Groundwater Allocation Plan

Exmouth Groundwater Subarea

Water and Rivers Commission
Policy and Planning Division

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Acknowledgments

Internal Contribution

Author
Wayne Astill, Environmental Engineer, Allocation Branch

Supervision
Rob Hammond, Program Manager
Leon English, Program Manager
Tim Katsavounidis, Senior Engineer

Drafting
Dianne Abbott, Drafting Officer, Allocation Branch

Comments
Roly Dowd, A/Regional Manager, North West Region
Kevin Firth, Water Resources Officer
Wade Dodson, Hydrogeologist, Groundwater Investigation Branch
Adrian Tomlinson, Engineer, Water Quality Protection
Sharon Stratico, Environmental Officer, Catchments and Waterways

External Review

Mike Martin, Water Corporation
Kathy Ryan, Water Corporation
Bill Humphreys, WA Museum
Doug Bathgate, Gascoyne Development Commission
Kerry Graham, Shire of Exmouth
Garry Whisson, Department of Environmental Protection
Geoff Bott, Department of Environmental Protection
John Bush, Department of Environmental Protection
Sue Woolhouse, Ministry for Planning
Kevin Meyers, Conservation and Land Management Exmouth
Rachel Siewert, Conservation Council of Western Australia

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Summary

The Exmouth Groundwater Subarea Allocation Plan has been developed to establish policies and principles for the sustainable allocation of groundwater resources in the Exmouth Groundwater Subarea. This plan has been prepared in response to concerns over rising groundwater salinities in the town of Exmouth and the impact of increased development in the area.

The groundwater resources of the Exmouth Groundwater Subarea comprise both unconfined and confined aquifers. The aquifers are, in increasing order of depth, from the Cape Range Group (unconfined) to the Birdrong Sandstone (confined).

The Cape Range Group aquifer is a thin lens of fresh water in delicate balance with the underlying saline water. This fresh water lens is susceptible to over pumping and needs to be carefully managed. The Birdrong Sandstone is found at depths of approximately 1 000 m and contains saline water. Due to its depth and poor quality it is unlikely to be used in the foreseeable future.

The water resources of the Exmouth Groundwater Subarea are limited and are already heavily utilised in the northern region of the North West Cape. A throughflow of 170 ML/annum/km has been estimated for the Cape Range aquifer based on groundwater monitoring over the past 30 years. Management policies have been formulated on the basis of these estimates, current trends in water quality, and existing water usage.

Groundwater is the major water resource in the Exmouth Groundwater Subarea. It is currently utilised to meet the public water requirements of the town of Exmouth plus private, tourism and industrial uses.

The Water Corporation is the major user of groundwater from the Cape Range aquifer providing public water supply of 1 029 ML per annum. The next major user of groundwater is the Harold E. Holt Naval Base, which draws 217 ML per annum.

There is evidence of increasing salinity in the town of Exmouth before 1993, while the period from 1994 to 1997 has given some indication that this trend has now stabilised. Investigation indicates that increases in salinity were primarily the result of mismanagement of wells[1], which was causing an upconing of saline water. However, the possibility that the increase in salinity may be due to abstraction being greater than throughflow has not been discounted.

The Cape Range aquifer is a karst environment that supports subterranean fauna of significant conservation value. Whilst little is known about this fauna, it is known that the interaction of a fresh water lens overlying brackish and saline quality water is of extreme importance. Whilst Ecological Water Requirements have not been established in the Exmouth Groundwater Subarea, Environmental Water Provisions have been provisionally set at the generalised condition of no degradation to water levels and water quality.

To help manage the groundwater resources, the subarea has been further divided into five: Exmouth West, Exmouth North, Exmouth Town, Exmouth Central and Exmouth South. These areas essentially comprise a northern zone of three subareas that are heavily utilised and require careful management, a western area where restricted land use will limit groundwater abstraction and the southern area that is currently under utilised with respect to groundwater abstraction.

Groundwater availabilities have been calculated for the Cape Range aquifer in the four eastern subareas. In the

[1] The term 'well' in this report is synonymous with bore.

Exmouth West Subarea the allocation limit has been set to the present level, which is consistent with the high conservation values of the west coast, the restrictive land use associated with the Cape Range National Park and the limited hydrogeological information. These groundwater availabilities are summarised in the table below:

Table 1: Groundwater availability from the Cape Range Group aquifer

SUBAREA	GROUNDWATER AVAILABILITY (kL/annum)	ALLOCATED RESOURCES (kL/annum)	NUMBER OF LICENCES	REMAINING RESOURCES (kL/annum)	GROUNDWATER SALINITY
Exmouth West	Limited	13 100	3	Nil	Potable to Marginal
Exmouth North	200 000	258 000	4	-58 000	Potable to Marginal
Exmouth Town	300 000	310 450 *	73	-10 450	Potable to Marginal
Exmouth Central	1 000 000	878 900 *	15	121 100	Potable to Marginal
Exmouth South	4 700 000	376 000	5	4 324 000	Potable
TOTAL	6 200 000	1 631 000	100	4 569 000	

Note * this includes future groundwater allocations for public water supply.

A rationalisation of the monitoring program of private wells is also proposed, restricting the sites monitored to 30 (down from 94). This rationalisation is based on retaining the wells with the most complete data set over strategic areas.

The Exmouth West Subarea allocation limit has been set at the current level of use. In this area further licences should not be issued.

In the Exmouth North and Town Subareas groundwater allocation is above the availability. In this area further licences should not be issued.

In the Exmouth Central and South Subareas significant groundwater is available for allocation. However, all new licence applications should be considered based on local availability with the allocation not breaching the 100 ML/annum/km estimated safe yield.

Licensing of all wells in the Cape Range Group aquifer is required, including all domestic wells (abstraction less than 1 500 kL/annum).

Metering is required in both the Exmouth Central and South subareas for abstractions greater than 5 000 kL/annum. This will require 20 existing licences to be covered by metering and should be enforced as licences approach renewal.

In order to reduce the risks of upconing it is advisable for the licensee to screen their wells in the upper sections of the fresh water lens and pump at a low rate.

If the salinity of a Water Corporation scheme well exceeds 1 000 mg/L TDS, then pumping should be reduced from this well. If the salinity continues to increase then pumping may ultimately need to cease. If further monitoring indicates inland movement of the saltwater interface then production from the wells in the area should be reduced and ultimately cease if no improvement is detected.

Similarly, if annual monitoring in private wells shows that salinity is above the historical maximum then the licensee should be encouraged to review and modify their pumping regime. Furthermore, if private wells in an area all exhibit an increase in salinity then reduction or even the cessation of pumping from all wells should be considered.

Additional work is required to estimate the Ecological Water Requirements and Environmental Water Provisions for the subterranean fauna of the Cape Range Group aquifer. Further monitoring is required which will include establishment of baseline data to help in the identification of acceptable environmental change.

1. Introduction

The Exmouth Groundwater Subarea Allocation Plan has been developed to establish policies and principles for the sustainable allocation of groundwater resources in the Exmouth Groundwater Subarea. This plan has been prepared in response to concerns over rising groundwater salinities in the town of Exmouth and the impact of increased development in the area.

1.1 Location

The Exmouth Groundwater Subarea covers 2 020 square kilometres of the Cape Range Peninsula (Fig. 1). The town of Exmouth, located 1 260 km north of Perth, is the largest centre in the subarea with a population of approximately 2 400. The other major centre within the subarea is Learmonth.

The Exmouth Groundwater Subarea is contained within the Gascoyne Groundwater Area (GGA).

1.2 Exmouth Groundwater Subarea

The Exmouth Groundwater Subarea was initially proclaimed under section 26 of the *Rights in Water and Irrigation Act 1914*, as part of the Pilbara Groundwater Area on 12 February 1965. In 1990 the subarea was excised from the Pilbara Groundwater Area and included as a subarea of the Gascoyne Groundwater Area.

By the early 1990s, data from wells drilled to service Exmouth indicated that the aquifer was under stress, with numerous wells experiencing elevated salinities. Initial suggestions were that the subarea was over allocated and saltwater from the ocean had intruded and entered a number of wells located near the coast. To limit any further inland movement of the saline water, and to gain a greater understanding of the hydrogeology of the area, a moratorium was placed over the subarea on 14 October 1991. Since that time a number of studies have been carried out to better determine the groundwater resources in the Exmouth Peninsula, resulting in the requirement to re-evaluate existing allocation policies.

To better manage the groundwater resources, the subarea has been further divided into five sections (Fig. 2). These subareas have been created to reflect hydrogeological features of the area, and population distribution with the correspondingly greater groundwater abstraction.

1.3 Groundwater overview

Groundwater is the major water source in the Exmouth Groundwater Subarea. It is currently utilised to meet the public water requirements of the town of Exmouth plus private, tourism and industrial uses.

The groundwater resources of the Exmouth Groundwater Subarea comprise both unconfined and confined aquifers. The aquifers are, in increasing order of depth, from the Cape Range Group (unconfined) to the Birdrong Sandstone (confined). The Birdrong Sandstone is found at depths of approximately 1 000 m and contains saline water, which is in low demand.

1.4 Water and Rivers Commission role

Groundwater resource utilisation and conservation in Western Australian country areas is administered by the Water and Rivers Commission in accordance with the *Rights in Water and Irrigation Act 1914* (RIWI Act) and the *Water and Rivers Commission Act 1995*. Under the RIWI Act, the right to use, flow and control of groundwater is vested in the Crown. This Act requires the compulsory licensing of all artesian wells throughout Western Australia. In addition, non-artesian wells require licensing in specific areas, proclaimed under the Act as groundwater areas. Provisions exist for the exemption of stock and domestic supplies from licensing requirements if considered appropriate.

Groundwater licensing administration in the Exmouth Groundwater Subarea is the responsibility of the Water and Rivers Commission's Mid-West Gascoyne Regional Office, located in Carnarvon. This management plan provides direction for the regional office in the issuing of groundwater licences, with further specialist advice on groundwater matters available from the Water and Rivers Commission's Allocation Branch. All applications for a groundwater well licence are made to the Water Resources Section of the Water and Rivers Commission's North West Regional Office in Carnarvon.

1.5 Objectives of management plan

Management of the groundwater resources, including regulatory controls on (any) abstraction, is based on the following objectives:

- To recognise and protect the environmental values of groundwater, thereby protecting the attendant beneficial (human) uses of groundwater for present and future generations.

- To harvest water at a sustainable level; to conserve and protect the long-term security of the groundwater resources in the region; and to ensure that the use of the resource benefits as many people as possible.

- To ensure that where possible, a reasonable quantity of water is available to existing enterprises dependent upon a continued supply of good quality groundwater.

- To promote the allocation of the available groundwater resource on a basis which provides the most beneficial use to the community.

- To encourage efficiency in water use through improvements to methods of agriculture and irrigation and encourage development consistent with the regional planning and land use objectives for the region.

The primary objective of this groundwater allocation plan can be summarised as the sustainable use of the groundwater resource. Management of the groundwater resources in the subarea can be broadly defined as review, assessment and allocation of groundwater resources on a local scale. This is carried out by the Water and Rivers Commission based on the information from wells monitored by the Commission or by licensees.

Studies have been undertaken to better define the groundwater resources in the subarea, on a local and regional scale. These studies have assisted in the development of more informed groundwater allocation policies that are outlined in this management plan.

1.6 Principles of groundwater allocation and licensing

Groundwater should be used efficiently to avoid wasting a valuable resource. All applicants for groundwater licences should be made aware of this and those planning to use large volumes of groundwater should demonstrate that water conservation has been considered and will be implemented where possible.

The general policies and procedures of groundwater licensing in Western Australia are detailed in a report by the Water Authority (Ventriss, 1990). Groundwater licence allocations are aimed at ensuring equitable use of the State's groundwater resources, while protecting the long-term security of these resources and having regard for the economic, social and environmental consequences.

The Cape Range should be managed according to sound ecologically sustainable development and biodiversity protection principles. These principles are further clarified in the following State and national agreements:

- Intergovernmental Agreement on the Environment, IGAE 1992;

- National Strategy for Ecological Development, Commonwealth of Australia, 1992;

- National Strategy for the Conservation of Australia's Biological Diversity, Commonwealth of Australia, 1996;

- National Water Quality Management Strategy, ANZECC/ARMCANZ, 1992. This includes *Guidelines for Groundwater Protection in Australia* (1995);

- National Principles for Provision of Water for Ecosystems, ANZECC/ ARMCANZ, 1996.

Inherent in the above are the following three key principles, which are a feature of best practice resource management:

1. Precautionary Principle - Where there are threats of serious or irreversible environmental damage, lack of full scientific uncertainty should not be used as a reason to postpone measures to prevent environmental degradation;

2. Intergenerational Equity - The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

3. Preservation of biological diversity and ecological sustainability.

2. Physical environment

2.1 Climate

The Exmouth Groundwater Subarea has a semi-arid climate with hot summers and mild winters. A significant feature of the area's climate is the difference in temperature between the eastern and western sides of Cape Range during summer months, as a result of the southwest breezes.

Long term average annual rainfall is about 260 mm at Exmouth, however the rainfall is unreliable and large annual and monthly variations exist as shown in Figures 3 and 4. Tropical cyclones occur every three to five years, with less intensive tropical lows occurring annually during January to March. Annual rainfall totals are erratic and there may be several consecutive years of low rainfall.

Mean maximum daily temperatures at Exmouth range from 37°C in January to 24°C in July. Average minimum temperatures range from 23°C in January to 14°C in July.

2.2 Geomorphology

Cape Range (also known as North West Cape) is a peninsula measuring about 96 km in length from north to south and 21 km from east to west. The town of Exmouth and the coastal plain between Cape Range and Exmouth Gulf rise to about 20 m Above Sea Level (ASL). From the coastal plain Cape Range rises steeply to about 300 m ASL. Ordinarily, with such a steep rise in topography there would be a steep hydraulic gradient towards the coast. However, the limestones are extremely permeable and so the groundwater gradient is small.

Landforms in the North West Cape Peninsula exhibit a high number of caves, rock shelters, sink holes, streams that disappear underground, biokarstic phenomena (such as Ningaloo Reef), protocaves and mesocaverns that suggest a karst landscape. Karst landscapes are terrain with distinctive landforms and drainage patterns arising from the high solubility of limestone in natural waters. They are the result of a complex interaction of climatic, geological, topographic, hydrologic, biological and temporal factors. The karst of the Cape Range Peninsula is unique as relatively few other karsts are formed in limestone of such young age. Most other karsts in eastern Australia have formed in much older, crystalline limestone.

2.3 Geology

The Exmouth Groundwater Subarea is located within the Carnarvon Basin (Hocking et al., 1987), and is underlain by Palaeozoic to Cainozoic rocks. The peninsula is formed of Tertiary age calcareous sediments, with minor Quaternary deposits near the coast. A generalised geological cross section is shown in Figure 5 (Martin, 1990).

Two main formations have been intersected during investigations for water in the Exmouth area. These are the Cape Range Group sediments consisting of Trealla, Tulki and the Mandu Limestone in increasing order of depth respectively and the Birdrong Sandstone. The limestone units form a comparable sequence that dips to the west and east from the axis of Cape Range. Contacts between the units are difficult to distinguish and are probably gradational.

There is limited information on the deeper formations in the Exmouth area.

2.3.1 Cape Range Group

The Cape Range Group comprises several geological units, which are exposed on Cape Range. These consist of friable to dense fossiliferous limestone and marl with local interbeds of sand. Some of the pure and friable limestone has undergone extensive solution with caves and large solution openings having developed, which is termed a karst environment.

Trealla Limestone - this unit is from 0 to 20 m thick near Exmouth and contains most of the accessible sink

holes and other karst features such as caves, pipes and solution cavities.

Tulki Limestone - is some 80 m thick. Karstic features are also strongly developed, similar in nature to the overlying Trealla Limestone. The lower part of the unit is less consolidated and commonly silty and is very similar to the upper part of the underlying Mandu Limestone.

Mandu Limestone - Layers of marl clay-like calcareous sediment) occur in this unit which may act as barriers to water flow.

2.3.2 Birdrong Sandstone formation

The Birdrong Sandstone is a fine to coarse friable, pebbly and silty sandstone about 30 m thick and is found between 1 000 and 1 500 m below sea level on the North West Cape. It extends over an area of about 50 000 km^2 and forms the most extensive aquifer in the Gascoyne Groundwater Area (GGA).

2.4 Environment

Changing water levels and quality due to abstraction from the unconfined (Cape Range Group) aquifer system could potentially affect vegetation. Limited investigation concerning the flora of the Cape Range area has been undertaken, with assessment primarily focused on the higher plants. Keighery and Gibson (1993) recorded 630 species of vascular plants on the peninsula. However, there are no gazetted rare plant species in the Exmouth and Cape Range area.

Preliminary investigations of the fauna along the Cape Range Peninsula had been undertaken by the Western Australian Museum (Humphreys & Adams, 1991). These studies have shown initial evidence of rare stygofauna and troglofauna in the karst environment of the region. Further investigations into the karst environment and the subterranean fauna have been undertaken by the Water Corporation as part of the Consultative Environmental Review (Muir, 1995) and in consultation with the Department of Environmental Protection (Hamilton-Smith, 1998; Humphreys, 1994, 1996; etc,); however, only an elementary understanding of the complex ecosystem that sustain subterranean fauna exists.

Faunas that spend their entire life cycle in caves are known as troglobites and if they are of aquatic form then they are stygobites. They are usually pale, eyeless, with enhanced non-optic sense organs and lack the ability to control water loss. The Cape Range karsts contain cave fauna that form the richest and most diverse troglobitic community in Australia and possibly the world. The area contains entire classes, orders, families and genera known elsewhere only in caves on either side of the North Atlantic. The stygofauna community contains 26 species, with two fish and two shrimp species included. There are at least 41 troglobitic species and there are many species that are not troglobitic but whose presence in this arid region is dependent on the subterranean habitat (Humphreys, 1994). Investigation is continuing into the extent of stygofauna in Cape Range.

Cave fauna is affected by pumping from the Cape Range Group aquifer (the Trealla and Tulki Limestone). The ways in which abstraction may alter the stygofauna environment include:

- Direct mortality. Abstraction of groundwater can entrain stygofauna, resulting in a loss to the system. However, it is accepted that the total portion entrained compared to the overall population is small.

- The stygofauna taxa Isopoda, Syncarida and some Amphioda are only known to exist in the fresh water layer at the surface of the water table. As the fresh water layer is thin, continued pumping can result in mixing or saltwater intrusion (by ingression or upconing) that conceivably could damage this part of the ecosystem available for the stygofauna. While the remaining stygofauna can occupy a wide range of salinities, nothing is known of their other environmental requirements. Within the saltwater layer a complex physio-chemical environment may occur (as found on the western side of the Cape Range Peninsula) with numerous layers of hydrogen sulphide, anoxic conditions and strongly negative Redox values. Ignorance of the significance of this in Cape Range is complete (Humphreys, pers. comm.).

- Troglobitic faunas that exist in cavities above the water table rely on the high humidity present to restrict water loss. Changes in water levels and possibly water quality could effect the humidity of many caves under the North West Cape (Humphreys, pers. comm.). However, the high transmissivity of the karst system will limit any decline in water levels.

Groundwater resource management needs to ensure that these subterranean fauna are protected, with the precautionary principle observed. Therefore, it would be expedient to limit if possible, the quantity of water abstracted from the aquifer and the physical area in which pumping occurs. The proper management of wells is also necessary to restrict saline upconing.

2.5 Social environment

The town of Exmouth is a sub-regional centre serving the northern section of the Gascoyne region. Until early 1993 it was supported by the existence of the US Harold E. Holt Naval Base; however, since the departure of the U.S. personnel it has proven its potential to survive. The town of Exmouth has diversified into a tourism and service centre, which will be enhanced by the soon to be completed marina facility.

The population projections for the Exmouth town (Ministry for Planning, 1998) show an increase to a permanent population of 3 200 by the year 2027, compared to the 2 058 in 1996. If all potential projects in the area eventuate for the permanent population to expand to 3 800, with the population including visitors expected to be approximately 7 800 compared to the population with visitors around 3 900 currently. This population increase will require an equivalent increase in groundwater abstraction. Therefore, the Water Corporation is expecting an increase in water consumption from approximately 700 ML/annum to over 1 000 ML/annum over the same period (Halpern Glick Maunsell, 1992; Muir, 1995).

The region is also a rich source of fish, molluscs and prawns. The fishing and pearling industries have been an important part of the region's economy for many years.

The area's mining sector is very limited, though Whitecrest Mining is proposing to develop the limestone resource, which has the potential to supply both domestic and international markets.

The primary industry in the region is expected to be tourism, and eco-tourism is progressively playing a larger role. The areas of particular interest include the Ningaloo Reef and Cape Range National Park.

The Western Australian Planning Commission in conjunction with the Gascoyne Development Commission has completed a draft structure plan for the North West Cape. This plan provides the framework for State and local government decision making on development proposals, and will provide a level of certainty to the local community in terms of the type and scale of developments. Consequently all development proposals that require groundwater will need to comply with the concepts within the structure plan.

3. Hydrogeology

Forth (1973), Martin (1990), Allen (1993) and Colman (1994) have described the hydrogeology of the area. This knowledge is based predominantly on investigations for the Exmouth wellfield and wellfield extension.

The most important aquifer, containing the largest volume of fresh water, is the Cape Range Group aquifer. There is limited information on the Birdrong Sandstone aquifer, which contains predominantly saline water at large depths.

3.1 Cape Range Group aquifer

The Cape Range Group aquifer consists of the Trealla, Tulki and Mandu Limestone karst environment.

The general hydrological model for oceanic islands can be applied to the groundwater of the Cape Range Peninsula (Allen, 1993). In this model, saltwater lies under the freshwater lens contained in the limestone. This model indicates that the high transmissivity of the limestone in an arid environment together with increased groundwater abstraction may induce the saltwater interface to migrate inland. In Exmouth, the freshwater - saltwater interface is currently about 5 km inland from the coast (Fig. 6), which is a considerable distance inland. The fresh water layer varies from negligible thickness near the coast to approximately 200 m thick inland.

3.1.1 Recharge

Recharge to the unconfined aquifer is mainly by direct infiltration of rainfall. Indirect recharge occurs through the beds of ephemeral streams, which carry storm runoff from the Cape Range. Forth (1973) estimated that recharge to the area west of the wellfield is around 25 mm/yr or about 10% of average annual rainfall.

Preliminary chloride studies by the Water Corporation (Martin, pers. comm.) have indicated that recharge in Exmouth may be between 16% and 18%, based on new data derived from chloride input taken over three years. However, until this study is validated the more conservative estimate of 10% is utilised.

3.1.2 Groundwater flow

An accurate map of the regional water table has not been produced because of the high transmissivity, lack of monitoring wells and the coarseness of water level measurements. The gradient of the water table is about 1.7×10^{-4} near the Water Corporation wellfield and gradually increases, to about 3.2×10^{-4} near Cape Range. The reduced gradient near the coast is representative of the karst features that permit easy passage of water through the limestone.

Flow direction is from the Cape Range anticline out to the sea, from west to east on the eastern side of the Range. Conversely, it would be expected that the flow is from east to west on the western side of the Cape Range.

Forth (1973), supported by Martin (1990 and 1992) and Colman (1994) utilised two methods to calculate the amount of groundwater available in the Exmouth area. Initially the transmissivity of the aquifer was estimated to be about 2 720 m^2/day which, coupled with the hydraulic gradient, results in a throughflow of approximately 460 kL/day/km along the length of the Range (equating to 168 ML/year/km). The weakness of this approach is that hydraulic testing is not necessarily appropriate in a karst environment, owing to large variations in hydraulic conductivity as a result of solution cavities.

The second method undertaken by Forth was to utilise a recharge rate of 10% of the annual rainfall over the recharge area. Due to the highly porous nature of the terrain in Exmouth, this includes all areas up gradient of the Water Corporation production wells. At the time of Forth's publication the wellfield was operated by the Public Works Department, and had an estimated recharge area of 54.4×10^6 m^2 over the 8 km length of wellfield. The resulting throughflow is 177 ML/annum/km. This value is comparable to the value calculated using Darcy's equation. These figures

support the assumption that the throughflow is of the order of 170 ML/annum/km coast.

Further work with rainfall chloride analysis has shown evidence of rainfall recharge as high as 16 to 18% (Martin pers. comm.). The resultant recharge could therefore be in the order of 280 to 320 ML/year/km. However, chloride analysis can yield dubious results when significant surface water runoff occurs following rainfall events. Until further work is done into the chloride analysis the more conservative throughflow estimate of 170 ML/yr is used.

Urbanisation generally increases groundwater recharge through the increased infiltration of rainfall placed in soaks and compensating basins. This effect, however, is expected to be small in Exmouth, as the area of the town site is small on a regional scale and the highly variable rainfall patterns in Exmouth ensure that the additional recharge is negligible. The major users of groundwater are situated up gradient or away from the town of Exmouth and therefore any additional recharge from the town site will not be available.

3.1.3 Discharge

Groundwater is discharged by abstraction from the wellfield, by evapotranspiration from vegetation on the coastal plain and by flow to the ocean and several springs along the coast.

3.1.4 Groundwater quality

The groundwater salinity is generally 400-600 mg/L TDS immediately to the east of the Cape Range anticline increasing eastwards towards the saltwater interface. Groundwater salinity to the north of Exmouth is brackish to saline.

In the existing Water Corporation wellfield, the groundwater salinity has increased, and since 1982 up to 60% of the wells have periodically produced water with salinity greater than 1 000 mg/L TDS. This is due to high instantaneous pump rates, inadequate spacing between wells and reduced long term rainfall. The investigations for the extension further south of the wellfield have shown that the quality of groundwater is in the range 500 to 700 mg/L TDS.

In the town of Exmouth there is evidence of deteriorating groundwater quality. In 1988, 33% of the private wells sampled gave salinities above 2 500 mg/L TDS; in 1991 this had increased to 55% of wells sampled, after which a moratorium on further groundwater abstraction was set. However, declines continued with 63% above 2 500 mg/L TDS in 1992 and 81% in 1993. Since then there is some evidence of improving salinities, with 70% in 1994 and 53% of all private wells sampled having salinities above 2 500 mg/L TDS in 1996. In 1997 fewer private wells were monitored, which saw the trend increased to 65% of private wells having salinity greater than 2 500 mg/L TDS. This trend can be seen in Figure 7, which illustrates the average salinity of private wells in Exmouth.

The reason behind these increases in salinity is difficult to determine, as water quality sampling from private wells is irregular. It is expected that the increases in salinity are due to the upconing of brackish water from below the freshwater lens as there is no distinct geographical trend to the increased salinity. This can result either from wells being screened too deep in the aquifer and the production zones intersecting the underlying brackish zone, or from groundwater abstraction at high rates for short periods of time, inducing saline water and exacerbating the problem.

The improvement in the three years 1994-1996 can be attributed to several factors:

- Several high rainfall events.
- The moratorium taking effect, with less new private abstraction taking place.
- Departure of US personnel from Harold E. Holt Naval Base, therefore lower consumption of water from both their and the Water Corporation's wellfields. The US personnel were heavily subsidised for their water and known for their water wastage. Their departure has resulted in a drastic decrease in the wastage of water.
- Decommissioning of Water Corporation wells up gradient of the town site.
- Increased salinities in private wells have necessitated better management from the owners, or the increased salinity has resulted in the owner no longer wanting to draw groundwater.

3.2 Birdrong Sandstone aquifer

The Birdrong Sandstone aquifer is a fine to coarse friable sandstone about 30 m thick. It extends over an area of about 50 000 km^2 and it forms the most extensive aquifer in the Gascoyne Groundwater Area (GGA). It is locally exposed along the eastern edge of the Gascoyne coastal lowland, but for most of its extent and including the Exmouth Groundwater Subarea it is confined beneath sediments of low permeability. Therefore artesian conditions occur in the subarea, but fresh groundwater is limited to the recharge areas outside of Cape Range.

Relatively large well yields of saline quality (20 000 to 30 000 mg/L TDS) water can be obtained, however well depths of over 1 000 metres are required near Exmouth (Hocking, 1987). There is limited information on this formation in the Exmouth Groundwater Subarea. Oil exploration on the Cape has provided some information on this formation (cited Halpern Glick Maunsell, 1992). Drill stem tests were carried out on this formation from Cape Range Wells No. 1 & 2. A water sample was taken between 1 083 and 1 088 m depth from Cape Range No. 1, with a chloride concentration of 19 800 mg/L TDS. In Cape Range No. 2, a sample taken at depth of between 1 111 and 1 115 m gave groundwater salinity of 33 038 mg/L TDS.

There is no well in the peninsula that is screened in the Birdrong Sandstone aquifer and therefore no studies have been carried out to estimate the groundwater availability of this aquifer. Because of its depth below the surface and the saline water it contains, it is unlikely to be utilised as a source of water in the future.

Because of these factors the Birdrong Sandstone is not likely to be utilised as a groundwater resource and therefore is not considered further in this management plan.

4. Groundwater use

The order for 'priority beneficial use' for groundwater in the Exmouth Groundwater Subarea is:

1. environment;
2. public water supply;
3. private and community use.

4.1 Ecological Water Requirements and Environmental Water Provisions

The Water and Rivers Commission has developed a methodology for allocating water quantity which includes the determination of Ecological Water Requirements (EWR).

The principles used in this process are applied to the Exmouth Groundwater Subarea. Ecological Water Requirements are the water regime required by the environment to maintain its current ecological values. This can include quantity and duration and applies both spatially and temporally.

Ecological Water Requirements are determined by identification of values and/ or beneficial uses of water dependent components of the environment, and the establishment of water quality and levels for ecosystem protection. The water quality and water levels define the EWR. Generally EWRs can be defined using the following process:

- Identification of groundwater dependent ecosystem components (wetlands, dependent vegetation, subterranean fauna);
- Selection of representative ecosystem components for which environmental water level requirements will be set to ensure appropriate protection for the region;
- Identification of values of those parts including social and environmental aspects;
- Determination of management objectives based on values/ beneficial uses; and
- Establishment of water level regimes for each ecosystem component that satisfy the identified management objectives, and definition of the EWR.

The EWR identified in this manner is the optimal level of water provision for the environment. The actual water provisions that have been made also take into consideration other requirements for the groundwater. Environmental Water Provision is that part of the Environmental Water Requirement that can be met and is provided after consideration of economic and social issues. Ideally the EWPs and EWRs will be the same.

Using the above approach, Ecological Water Requirements for the Exmouth Groundwater Subarea take account of the following:

- The stygofauna and troglofauna are the dominant groundwater dependent ecosystems;
- No groundwater dependent Vegetation communities have been identified.

There is difficulty in determining EWRs for the subterranean fauna for two major reasons:

1. The subterranean fauna has been found throughout the North West Cape whenever access to the groundwater aquifer is possible. However, this spatial distribution is limited to wells and known caves which excludes a large portion of the coast. It could be possible to select sites that are representative of environmentally significant sites from the current sites, however this will not ensure appropriate cover for the whole region.
2. It is not known what water level and water quality values should be maintained in the Exmouth Groundwater Subarea to protect the majority of the stygofauna, as the effect of changes in water levels and quality have not been completely studied for subterranean fauna. There is uncertainty associated with the effect of water level and water quality changes upon the subterranean fauna. Nevertheless this lack of scientific certainty can not be utilised as a basis for not setting an allocation limit and consequently preventing environmental degradation. The precautionary principle is therefore utilised to assist in the setting of Environmental Water Provisions. It is proposed that water levels and water quality be maintained at their present levels.

As described in Chapter 2 various impacts on stygofauna have been investigated as part of the Consultative Environmental Review undertaken by the Water Corporation for the extension of the town water supply scheme. The managed removal of groundwater from the unconfined aquifer will not deplete the system of significant stygofauna populations and energy sources. Conversely, improperly managed groundwater abstraction may affect the fresh/ brackish/ saline water interface, which could affect the population ratios of stygofauna. Consequently, any evidence of saline upconing is an indication that this interface is being compromised.

It is considered that due to the high transmissivity of the Cape Range Group aquifer the levels of abstraction will not affect water levels. Therefore to maintain water quality standards at the current levels, it is proposed to reserve 70 ML/annum/km (40% of the available throughflow) for environmental water provisions.

If the salinity of a Water Corporation scheme well exceeds 1 000 mg/L TDS, then pumping should be reduced from this well. If the salinity continues to increase then pumping may ultimately need to cease. If further monitoring indicates inland movement of the saltwater interface then production from the wells in the area should be reduced and ultimately cease if no improvement is detected.

If the annual salinity monitoring in private wells is above the historical maximum then the licensee should be encouraged to review and modify their pumping regime. Furthermore, if private wells in an area all exhibit an increase in salinity then consideration should be given to reducing or even ceasing pumping from all wells.

The Water and Rivers Commission utilises an adaptive approach to the management of groundwater resources. This is based upon setting an allocation limit, monitoring the effects of abstraction and then utilising any new information with modelling and best scientific knowledge to adapt a new allocation limit (Fig. 12).

Stringent regional groundwater monitoring will need to be implemented to examine any changes in water quality or levels that may affect the subterranean fauna. This monitoring will provide research data to update Ecological Water Requirements and Environmental Water Provisions.

4.2 Public water supply

Public water supply by the Water Corporation is the major user of groundwater within the Exmouth Groundwater Subarea with 63% of the total allocation. Abstraction for the town water supply has averaged 755 ML per year from 1964 to 1987 (Fig. 8). For the period 1987-1992, the total annual abstraction had increased to an average of 895 ML per annum. With the departure of the US personnel in 1993 the annual abstraction decreased to 726 ML for 1992 - 1993. Abstraction remained relatively constant until 1995 - 1996 when it dropped again to 580 ML, since when, it has remained constant.

As Exmouth goes through a period of readjustment, it is unclear whether annual demand will remain at this level. The departing US naval personnel, who had their water heavily subsidised, are being replaced by permanent residents who have to pay for their domestic water, therefore, it is expected that a decrease in excessive water use will continue due to higher costs associated with higher consumption.

The current number of services in Exmouth is 866 (January 1996). The population projections for the Exmouth Town (Ministry for Planning, 1998) show an increase to a permanent population of 3 200 by the year 2027, compared to the 2 058 in 1996. This population increase will require an equivalent increase in groundwater abstraction. Therefore, the Water Corporation is expecting an increase in demand from 580 ML/annum to over 1 000 ML/annum. Initially, this increase will need to be covered by increases in groundwater abstraction (to 1 029 ML/annum) by the extension of the existing wellfield.

This extension was approved in May 1996, with the Water and Rivers Commission issuing a licence for the increase to 1 029 ML/annum in March 1998.

4.3 Private water supply

The Harold E. Holt Naval Base is the biggest private user of water in the Exmouth Groundwater Subarea, and has an allocation of 217 ML per annum. Learmonth air base is licensed to abstract 17 ML/annum, and has recently been granted a temporary licence for 229 ML/annum of brackish water to cover the upgrade of the air field.

Fishing is the next major groundwater user in the area with a total allocation of 137 ML/annum attributed to three licences. Other major allocations, by use type, include domestic (52.2 ML/annum, 67 licences), tourism (57.1 ML/annum, 5 licences), public amenities (48.3 ML/annum, 7 licences), parks and gardens (39 ML/annum, 9 licences), mining (19 ML/annum, 2 licences) and horticulture (8.5 ML/annum, 1 licence) (Fig. 9).

The total allocated abstraction from the subarea is therefore 1 029 ML/annum for public water supply and 824 ML/annum for private abstraction. From north of the town, where the Cape Range Group is brackish, to the southern boundary of the Exmouth Groundwater Subarea there is approximate 62 km of peninsula with about 6 200 ML of fresh to potable groundwater available[2], indicating that 30% of the groundwater has been allocated.

According to the 1997 licensed allocation[3] most of abstraction occurs in localised areas, predominantly around the town of Exmouth (Fig. 10). The total abstraction within the stretch of coastline between the Skipjack Cl on the northern extent of the town and Preston St to the south of town (AMGs 7 567 000 mN to 7 573 250 mN) amounts to 780 000 kL/annum. Over this portion of land the estimated safe yield is 620 000 kL/annum, suggesting that the area is over allocated.

The future town water supply scheme that has been proposed by the Water Corporation and approved by the EPA will help to elevate this localised abstraction (Fig. 11). The total abstraction within the stretch of coastline between Skipjack Cl and Preston St will be reduced to 620 000 kL/annum, equivalent to the estimated safe yield.

The above estimates assume that licensees utilise all of their licensed allocation. This is unlikely as many licensees do not utilise their full allocation and some remove their pumps due to elevated groundwater salinities.

[2] There is more throughflow available over the whole coast, however north of the town of Exmouth the groundwater is brackish to saline and has not been included in these calculations.
[3] The 1997 licensed allocation includes the actual pumping from the Water Corporation for the 1996 - 1997 period.

5. Monitoring program

The first groundwater monitoring program in the Exmouth region was carried out by the Public Works Department in 1972-73 and consisted of 29 wells, which were later utilised as production wells for the town. In 1975, this network was extended to 40 wells; later most of these were incorporated into the town water supply. The monitoring scheme is spread over 10 km, in a north-south direction along the Cape. Monitoring data from these wells is affected by the pumping regime. However, pumping has not significantly altered the water level, as drawdowns remain small due to the highly porous nature of the karst environment.

Private wells are another source of monitoring data, although monitoring has been haphazard since 1980. In 1991 an annual monitoring program was established for private wells, but during 1995 no samples were taken. These private wells are centred on the town of Exmouth and provide data on the effects of abstraction to the local aquifer in this high use area.

The Water Corporation is expected to provide additional monitoring wells when it converts former production wells into monitoring wells. Furthermore, two sets of Salt Water Interface Monitoring wells (SWIM wells) and four dedicated stygofauna observation wells have recently been constructed though no data has been processed. The expansion of the Water Corporation's monitoring program will dramatically improve the available data for the region.

5.1 Limitations of current program

Private wells are not monitored at regular intervals, and when monitoring is undertaken many of the wells are not sampled. Private wells have not been monitored systematically to facilitate the assessment of water quality trends in the Exmouth town area. If inconsistent monitoring continues then the usefulness of this data set is questionable.

Currently there are no wells dedicated exclusively to monitoring groundwater. The collected data is therefore affected by the pumping regime of the sample wells. With the decommissioning of the northern sector of the wellfield there should be provision to change the production wells into observation wells.

Groundwater monitoring is very limited over the Exmouth Groundwater Subarea. Most of the monitoring data available is from the region around Exmouth, from the production wells nearby and the private wells within the town. This covers approximately 20% of the coastline on the northern extension of Cape Range, leaving around 70 km of coastline with limited hydrogeological information.

5.2 Proposed monitoring program

The proposed monitoring program takes into account the deficiencies of the existing program and the high abstraction around the townsite.

The main change to the current program is limiting the number of private wells monitored, and ensuring that they are monitored annually. The private wells chosen for continued salinity monitoring are given in Table 5.1.

Table 2: Private wells that should continue to be monitored

Private wells to continue monitoring		
G70 518 200	G70 518 205	G70 518 214
G70 518 223	G70 518 224	G70 518 225
G70 518 228	G70 518 230	G70 518 232
G70 518 233	G70 518 234	G70 518 237
G70 518 242	G70 518 249	G70 518 250
G70 518 253	G70 518 255	G70 518 262
G70 518 267	G70 518 269	G70 518 270
G70 518 271	G70 518 272	G70 518 274
G70 518 276	G70 518 278	G70 518 280
G70 518 281	G70 518 282	G70 518 285

As part of the Consultative Environmental Review for the extension of the water supply wellfield the Water Corporation recommended that 17 wells (ex-production wells) be dedicated to water level monitoring. Also there are four dedicated stygofauna observation wells (DSO wells) and two sets of Salt Water Interface Monitoring wells (SWIM wells). Extraneous ex-production wells are to be securely capped which will restrict the access of pollutants to the aquifer.

The effect of the saltwater interface on subterranean fauna is poorly understood. The commissioning of two SWIM wells will enhance our understanding of the interface in the existing and new stage(s) of the scheme. A SWIM well constructed closer to the town would further enhance our understanding of the area, in particular the interaction between the Water Corporation wellfield and the private abstracters in town.

Data collected from wells should be as accurate as is practicable, to assist in correctly assessing the aquifer performance. Accurate data is even more important when wells are not monitored regularly, as is the case with the private licensees.

The location of the DSO, SWIM, and dedicated water level monitoring wells will provide a strategic set of monitoring wells. Developing a comprehensive monitoring program will enable research to be conducted into the effect of changes in water quality and water levels on the subterranean fauna.

If monitoring wells indicate decaying water quality then the appropriate action should be taken to rectify this, as outlined in Chapters 4 and 7.

The Water and Rivers Commission utilises an adaptive approach to the management of groundwater resources. The allocation of groundwater will need to evolve with improvements in the information base, any changes in regional land use and various other social demands. This requires a regular review of strategies, priorities, effectiveness and deficiencies, to produce adapted strategies in order to meet protection objectives (Fig. 12). In practical terms this results in the need for a regular review (annual) of the water quality and water level measurements attained from the private monitoring. If these indicate degradation of the aquifer that has resulted from the allocation limits set in this management plan, then this allocation plan and in particular the sustainable limits within it will need to be reviewed. Furthermore, in the longer term a review will need to be undertaken into all aspects of this allocation plan.

6. Groundwater availability

Groundwater availability, or long term safe supply, depends on a number of factors including recharge, maintenance of water levels, environmental water requirements, water quality and enhanced recharge. Over exploitation of the groundwater in the area could lead to the destruction of the fresh water lens, by up-coning from the deeper saline waters or by the inland propagation of the saltwater interface.

6.1 Cape Range Group aquifer

Most of the groundwater flow in the Exmouth area is from west to east originating at the Cape Range anticline. Recharge occurs continuously along the coast due to the highly porous nature of the karst environment.

On the western side of the Cape Range groundwater is expected to flow from east to west. However the geography of the area limits groundwater recharge on this side of the range. Most rainfall falls on the eastern side of the Cape Range. The recharge area is smaller on the western side than on the eastern side of the Range. The 'A' class Cape Range National Park covers most of the western side and because land use is restricted, the need for groundwater is limited.

6.2 Throughflow / recharge

Groundwater resources for allocation in the Exmouth Groundwater Subarea have been determined from an estimate of groundwater throughflow for the Cape Range Group Aquifer. Groundwater throughflow is estimated from the hydraulic gradient and transmissivity estimates for the Water Corporation wellfield and is reported as 460 kL/day/km (Martin, 1990). This equates to 170 ML/annum/km, which is comparable to estimates based on the wellfield catchment area and a recharge rate of 10% given by Forth (1973).

However, 40% of groundwater throughflow has been designated for Ecological Water Requirements for the protection of the stygofauna ecosystem and to maintain the saltwater interface beyond the eastern limits of Exmouth town site. The resultant throughflow available is therefore 100 ML/year/km of coastline for the eastern side of the Exmouth Groundwater Subarea.

6.3 Total availability

Due to the current level of use there is no further groundwater available for allocation in the Exmouth West, North and Town Subareas.

Conversely in the Exmouth Central Subarea there are limited quantities of groundwater available for further allocation.

Approximately 12 km south of Exmouth at the light air strip (AMG 7 560 000), within the Exmouth South Subarea, there is groundwater available. However there are licences in the region of Learmonth that would need to be taken into consideration.

6.4 Water quality

Water quality on the surface of the Cape Range Group aquifer is generally between 300 mg/L and 1 000 mg/L TDS. There is a risk that salinities may increase further through either the upconing of the lower lying saline water or the inland propagation of the saltwater interface.

7. Groundwater licensing process

7.1 Application for a groundwater licence

The process of issuing a groundwater well licence begins when an application on a prescribed form is received at a Water and Rivers Commission office. An application is required under the following circumstances:

- The well is defined as artesian under the *Rights in Water and Irrigation Act*; and
- The property on which the non-artesian well is to be situated is within a Groundwater Area proclaimed under the *Rights in Water and Irrigation Act.*

In either of the above circumstances, an applicant must gain approval, in the form of a groundwater well licence, to start to construct, enlarge, deepen, alter or draw water from any artesian or non-artesian well.

A person in breach of these requirements is liable to a fine.

There are circumstances where some groundwater usage is exempted from the provisions of licensing from non-artesian (unconfined) aquifers in specified Groundwater Areas proclaimed under the *Rights in Water and Irrigation Act.*

7.2 The approval process

Applications for a groundwater well licence in the Exmouth Groundwater Subarea are made to the Carnarvon Regional Office of the Water and Rivers Commission. In many cases, the Regional Office can directly approve and issue a groundwater well licence if the licence conforms to appropriate policies given in the Exmouth Groundwater Subarea Allocation Plan (1999). However, before a groundwater licence is issued, all other necessary planning (e.g. Exmouth Shire) and environmental (e.g. Department of Environmental Protection) approvals must have been granted. It is the licensee's responsibility to ensure all necessary approval have been granted.

In addition, the applicant may be required to submit to the Water and Rivers Commission either a copy of the Certificate of Title or a copy of a Lease Agreement for the property where the development is to occur.

A Letter of Intent may be issued by the Water and Rivers Commission to a groundwater licence applicant, before granting all other necessary approvals, if the proposed abstraction complies with policies in the Exmouth Groundwater Subarea Allocation Plan (1999). This letter does not authorise the applicant to proceed with abstraction of groundwater, but rather gives an assurance that a groundwater well licence will be forthcoming if all other necessary approvals from authorities are granted.

If an applicant is refused a groundwater well licence following the assessment procedure, or objects to a licence condition imposed by the Water and Rivers Commission, the applicant may within 30 days of notification of refusal, or the imposing of conditions, appeal to the Minister for Water Resources. The Minister is then required to direct an inquiry into the matter. A three-person inquiry panel, having heard all the evidence, makes a recommendation to the Minister. The Minister is not obliged to follow the recommendation. There can be no further appeal by either party. *However, in all circumstances the appeal is discussed informally with the applicant to attempt a solution that would avoid a formal appeal and inquiry.*

7.3 Water Resource Allocation Committee

The Water Resource Allocation Committee (WRAC) is a committee of the Water and Rivers Commission, constituted under the *Water and Rivers Commission Act.* It consists of a Board member of the Water and Rivers Commission, the Director of Policy and Planning and the Director of Regional Services at the Water and Rivers Commission.

The water resource functions of the committee are:

- To guide the Water and Rivers Commission, through the Director of Policy and Planning Division, on the development of its policies and operations in relation to the allocation and management of the use of water resources across the State, and

- To consider surface water diversion and groundwater abstraction licence applications that the Water and Rivers Commission proposes to refuse, and recommend refusal or other appropriate action to the Board of the Water and Rivers Commission.

WRAC reviews groundwater allocation plans and, following approval, forwards them to the Board of the Water and Rivers Commission for endorsement.

8. Allocation management issues

The general groundwater allocation guidelines and policies that apply to the Exmouth Groundwater Subarea are discussed in this chapter, and specific policies pertaining to the subareas are discussed in Chapter 9.

8.1 Groundwater allocation

8.1.1 Issue of groundwater well licence

All new groundwater well licences will be issued for a two-year period. Following this period, providing the licensee has met licence conditions, including satisfactory progress with development, and providing water is available, the licence may be renewed for up to a maximum of 10 years.

Construction of a well into the Cape Range Group aquifer must be done by an individual who holds a Class 1 Water Well Driller's Certificate issued by the Western Australian Branch of the Australian Drilling Industry Association.

8.1.2 Priority use of groundwater

In proclaimed Groundwater Areas controls are applied to limit abstraction to sustainable levels in accordance with the State's conservation strategy. Therefore regulatory controls are aimed at achieving the following:

- Maintaining abstraction from the aquifer at a level sustainable over the long term.
- Allocating the available resources for beneficial public and private purposes, while securing those environmental needs such as maintaining the karst environment for subterranean fauna.
- Sharing the groundwater resource in an equitable manner.

The order for 'priority beneficial use' for groundwater in the Exmouth Groundwater Subarea is:

1. environment;
2. public water supply;
3. private and community use;

Environment

Groundwater abstraction is generally not licensed in conservation areas, such as Cape Range National Park, which have been recommended for the conservation of flora, fauna and the local geography. The Department of Conservation and Land Management (CALM) have indicated that no major activity is planned on the western side of the anticline. Currently three low yielding wells are in operation there and it is unlikely that groundwater demand in the area will increase significantly.

On the western side of Cape Range freehold land does exist, north of the National Park, and it is therefore possible that groundwater abstraction will occur. However it is situated on low lying land that will predominantly yield brackish water for which there will be low demand. Fresh water availability has been set at the current level of abstraction on the western side of the Cape Range.

The majority of the known karst environment and troglobitic fauna occurs in an area that is currently not conservation zone. This requires that the environment be considered in the management of groundwater and has been given the priority use. The environment is given priority in the region because:

- Part of Ningaloo Reef is being built up above the discharge point of the groundwater flow system that originates in Cape Range.
- The young age of the karst environment (there may be no comparable karst environment in the world).
- The richest and most diverse troglobite community in Australia and most likely in the world.

Evidence is available (Keighery, 1993; Humphreys, 1996) that stygofauna can survive in many extremes of

the groundwater ecosystem. However, the precautionary principle is required for the effective management of the groundwater resources.

The major limit to groundwater abstraction in relation to the subterranean fauna of the North West Cape, is the maintenance of the saltwater interface. Proper well management should be encouraged to prevent upconing and saline intrusion that would result in a breakdown of the fresh water lens.

Consequently, if the annual salinity monitoring in private wells is above the historical maximum then the licensee should be encouraged to review and modify their pumping regime. Furthermore, if many private wells in an area exhibit an increase in salinity then consideration should be given to reducing or even ceasing pumping from all wells.

As described in section 4.2 the precautionary principle has been utilised to limit any degradation of environmental values that may be brought about by groundwater abstraction. Consequently this allocation plan limits abstraction in the subareas on the east of the Cape Range anticline to 60% of the average annual recharge.

All groundwater licence applications need to be considered with reference to the precautionary principle. Maintaining ecosystem processes within the karst environment provides the means of protecting a broad range of environmental values. The Environmental Protection Authority believes the following key considerations are essential for the precautionary principle in Exmouth (EPA, 1998):

- Identifying the threats to the environment from the proposal;
- Identifying the seriousness of the threats;
- Establishing whether the threats are reversible or irreversible and over what time frames;
- Examining the likelihood of the threats occurring;
- Where there is reasonable scientific certainty and a high degree of confidence about the threats, establishing the most appropriate preventative measures that should be applied. Conversely, a high degree of threat to a high value environmental element with low level of knowledge of how to manage the impact would make the proposal environmentally unacceptable.

Public water supply

The Water Corporation has EPA approval to expand its wellfield to the south. As future scheme water demands increase above the proposed wellfield capacity further expansion to south is possible, though it may be cost prohibitive.

Private and community use

Private abstraction can detrimentally affect water quality as a result of two mechanisms.

Some individual users will over pump and cause a vertical movement of saline groundwater. This may be due to the pump inlet of a well being set too close to the fresh water/ brackish water interface and/or from operating at a high abstraction rate for a short period of time. This is a major problem in Exmouth, as the fresh water lens that most of the wells are screened against is only several metres thick.

Examination of well logs shows that most of the private wells were constructed to between 2 and 7 m below the water table and on average 5 m. The freshwater lens is negligible near the coast, but increases in thickness to between 7 m and 25 m towards the western edge of the town.

Dagan and Bear (cited in Domenico and Schwartz, 1990) suggested that the upconing of the saline wedge due to pumping will be stable for a value of 30% of the difference between the pumping level and the depth to the interface. Therefore, the distance between the pumping level (just above the bottom of the screen) and the interface is between 2 and 20 m on average. This results in a maximum possible upconing of between 0.66 m and 6.6 m, which according to the Ghyben-Herzberg relationship will result from a drawdown of between 2 cm and 16 cm. Consequently, pump rates have to be low to avoid this drawdown.

Wells situated close to the coast will be unable to prevent saline upconing. However, future wells constructed further from the coast should meet the following requirements:

- Well holes should only be constructed into the first three metres of the aquifer. As there is limited seasonal variability in water levels, since the water table is controlled by sea level, wells are unlikely to go dry.

- Low yielding wells should be installed.

The other mechanism causing degradation of groundwater quality is the horizontal inland movement of saline water. This occurs when the combined abstraction over a portion of the coast is too great, so that fresh water throughflow can not maintain the saltwater wedge. This allocation plan has set the maximum sustainable limit to 100 ML/annum/km of coast. If this value is breached for an extended period of time then the saltwater wedge could propagate inland. This is unacceptable for the long term sustainability of the resource.

8.2 Licensing conditions

A number of conditions are normally applied to a groundwater well licence. These can be of a general nature, or specific to a particular licence. Licensing conditions specific to subareas are listed in the Fact Sheets (Chapter 9). The following condition applies to all licences:

- All licences shall stipulate an annual groundwater allocation.

8.2.1 Cement grouting

When a well is drilled through the Cape Range Group aquifer into the underlying aquifer, inter-aquifer groundwater flow may occur, resulting in deterioration of groundwater quality. These wells should be cement grouted, at the owner's expense, to prevent the intermixing of groundwater from the aquifers. Grouting also assists in stabilising the well and increasing its life by reducing casing corrosion.

Construction of a well requiring cement grouting must be done by an individual who holds a Class 2 Water Well Driller's Certificate issued by the Western Australian Branch of the Australian Drilling Industry Association.

8.2.2 Hydrogeological assessment

In locations with limited hydrogeological data, applicants requiring significant quantities of water may be asked to carry out hydrogeological assessments, including groundwater monitoring, to investigate the sustainability of available resources. This report is to be completed by a professional in the field of hydrogeology, employed at the applicant's expense. The report will need to assess the possible local and regional impacts of such abstraction on the hydrology, the environment and other groundwater users.

In the Exmouth Groundwater Subarea these reports are required for proposed projects requiring equal to or greater than 10 000 kL/annum of potable groundwater.

8.2.3 Metering

Metering is required in all subareas for allocations greater than 5 000 kL/annum (5% of available throughflow), due to the limited availability of groundwater. This policy should be enforced as licences approach renewal.

8.2.4 Water use efficiency

Water use efficiency measures could significantly enhance the long term viability of the current groundwater resource. The Water and Rivers Commission has approached Dr Stuart White to prepare a preliminary study into the potential for water resource use efficiency in Exmouth. It is anticipated that the efficient use of groundwater by the current users will free up water that will primarily alleviate over allocation (if it exists) and secondly allow further water for the development of the town and surrounding shire.

Existing and potential applicants for groundwater licences should be made aware that groundwater is an important resource and should be used efficiently. Those planning to use significant volumes of groundwater may be required to demonstrate that water conservation methods have been considered and will be implemented where possible.

8.3 Groundwater quality

Groundwater quality is affected in two ways. One is the introduction of inferior quality water, and the other pollution.

The introduction of inferior quality water is caused by the over abstraction of groundwater, dealt with in previous sections.

Groundwater pollution is caused by activities such as waste discharge by industry, agricultural activities, human waste disposal, or storage tank leakage. There are two types of groundwater pollution:

- Point Source (e.g. petrol tanks), and
- Diffuse sources (e.g. fertilisers)

Both types of pollution are believed to be limited in the Exmouth Groundwater Subarea. Further information can be found in the Exmouth Water Reserve - Water Source Protection Plan (Tomlinson, 1997).

The karst environment is particularly susceptible to the introduction of pollutants. The high permeability of the landscape ensures that any pollutants in contact with the ground will leach into the aquifer. Evidence from other parts of the world shows that subterranean fauna are particularly susceptible to groundwater contamination (Humphreys pers. comm.).

A feature of groundwater pollution is that once it has occurred it can rarely be rectified without considerable expense, and therefore prevention is the best management strategy.

8.4 Effective subarea management

To assist with the management of the groundwater resources, the subarea has been further divided into five: Exmouth West, Exmouth North, Exmouth Town, Exmouth Central and Exmouth South Subarea (Fig. 2). These areas essentially comprise a northern zone of three subareas that are heavily utilised and require careful management, a western area where restricted land use will limit groundwater abstraction and the southern area that is currently under utilised with respect to groundwater abstraction.

The Exmouth South Subarea is between the southern boundary of the Exmouth Subarea and approximately 12 km south of Exmouth (AMG 7 560 000 mN) near the light airstrip. Further north of this point to where Reid St crosses Murat Rd (AMG 7 570 000 mN) is the Exmouth Central Subarea. North of this point to the northernmost point of the town, approximately Skipjack Close (AMG 7 573 250 mN), is the Exmouth Town Subarea. From here to the tip of the North West Cape is the Exmouth North Subarea (Fig. 2).

The Exmouth West Subarea has been defined as that portion west of the North West Cape anticline. However, the understanding of the groundwater system on the west coast is very limited and no accurate allocation estimate can be made. Therefore groundwater availability has only been calculated for the east coast. This is viewed as consistent with the policy of preserving the west coast of the North West Cape (Ministry for Planning, 1998; Environmental Protection Authority, 1998) and the land use restrictions associated with the Cape Range National Park. This policy would need to be reviewed if either our understanding changes or the current government policy is reviewed.

The characteristics of the Cape Range Group aquifer in the Exmouth North, Town, Central, West and South Subareas are summarised in the next chapter, with a focus on the following points:

1. Hydrogeology
2. Groundwater resources and availability
3. Groundwater use
4. Groundwater licensing policy
5. Groundwater monitoring, and
6. Recommendations for changes

9. Management by subareas

9.1 Exmouth North Subarea

Exmouth North Subarea Description	
Area	11 897 ha
Council/Shire	Shire of Exmouth
Comments	Covers the tip of Cape Range, north of 7 573 250 mN

Hydrogeology	
Cape Range Group aquifer	• Thin fresh water lens on saline water. • High porosity. Groundwater levels only marginally above sea level.

Groundwater Resources	
General water quality	Fresh to saline, depending on depth / location
Total fresh groundwater available	200 000 kL/annum
Existing scheme use	Nil
Future scheme use	Nil kL/annum
Current private use	258 000 kL/annum
Unallocated resources	**Over allocated (-58 000 kL)**

Groundwater Use	
Cape Range Group aquifer	• Harold E. Holt Naval Base 217 ML/annum. • Other major uses: tourism.
Constraints	• Cape Range Group - proximity to the ocean, the location of the saltwater interface plus the thin fresh water lens. Protection of the karst flora and fauna.

Groundwater Monitoring			
Aquifer	**Well**	**Potentiometric surface and range (m AHD)**	**Salinity (mg/L TDS)**
Cape Range Group	Nullagine No1	370, 2 m range	400, in 1995
	Mulga Mines	370, 2 m range	500, rising
	Nullagine Lot 106	370, 2 m range	1 000, rising

Groundwater Licensing Policy	
General Policy	• All abstraction in Cape Range Group must be licensed. • Licensee to install meters if allocation exceeds 5 000 kL/annum. • No new allocations from the Cape Range Group. • Applications for saline water will be considered on their merit. • If salinities increase in any particular well the licensee should limit the yield from that well.

Recommendations
Monitoring should continue from private abstractors

9.2 Exmouth Town Subarea

Exmouth Town Subarea Description	
Area	3 515 ha
Council/Shire	Shire of Exmouth
Comments	Covers the town site of Exmouth

Hydrogeology	
Cape Range Group aquifer	• Thin fresh water lens on saline water. • High porosity. Groundwater levels only marginally above sea level.

Groundwater Resources	
General water quality	Fresh to saline, depending on depth / location
Total fresh groundwater available	300 000 kL/annum
Existing scheme use	298 600 kL/annum
Future scheme use	-121 600 kL/annum
Current private use	133 450 kL/annum
Unallocated resources	**Over allocated (-10 450 kL[4])**

Groundwater Use	
Cape Range Group aquifer	• Mainly water supply: Water Corporation 298 ML/annum reduced to 177 ML/annum. • Other major uses are domestic, amenities and tourism.
Constraints	• Cape Range Group - proximity to the ocean, the location of the saltwater interface plus the thin fresh water lens. Protection of the karst flora and fauna.

Groundwater Monitoring

Aquifer	Well	Potentiometric surface and range (m AHD)	Salinity (mg/L TDS)
	E 1	0.5 m, stable	1 500, rising in 1994
	E 2	0.5 m, stable	1 400 stable
	E 3	0.6 m, stable	1 500, stable
	E 4	0.4 m, 1 m range	1 100, stable
	E 5	0.2 m, stable	1 200, in 1992
	E 7	-1 m, 1 m range	1 100, stable
	E 8	0.2 m, stable	1 000, in 1992
	E 9	0.1 m, stable	800, stable
	E 10	0.7 m, stable	900, stable
	E 12	0.3 m, stable	1 300, slight decline
	E 13	0.5 m, stable	1 200, stable
	E 14	0.7 m, stable	1 200, slight rise
	E 15	0.5 m, stable	1 100, in 1995
	E 16	0.1 m, 1 m range	1 300, slight rise
	E 17	0.3 m, stable	700, stable
	E 18	0.8 m, stable	500, slight decline

[4] Includes the future reduction in scheme use. Current unallocated resources is –132 050 kL.

Groundwater Monitoring (continued)			
Aquifer	**Well**	**Potentiometric surface and range (m AHD)**	**Salinity (mg/L TDS)**
	E 19	0.1 m, 1 m range	800, stable
	E 20	0.4 m, stable	1 200, slight rise
	E 43	0.3 m, stable	900, stable
	E 44	0.4 m, stable	600, slight rise

Groundwater Licensing Policy	
General Policy	• All abstraction in Cape Range Group must be licensed. • Licensee to install meters if allocation exceeds 5 000 kL/annum. • No new allocations from the Cape Range Group. • Applications for saline water will be considered on their merit. • If salinities increase in any particular well the licensee should limit the yield from that well.

Recommendations
Monitoring should continue from Water Corporation production wells and private abstractors

Note: Wells prefixed with E are part of the Exmouth Town Water Supply Scheme. The recently completed stygofauna investigation wells have not been included here, as data from these wells is very limited.

9.3 Exmouth Central Subarea

Exmouth Central Subarea Description	
Area	19 003 ha
Council/Shire	Shire of Exmouth
Comments	Covers the region of Cape Range, between 7 560 000 mN and 7 570 000 mN inland to the Cape Range anticline

Hydrogeology	
Cape Range Group aquifer	• Thin fresh water lens on saline water. • High porosity. Groundwater levels only marginally above sea level.

Groundwater Resources	
General water quality	Fresh to saline, depending on depth / location
Total fresh groundwater available	1 000 000 kL/annum
Existing scheme use	433 560 kL/annum
Future scheme use	418 440 kL/annum
Current private use	26 900 kL/annum
Unallocated resources	**Minimal 121 100 kL/annum**

Groundwater Use	
Cape Range Group aquifer	• Mainly water supply: Water Corporation 434 ML/annum.
Constraints	• Cape Range Group - proximity to the ocean, the location of the saltwater interface plus the thin fresh water lens. Protection of the karst flora and fauna.

Groundwater Monitoring

Aquifer	Well	Potentiometric surface and range (m AHD)	Salinity (mg/L TDS)
	E 21	0.8 m, stable	1 500, stable
	E 23	0 m, stable	1 200, slight rise
	E 25	0.4 m, stable	1 200, slight rise
	E 26	0.4 m, stable	900, slight decrease
	E 28	0.6 m, stable	1 100, rising to 1989
	E 29	0.4 m, stable	700, slight decrease
	E 30	0.4 m, stable	800, stable
	E 31	0.6 m, stable	600, slight increase
	E 32	0.5 m, stable	1 000, stable
	E 33	1.0 m, stable	900, stable
	E 34	0.4 m, stable	700, stable
	E 35	0.5 m, stable	500, slight increase
	E 36	0.6 m, stable	1 000, in 1995
	E 37	0.4 m, stable	700, slight decrease
	E 38	0.5 m, stable	700, stable
	E 39	0.6 m, stable	600, stable
	E 40	0.2 m, stable	450, stable
	E 45	0.4 m, stable	600, stable
	E 47	0.5 m, stable	500, slight increase

Groundwater Licensing Policy	
General Policy	• All abstraction in Cape Range Group must be licensed. • Licensee to install meters if allocation exceeds 5 000 kL/annum. • Applications >1 500 kL/annum in Cape Range Group are considered on local availability, and the allocation should not breach the safety margin of 100 ML/annum/km of coastline. • Applications greater than 5 000 kL/annum should be forwarded to the Allocation Branch for review. • Applications greater than 10 000 kL/annum should be supported by a hydrogeological assessment. • Applications for saline water will be considered on their merit. • If salinities increase in any particular well the licensee should limit the yield from that well.

Recommendations
Monitoring should continue from Water Corporation production wells and private abstractors

Note: Wells prefixed with E are part of the Exmouth Town Water Supply Scheme. The recently completed stygofauna investigation wells have not been included here, as data from these wells is very limited.

9.4 Exmouth West Subarea

Exmouth West Subarea Description	
Area	82 824 ha
Council/Shire	Shire of Exmouth
Comments	Covers the region west of the Cape Range anticline, north of 7 560 000 mN

Hydrogeology	
Cape Range Group aquifer	• Expected to contain a thin fresh water lens on saline water. • Unknown porosity, though it is expected to be medium to high.

Groundwater Resources	
General water quality	Fresh to saline.
Total fresh groundwater available	Limited kL/annum
Existing scheme use	Nil
Future scheme use	Nil
Current private use	13 100 kL/annum
Unallocated resources	**No further allocation**

Groundwater Use	
Cape Range Group aquifer	• Main water user: Yardie Creek Caravan Park. • Other users are public amenities associated with the Cape Range National Park.
Constraints	• Cape Range Group - proximity to the ocean, the location of the saltwater interface plus the thin fresh water lens. Restricted land use within the Cape Range National Park. Protection of the karst flora and fauna.

Groundwater Monitoring			
Aquifer	**Well**	**Potentiometric surface and range (m AHD)**	**Salinity (mg/L TDS)**
Cape Range Group	None	N/A	N/A

Groundwater Licensing Policy	
General Policy	• All abstraction in Cape Range Group must be licensed. • Licensee to install meters if allocation exceeds 5 000 kL/annum. • No new licences are to be issued. • Applications for saline water will be considered on their merit. • If salinities increase in any particular well the licensee should limit the yield from that well.

9.5 Exmouth South Subarea

Exmouth South Subarea Description	
Area	90 582 ha
Council/Shire	Shire of Exmouth
Comments	Covers the southern region of Cape Range, south of 7 560 000 mN

Hydrogeology	
Cape Range Group aquifer	• Thin fresh water lens on saline water. • Geology and hydrogeology are presumed to be similar to the northern portions of Cape Range.

Groundwater Resources	
General water quality	Fresh to saline, depending on depth / location
Total fresh groundwater available	4 700 000 kL/annum
Existing scheme use	0 kL/annum
Future scheme use	0 kL/annum
Current private use	376 000 kL/annum
Unallocated resources	**Substantial 4 324 000 kL/annum**

Groundwater Use	
Cape Range Group aquifer	• Mainly used by the fishing industry. Kailis Brothers have two licences for 130 ML/annum. • The other user is Learmonth for water supply of 17 ML/annum. Plus a short term licence for the upgrade of the airport of 229 ML/annum.
Constraints	• Cape Range Group - proximity to the ocean, the location of the saltwater interface plus the thin fresh water lens. Protection of the karst flora and fauna

Groundwater Monitoring			
Aquifer	**Well**	**Potentiometric Surface or Range (m AHD)**	**Salinity (mg/L TDS)**
Cape Range Group	None	N/A	N/A

Groundwater Licensing Policy	
General Policy	• All abstraction in Cape Range Group must be licensed. • Licensee to install meters if allocation exceeds 5 000 kL/annum. • Applications >1 500 kL/annum in Cape Range Group are considered on local availability, and the allocation should not breach the safety margin of 100 ML/annum/km of coastline. • Applications greater than 5 000 kL should be forwarded to the Allocation Branch for review. • Applications greater than 10 000 kL should be supported by a hydrogeological assessment. • If salinities increase in any particular well the licensee should limit the yield from that well.

Recommendations
Currently there is very little exploration of the groundwater resources in this area, and no recorded groundwater monitoring. Therefore additional exploration and monitoring wells are required in the area.

10. Conclusions

10.1 Monitoring

10.1.1 Monitoring wells

The majority of wells that are regularly monitored in the Exmouth Groundwater Subarea are Water Corporation production wells. The other sources of monitoring data are private abstractors in the town of Exmouth, however monitoring has occurred irregularly since 1980. The current monitoring network consists of 179 wells, all located in the Cape Range Group aquifer. Currently there are no wells dedicated to monitoring in the Exmouth Groundwater Subarea, though a series of new wells have been constructed for this purpose by the Water Corporation. Data is stored in the SWRIS data base.

10.1.2 Limitations of current program

There are several major deficiencies in the current monitoring program.

Private wells are not monitored at regular intervals, and when monitoring is undertaken many of the wells are not sampled. Private wells have not been monitored systematically to facilitate an assessment of water quality trends in the Exmouth town area. If this practice of inconsistent monitoring continues then this data set will be rendered useless.

Currently there are no wells dedicated exclusively to monitoring the groundwater, with all wells affected by pumping. This results in the data collected being strongly influenced by the pumping regime of the wells in question. With the decommissioning of the northern sector of the wellfield there is provision to change production wells into observation wells. The Consultative Environmental Review for the expansion of the Water Corporation wellfield has included the commitment to monitor two sets of SWIM wells, four dedicated stygofauna observation wells (DSO) and seventeen dedicated water levels wells (converted from old production wells). These wells should include quarterly conductivity testing. This will assist in the establishment of baseline environmental data for the subterranean fauna of the region.

Groundwater monitoring is very limited the Exmouth West and South Subareas. Most of the monitoring data available is from the region immediately around Exmouth, from production wells and the private wells within the town. This covers approximately 20% of the coastline in the north of Cape Range, leaving around 42 km of coastline with limited hydrogeological information.

10.1.3 Proposed monitoring program

The proposed monitoring program takes into account the deficiencies of the existing program and the high abstraction of the Exmouth North Subarea.

The main change necessary to the current program is to limit the number of private wells monitored, and to ensure that they are monitored annually. The private wells chosen for continued salinity monitoring are given in Table 5.1.

Data collected from wells should be as accurate as is practicable, to assist in correctly assessing the aquifer performance. Accurate data is even more important when wells are not monitored regularly, as is the case with the private licensees.

10.1.4 Additional monitoring wells required

Additional exploratory drilling needs to be carried out in the Exmouth South Subarea to provide additional information about the Cape Range Group aquifer. This will be accomplished primarily as licensees develop the water resource and install the necessary monitoring networks.

The effect of the saltwater interface on subterranean fauna is poorly understood. The commissioning of two SWIM wells by the Water Corporation will enhance our understanding of the interface in Exmouth to the

east of the town. However, a SWIM well constructed closer to the town would further enhance our understanding of the area.

10.2 Aquifer performance

Cape Range Group aquifer

There is evidence of increasing salinities in the town of Exmouth before 1993, while the period 1994 to 1996 has given some sign that this trend may now be reversed. This is an indication that groundwater abstraction can be better managed, and it may indicate that the Exmouth Town Subarea is close to an allocation limit.

10.3 Groundwater availability

Throughflow has been calculated from Darcy's equation and is 170 ML/annum/km (Martin, 1990). Of this, 70 ML/yr/km is allocated to maintain the saltwater interface and Ecological Water Requirements (stygofauna). Therefore over the available 62 kilometres of coastline, which is perpendicular to the direction of groundwater flow, on the eastern side of Cape Range there is approximately 6 200 ML/yr of fresh groundwater available.

10.4 Groundwater allocation

Groundwater resources in the Exmouth North Groundwater Subarea are heavily utilised by the public water supply scheme. The total groundwater allocated throughout the groundwater subarea is 1 852 ML/yr, of which 1 029 ML/yr is for public water supply purposes. This results in a total remaining resource of 4 348 ML/yr.

Although there are substantial quantities of groundwater still available for use over the whole of the Cape Range, in the Exmouth North and Town Subareas there is at present no groundwater available due to the concentration of abstraction within a small portion of the aquifer (Table 10.1). Furthermore, the Exmouth West Subarea has limited groundwater available due to the limited hydrogeological data, high environmental values and restrictive land uses.

Table 1: Groundwater availability from the Cape Range Group aquifer

SUBAREA	GROUNDWATER AVAILABILITY (kL/annum)	ALLOCATED RESOURCES (kL/annum)	NUMBER OF LICENCES	REMAINING RESOURCES (kL/annum)	GROUNDWATER SALINITY
Exmouth West	Limited	13 100	3	Nil	Potable to Marginal
Exmouth North	200 000	258 000	4	-58 000	Potable to Marginal
Exmouth Town	300 000	310 450 *	73	-10 450	Potable to Marginal
Exmouth Central	1 000 000	878 900 *	15	121 100	Potable to Marginal
Exmouth South	4 700 000	376 000	5	4 324 000	Potable
TOTAL	6 200 000	1 631 000	100	4 569 000	

Note * this includes future groundwater allocations for public water supply.

10.5 Allocation policies

Licensing of all wells in the Cape Range Group aquifer is required, including all domestic wells (abstraction less than 1 500 kL/annum).

Metering is required in all subareas for abstraction greater than 5 000 kL/annum (5% of available throughflow), due to the limited availability of groundwater. This will currently require 20 licences to be covered by metering, which have a total allocation to pump 1 330 ML/annum. In this way it will exclude most wells used for domestic and stock purposes, which are less likely to over abstract, yet it does include the group of users who could over abstract by a significant degree. This policy should be enforced as licences approach renewal.

In the Exmouth North and Town Subareas groundwater allocation is above the availability. In this area further licences should not be issued.

In the Exmouth West Subarea the groundwater allocation limit has been set at the current level of use. In this area further licences should not be issued.

The expansion of the Water Corporation wellfield to 1 029 ML/annum is supported by this plan.

In order to reduce the risks of upconing it is advisable for the licensee to screen their wells in the upper sections of the fresh water lens and pump at a low rate. However, the Water and Rivers Commission should advise new applicants of the location and depth of existing wells in their vicinity, and then the new licensee may be advised to screen their well at a suitable depth to minimise upconing of saline water.

If the salinity of a Water Corporation scheme well exceeds 1 000 mg/L TDS, then pumping should be reduced from this well. If the salinity continues to increase then pumping may ultimately need to cease. If further monitoring indicates inland movement of the saltwater interface then the production from the wells in the area should be reduced and ultimately cease if no improvement is detected.

If the annual salinity monitoring in private wells is above the historical maximum then the licensee should be encouraged to review and modify their pumping regime. Furthermore, if private wells in an area all exhibit an increase in salinity then reduction or even the cessation of pumping from all wells should be considered.

Applications greater than 5 000 kL/annum should be forwarded to the Allocation Branch of the Water and Rivers Commission. All new applications need to be considered based on local availability with the allocation not breaching the 100 ML/annum/km estimated safe yield.

10.6 Other

All groundwater licence applications need to be considered in reference to the precautionary principle. Maintaining ecosystem processes within the karst environment provides the means of protecting a broad range of environmental values. The Environmental Protection Authority believes the following key considerations are essential for the precautionary principle in Exmouth (EPA, 1998):

- Identifying the threats to the environment from the proposal;
- Identifying the seriousness of the threats;
- Establishing whether the threats are reversible or irreversible and over what time frames;
- Examining the likelihood of the threats occurring;
- Where there is reasonable scientific certainty and a high degree of confidence about the threats, establishing the most appropriate preventative measures that should be applied. Conversely, a high degree of threat to a high value environmental element with low level of knowledge of how to manage the impact would make the proposal environmentally unacceptable.

Licensees drilling new production wells into the Cape Range Group or Birdrong Sandstone are required to log their wells and provide copies to the Water and Rivers Commission. This is required for the Cape Range Group aquifer in Exmouth South Subarea where the data is needed to increase the knowledge of the aquifer and assist in managing the groundwater resources.

It is important to note that there are no objections from the Water and Rivers Commission to a proponent wishing to abstract saline water from deeper in the Cape Range Group (or in the Birdrong Sandstone). The proximity of the ocean and the high permeability of the aquifer limit the drawdown of groundwater, which will therefore limit the mixing of different quality waters. However, the prospective licensee needs to satisfy other Commission licensing requirements.

This management plan should be reviewed if proposed groundwater abstraction in the Cape Range National Park is increased. Currently the Department of Conservation and Land Management has no intention of significant development in the park that will require groundwater.

Research should be carried out to establish a greater understanding of the effect that changes in water level and water quality have on subterranean ecosystems. Funding should be sought, and a methodology established as a matter of urgency. This would allow for a comprehensive management system for the groundwater resources to be implemented in the Exmouth region.

This management plan should be reviewed if further investigation undertaken into chloride analysis in the Exmouth area alters our understanding of throughflow.

This management plan should be reviewed if groundwater abstraction from the Exmouth South Subarea becomes significant, or if further groundwater investigation alters our understanding of this system.

10.7 Additional work required

Currently insufficient data exists to estimate the Ecological Water Requirements and Environmental Water Provisions for the subterranean fauna of the Cape Range Group aquifer. Additional monitoring work is required, this will include establishment of baseline data to help in the identification of acceptable environmental change. Also increased monitoring and investigation into the effects of regional and local drawdown(s) and the related water quality changes upon subterranean fauna and their habitat is required.

11. Commitments, desirables and implementation

The following are commitments by the Water and Rivers Commission and should to be implemented:

Commitments	Implementation	Time Frame
1. Separation of current Exmouth Groundwater Subarea into the following 5 subareas: • Exmouth West Subarea • Exmouth North Subarea • Exmouth Town Subarea • Exmouth Central Subarea • Exmouth South Subarea This is to be implemented on the Water Resources Licensing database, with the regional officers informed.	WRL Custodian Regional Officers	Upon Board approval
2. Licensing of all wells, including stock and domestic, is still required.	WRL Custodian	Current policy
3. Metering of allocations greater than 5 000 kL/annum.	Regional Office	Upon licence renewal
4. New private wells should be screened in the upper sections of the fresh water lens and pumped at low rates.	Regional Office	As groundwater licence applications are received
5. Applications for more than 5 000 kL/annum should be referred to the Allocation Branch for comment.	Regional Office	Upon Board approval
6. Provision of 2 SWIM wells, 4 dedicated stygofauna wells and 17 dedicated water level wells and continued monitoring as per operating strategy.	Water Corporation	Current policy
7. Groundwater monitoring is to be rationalised from 94 private well sites down to 30 private wells that are strategically positioned.	Regional Office	Started 1998
8. Internal review of water quality and water level measurements for any degradation of the Cape Range aquifer	Allocation Branch	Annual basis, after the monitoring of private wells.
9. Establish baseline environmental data, to enable the identification of acceptable levels of environmental change	Water Corporation & Water and Rivers Commission	Started 1998

10. An educational pamphlet should be produced to promote the policies of this document.	Allocation Branch/ Communications Branch	Upon Board approval
11. This plan will be replaced by the Gascoyne Groundwater Area Allocation Plan.	Allocation Branch	Upon completion of Gascoyne Allocation Plan.
12. This allocation plan should be reviewed if one of the following occurs: • Further investigations yield evidence of a difference in throughflow; • Abstractions in the Exmouth South Subarea or the Exmouth West Subarea are significantly increased; • Examination of data from monitoring wells increases our understanding of Ecological Water Requirements and Environmental Water Provisions for the North West Cape, particularly with respect to subterranean fauna.	Allocation Branch	As required.

The following items are seen as desirable and should to be implemented when they align with the Commission's strategic objectives.

Desirable	**Implementation**	**Time Frame**
1. Funding should be sought to investigate the effects of regional and local drawdown on the caves and troglobitic fauna within.	WRC	In line with strategic objectives of the WRC
2. Funding should be sought to investigate the effects of water quality changes on subterranean fauna.	WRC	In line with strategic objectives of the WRC
3. Funding should be sought for the construction of a SWIM well near the town	WRC	In line with strategic objectives of the WRC
4. Funding should be sought for further chloride analysis to investigate rainfall recharge of the aquifer.	Water Corporation & Water & Rivers Commission	In line with strategic objectives of the WRC
5. Investigate sites for exploratory drilling and monitoring in Exmouth South Subarea	WRC	In line with strategic objectives of the WRC

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Glossary

Abstraction	Pumping groundwater from an aquifer.
mAHD	Australian Height Datum. Height in metres above Mean Sea Level +0.026 m at Fremantle.
Allocation	The quantity of groundwater permitted to be abstracted by a well licence, usually specified in kilolitres/year (kL/a).
Aquifer	A geological formation or group of formations able to receive, store and transmit significant quantities of water.
Beneficial Use	The current or future uses for a water resource which have priority over other potential uses because of their regional significance to the community.
Confined Aquifer	An aquifer that is confined between shale and siltstone beds and therefore contains water under pressure.
Environmental Water Provisions	Actual allocation levels made after consideration of the economic and social requirements for the water. It may be equal to or less than the Environmental Water Requirements.
Environmental Water Requirements	Water level that will maintain current ecological values.
Evaporation	The vaporisation of water from a free-water surface above or below ground level, normally measured in millimetres.
Evapo-transpiration	A collective term for evaporation and transpiration.
Groundwater Area	An area proclaimed under section Area 26B of the *Rights in Water and Irrigation Act, 1914*.
Hectare (ha)	10 000 square metres or 2.47 acres.
Kilolitre (kL)	1 000 litres, 1 cubic metre or 220 gallons.
Potentiometric Level (surface)	Imaginary surfaces representing the total head of groundwater and defined by the level to which water will rise in a well.
Recharge	The downward movement of water that is added to the groundwater system.

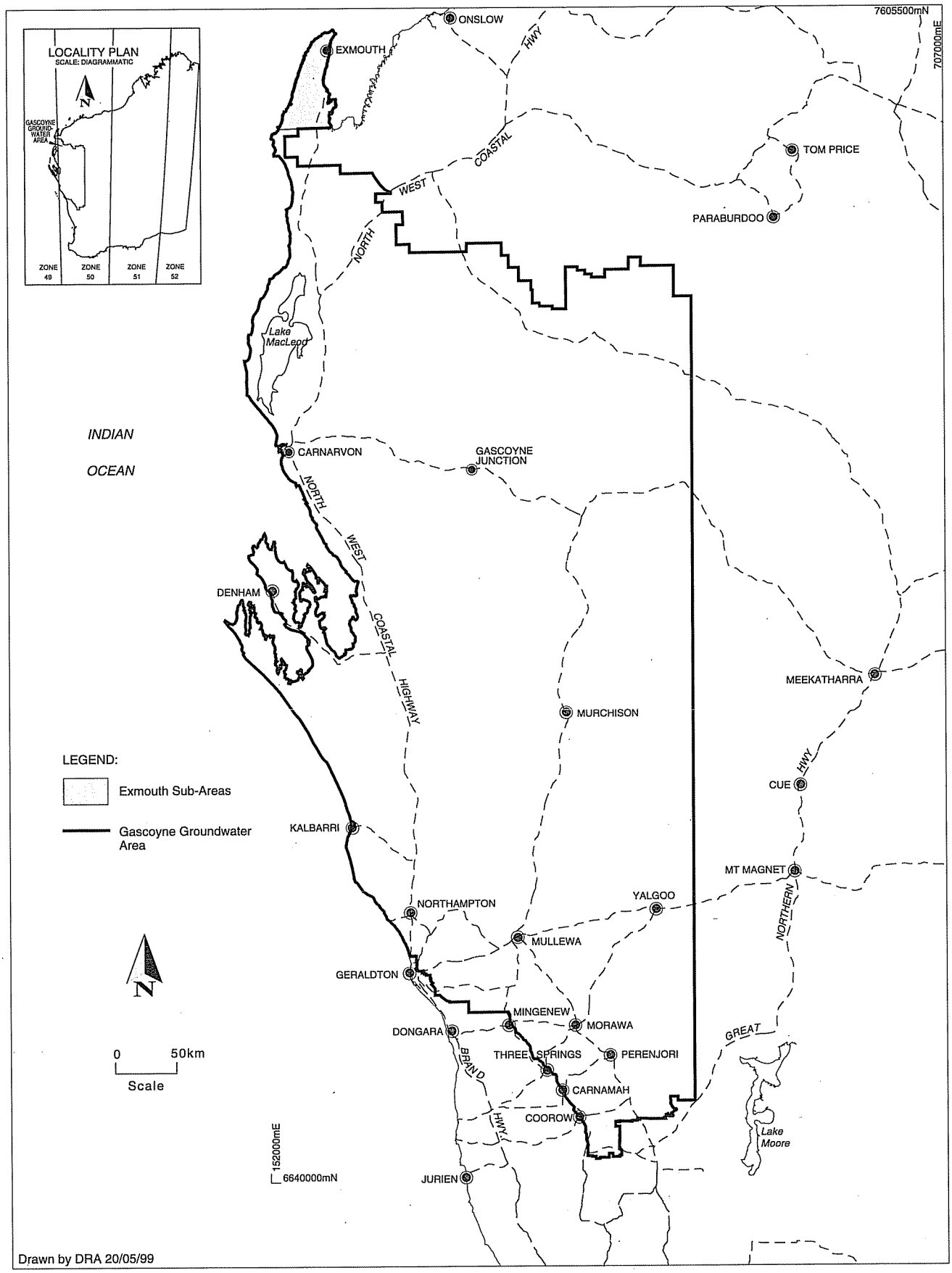

Figure 1: Location of Gascoyne Groundwater Area.

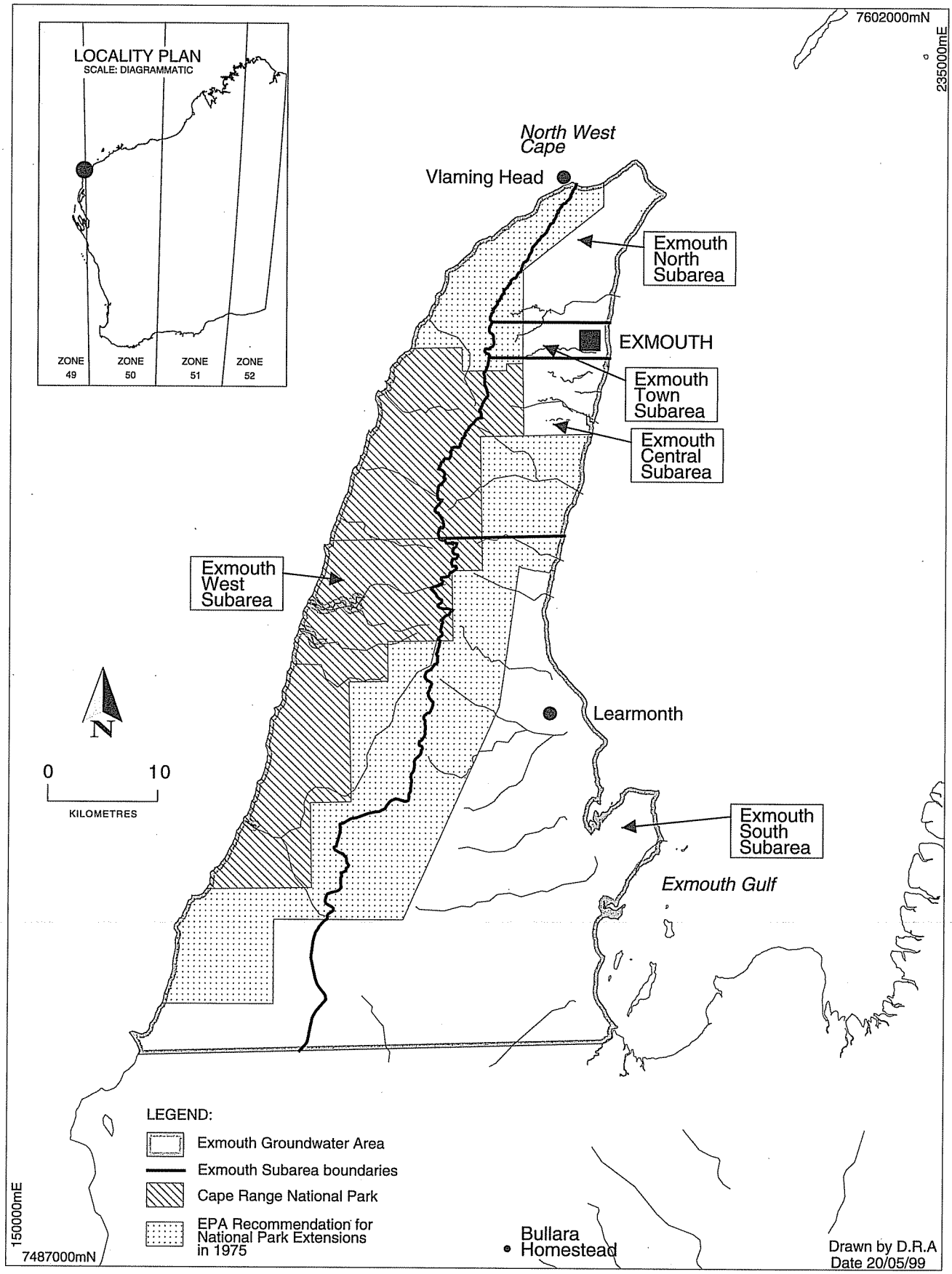

Figure 2: Exmouth Subarea boundaries.

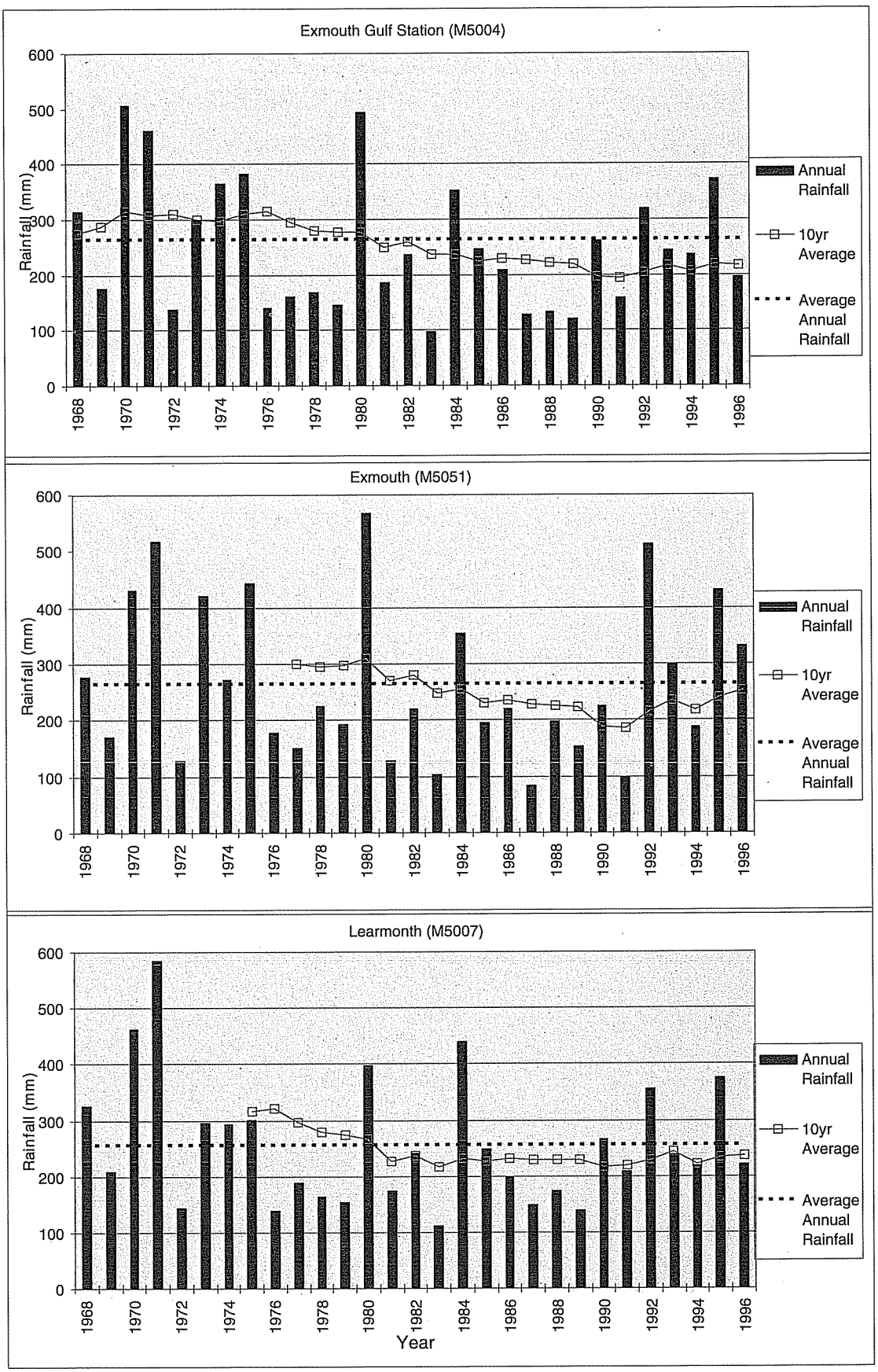

Figure 3: Annual Rainfall for three sites around the North West Cape

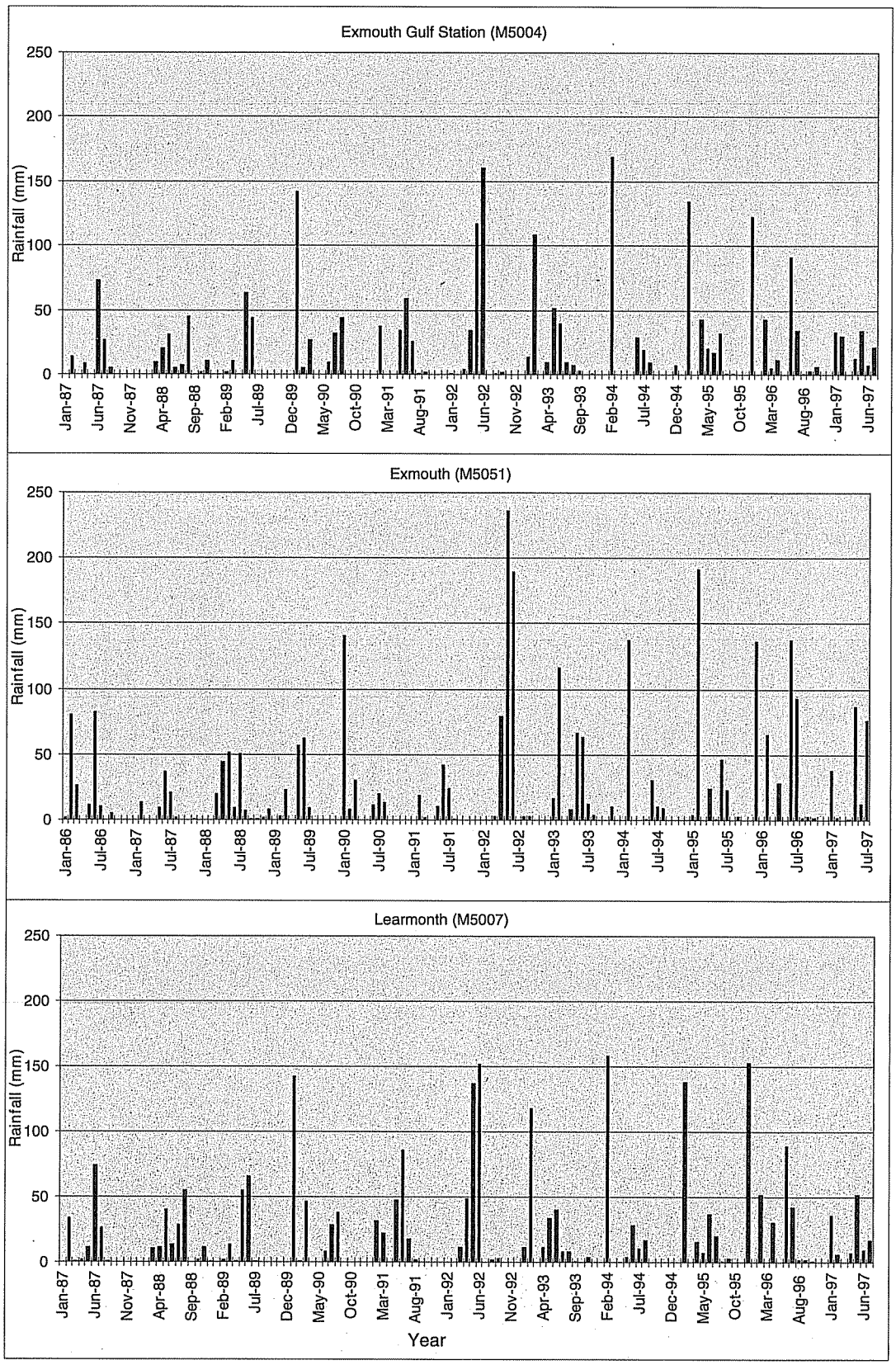

Figure 4: Monthly Rainfall for three sites on the North West Cape

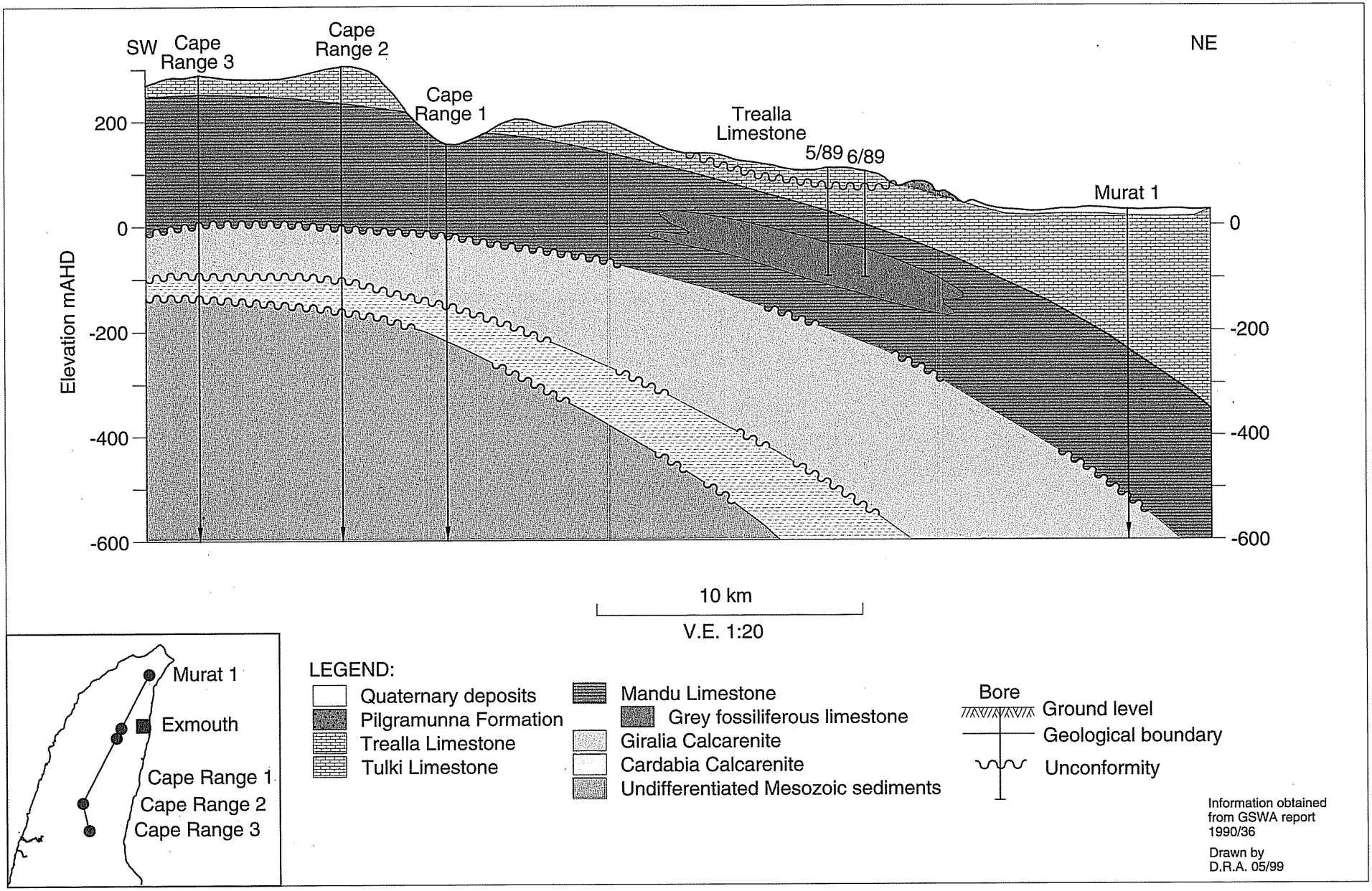

Figure 5. General Tertiary Geology in the Cape Range Area

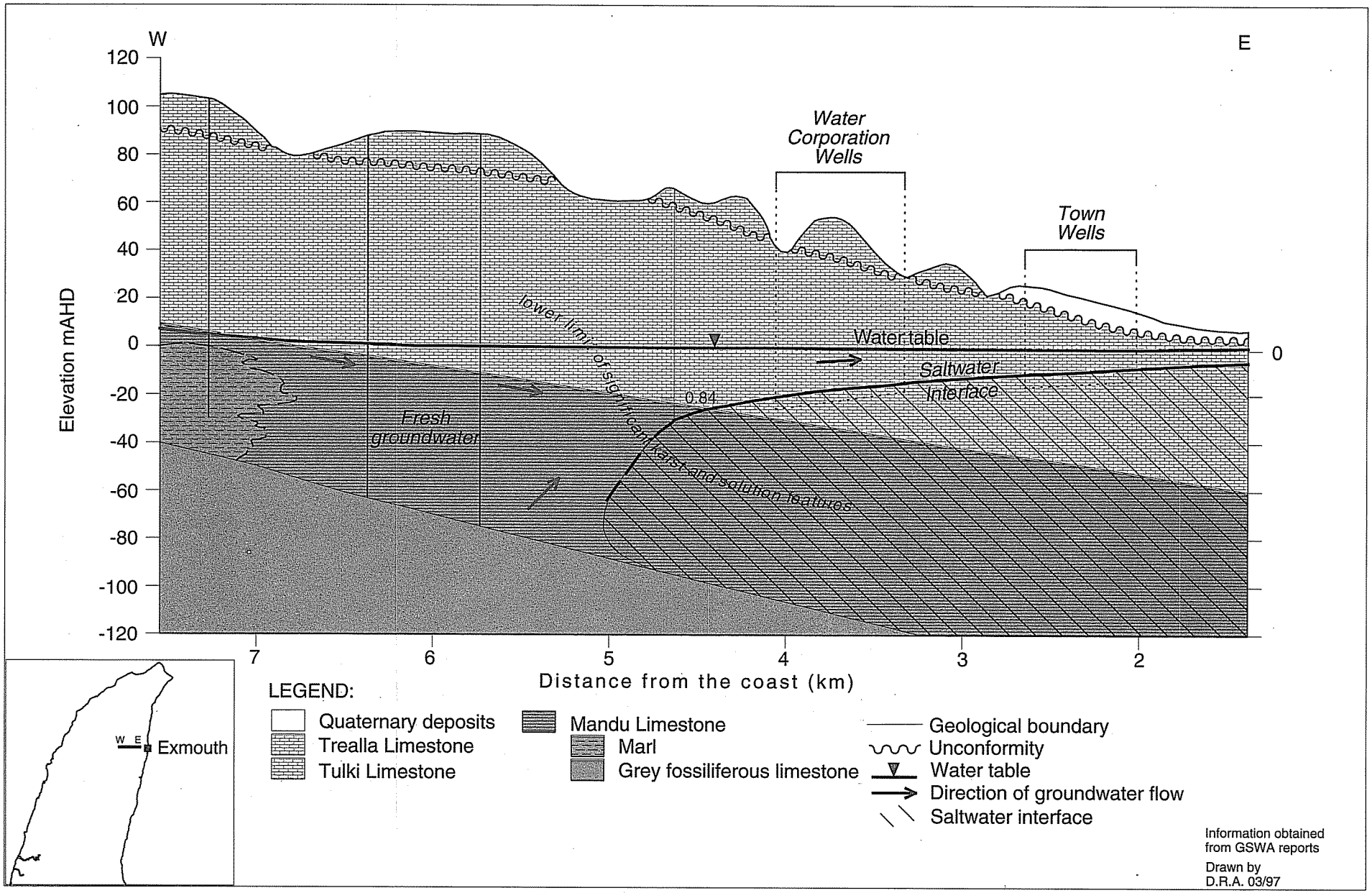

Figure 6. Hydrogeological Cross Section of the Exmouth Groundwater Area

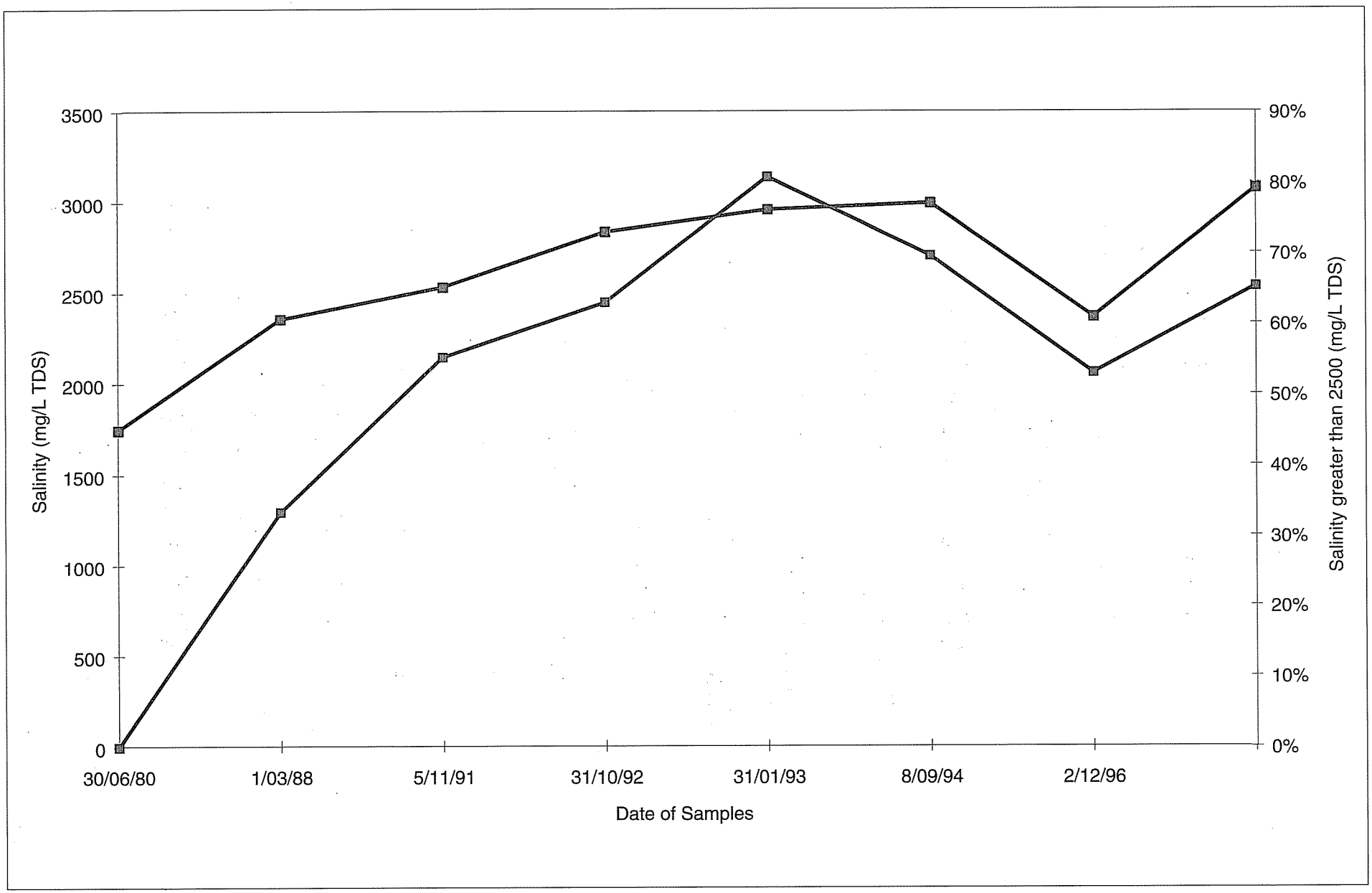

Figure 7: Average groundwater salinities for private bores

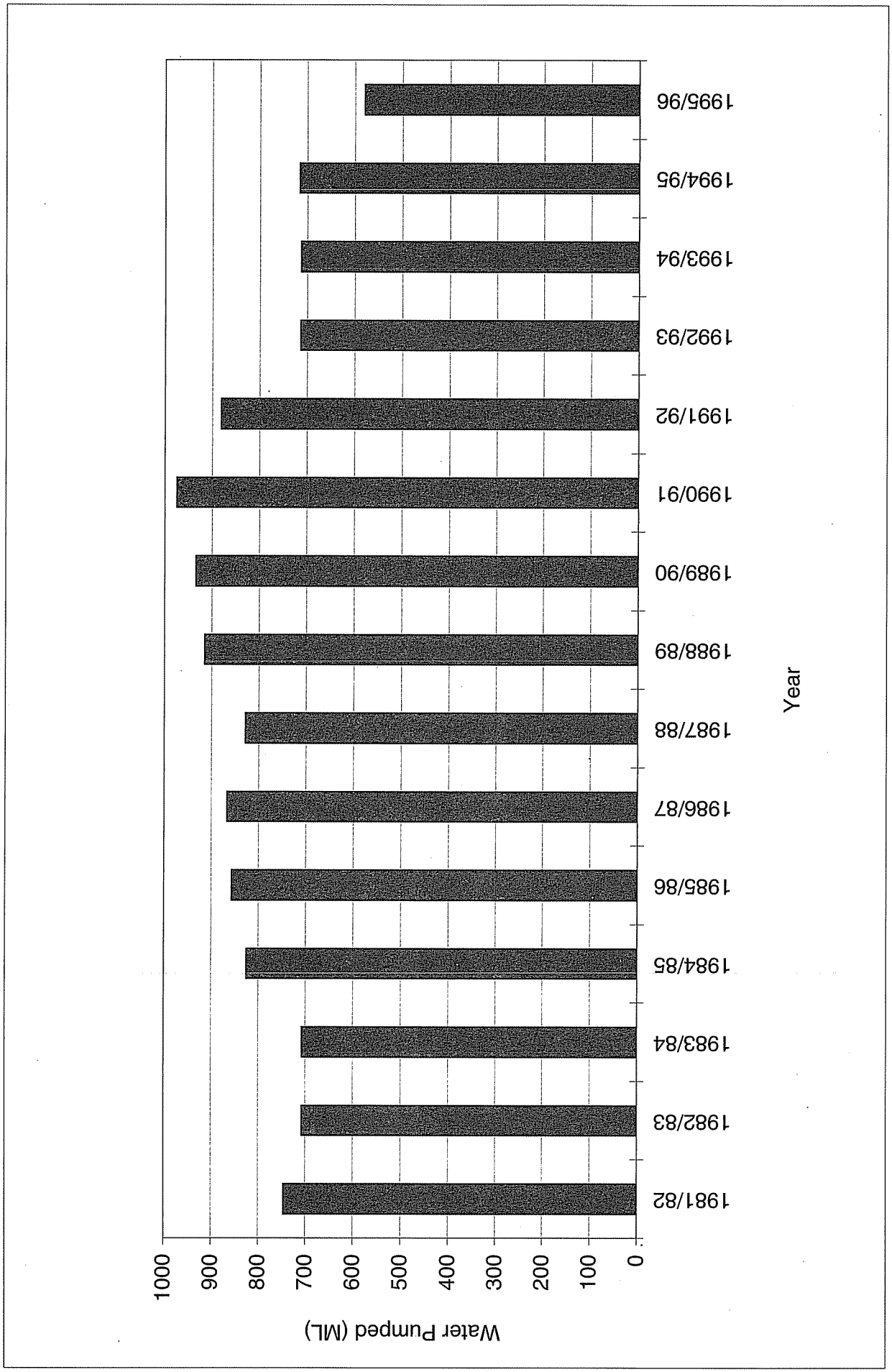

Figure 8: Water Corporation pumping

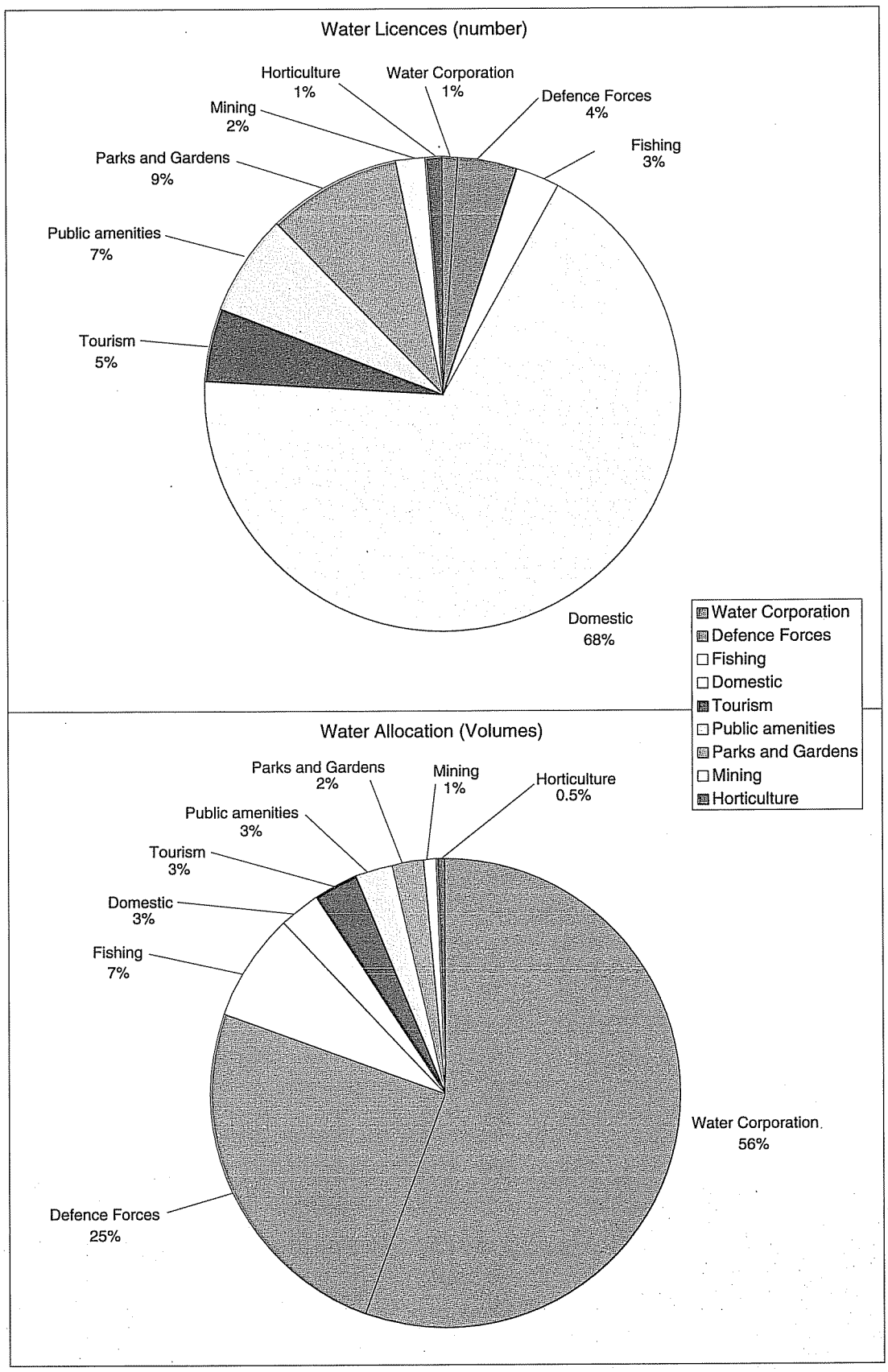

Figure 9: Licenced Groundwater Use

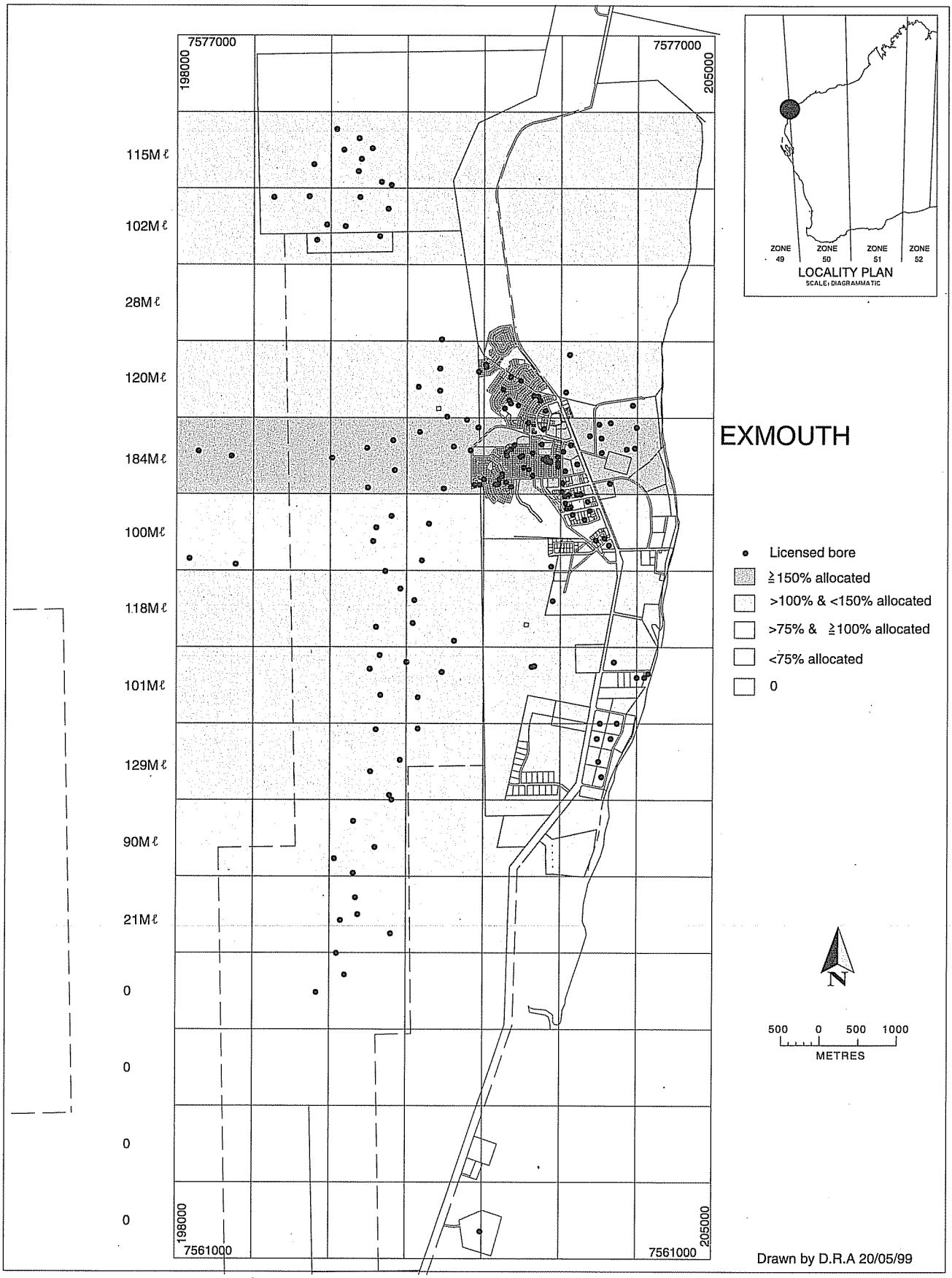

Figure 10: Groundwater allocation relative to throughflow in 1997

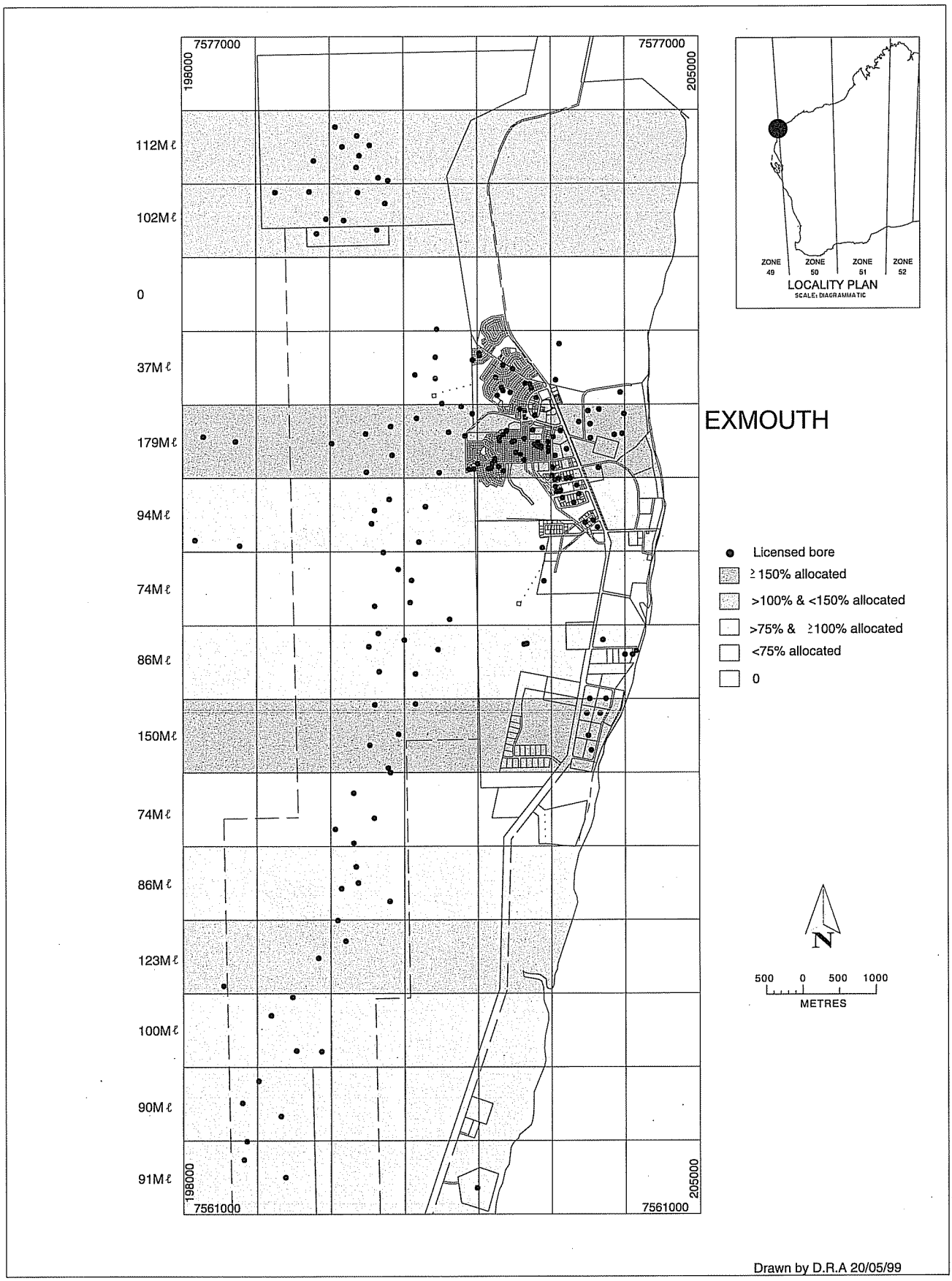

Figure 11: Groundwater allocation relative to throughflow with the establishment of the Water Corporation extended scheme

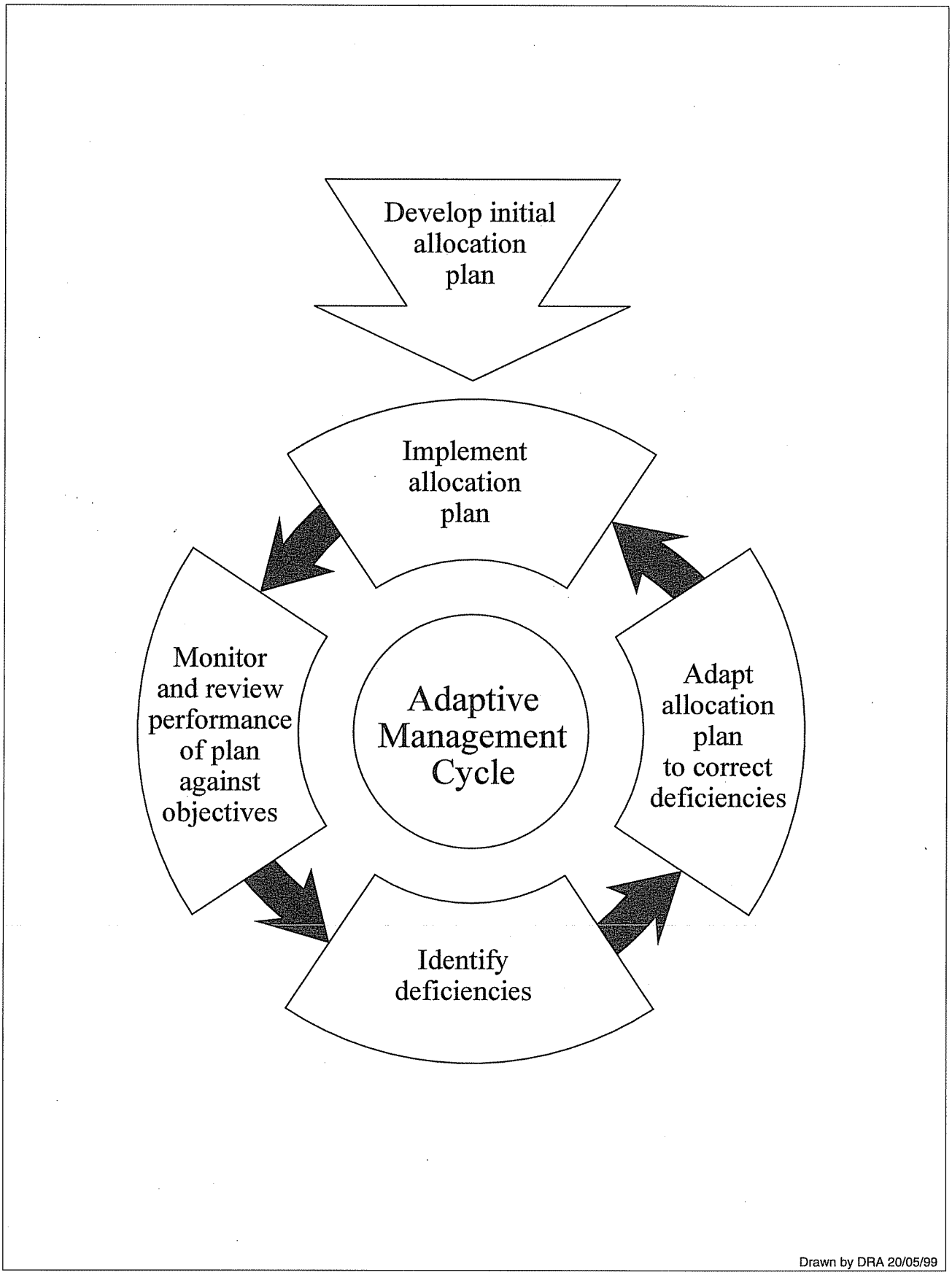

Figure 12. Adaptive Management approach to Groundwater Allocation (from NWQMS, 1995)