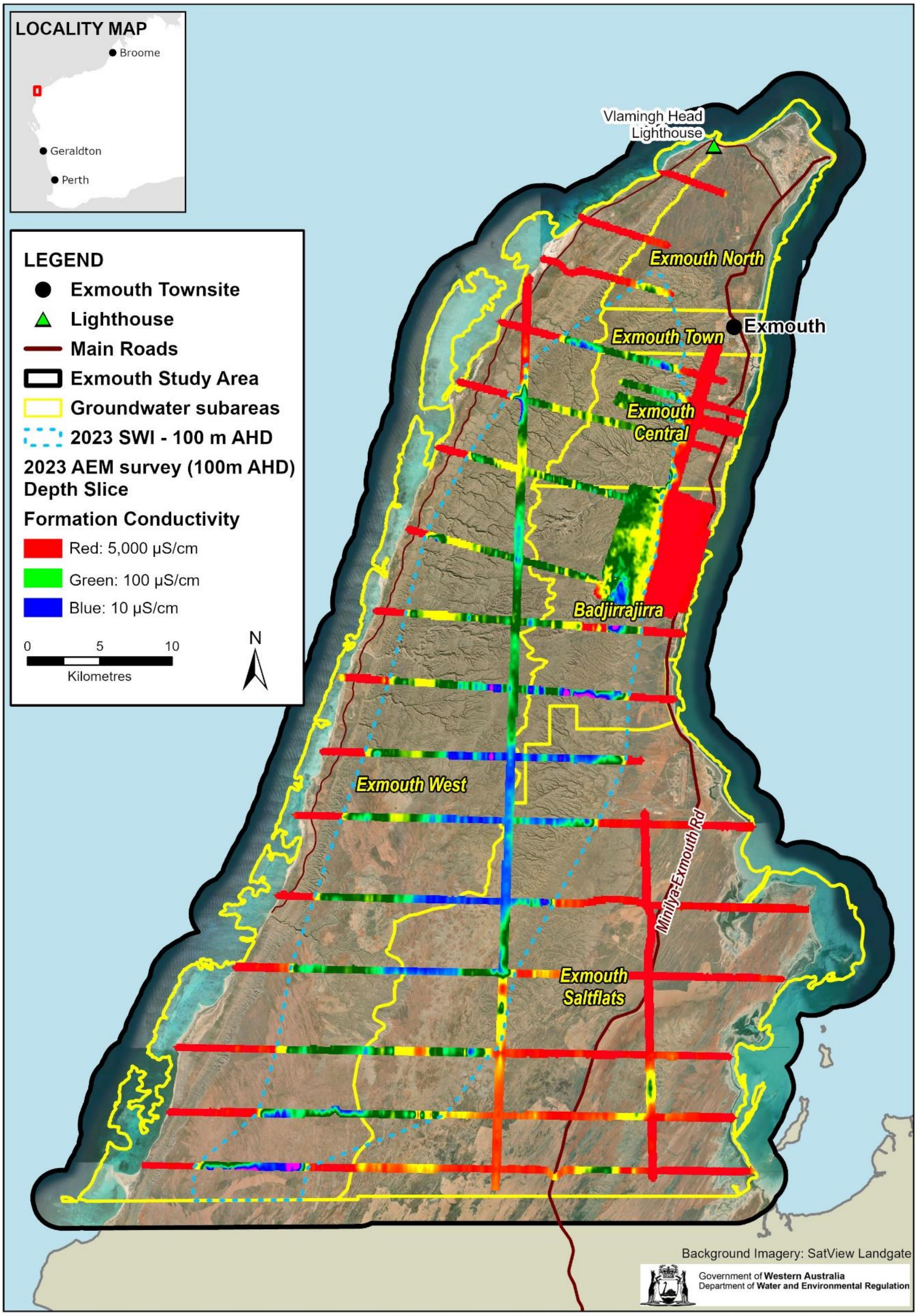

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Figure A3 Formation conductivity at -100 m AHD along flights paths of the AEM in 2023

The 2023 AEM survey (formation conductivity data at 0 m AHD, Figure A2) indicates that the freshwater lens is absent or of very limited thickness at the northern end of the peninsula. In Exmouth Town, Exmouth Central and Badjirrajirra subareas, the freshwater lens is present within 500 m of the coast, while on the western side of the peninsula it is generally within 500 m to 2.5 km of the coast. In the Exmouth Saltflats subarea, the freshwater lens is absent or of very limited thickness beneath most of the coastal plain. This is an impost to the development of water supplies in the area, as freshwater supplies will only be accessible in higher elevation areas, where significant depths to water increase bore construction and pumping costs.

Completion of the Exmouth marina (2006) likely disrupted the freshwater lens in the immediate area, as the newly constructed canals brought sea water and tidal influences further inland. It is likely the local seawater interface rapidly reached a new equilibrium because of the high hydraulic conductivity of the karstic strata. Therefore, it is inferred that the position of the seawater interface shown in the 2016 AEM data is representative of stabilised conditions around the marina. The 2016 -2 m AHD AEM conductivity grid also shows the presence of fresh groundwater immediately to the west of the canals. This indicates that impacts from the project were quite localised, with no adverse impacts on nearby environmental sites such as Camerons Cave (located further inland).

The 2023 AEM survey (formation conductivity data at -100 m AHD, Figure A3) shows the maximum inland progression of the saline intrusion throughout the peninsula. In the Exmouth North subarea, seawater has intruded into the entire unconfined aquifer, except the part underlying Cape Range in the south-west corner of the subarea. In Exmouth West, Exmouth Town, Exmouth Central and Badjirrajirra subareas, the maximum inland extent of the saline intrusion is generally between 2 to 5 km from the coast. In Exmouth Saltflats subarea, high formation conductivity has been detected up to 28 km from the coast near the southern subarea boundary, with a low conductivity area underlying Rough Range. This could represent the inland extent of the seawater interface, or alternatively may represent high clay content strata between the Cape and Rough ranges. Lack of drilling data from this area means that the correct interpretation cannot currently be confirmed; however, in either case, that part of the subarea is unlikely to contain large fresh groundwater supplies.

On the Exmouth Peninsula, the seawater intrusion does not form a typical wedge-shaped body which decreases in thickness with distance from the coast. Instead, the morphology of the intrusion is variable due to the heterogeneity of the hydraulic characteristics of the hosting strata. In some sections of the peninsula (Figure 9), seawater intrudes further inland at shallow depths before abruptly terminating in a steeply dipping seawater interface angled towards the coast. This is likely due to shallower strata being significantly more transmissive than the deeper strata in these areas, with the shape of the seawater interface conforming to these hydraulic boundaries. It is unclear if these boundaries correlate to stratigraphic units or the degree of secondary porosity due to karstification in the geological units.

Appendix B Revised groundwater recharge rate

This section summarises the previous and updated groundwater recharge methods that the department has used to inform this allocation limits review. This appendix follows on from Section 3.2 of this report.

Previous groundwater recharge estimates for the Cape Range Limestone aquifer

Forth (1973) provided the previous estimates of rainfall recharge to the aquifer for the Exmouth Peninsula. Forth's report details recharge estimates calculated using both Darcy's Law and sodium chloride content methodologies. These methods respectively estimated that the groundwater recharge at the town water supply borefield was 9.8 and 8.9 per cent of an average annual rainfall of 254 mm.

As groundwater recharge calculated for Exmouth from Darcy's Law and sodium chloride methods gave similar recharge estimates, Forth concluded that annual recharge for the Cape Range Limestone aquifer could reasonably be accepted as around 10 per cent of annual rainfall. These methods, though appropriate with the limited data available at the time, have the following deficiencies:

1. The assumed hydraulic conductivity is based on the average of field tests that had a large range, from 10 to 1000 m/d (Forth 1972). This variability indicates the aquifer is heterogeneous and introduces uncertainty into any calculations. In addition, groundwater-level drawdown in these tests was generally small (<1.0 m), indicating the tests may not have adequately stressed the aquifer to allow for the calculation of reliable aquifer parameters.
2. The Darcy's Law method only calculated throughflow for the 8 km length of the borefield. Upscaling the result to the entire peninsula is problematic due to the heterogeneity of the aquifer.
3. Groundwater gradients calculated using groundwater-level data from Water Corporation bores, when first constructed, are between 0.0002 to 0.0007. These are significantly higher than those used by Forth (0.00017).
4. Sodium chloride content recharge calculations were only performed on one datapoint. This does not quantify the possible natural variation of recharge over the peninsula.

Updated groundwater recharge estimates

As outlined above, the Darcy's Law recharge estimation method has several deficiencies. There have been no further large-scale aquifer testing programs on the peninsula to further refine these aquifer parameters, and so the shortcomings of this methodology cannot currently be addressed. Therefore, based on the data available, we determined that the best method to estimate recharge was via the chloride mass balance (CMB) method. The CMB method is particularly suitable in low recharge environments, with arid to semi-arid climates, and areas with minimal human-induced chloride sources such as Exmouth.

To achieve this, we collated chloride data for 88 bores from the department's WIN database and data provided by Water Corporation. Corresponding chloride deposition rate point data was then extracted from the CSIRO 1937 to 2021 grid (Wilkins et al. 2022). Average annual recharge was calculated for each site using the CMB method. The average annual rainfall at the Exmouth Town Bureau of Meteorology station (272.4 mm) was used as the long-term mean as it is the closest to the town water supply borefield.

Most of the bores (82 out of 88) are located on the coastal plain or in the foothills of Cape Range, where the freshwater lens overlies intruded seawater. High chloride concentrations (>400 mg/L) indicate that many of these bores are impacted by upconing, diffusion or have inadvertently been screened in the mixing zone, making them unsuitable for CMB analysis. To negate these possible influences, pre-pumping chloride results from six bores screened in the entirely freshwater part of the aquifer, to the west of the seawater interface, were used to calculate average annual recharge (Table B1).

Table B1 Chloride mass balance for six groundwater bores within the Exmouth Water Corporation town water supply borefield

Bore ID	Coordinates (MGA 2020, Z50)		Chloride (mg/L)	Chloride deposition rate (kg/ha/year)	Average annual recharge	
	Easting	Northing			(mm/year)	Per cent
2/90	198,923.9	7,570,208.0	95.0	46.65	49.1	18.0
2/91	198,358.0	7,570,310.0	125.0	46.65	37.3	13.7
4/96	199,548.0	7,564,116.5	91.2	45.90	50.3	18.5
13/96	199,211.0	7,570,207.5	92.5	46.65	50.4	18.5
1/08	198,836.0	7,564,206.5	60.0	45.90	76.5	28.1
2/08	199,311.0	7,564,206.5	225.0	45.90	20.4	7.5
				Average	**47.3**	**17.4**

These representative bores have chloride concentrations between 60.0 to 225.0 mg/L, with a corresponding estimated annual recharge of between 20.4 to 76.5 mm, or 7.5 to 28.1 per cent of annual rainfall. The average annual recharge rate of the sites, 17.4 per cent, is significantly higher than that calculated by Forth (1972), which estimated recharge to be 10 per cent of annual rainfall. These estimates indicate that the calculations used to set allocation limits in the current groundwater allocation plan (WRC 1999) likely underestimated the total inflows into the aquifer.

This is supported by a Water Corporation (2020) study, which measured sodium chloride content in rainfall and dryfall (aerosol salt deposition) from 1992 to 1995, comparing it with the groundwater salinity in the borefield. The results of this study estimated recharge was between 16 and 20 per cent of annual rainfall.

Appendix C Considering future climate in allocation limit setting

The department has used a climate storyline approach to consider the impacts of future climate on groundwater allocation limits. The approach is consistent with the department's *Guide to future climate projections for water management in Western Australia* (DWER 2024). We considered the 32 NHP projections and used a 30-year period centred on the planning horizon of 2040 (2025 to 2054) for projected rainfall.

With the recent occurrence of two consecutive dry years shown to be a limiting factor, we focused on storylines that centred around the length of projected periods of consecutive dry years. To best represent the distribution of these projected changes across the Exmouth Peninsula, and the potential effects on groundwater resources, we developed five climate storylines.

We based three main storylines on a set of primary selection criteria to represent whether the length of projected consecutive dry years either 1) increased, 2) remained the same, or 3) decreased, compared with the historical climate. With multiple projections fitting the primary criteria, we used secondary selection criteria (Table C2) to further differentiate the projections that aligned with each storyline and to select a singular projection to represent each storyline.

We developed three storylines to represent and consider longer periods of consecutive dry years (storyline 1c), differentiated by the number of occurrences. The projections that fit the criteria had a large distribution in occurrences and average annual rainfall, so we also considered average annual rainfall to select the representative projections for each storyline.

The climate storylines can be summarised as:

1. A future climate with three or more consecutive dry years and either:
    a. a low number of consecutive dry years, high average annual rainfall
    b. at the mid-point of selected projections, mid-point average annual rainfall
    c. a high number of consecutive dry years, low average annual rainfall.
2. A future climate with consecutive dry years similar to the historical climate (i.e. a similar occurrence of two consecutive dry years).
3. A future climate with no consecutive dry years.

We also considered the vulnerabilities of the aquifer by assessing how each climate storyline might impact on achieving the objectives and outcomes if the allocation limits did not change and existing abstraction continued. This qualitative assessment is based on the Exmouth Town and Exmouth Central subareas where monitoring data is available to inform such an assessment and abstraction volumes are higher (Table C1). This guided development of the selection criteria that we used to select the representative NHP for each storyline (Table C2).

Table C1 Storyline vulnerabilities assessment of the potential impacts and consequences of climate change on the environment and water use

<table>
<tr><th rowspan="2">Climate storyline</th><th colspan="2">Vulnerabilities assessment:
potential impacts and consequences
of previous allocation limits remaining</th></tr>
<tr><th>Environment</th><th>Water use</th></tr>
<tr><td>1. A future climate with three or more consecutive dry years

(with either a low (a), mid-range (b), or high (c) occurrence of consecutive dry years)</td><td>• Reduced groundwater recharge available to the environment.
• Increased risk of impacts on groundwater-dependent values and the water resource, including:
  o salinisation of or reduced flows to groundwater-dependent values
  o loss of subterranean habitat
  o reduced freshwater discharge to the nearshore marine environment.
• Risks and impacts would increase the longer and more often the dry periods occurred.</td><td>• Increased salinisation of groundwater would occur from saline upconing or inland movement of the seawater interface, especially during dry periods, in both:
  o private bores
  o public abstraction bores
• Current levels and rates of abstraction at Water Corporation’s production bores may not be possible (i.e. may cause unacceptable impacts or bores to become saline) without borefield reconfiguration or additional sources being brought online.</td></tr>
<tr><td>2. A future climate with consecutive dry years similar to the historical climate</td><td>• Current risks of impacts on groundwater-dependent values would remain.
• This includes local short-term impacts of increased salinity levels during dry periods at:
  o individual production bores
  o private bores.</td><td>• Some additional management would be required to manage occurrences of saline upconing while maintaining current abstraction rates.
• No changes in availability of the freshwater resource for allocation as previous allocation limits under the current climate appear to be appropriate.</td></tr>
<tr><td>3. A future climate with no consecutive dry years</td><td>• More groundwater recharge would be available to the environment.
• Reduced risks of impacts on:
  o groundwater-dependent values
  o the water resource.</td><td>• Minimal risks of impacts from current abstraction rates (such as limited to no occurrences of increased salinity).
• No major change in the availability of the freshwater resource due to the high transmissivity of the aquifer.</td></tr>
</table>

The storylines and selection criteria that we applied to select climate projections from the 32 scenarios are detailed in Table C2.

Table C2 Climate projection selections for each storyline (the bold projections were those used in setting allocation limits)

Storyline	Criteria for selecting a singular, representative projection	Exmouth North subarea		Exmouth Town and Central subareas		Exmouth West subarea		Badjirrajirra subarea		Exmouth Saltflats subarea	
		Projection	Average annual rainfall (mm)[1]	Projection	Average annual rainfall[1] (mm)	Projection	Average annual rainfall[1] (mm)	Projection	Average annual rainfall[1] (mm)	Projection	Average annual rainfall[1] (mm)
Storyline 1: A future climate with three or more consecutive dry years	a) with a high occurrence: 1. Consecutive dry year period of three or more years. 2. Lowest number of consecutive dry years, excluding the first dry year of each consecutive dry year period. 3. Highest average annual rainfall.	RCP 4.5 ACCESS1-0-MRNBC	263.2 (+4.2%)	RCP 4.5 ACCESS 1-0-ISIM2b	301.6 (+19.4%)	RCP 4.5 ACCESS 1-0-ISIM2b	300.5 (+31.8%)	RCP 4.5 ACCESS 1-0-ISIM2b	309.1 (+35.5%)	RCP 4.5 ACCESS 1-0-ISIM2b	289.8 (+27.1%)
	b) with a mid-range occurrence: 1. Consecutive dry year period of three or more years. 2. Mid-point of projections, excluding the first dry year of each consecutive dry year period. 3. Select projection with mid-point of average annual rainfall.	RCP 8.5 ACCESS 1-0-ISIM2b	241.0 (-4.5%)	RCP 4.5 ESM2M-QME	219.3 (-13.2%)	RCP 4.5 ACCESS 1-0-CCAM-ISIM2b	218.9 (-13.3%)	RCP 8.5 ESM2M-MRNBC	211.8 (-7.3%)	RCP 8.5 ESM2M - CCAM-ISIM2b	199.1 (-21.2%)
	c) with a low occurrence: 1. Consecutive dry year period of three or more years. 2. Highest number of consecutive dry years excluding the first dry year of a consecutive dry year period. 3. Lowest average annual rainfall.	**RCP 4.5 ESM2M-ISIM2b**	164.8 (-34.7%)	RCP 4.5 ESM2M-ISIM2b	162.9 (-35.5%)	RCP 4.5 ESM2M-ISIM2b	160.7 (-36.4%)	RCP 8.5 MIROC5-CCAM-ISIM2b	187.7 (-17.7%)	RCP 8.5 MIROC5-CCAM-ISIM2b	179.9 (-28.8%)
Storyline 2: A future climate with consecutive dry years similar to the historical climate	1. Consecutive dry year period/s of two years (maximum length). 2. Number of occurrences of consecutive dry years is near historical average. 3. Number of dry years is near historical average. 4. Average annual rainfall is closest to historical average.	**RCP 8.5 MIROC5-QME**	**307.4 (+21.7%)**	**RCP 8.5 ACCESS 1-0-ISIM2b**	**250.2 (-0.9%)**	**RCP 8.5 ACCESS 1-0-ISIM2b**	**248.0 (+8.7%)**	**RCP 8.5 CNRM-QME**	**241.2 (+5.8%)**	**RCP 8.5 MIROC5-QME**	**285.4 (+25.2%)**
Storyline 3: A future climate with no consecutive dry years	1. No consecutive dry years. 2. Lowest number of dry years. 3. Highest average rainfall.	RCP 4.5 MIROC5-MRNBC	329.3 (+30.4%)	RCP 4.5 MIROC5-MRNBC	325.6 (+28.9%)	RCP 4.5 MIROC5-MRNBC	325.0 (+28.7%)	RCP 4.5 MIROC5-MRNBC	334.4 (+46.7%)	RCP 4.5 MIROC5-MRNBC	308.2 (+22.1%)

[1] Average annual rainfall for 2025 to 2054, with the percentage difference compared with the historical average annual rainfall for 1976 to 2005 (in brackets).

The figures below show the historical and projected rainfall for each subarea reference site, with the 32 NHP climate scenarios in grey and the five storyline scenarios in various colours. These figures demonstrate the potential variations in future climate that are possible across the peninsula. See Section 7.1 for the Exmouth Town/Central reference site.

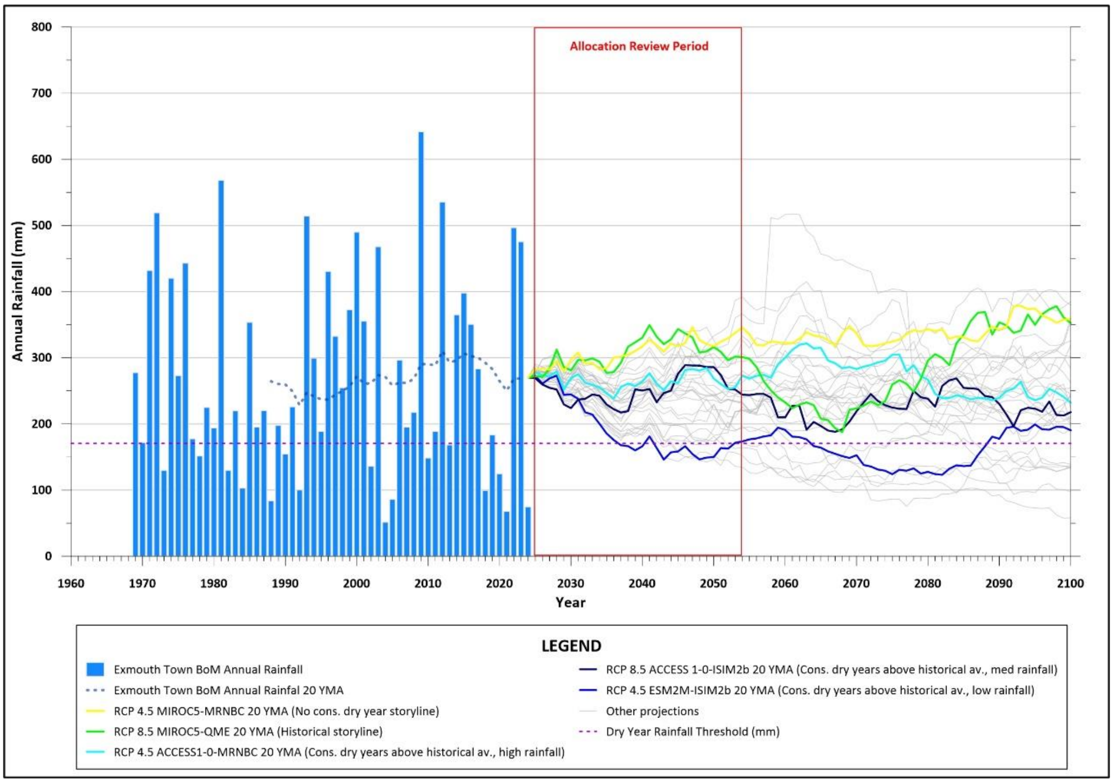

Figure C1 Exmouth North reference site – historical and projected rainfall (NHP 20-year moving averages), with storyline projections highlighted

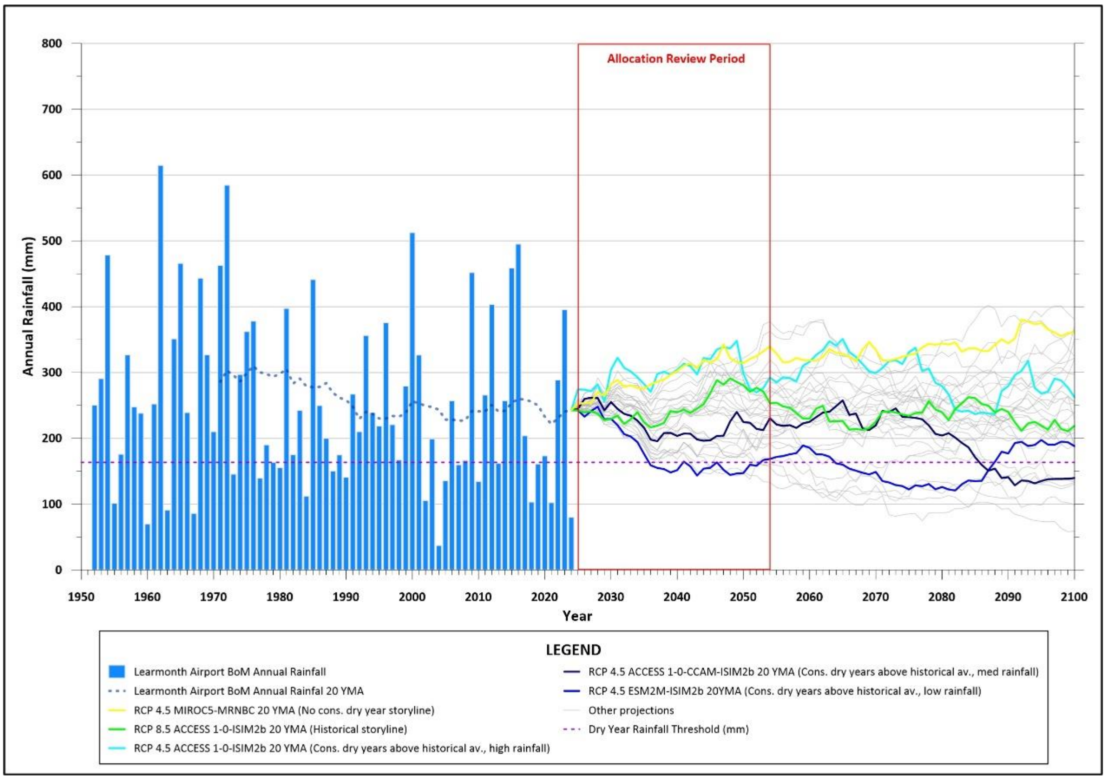

Figure C2 Exmouth West reference site – historical and projected rainfall (NHP 20-year moving averages), with storyline projections highlighted

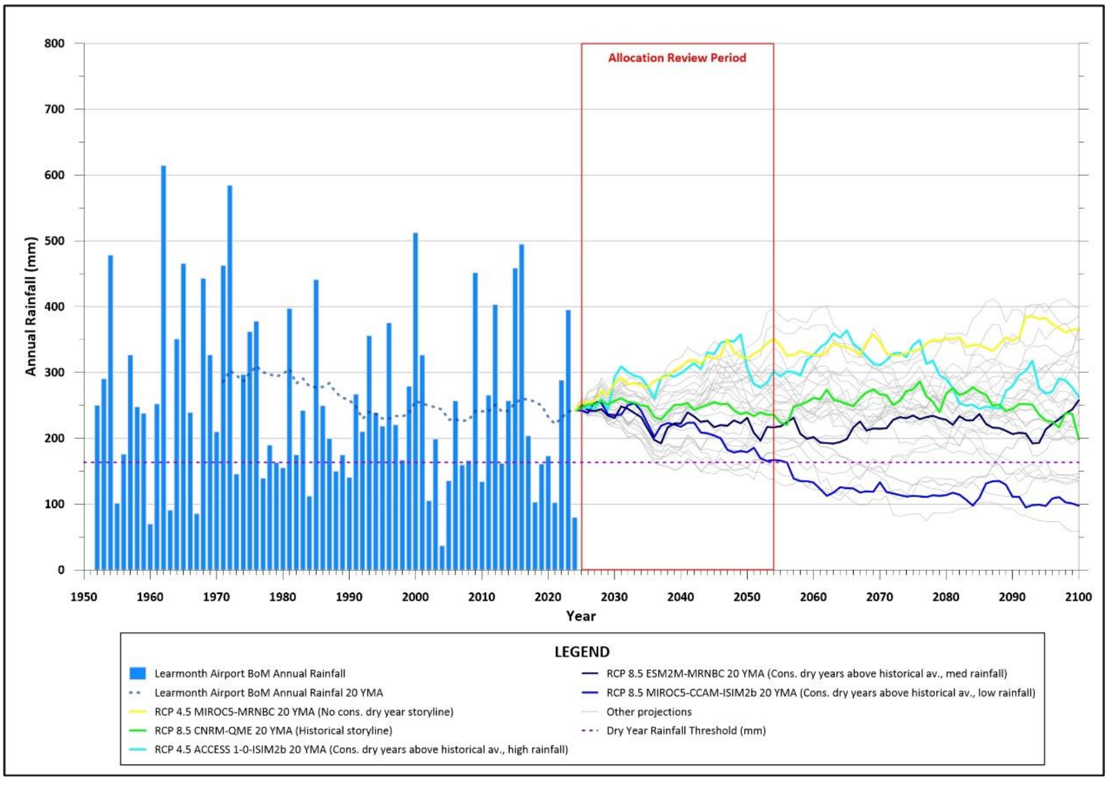

Figure C3 Badjirrajirra reference site – historical and projected rainfall (NHP 20-year moving averages), with storyline projections highlighted

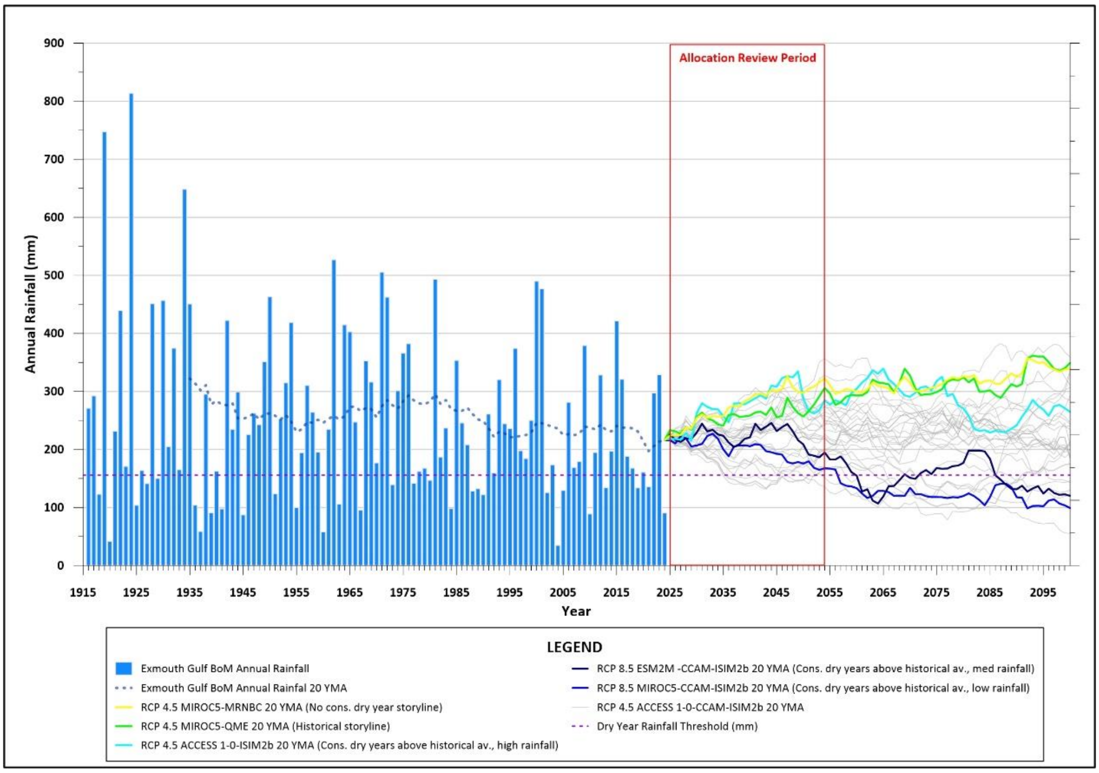

Figure C4 Exmouth Saltflats reference site – historical and projected rainfall (NHP 20-year moving averages), with storyline projections highlighted

Appendix D Values used to calculate allocation limit options and understand decisions

Table D1 Allocation limit options under projected future climate storylines and development risk (allocation limit decisions highlighted)

Subarea	Allocation scenario (storyline/ development risk)	Rainfall for selected storyline m	Adopted rainfall recharge rate	Recharge area m^2	Total recharge kL/year	Water to stay in the environment	Water to allocate for use	Allocation limit options kL/year	Allocation limit decisions kL/year	Current licensed entitlements kL/year	Estimated exempt use kL/year	Amount remaining for further allocation kL/year
						Proportion of recharge						
Exmouth North	2/medium risk	0.3070	0.15	34,854,677	1,605,058	0.75	0.25	401,264				
	1c/medium risk	**0.1648**	**0.15**	**34,854,677**	**861,608**	**0.75**	**0.25**	**215,402**	**215,400**	**0**	**188,000**	**27,400**
	1c/low risk	0.1648	0.15	34,854,677	861,608	0.95	0.05	43,080				
Exmouth Town	2/medium risk	0.250	0.15	32,720,038	1,227,001	0.75	0.25	306,750				
	1c/medium risk	0.1630	0.15	32,720,038	800,005	0.75	0.25	200,001				
	1c/high risk	0.1630	0.15	32,720,038	800,005	0.50	0.50	400,002				
	1c/existing allocation limit	**0.1630**	**0.15**	**32,720,038**	**800,005**	**about 0.62**	**about 0.38**	**300,000**	**300,000**	**279,150**	**20,300**	**550**
Exmouth Central	2/medium risk	0.2500	0.15	108,775,242	4,079,072	0.75	0.25	1,019,768				
	1c/medium risk	0.1630	0.15	108,775,242	2,659,555	0.75	0.25	664,889				
	1c/high risk	0.1630	0.15	108,775,242	2,659,555	0.50	0.50	1,329,777				
	1c/existing licensed entitlements and exempt use	**0.1630**	**0.15**	**108,775,242**	**2,659,555**	**about .67**	**about 0.33**	**872,748**	**872,748**	**840,898**	**31,850**	**0**
Badjirrajirra	2/medium risk	0.2410	0.15	187,242,083	6,768,801	0.75	0.25	1,692,200				
	1c/medium risk	**0.1880**	**0.15**	**187,242,083**	**5,280,227**	**0.75**	**0.25**	**1,320,057**	**1,320,050**	**100,000**	**2,000**	**1,218,050***
	1c/low risk	0.1880	0.15	187,242,083	5,280,227	0.95	0.05	264,011				
Exmouth West	2/medium risk	0.2480	0.15	553,762,845	20,599,978	0.75	0.25	5,149,994				
	1c/low risk	0.1607	0.15	553,762,845	13,348,453	0.95	0.05	667,423				
	1c/existing allocation limit	**0.1607**	**0.15**	**553,762,845**	**13,348,453**	**>0.99**	**< 1**	**50,000**	**50,000**	**33,800**		**16,200**
	2/medium risk	0.285	0.15	551,529,534	23,610,979	0.75	0.25	5,902,745				

Subarea	Allocation scenario (storyline/ development risk)	Rainfall for selected storyline m	Adopted rainfall recharge rate	Recharge area m^2	Total recharge kL/year	Water to stay in the environment	Water to allocate for use	Allocation limit options kL/year	Allocation limit decisions kL/year	Current licensed entitlements kL/year	Estimated exempt use kL/year	Amount remaining for further allocation kL/year
						Proportion of recharge						
Exmouth Saltflats	1c/medium risk	0.1799	0.15	551,529,534	14,883,024	0.75	0.25	3,720,756				
	1c/low risk	**0.1799**	**0.15**	**551,529,534**	**14,883,024**	**0.95**	**0.05**	**744,151**	**744,150**	**20,000**	**231,350**	**492,800**

Notes: Where the Exmouth South subarea was split, the existing allocation limit was divided proportional to land area in the proposed Exmouth Badjirrajirra and Exmouth Saltflats subareas. Proposed allocation limits are rounded to the nearest 50 kL from the estimated sustainable yield, except for Exmouth Central which was capped at licensed entitlements and exempt use, given the yield was close to this.

* The remaining amount in the Badjirrajirra subarea includes the 500,000 kL/year which has been set aside in a public water reserve as a future water source option for drinking water.

Appendix E Subarea risk assessments

The department assessed the in situ and development risks for each subarea (Table E1 to Table E6), as part of developing allocation limit options for the Cape Range Limestone resource (Section 8.1). The risk assessment follows the process set out in the *Groundwater risk-based allocation planning process* (DWER 2011), which provides a qualitative approach to balancing the protection of groundwater-dependent values with meeting water user needs.

The risk-based process asks a series of questions to rate:

- the risk to groundwater-dependent values and aquifer properties from allocating water for use (in situ risk)
- the risk to water users of not allocating water for use (development risk).

We then determined an overall risk and used this to develop allocation limit options for each subarea as a proportion of groundwater recharge, using the risk matrix shown in Table 8 (Section 8.1).

Table E1 Subarea risk assessment for Exmouth North

Subarea: Exmouth North					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating (high, medium, low)**	**Overall risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction? How likely are they to occur?**	**How significant would the impact be?**		**High**
		Risk of localised saline upconing from abstraction across much of the subarea with some impacts already observed. AEM data indicates a limited freshwater resource here (thickest under Cape Range). Where fresh groundwater is available, there is a risk of localised saline upconing from abstraction with some impacts already observed.	High: impacts to potable water supply.	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Subterranean fauna are highly groundwater dependent. There is currently very limited information on the ability of listed stygofauna in this area to move away from localised salinity change.	High: impacts to conservation-listed fauna and DIWA-listed subterranean waterways.	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Unknown: sites listed under *Aboriginal Heritage Act 1972* do not reference groundwater dependency.	High: registered sites under the *Aboriginal Heritage Act 1972*.	Unknown	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Offshore groundwater discharge is possible and may support nearshore marine values.	High: impacts to conservation-listed fauna and world and national heritage-listed marine areas.	High	
Development risk	Current water use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Medium or Low**
		The Department of Defence is the primary user of fresh groundwater in this area. There are private licences taking from the saline resource for desalination (tourism enterprise) and for dust suppression. There are no alternative sources.	Moderate: existing demand is being met. Groundwater supply for the defence base is a federal priority.	Med	
	Future demand	Minimal future demand for water at present.	Low.	Low	

Table E2 Subarea risk assessment for Exmouth Town

Subarea: Exmouth Town					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating**	**Overall risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction. How likely are they to occur?**	**How significant would the impact be?**		**High**
		Risk of localised saline upconing from abstraction with some impacts already observed. Risk of movement of the seawater interface. Licensed use is managed through licensing but there is domestic water use exempt from licensing.	High: impacts to public water supply and domestic bores.	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Subterranean fauna are highly groundwater dependent. There is currently very limited information on the ability of listed stygofauna in this area to move away from localised salinity change.	High: impacts to conservation-listed fauna and DIWA-listed subterranean waterways.	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Unknown: sites listed under *Aboriginal Heritage Act 1972* do not reference groundwater dependency.	High: registered sites under the Act.	Unknown	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Unknown: likely groundwater discharge to nearshore marine environment.	Not mapped.	Unknown	
Development risk	Current water use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Medium or High**
		Groundwater is critical to support public water supply and domestic use.	High: significant for the community, especially until alternative water sources are added to the scheme.	High	
	Future demand	There is future demand; however, due to constraints on this resource it is likely to be met through alternative water sources.	Medium: opportunities exist for alternative water supplies to meet future demand through accessing groundwater from Badjirrajirra or seawater desalination.	Med	

Table E3 Subarea risk assessment for Exmouth Central

Subarea: Exmouth Central					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating**	**Overall risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction? How likely are they to occur?**	**How significant would the impact be?**		**High**
		Risk of localised saline upconing from abstraction with some impacts already observed.	High: impacts to public water supply and domestic bores.	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Highly dependent ecosystem values including the Cape Range subterranean waterways, subterranean fauna habitat, ephemeral wetlands, and groundwater discharge to nearshore marine habitat.	High: impacts to conservation-listed fauna and DIWA-listed subterranean waterways	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Qualing Pool and Mowbowra Creek values are likely to be groundwater dependent.	High: significant cultural values may be impacted	High	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Qualing Pool and Mowbowra Creek values are likely to be groundwater-dependent; groundwater discharge may support nearshore marine values.	High: significant social values may be impacted.	High	
Development risk	Current water use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Medium or High**
		Groundwater is critical to support public water supply and domestic use.	High: significant for the community	High	
	Future demand	There is future demand; however, due to constraints on this resource it is likely to be met through alternative sources.	Medium: opportunities for alternative supplies to meet future demand through accessing groundwater from Badjirrajirra or desalination.	Med	

Table E4 Subarea risk assessment for Badjirrajirra

Subarea: Badjirrajirra					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating**	**Overall risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction. How likely are they to occur?**	**How significant would the impact be?**		**High**
		Sensitive to localised saline upconing from abstraction if not managed appropriately.	High: risk to future users through salinisation of water supplies.	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Highly dependent ecosystem values including Cape Range subterranean waterways, subterranean fauna habitat, ephemeral wetlands, and groundwater discharge to nearshore marine habitat.	High: impacts to DIWA-listed subterranean waterways and conservation-listed fauna.	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Unknown: site listings under the *Aboriginal Heritage Act 1972* do not reference groundwater dependency.	High: significant cultural values.	Unknown	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Unknown: likely groundwater discharge to nearshore marine environment.	Not mapped.	Unknown	
Development risk	Current water use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Low or Medium**
		Demand is low at present.	Low: based on current low demand.	Low	
	Future demand	Possible future extension of scheme borefield for town water supply into this subarea. Possibility of a future water reserve for native title holders, for potential future water developments in this area.	Moderate: development of this resource to meet future demand for town water supply will reduce risks in the Town and Central subareas.	Med	

Table E5 Subarea risk assessment for Exmouth Saltflats

Subarea: Exmouth Saltflats					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating**	**Overall risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction. How likely are they to occur?**	**How significant would the impact be?**		**High**
		Sensitive to localised saline upconing from abstraction if not managed appropriately. AEM indicates the seawater interface extends much further inland than subareas to the north.	High: risk to future users through salinisation of water supplies.	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Highly dependent ecosystem values including the Cape Range Subterranean Waterways, subterranean fauna habitat, ephemeral wetlands and saltflat communities, waterways including Wapet Creek, and groundwater discharge to nearshore marine habitats. Possible groundwater-dependence of mangrove community in the Bay of Rest.	High: impacts to conservation-listed flora and fauna, and DIWA-listed Subterranean Waterways threatened ecological community and the extensive stands of mangroves.	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Highly dependent cultural values; Billy Wells and Monajee Cave listed as water sources.	High: impacts to listed or registered sites.	High	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Unknown: likely groundwater discharge to Bay of Rest and popular fishing and tourist locations.	Unknown groundwater dependence.	Unknown	
Development risk	Current use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Low**
		The Department of Defence is the primary user of fresh groundwater in this area for the Learmonth airbase and facilities.	Moderate: existing demand is being met. Groundwater supply for the defence base is a federal priority.	Medium	
	Future demand	Minimal future demand for water at present.	Low	Low	

Table E6 Subarea risk assessment for Exmouth West

Subarea: Exmouth West					
Risk type	**Values**	**Likelihood and/or sensitivity**	**Consequences**	**Risk rating**	**Overall Risk**
In situ risk	Aquifer properties	**What are the risks to the aquifer from abstraction. How likely are they to occur?**	**How significant would the impact be?**		**High**
		Sensitive to localised saline upconing from abstraction if not managed appropriately. AEM indicates limited freshwater resource here (thickest under Cape Range).	High: risk to future users through salinisation of water supplies	High	
	Groundwater Dependent Environmental (GDE) values	**How dependent are they and how susceptible to change are they?**	**How significant are the GDEs?**		
		Highly dependent and susceptible: Cape Range subterranean waterways and subterranean fauna habitat (incl. Bundera Sinkhole TEC), waterways (e.g. Yardie Creek) and ephemeral wetlands; high values of groundwater discharge supporting nearshore values of the Ningaloo Marine Park and potential dependence of mangroves at Mangrove Bay.	High: impacts to conservation listed flora and fauna, Threatened ecological community and the Ningaloo Marine park on discharge boundary.	High	
	Cultural values	**How dependent are they and how susceptible to change are they?**	**How significant are the cultural values?**		
		Highly dependent sites associated with creeklines and rock holes.	High: impacts to registered sites	High	
	Social values	**How dependent are they and how susceptible to change are they?**	**How significant are the social values?**		
		Likely dependent – groundwater discharge to areas of Ningaloo coast and supporting terrestrial values of the Cape Range National Park.	High: impacts to world, national and Commonwealth listed areas which are also highly valued for tourism and nature visitation.	High	
Development risk	Current water use	**How important is the water for meeting current and future development needs? Are there alternative water sources?**	**How significant is current and future use or development for the community?**		**Low**
		Low level of current groundwater use; all tourism related to and sensitive to the National Park and Ningaloo. Yardie Homestead caravan park, and ablutions/other facilities for DBCA and Shire.	Low: minimal current use and demand.	Low	
	Future demand	Potential further demand for tourism services.	Low: future interest in water will be constrained by inaccessible land tenure. Minor future demand anticipated.	Low	

Map information

Datum and projection information

Projection: GDA94 MGA zone 51

Spheroid: GRS 1980

Map Author: Carolyn McMillan

Filepath:

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With some figures from:

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Compilation date: August 2024

Disclaimer

The maps in this report are a product of the Department of Water and Environmental Regulation. These maps were produced with the intent that they be used for information purposes within this document and at the scale shown if printing.

While the department has made all reasonable efforts to ensure the accuracy of this data, the department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Map sources

The Department of Water and Environmental Regulation is custodian of the following datasets used in production of the maps in this report:

- Towns - DWER, **DWER**.
- WRIMS – Groundwater subareas (DWER-083), **DWER**.
- WA Coastline – WRC (poly), **DWER**.
- Exmouth Study Area, **DWER.**

Other sources
(name, custodian, source, source link)

- Roads (LGATE_012), **Landgate**, SLIP: https://catalogue.data.wa.gov.au/dataset/roads-lgate-012
- Hydrography – Inland Waters – Water Polygons (LGATE-016), **Landgate**, SLIP: https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-water-polygon-lgate-016
- Hydrography WA 250K - Surface Waterbodies (GA 2015), **Geoscience Australia**, https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/83135

- Geonoma (LGATE-013), **Landgate**, SLIP: https://catalogue.data.wa.gov.au/dataset/geographic-names-geonoma
- Airport Landing Grounds, **Landgate**, Landgate supplied.
- Heritage Council WA – State Register (DPLH-006), **DPLH** https://catalogue.data.wa.gov.au/dataset/heritage-council-wa-state-register
- National Heritage List Spatial Database, **DCCEEW,** https://fed.dcceew.gov.au/datasets/erin::national-heritage-list-spatial-database-nhl-public/about
- Commonwealth Heritage List Spatial Database, **DCCEEW,** https://fed.dcceew.gov.au/datasets/erin::commonwealth-heritage-list-1/about
- Aboriginal Sites and Heritage Places, **DPLH,** https://catalogue.data.wa.gov.au/dataset/aboriginal-heritage-places
- DBCA Legislated Lands and Waters, **DBCA**, https://catalogue.data.wa.gov.au/dataset/dbca-legislated-lands-and-waters
- Threatened Ecological Communities, **DBCA,** https://catalogue.data.wa.gov.au/dataset/threatened-ecological-communities
- Hydrography – Inland Waters – Waterlines (named rivers only), **Landgate**
- Wetlands DIWA updated (DBCA), **DBCA,** https://catalogue.data.wa.gov.au/dataset/directory-of-important-wetlands-in-western-australia
- Wetlands DIWA 2018 (Repealed version), **DCCEEW.**
- Threatened and Priority Fauna – Planning, **DBCA**, DBCA supplied.
- Threatened and Priority Flora – Planning, **DBCA**, DBCA supplied.
- WA Herb – Planning Data, **DBCA,** DBCA supplied.
- Seabird Breeding Islands, externally supplied under license.
- Dugong Habitat, externally supplied under license.
- Hydrography – Coastal Flat (LGATE-122), **Landgate,** https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-coastal-flat-polygon-lgate-122
- Seagrass, AU_seagrass05_POLY, **IMAS,** https://metadata.imas.utas.edu.au/geonetwork/srv/api/records/61F2E4F8-96DB-4723-AADE-08274DAF2268

Background imagery

- SatviewWA (LGATE-317),17/04/2024, **Landgate**, SLIP: https://services.slip.wa.gov.au/arcgis/rest/services/Landgate_Restricted_Imagery/SatViewWA/MapServer

Shortened forms

AH Act	*Aboriginal Heritage Act 1972*
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ANZECC	Australian and New Zealand Environment and Conservation Council
BC Act	*Biodiversity Conservation Act 2016* (WA)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Department of Biodiversity, Conservation and Attractions
DPLH	Department of Planning, Lands and Heritage
DoW	Department of Water (former department)
DWER	Department of Water and Environmental Regulation
EP Act	*Environmental Protection Act 1986* (WA)
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
IUCN	International Union for Conservation of Nature
PEC	priority ecological community
TDS	total dissolved solids or salts
TEC	threatened ecological community
WRC	Water and Rivers Commission (former department)

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)

Units of measure

°C	degrees centigrade, a unit of measure for temperature
ha	hectares
km^2	kilometres squared
m	metres
mm	millimetres
mS/cm	millisiemens per centimetre, a unit of measure used for salinity
mbgl	metres below ground level

Glossary

Term	Meaning
Abstraction	The permanent or temporary take of water from any source of supply, so that it is no longer part of the resources of the locality.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water. Usually described by whether they consist of sedimentary deposits (sand and gravel) or fractured rock. Aquifer types include unconfined, confined, and artesian aquifers.
Aquitard	A geological formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients.
Biodiversity	The variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems.
Bore	A narrow, normally vertical hole drilled in soil or rock to monitor or withdraw groundwater from an aquifer.
Confined aquifer	An aquifer lying between confining layers of low permeability strata (such as clay, coal or rock) so that the water in the aquifer cannot easily flow vertically.
Consecutive dry years	A period of two or more successive calendar years (January to February) where the total annual rainfall of each calendar year is below the third decile of the corresponding climate reference point's annual rainfall between 1976 and 2005.
Country (when used in connection to Aboriginal people)	Country means the lands, waterways, seas and skies to which Aboriginal people are intrinsically linked. The wellbeing, law, place, custom, language, spiritual belief, cultural practice, material sustenance, family and identity are all interwoven as one.
Cultural value	Cultural values are the core principles and value systems that underpin a community, a society or, in the case of Traditional Owners, a nation, clan or language group. They may be associated with a site of cultural significance or associated with the living, historical and traditional observances, practices, customs, beliefs, values, knowledge, relationships and skills of Aboriginal people. Cultural values of Traditional Owners can only be determined by them and are expressed in many ways such as narratives, songlines, art and maps.
Discharge	The water that moves from the groundwater to the ground surface or above, such as a spring. This includes water that seeps onto the ground surface, into the ocean, or into a watercourse or wetland; evaporates from unsaturated soil; and that is extracted from groundwater by plants (see Evapotranspiration) or engineering works.
Dry year	A calendar year period (January to December) where the total annual rainfall of a location is below the third decile of the corresponding climate reference point's annual rainfall between 1976 and 2005.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.

Term	Meaning
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact (e.g. a lake), including all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environment	Living things, their physical, biological, cultural and social surroundings, and interactions between all these as defined under section 3, *Environmental Protection Act 1986* (WA).
Environmental outcome	Where water management benefits or supports ecosystem, cultural or social values. Managing water for environmental outcomes aligns with achieving the department's following legislative responsibilities: • Section 26GX 'plans for management of water resources' and Schedule 1, Division 2, clause 7(2) in the *Rights in Water and Irrigation Act 1914* (WA). • Underpinning the conservation of biodiversity and ecological integrity as per the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (to protect matters of national environmental significance, such as the Ningaloo Marine Park) and the *Environmental Protection Act 1986* (WA) and *Biodiversity Conservation Act 2016* (WA). • Under WA's Aboriginal heritage laws, to ensure that activities that result from water licensing and regulation, including those where the department is the applicant, do not harm Aboriginal heritage.
Evaporation	Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.
Evapotranspiration	The combined loss of water by evaporation and transpiration. It includes water evaporated from the soil surface and water transpired by plants.
Flow	Groundwater throughflows that maintain the location of the seawater interface to protect stygofauna habitat, and to maintain the water quality of nearshore freshwater seeps and submarine springs.
Groundwater	Water which occupies the pores and crevices of rock or soil beneath the land surface.
Groundwater area	The boundaries that are proclaimed under the *Rights in Water and Irrigation Act 1914* (WA) 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 values	The ecological, social, heritage and cultural values that depend on groundwater to some extent.
Groundwater recharge	Water from all sources that infiltrates into and replenishes an aquifer.
Heritage values	Places of world and national heritage, including Aboriginal cultural heritage listed under EPBC Act, and places of state significance: Aboriginal heritage places listed under the *Aboriginal Heritage Act 1972* (WA) and significant cultural or natural heritage registered under the *Heritage Act 2018* (WA).
Hydrogeology	The hydrological and geological science concerned with the occurrence, distribution, quality and movement of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.

Term	Meaning
Hydrograph	A graph showing the height of a water surface above an established datum plane for level, flow, velocity, or other property of water with respect to time.
Licence	A formal instrument granted under the *Rights in Water and Irrigation Act 1914* (WA) that entitles a licensee to take water (the licensed entitlement) from a water resource in accordance with the specified terms, conditions and restrictions on the licence.
Native title	The recognition that a group of Aboriginal people have rights and interests to land and waters according to their traditional law and customs as set out in Australian law – *Native title Act 1993* (Cth.).
Native title party	In relation to an area of land where a water licence or permit is applied for the relevant native title party has the meaning given in section 24HA(7)(a) of the *Native Title Act 1993* (WA), including: • a representative Aboriginal/Torres Strait Islander body • a registered native title body corporate • a registered native title claimant.
Rainfall recharge	Rain that infiltrates into the soil to replenish an aquifer.
Salinity	The measure of total soluble salt or mineral constituents in water. Water resources are classified based on salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt).
Social value	Behaviours and beliefs that people share within a community or social group that contribute to wellbeing, sustainability, society and diversity.
Soak	An excavation below ground level that usually intercepts groundwater. Where a wall is also constructed above ground, a combination of surface runoff and groundwater may be captured. Soaks may also be constructed close to a watercourse to obtain water. Other names for soaks may include excavations, dugouts or sumps.
Spring	As defined in s 2(1) of the *Rights in Water and Irrigation Act 1914*, a spring means a spring of water naturally rising to and flowing over the surface of land but does not include the discharge of underground water directly into a watercourse, wetland, reservoir or other body of water.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Traditional Owner	An Aboriginal person/s is a Traditional Owner if they are: • a native title holder • a registered native title claimant or claim group • a member of a Regional Aboriginal Corporation established under a settlement agreement with the government • a person who is recognised as having the cultural authority to speak for a place.
Upconing	The upward movement of saline water within an aquifer caused by groundwater abstraction.

Term	Meaning
Watercourse	(a) Any river, creek, stream or brook in which water flows (b) Any collection of water (including a reservoir) into, through or out of which anything coming within paragraph (a) flows c) Any place where water flows that is prescribed by local bylaws to be a watercourse. A watercourse includes the bed and banks of anything referred to in paragraph (a), (b) or (c).
Water-dependent ecosystems	Those parts of the environment, the species composition, and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.
Water regime	A description of the variation of flow rate or water level over time. It may also include a description of water quality.
Watertable	The saturated level of the unconfined groundwater. Wetlands in low-lying areas are often seasonal or permanent surface expressions of the watertable.
Waterways	All streams, creeks, stormwater drains, rivers, estuaries, coastal lagoons, inlets and harbours.
Well	An opening in the ground made or used to obtain access to underground water. This includes soaks, wells, bores and excavations.
Wetland	As defined in section 2 of the *Rights in Water and Irrigation Act 1914*, a wetland is a natural collection of water, whether permanent or temporary, on the surface of any land and includes — a) any lake, lagoon, swamp or marsh b) a natural collection of water that has been artificially altered but does not include a watercourse.

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