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PRELIMINARY ASSESSMENT

DISCHARGE OF NITROGEN BY GROUNDWATER TO THE MARINE ENVIRONMENT IN THE PILBARA REGION

By

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INTRODUCTION

The Pilbara Region is considered to be important for sustaining economic development for Australia. The economic potential of the Pilbara is based primarily on its mineral resources, primarily iron ore and natural gas production, and also on fishing and tourism. As development in the region increases, there will be increased pressure on the marine environment from land-based activities.

The North West Shelf Marine Environmental Management Study (NWSMEMS) has been established to look at current impacts of land-based and offshore activities on the marine environment, and to provide a baseline to assess future environmental impacts. It is a joint initiative between State and Commonwealth government agencies. A major task of NWSMEMS is a contaminant input inventory to assess inputs to the marine environment from a variety of sources, including groundwater inputs.

The purpose of this study is to compile existing groundwater data in the region to give preliminary estimates of groundwater discharge rates, and of the load of nitrogen discharged by groundwater to the marine environment between Exmouth and Port Hedland (Fig. 1) for the NWSMEMS. The basis for much of the work in this report are groundwater resource appraisals undertaken for the Pilbara by Skidmore (1996) and Wright (1997); a review of the groundwater resources of the Canarvon Basin by Allen (1988); a review of the groundwater resources of the southwestern part of the Canning Basin by Leech (1979), and water supply investigations for Exmouth undertaken by Martin (1990).

HYDROGEOLOGICAL SETTING

The Pilbara Region has undergone a long geological evolution over a period of about 3500 million years (Trendall, 1990), and basement rocks in the region comprise granitic and volcanic rocks of Precambrian age which form the Pilbara Craton, and Hamersley and Ashburton Basins (Fig. 2). These rocks are overlain by sediments of the Canning Basin in the north, and the Canarvon Basin in the southern part of the region (Fig. 2). In coastal areas, Precambrian and Phanerozoic rocks are generally overlain by a veneer of alluvial and aeolian sediments, and chemical precipitates (calcrete and pisolitic limonite deposits) of Cainozoic age.

AQUIFERS IN THE REGION

Groundwater occurs throughout the Pilbara Region in the Precambrian basement rocks, Phanerozoic sedimentary basins and Cainozoic deposits. It originates from direct rainfall recharge into outcropping basement rocks, and from the infiltration of rainfall and runoff through Cainozoic sediments. The amount of groundwater that can be obtained from a particular area depends on rock type. Rocks that contain and can transmit substantial amounts of groundwater are known as aquifers. There are four main types of aquifers which are important in the Pilbara Region: unconsolidated sediment aquifers; chemically deposited rock aquifers (mainly calcrete and pisolitic limonite deposits in river channels); sedimentary rock aquifers, and fractured rock aquifers. The spatial variability of aquifers in the region means that the same land-based activity has the potential to have a wide range of possible impacts on the marine environment through variations in groundwater discharge and associated contaminant loads.

In coastal areas of the Pilbara, unconsolidated sediment aquifers are the most important source of groundwater discharge to the marine environment (Fig. 3), except near Exmouth where cavernous limestone is a major source of groundwater discharge. Cavernous (karstic) limestone is a particular type of sedimentary rock aquifer which has the potential to transmit a large variety of contaminants rapidly from land-based activities into the marine environment and can cause significant environmental impacts if land use is not well managed.

GROUNDWATER DISCHARGE

Groundwater flows from high parts of the landscape, and is discharged to the surface environment at the lowest parts of the landscape. Although some groundwater is discharged by evaporation and by transpiration by trees in major river channels in the Pilbara Region, much of the groundwater in the region is eventually discharged into the ocean. Variations in hydrogeological conditions in a region can affect how and where groundwater is discharged to the ocean, and can in turn determine the distribution of dissolved constituents transported by groundwater into the marine environment.

Figure 4 is a schematic diagram showing the major hydrogeological controls on groundwater discharge to the ocean in the Pilbara Region. Groundwater discharge to the ocean generally takes place above a saltwater interface, where fresh to brackish groundwater is forced to ride over a wedge of denser, saline water at the coast. Where there are extensive tidal flats at the coast, groundwater discharge may take place into a saltmarsh or mangrove vegetation (Fig. 4A). In other areas, discharge takes place directly to the ocean though a groundwater discharge zone located near the shoreline (Fig. 4B). The width of the discharge zone may be quite variable, but is commonly about 10-100 m wide. In coastal areas near Onslow, groundwater discharges from two aquifers: at the coastline from a shallow unconfined aquifer, and offshore from a deeper confined aquifer (Fig. 4C). Groundwater discharge from the confined aquifer occurs where there are breaches in an overlying confining bed, and may take place offshore. Groundwater from North West Cape near Exmouth is discharged into Exmouth Gulf both from seepage through a groundwater discharge zone at the coast, and through offshore springs where groundwater flows through cavernous (karstic) limestone (Fig. 4C).

GROUNDWATER-DEPENDENT ECOSYSTEMS

In the seasonally dry Pilbara Region, groundwater flow and discharge is important for sustaining some terrestrial ecosystems. Groundwater is extremely important for sustaining ecosystems in river pools and sustaining the Eucalypt woodlands that line rivers and large creeks in the Pilbara Region. Groundwater in the Exmouth area also sustains a diverse and unique cave fauna (stygofauna), and the protection of this community is a critically important part of protecting the groundwater supply for Exmouth. Work by the Museum of WA suggests that stygofauna assemblages may be widespread in the State, and may occur in cavernous calcrete and laterite deposits, and in sediments near the saltwater interface in coastal areas.

Although less well understood, overseas evidence suggests that groundwater discharge may also be important in maintaining some marine benthic environments, particularly near offshore springs in karstic area, and where confined aquifers discharge offshore. These types of environments may occur in Exmouth Gulf adjacent to North West Cape, and in coastal areas near Onslow and to the east of Port Hedland. They could be adversely affected by groundwater discharge from poorly planned and managed coastal development in these areas.

GROUNDWATER QUALITY IN DISCHARGE AREAS

The marine environment can be affected by a wide range of chemicals discharged from land based activities. However, with the exception of karst aquifers, the range of chemical compounds that can be readily transported in groundwater flow systems is generally more limited, and is restricted by solubility, the extent to which compounds are adsorbed onto aquifer materials, and the extent to which they are degraded by chemical and microbiological processes in aquifers. Karst aquifers often have large interconnected voids that may allow contaminants to be transported rapidly with the opportunity for attenuation. These aquifers may allow transport of microorganisms that are normally filtered by aquifer sediments. This is of particular concern for unsewered coastal development, where microorganisms from wastewater disposal may be transported into the marine environment via groundwater discharge.

On a regional scale, the contaminant of concern to marine environments that is most readily transported in groundwater is nitrogen, which is mostly present in groundwater as nitrate. Nitrate in groundwater is derived both from natural sources, from excessive use of fertilisers, from high stock densities in agricultural areas, and from unsewered development. In the Pilbara, most of the nitrate in groundwater is of natural origin and is derived from nitrogen fixing vegetation and termite activity (Jacobson et al, 1990).

There are very limited data on the distribution of nitrate in groundwater in coastal parts of the Pilbara. A search of the Water and Rivers Commission bore database (AQWABASE) indicated that there are only 85 bore records at 26 sites with nitrate data between North West Cape and Port Hedland. Nitrate concentrations range between 1 and 126 mg/L, with a mean concentration of 40 mg/L (equivalent to an average nitrogen concentration of 10 mg/L). Nitrate concentrations of this magnitude seem to be widespread in the Pilbara in both unconfined and confined aquifers (Leech, 1979).

GROUNDWATER AND NITROGEN DISCHARGE ESTIMATES

The Pilbara coastline was divided into six zones with common hydrogeological characteristics (Fig. 5) to allow groundwater and nitrogen fluxes to be determined in the region. The six zones are:

Zone 1 – North West Cape coastline. Aquifers are generally karstic limestone.

Zone 2 – Yanrey coastline. This consists of an unconfined aquifer comprised of unconsolidated sediments overlying confined sedimentary rock aquifers.

Zone 3 – Onslow coastal plain. This consists of an unconfined aquifer comprised of unconsolidated sediments overlying confined sedimentary rock aquifers with additional resource information compiled by Skidmore (1996).

Zone 4- Karratha coastline. Very limited groundwater resources occur in fractures in hard bedrock

Zone 5 – Port Hedland coastal plain. This consists of an unconfined aquifer comprised of unconsolidated sediments.

Zone 6 – Southwestern Canning Basin coastline. This consists of unconfined and confined sedimentary rock aquifers.

In all areas except Zone 4, the total groundwater discharge to the ocean across the full width of the zone was determined using previously compiled resource appraisal information. The discharge from Zones 2, 3 and 5 was assumed to be equivalent to the total groundwater recharge, that is groundwater flow is assumed to be in a state of steady-state equilibrium with losses by evaporation and groundwater pumping being ignored. The discharge from Zone 4, the Karratha coastline, was assumed to be 1% of the equivalent area of unconsolidated sediments, which is likely to be a generous estimate of the available groundwater resources in this area. The discharge from Zones 1 and 6 were based on groundwater throughflow estimates resulting from regional groundwater investigation programs.

Groundwater discharge estimates for each zone are presented in Table 1, together with groundwater flux estimates, that is the annual rate of discharge of groundwater for each kilometre of coastline in each zone.

There are insufficient bore records in the area to indicate the spatial distribution of nitrate in groundwater in the region, so the mean value of 40 mg/L determined from existing bore records was assumed for all groundwater discharging to the ocean along the Pilbara coastline (i.e. an average nitrogen concentration of 10 mg/L). The total nitrogen load for each discharge zone is the product of average nitrogen concentration and total discharge for each zone. The average nitrogen flux for each zone is the product of average nitrogen concentration and groundwater flux for each zone. These data are also presented in Table 1.

Table 1. Groundwater and nitrogen discharge to the ocean along the Pilbara coastline

Zone	Coast length (km)	Groundwater discharge (x 10^6 m^3/yr)	Groundwater flux (x 10^5 m^3/yr/km)	Nitrogen load (x 10^5 kg/yr)	Nitrogen flux (x 10^3 kg/yr/km)
1	90	14	1.5	1.4	1.5
2	140	16	1.4	1.6	1.4
3	170	21	1.2	2.1	1.2
4	150	0.2	1.3	0.02	1.3
5	240	45	1.9	4.5	1.9
6	70	42	6	4.2	6

CONCLUSIONS

Estimates of the amount of nitrogen discharged by groundwater to the ocean in the Pilbara Region are presented in Table 1. Based on a number of assumptions discussed previously, the following conclusions can be made:

- The total load of nitrogen discharged annually from groundwater to the ocean in the region is about 1400 tonnes.
- Most of the nitrogen discharged is likely to be of natural origin.
- It is likely that the flux of nitrogen from groundwater is probably more influenced by variations in groundwater discharge rates rather than by variations in the distribution of nitrate in groundwater in the region, although there are limited water quality data to support this hypothesis.
- The flux of nitrogen is probably highest along the Southwestern Canning Basin coastline (Zone 6) due to high groundwater discharge rates of groundwater from regionally extensive aquifers in the Canning Basin.
- The flux of nitrogen is probably lowest along the Karratha coastline (Zone 4) because of the limited groundwater resources in this area.
- The area of coastline that is most susceptible to development pressures is likely to be North West Cape adjacent to Exmouth Gulf. Karstic limestone aquifers in the area are likely to be extremely vulnerable to contamination from intense coastal development. There is a risk that a wide range of contaminants including microorganisms could be discharged to the marine environment by groundwater, particularly from unsewered development.

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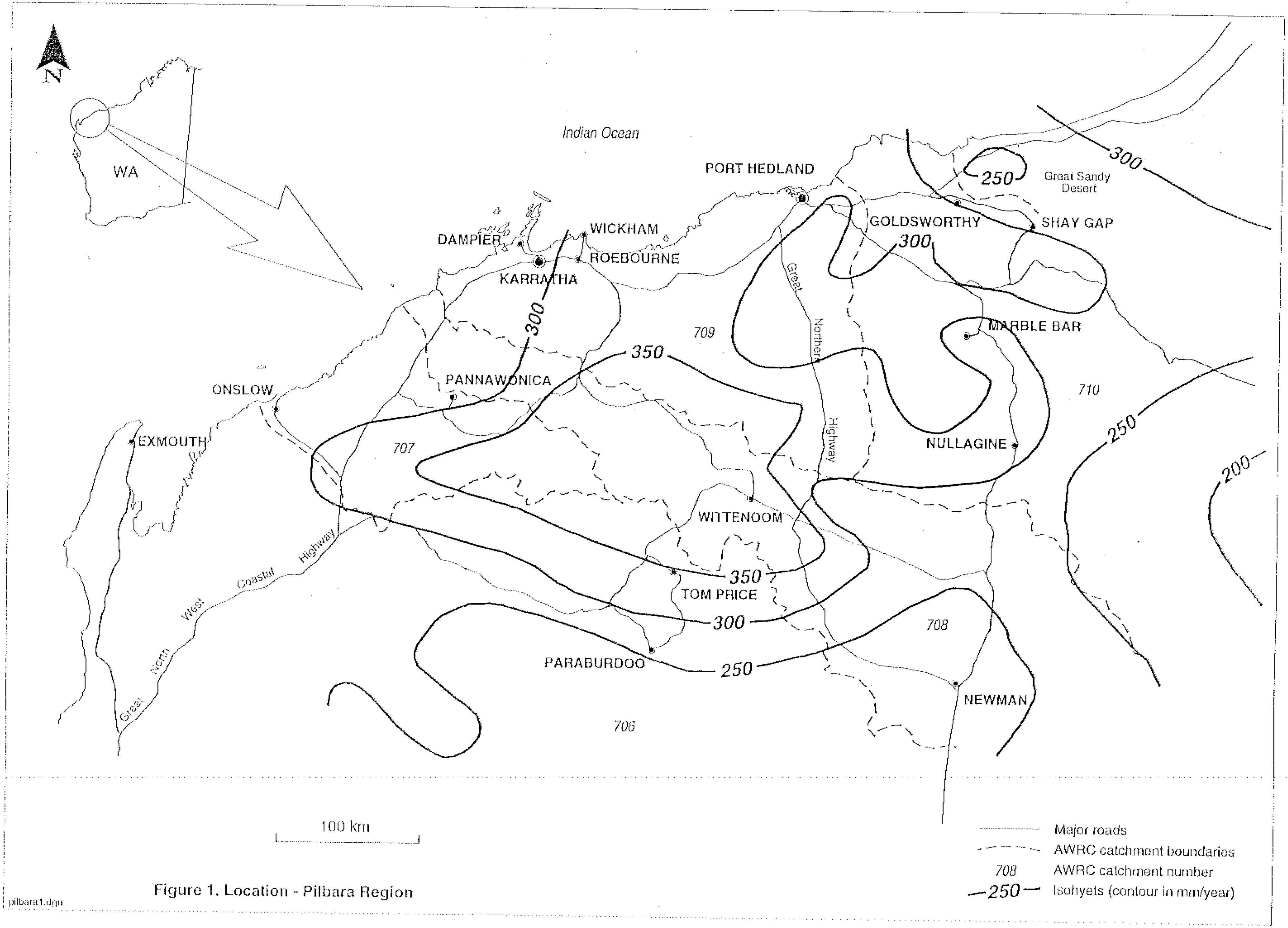

Figure 1. Location - Pilbara Region

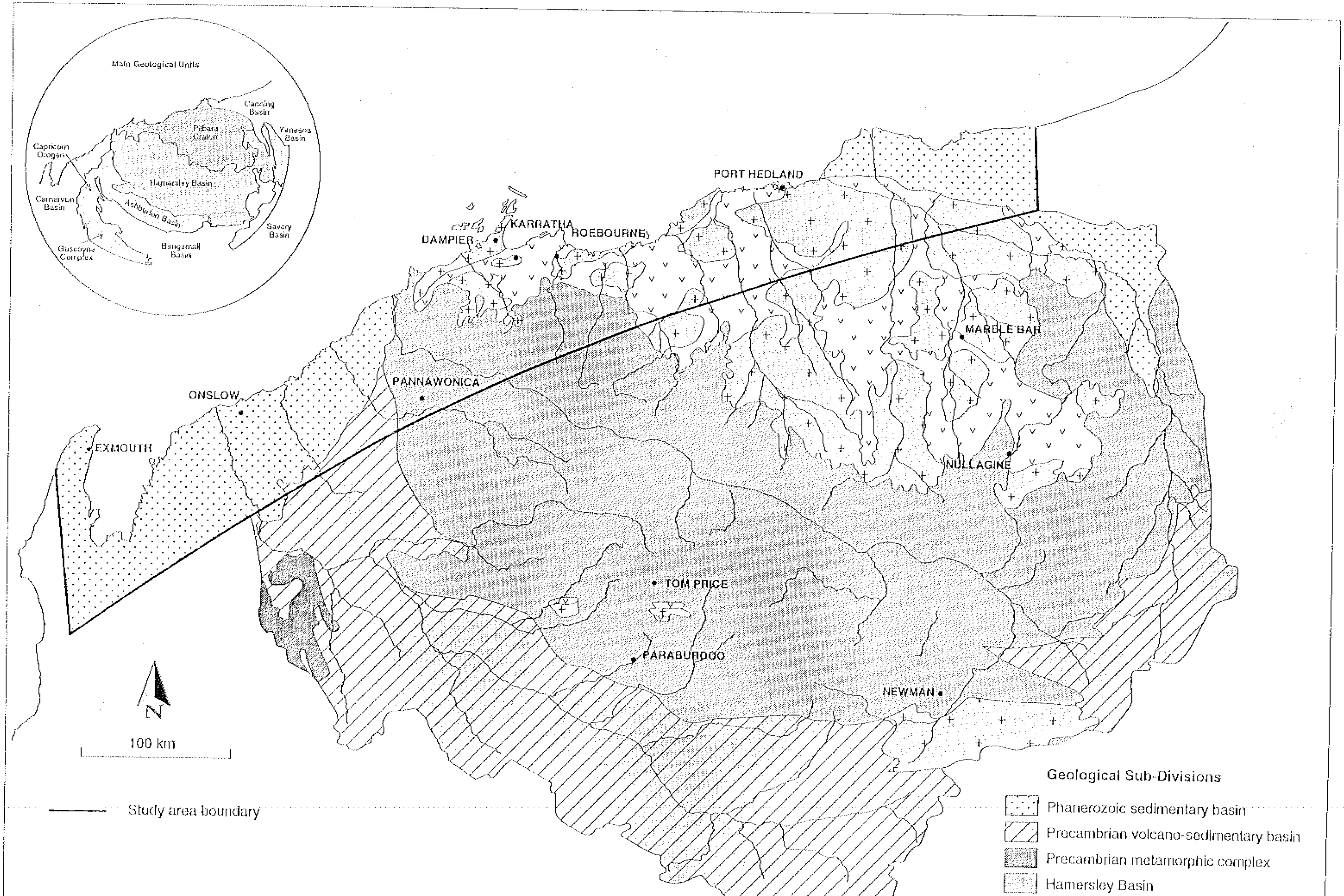

Figure 2. General geology

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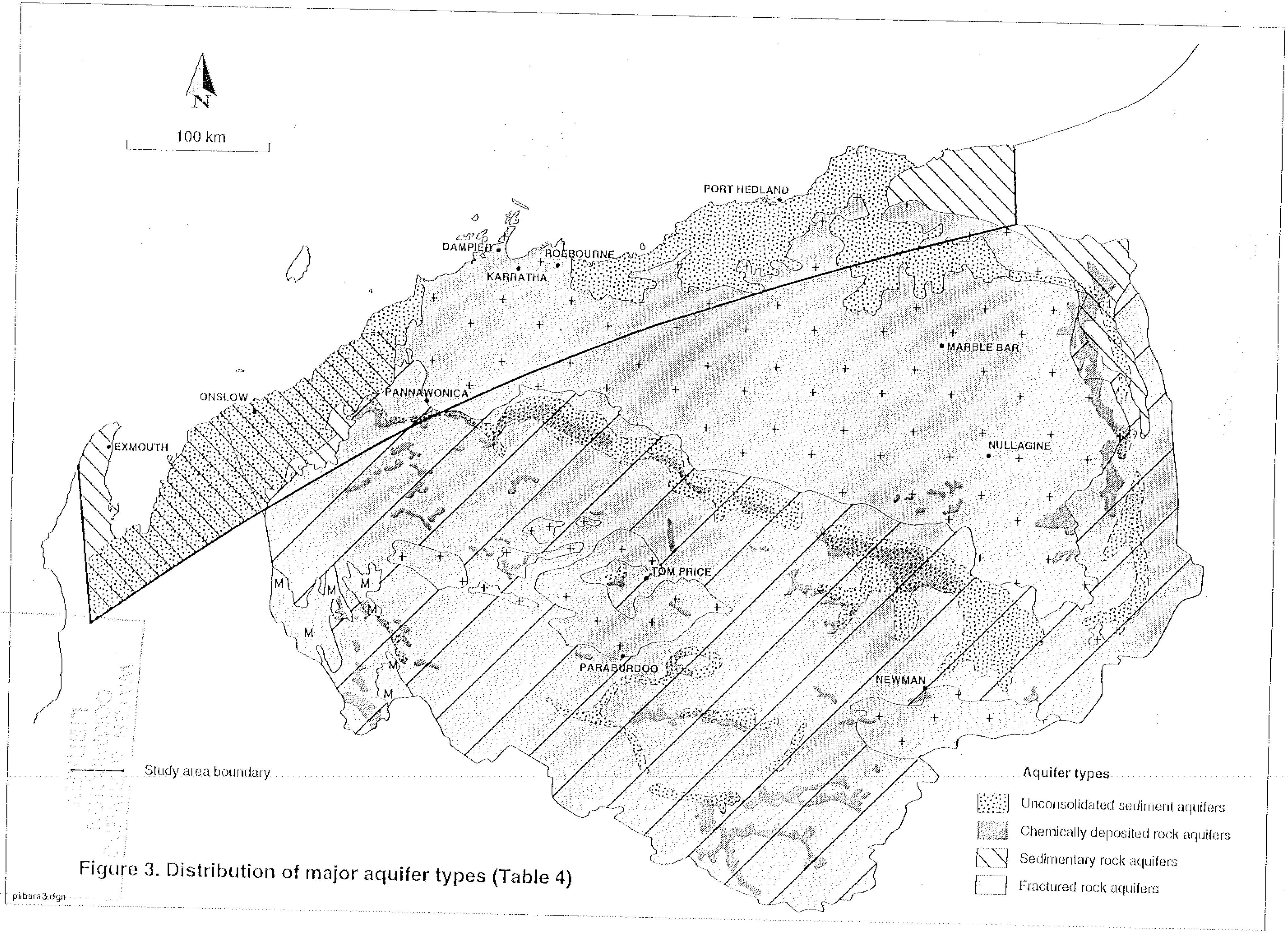

Figure 3. Distribution of major aquifer types (Table 4)

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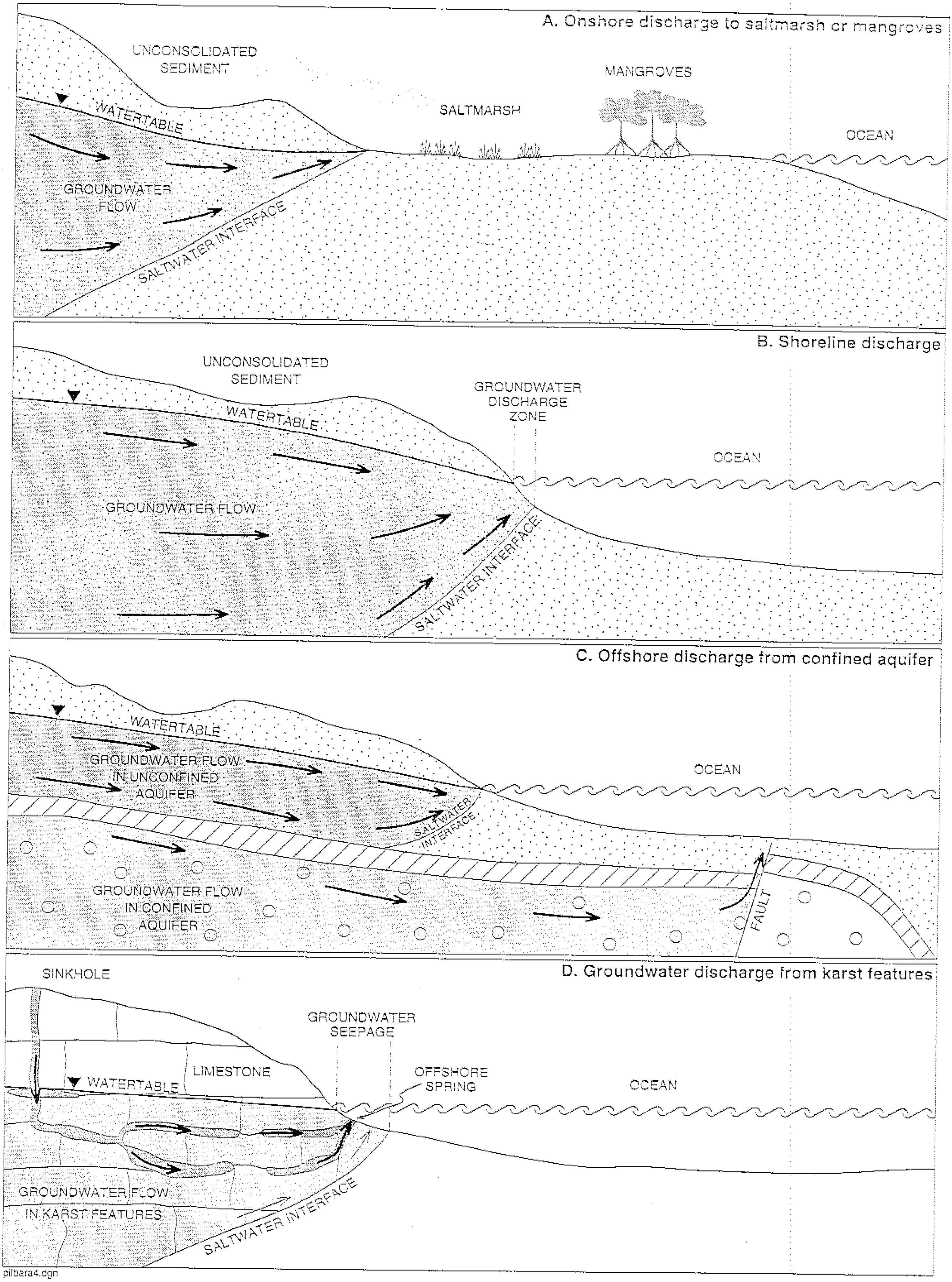

Figure 4. Groundwater discharge to the ocean in the Pilbara

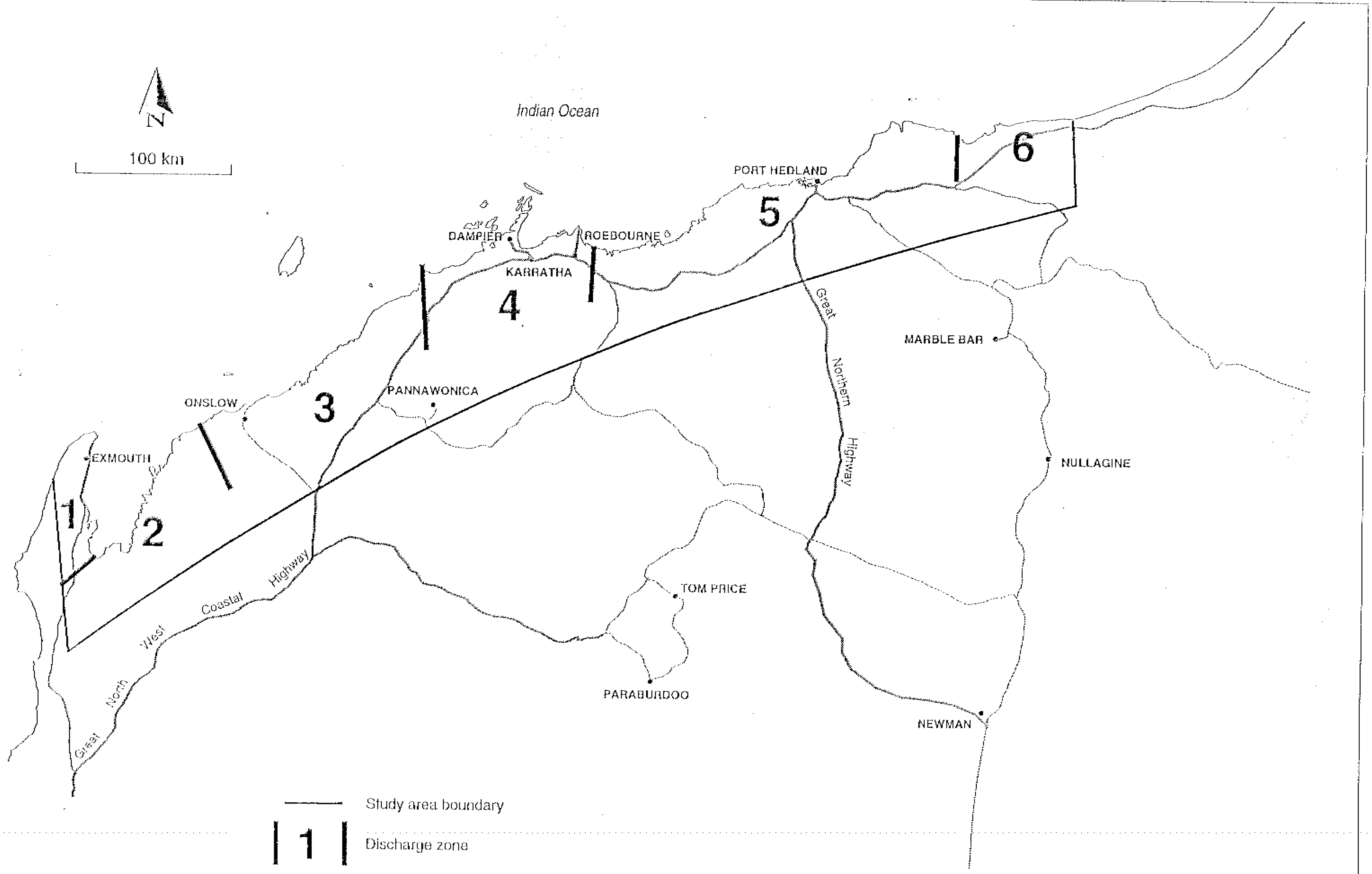

Figure 5. Groundwater discharge zones along the Pilbara coastline

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