CONSULTATIVE ENVIRONMENTAL REVIEW: PROPOSED SPECIAL RESIDENTIAL DEVELOPMENT, EXMOUTH: LYNDON LOCATIONS 222 AND 223

by

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SHIRE OF EXMOUTH

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INVITATION

The Environmental Protection Authority invites people to make a submission on this proposal.

This Consultative Environmental Review for a proposed special residential subdivision on Exmouth Lyndon Locations 222 and 223, 10km to the south of Exmouth, has been prepared by W G Martinick and Associates Pty Ltd on behalf of the Shire of Exmouth in accordance with the requirements of the Western Australian Environmental Protection Act. The review will be available for public comment for four weeks, commencing on 6 November 1995 and finishing on 4 December 1995.

Comments from government agencies and from the public will assist the Environmental Protection Authority to prepare an Assessment Report in which it will make recommendations to Government.

Copies of this document may be obtained for the sum of $5.00 (including postage) from:

W G Martinick and Associates Pty Ltd
4/114 Churchill Avenue
SUBIACO WA 6008

Following receipt of comments from Government agencies and the public, the Environmental Protection Authority will discuss these comments with the proponent and may ask for further information. The Environmental Protection Authority will then prepare an Assessment Report with recommendations to Government, taking into account issues raised in the public submissions.

WHY WRITE A SUBMISSION?

A submission is a way to provide information, express your opinion and put forward your suggested course of action including any alternative approach. It is helpful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submission will be treated as public documents, unless received in confidence, subject to the requirements of the Freedom on Information Act, and may be quoted in full or in part in each report.

WHY NOT JOIN A GROUP?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

DEVELOPING A SUBMISSION

You may agree or disagree, or comment on, the general issues discussed in the Consultative Environmental Review or with specific proposals. It helps if you give reasons for your conclusions, and substantiate this with relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the Consultative Environmental Review:

- clearly state your point of view, and
- indicate the source of your information or argument if this is applicable.

POINTS TO KEEP IN MIND

By keeping the following points in mind you will make it easier for your submission to be analysed.

- Attempt to list points so that the issues raised are clear. A summary of your submission is helpful.

- Refer each point to the appropriate section, chapter or recommendations in the Consultative Environmental Review.

- If you discuss different sections of the Consultative Environmental Review keep them distinct and separate, so there is no confusion as to which section you are considering.

- Attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Remember to include your name, address, date, and whether you want your submission to be confidential.

THE CLOSING DATE FOR SUBMISSIONS IS 4 DECEMBER 1995.

Submission should be addressed to:

Department of Environmental Protection
Westralia Square
141 St Georges Terrace
PERTH WA 6000

Attention: Ms Karen Sanders

Submission can be faxed on: (09) 322 1598.

SUMMARY

A special residential development is proposed for Lyndon Locations 222 and 223 which are located on the coast approximately 10km to the south of the town of Exmouth on the Cape Range Peninsula. The Study Area consists of approximately 158ha and lies between the coastal highway (Murat Road) and Exmouth Gulf. A locality map is shown in Figure 1 and a map of the Study Area is shown in Figure 2.

Currently the Study Area consists of **Vacant Crown Land** which is in the process of being transferred by the Department of Land Administration to the Shire of Exmouth which will hold title to the land in fee simple. The **Shire of Exmouth is the proponent and is developing the land in a joint venture with Greenough Holdings Pty Ltd. The latter will be responsible for overall project management.**

The proposed subdivision is intended to be supplied with water from a **proposed reticulated water supply system** which is currently being assessed as a separate proposal by the Environmental Protection Authority by means of the Consultative Environmental Review process. This supply system will be developed by the **Water Authority of Western Australia** subject to necessary approvals being secured. **In the event that this water supply is not approved by the Minister for the Environment, then the proposed subdivision will be supplied with water from an existing water supply system** which is operated by the Water Authority of Western Australia. Necessary agreements are in place with the Water Authority of Western Australia.

The Water Authority of Western Australia will **not permit the establishment of private bores** within the proposed subdivision.

The development proposal consists of six precincts entitled A to F (Figure 2) which are bounded by natural terrain features and have been set well back from sensitive landscape features such as coastal dunes and creeks. All of the precincts have a minimum setback distance of 100m from the high water mark, are inland of the coastal dunes and bounded to the north and south by major creeks. The proposed lots for each precinct are **set well back from major creeks** all of which will be included in **Public Open Spaces**. The width of these Public Open Spaces depends on the terrain features and the size of the creek and varies from 30m to 200m to provide adequate protection for the respective creeks and fringing vegetation.

A total of **177 lots are proposed** giving an **average lot size of 8,900m^2.** The proposed lots are shown in Figure 2 and they **vary in size from approximately 4,000m^2 to 34,000m^2.**

The **geology and hydrogeology** of the Cape Range Peninsula has been reviewed by Allen (1993). The rocks which immediately underlie and form the core of the Cape Range Peninsula are a sequence of limestone formations. These rocks are susceptible to leaching by the weak acidic condition of natural rainfall and this has resulted in the formation of an extensive system of caverns and micro-caverns in the upper layers of limestone which are very permeable. The regional water table of the Peninsula is contained mainly within the permeable limestone system beneath the Ranges of the Peninsula and coastal plain. Groundwater flow is from the Ranges via the coastal plain to the ocean, where it discharges, largely as sub-sea springs. Some losses of groundwater are also attributable to uptake by plants and seepage into pools along the lower reaches of some creeks. The rate of **groundwater flow** beneath the coastal plain to the coast varies with terrain and soil conditions, and **is considered to be of the order of hundreds of metres per year** (pers, comm. Mr M Martin, Geological Surveys, Hydrology Section).

The Cape Range Peninsula is known to have a very diverse **fauna population**. Much of this is due to the range of habitats which are found within the Peninsula, extending from the mountains of the Cape Range to mangrove communities along sections of the coast. The most important fauna habitats are located within the complex terrain of the Cape Range and within mangrove communities on the eastern and southern side of Exmouth Gulf, some distance from the Study Area. The habitats of the Study Area are typically **open shrublands over spinifex on an undulating plain** which is common to vast regions of the central west of Western Australia. Consequently the habitats of the Study Area are very widespread and

do not have a unique conservation value. The vertebrate fauna of the Cape Range Peninsula was reviewed by Kendrick (1993) and the mammalian fauna by Baynes and Jones (1993). None of the terrestrial species listed in these reviews are gazetted under the Wildlife Conservation Act of 1950. Evidence of the Pebble-mound mouse, a gazetted rare species, has recently been found inland of the Study Area. No pebble-mounds were located within the Study Area. Certain bird species which have been gazetted rare under the Wildlife Conservation Act, such as the Grey Falcon and the Peregrine Falcon, are likely to be found from time to time within the Cape Range Peninsula. They will not be affected by activities within the Study Area due to the wide-ranging habits of these birds and because the habitats of the Study Area are not specific to the needs of these birds.

Extensive **underground habitats** exist within the limestone cavities beneath the Cape Range Peninsula and these are known to have a unique **cave fauna**. The cave fauna consist of a range of animals, which utilise various underground habitats depending on the void size and habitat type, and whether these voids are under water or dry (Humphreys, 1993). Thus void sizes may vary from minute spaces in gravels to caverns larger than 20cm in diameter and which probably form honeycomb cavities through the limestone. The cave fauna include the Blind Gudgeon Fish and Blind Cave Eel and an extensive range of invertebrate groups which occupy habitats ranging from the dry caves of the Cape Ranges to the fresh water and brackish environs below the coastal plain. It is estimated that 21 to 34 species could have habitats beneath the coastal plain (Dr W Humphreys, pers.comm., 1995). The total extent of the caverns is not known, but both the vertebrate and invertebrate aquatic cave fauna have been found in wells to the east and west of the Cape Range Peninsula (Knott, 1993 and Humphreys, 1995).

Among the large number of cave fauna species which have been identified in the underground habitats of the Cape Range Peninsula, several species have been gazetted rare (1994) under the Wildlife Conservation Act of 1950. These include a spider and a cockroach which occupy the dry caves of the Cape Range, and the Blind Gudgeon Fish, Blind Cave Eel and two shrimp species which occupy habitats beneath the coastal plains (Adams and Humphreys, 1993; Humphreys, 1993).

Considering the proximity of the Study Area to the ocean and the existence of underground habitats in the region, the **principal issues for the environmental management of the subdivision are:**

- the impact of phosphates and nitrogen in domestic effluent on aquatic cave fauna and adjoining marine systems;
- the management of coastal dunes which could be disturbed by uncontrolled pedestrian and vehicle access to the beach;
- ensuring the environmental integrity of the major creeks of the Study Area;
- flood risks from creeks under cyclonic conditions; and
- oceanic storm surges.

Almost all of the phosphorus in domestic effluent water is in the form of phosphates. To assess the potential environmental impacts of phosphates and nitrogen in domestic effluent water the **soils** of the Study Area were studied at representative sites. A backhoe was used to excavate trenches to the underlying limestone to facilitate inspection of the different horizons which make up soils, to allow soil sampling and to conduct water infiltration tests. The potential of the soils remove phosphates from solution and to "fix" these phosphates was determined by laboratory analysis of their Phosphate Retention Index.

The potential environmental impacts of phosphates from domestic wastewater on the quality of groundwater will be minimal due to the phosphate fixing ability of the soils surrounding the leach drains and the high calcium content of the underlying limestone. This will remove most of the phosphates from solution. The remaining phosphates of the effluent water are likely to be precipitated in the groundwater as insoluble calcium phosphate compounds because of the high calcium content of the groundwater. It is thus concluded that it is highly unlikely that any phosphates from the domestic effluent of the Study Area

will move any great distance from the point of discharge and that probably none will leach to the ocean.

The various **nitrogen** forms in domestic effluent are all relatively soluble and not readily fixed by soils. Nitrogen contained in domestic effluent will be dispersed and removed from the soil in different ways. The very dry climate and high evaporation rate of the region and the moist soil environment in the immediate vicinity of leach drains will result substantial losses as gaseous nitrogen to the atmosphere. Such losses and the evaporation of effluent water will be aided by installing two shallow leach drains each of 20m length per septic tank system rather than the standard single length of 13m which is currently used in the Shire of Exmouth. The planting of deep rooted species of shrubs and trees above the leach drains will also ensure that effluent water, phosphates and nitrogen are taken up by plants.

Some of the effluent, from which a substantial percentage of the nitrogen has been removed, will leach from below the leach drains to the groundwater table and then move laterally in the general direction of groundwater flow towards the ocean where it will be discharged. It is concluded that for an average household the nitrogen of the respective septic tank systems will be "drip-fed" into the groundwater at a rate which will ensure that the resultant concentrations of nitrogen in groundwater will be similar to natural background concentrations for nitrogen. Consequently, this is likely to be harmless to the cave fauna which may occur below the Study Area. The low nitrogen input to the groundwater will be rapidly dispersed because of the high rate of groundwater movement to the sea.

The moderate tidal movements will ensure that the small concentrations of nitrogen which are likely to leach to the **ocean** will be dispersed rapidly along the western coastline of Exmouth Gulf.

The **water infiltration** rates of the soils of the Study Area were measured in the field as recommended by the Department of Health. This confirmed that the soils have rapid infiltration rates and are capable of readily accepting all domestic wastewater from conventional septic tank systems. This will assist in assuring that the proposed septic tank systems will function properly.

Groundwater levels were located at a depth of approximately 0.2m AHD at one low-lying site. No groundwater was found at other sites where the soil was excavated to the underlying calcrete or to a depth of 2.1m. Shallow groundwater levels therefore do not occur within the Study Area and will not affect the functioning of leach-drain systems.

Possible oceanic **storm surges** which could occur during severe storm, especially a cyclone have the potential to increase water heights to 0.6m above existing conditions which, if imposed on the level of a Mean High Water Spring Tide, could temporarily raise the sea level to 1.7m AHD. This level will result in seawater entering the creeks but it will not result in flooding. A 0.6m oceanic storm surge coinciding with a Mean High Water Spring Tide is a 1 in 4200 years event whilst the oceanic storm surge of 0.6m is a 1 in 50 years event.

The Water Authority of Western Australia has not calculated flood risks for the Cape Range Peninsula. **Flood discharge from creeks** is a common occurrence during cyclones and it can result in some flooding. Rainfall records from Exmouth over an 80 year period show three events where rainfall has exceeded 200mm in one day and could have caused flooding of low lying areas behind coastal dunes. Inspection of the terrain of the Study Area suggests that such flooding is likely to affect areas of less than 2m AHD which are adjacent to creeks. Such flooding is a possibility in areas adjacent to the creek which separates Precincts A and B, and may affect five of the proposed lots. However, these lots are relatively large and each of them have areas of higher ground which are very likely to be above the flood zone. It is recommended that building envelopes are located on these more elevated sites and that they are built up, if necessary, to 3m AHD. The investigations have shown that flooding from creeks is a greater risk than flooding from oceanic storm surges, and that the probability of such events occurring simultaneously is very remote.

Exmouth Airfield, a small **airfield,** is located adjacent to the Study Area. The orientation of the runway is such that it will direct air traffic away from the airspace above the proposed development. The aircraft which use the nearby runway are generally small and, using Australian Standard 2021 (Aircraft Noise) it is estimated that noise will not be a nuisance value to future residents of the proposed development.

The large lot sizes and predominant bushland of the Study Area will present a bush-fire hazard to future residents. It will be the responsibility of the Shire of Exmouth to enforce Bush Fire Control Board Regulations.

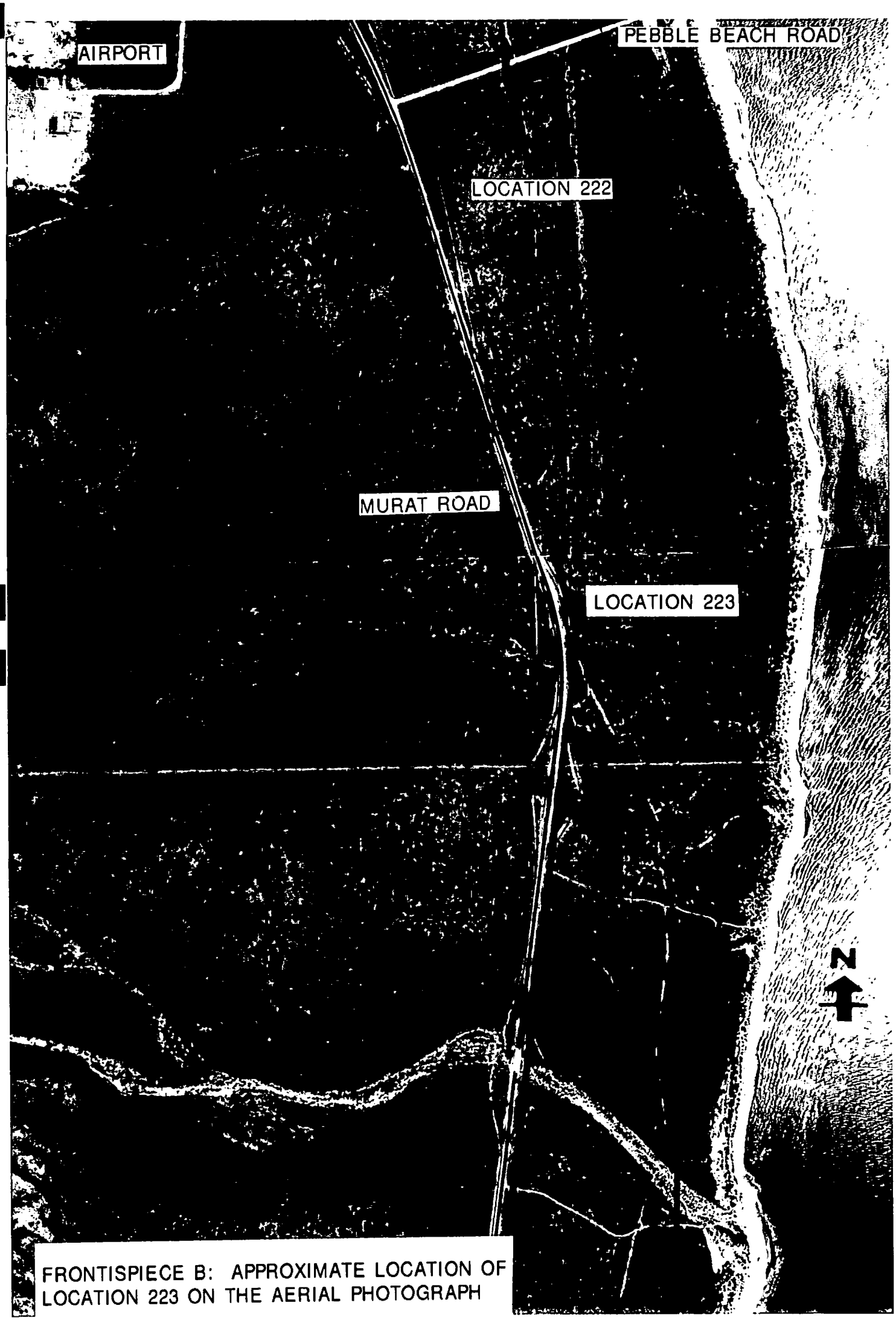
The proposed subdivision has been designed to capitalise on the environmental **opportunities and constraints** which the terrain, soils and vegetation of the Study Area offer for a rural housing development. The large lot sizes maximise the potential which the landscape and soils offer for fixing phosphates and the dispersal and loss of nitrogen from domestic effluent water. Individual lots of the proposed subdivision are well set back from the coastal dunes which adjoin the Study Area and major creeks which flow across the Study Area. The large sizes of the proposed lots limit the number of residents and thus provide a measure of protection for the coastal dunes and the vegetation of the Study Area. A fence will be erected between the proposed subdivision and the coastal dunes to prevent the dunes from being traversed by pedestrians, four wheel drive vehicles, motorcycles and horses. The fence will also direct pedestrians to the beach via natural creek cuttings through the dunes, thereby avoiding the need to disturb the dunes.

A Coastal Strategy, the Exmouth Coastal Strategy Document (DPUD, 1992) has been prepared for the Cape Range Peninsula, and it encourages development on the coastal region south of Exmouth and north of Wapet Creek, subject to several constraints on coastal development. The proposed subdivision of Lyndon Locations 222 and 223 addresses all of these constraints.

A summary of the main environmental issues which were identified during the course of the study as being in special need for attention for the design and management of the proposed subdivision is tabulated below together with potential environmental impacts and proposed management considerations to minimise adverse risks.

TOPIC	DESCRIPTION	POTENTIAL IMPACTS	MANAGEMENT/ASSESSMENT
Biophysical			
Potential impacts on flora and fauna.	Clearing of land for homesites and roads.	No rare flora or terrestrial fauna within the Study Area.	Limit clearing of native vegetation, especially on large lots.
	Domestic animals in proposed development.	Could provide a reservoir for feral animals.	Limitations on stock ownership and education on responsible pet ownership.
Coastal management.	Effect of pedestrian traffic to the beach.	Destabilisation of coastal dunes.	Fencing of dunes. Pedestrian access only via creek outlets to beach.
Water supply.	To be obtained from WAWA borefield which is presently subject of Consultative Environmental Review.	N/A	Alternative scheme water supply is available if Consultative Environmental Review not approved. Private bores will not be permitted.
Pollution			
Disposal of domestic effluent.	Use septic systems for effluent disposal.	Nitrogen compounds could have adverse impacts on cave fauna with habitats in groundwater.	Use of long, shallow leach drains will maximise nitrogen dispersal before it enters groundwater and flows to coast. Inputs of nitrogen to groundwater equivalent (or substantially less than) to existing background concentrations.
		Phosphates could have adverse impact on cave fauna with habitats in groundwater.	Soils, limestone and calcium content of groundwater will fix or precipitate phosphates.
		Could have adverse impact on coastal waters.	Only negligible volumes of nitrogen are likely to reach the sea. No phosphates are expected to reach the sea. Tidal movement adjacent to the Study Area will provide mixing.
Noise.	Noise from nearby airfield.	Noise levels could be of nuisance to future residents.	Calculated noise contours and noise frequencies well below limits set by Australian Standard 2021.
Flooding			
Creek flooding.	High rainfall may cause flash flooding in creeks.	Flooding in low-lying areas could affect future housing.	Areas below 2.0m AHD which could be flooded not to be used for home construction.
Oceanic storm surges.	Severe storms, especially cyclones can cause surges above usual sea levels which could add to Spring High Tide level.	Oceanic storm surges could flood creeks.	Estimated level of oceanic storm surges are below planned minimum building levels. Very low probability of an oceanic storm surge and a Spring High Tide occurring simultaneously.
Aboriginal heritage			
Archaeological	Possible existence of archaeological sites in Study Area.	Destruction of important sites.	Two sites of low archaeological value found. Permission obtained from the Minister for Aboriginal Affairs to use land.
Cultural	Possible existence of cultural sites in Study Area.	Destruction of sites of cultural importance.	Survey revealed no cultural sites within Study Area.

FRONTISPIECE A: APPROXIMATE LOCATION OF LOCATION 222 ON THE AERIAL PHOTOGRAPH



FRONTISPIECE B: APPROXIMATE LOCATION OF LOCATION 223 ON THE AERIAL PHOTOGRAPH

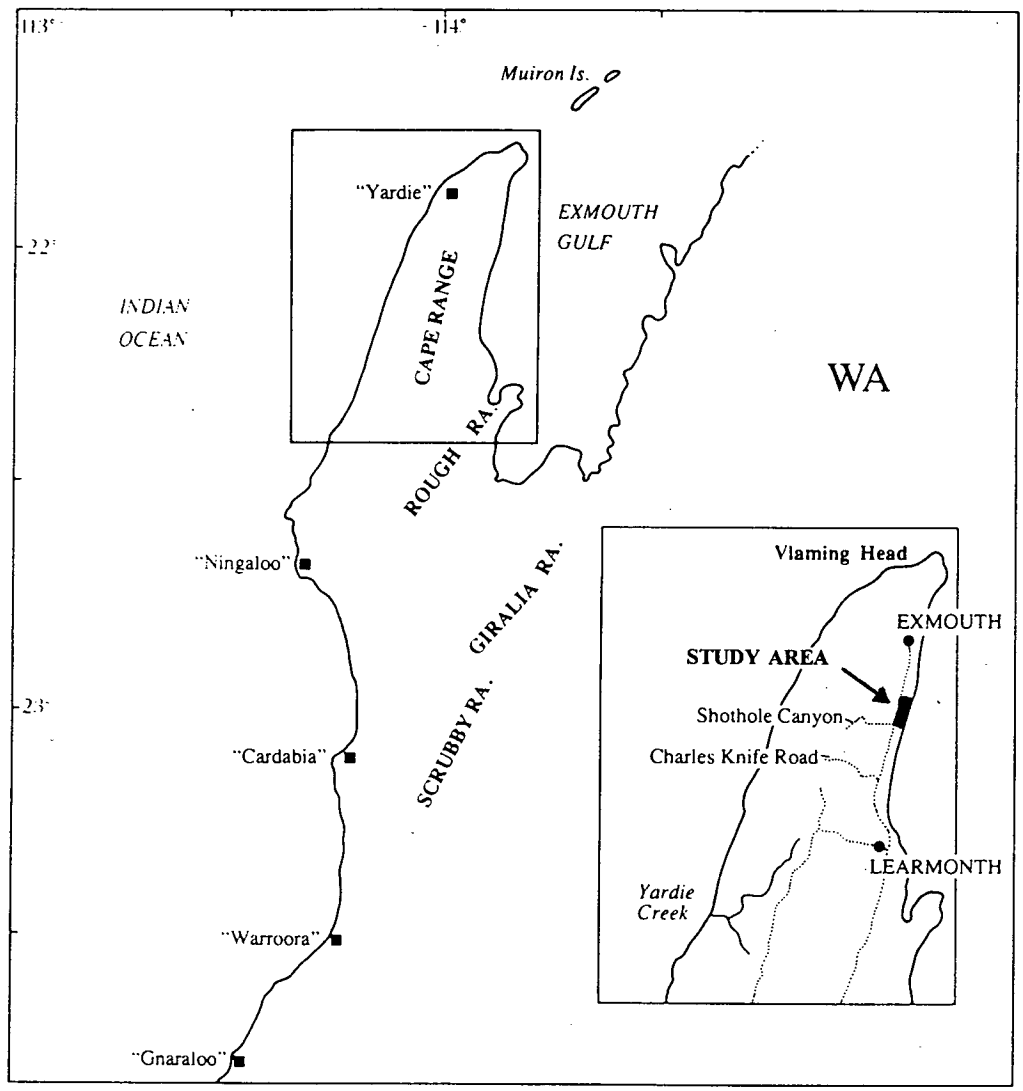


FIGURE 1: LOCALITY MAP SHOWING THE STUDY AREA IN A REGIONAL CONTEXT

CONTENTS

1.0 INTRODUCTION

1.1 The proposal

The proposal is to develop Lyndon Locations 222 and 223 (the Study Area) which are located approximately 10km to the south of Exmouth, into 177 special residential lots, ranging in area from approximately 4,000m² to 34,000m². The subdivision consists of 158 hectares of gently undulating to flat terrain immediately inland of the coastal dunes along the western shoreline of the Gulf of Exmouth. The location of the Study Area is shown in Figure 1 and an outline of the proposed subdivision is given in Figure 2.

The Study Area is located on terrain bounded by coastal dunes to the east and Murat Road to the west, and it extends approximately from Shothole Canyon Road in the south to Rifle Range Road in the north, in the vicinity of Exmouth Airfield.

1.2 Objectives

The overall objective of this study is to determine the environmental attributes of the Study Area and identify environmental constraints and opportunities so that the subdivision can be undertaken along sound ecological guidelines.

The objectives of the Consultative Environmental Review are to:

- place this project in the context of the regional environment and the progressive development of resources in the region,
- explain the issues and decisions which led to the choice of this project at this place and time,
- set out the environmental impacts that the project may have, and
- develop design and management criteria to avoid, mitigate or ameliorate each potentially adverse environmental impact.

Specific objectives relevant to the local environment include:

- determining the suitability of septic tank systems for the proposed subdivision, and, if necessary, recommend suitable soil amelioration or alternative systems,
- studying the fate and movement of phosphates and nitrogen within the proposed subdivision from proposed effluent disposal systems, and recommend proposals to minimise potentially adverse environmental impacts,
- identifying the presence of environmentally sensitive areas and issues within or near to the Study Area and management options for their protection,
- assessing the presence of rare plant species and important ecological habitats within or near to the Study Area and developing management options for the protection of these and other habitats, and
- assessing and managing potential impacts on aquatic cave fauna which may reside in groundwater below the Study Area.

To achieve the objectives it was necessary to:

- describe and appraise the terrain, soils, vegetation, flora and fauna of the Study Area and its surrounds,

- determine the ability of the soils of the Study Area to retain phosphates and assess the fate of phosphates and nitrogen which are likely to be released in effluent water to the soils of the Study Area,
- assess the water infiltration characteristics of the soils,
- assess likely soil erosion and surface drainage problems, and
- formulate appropriate recommendations.

2.0 METHODS

The Study Area was visited in mid-April 1995 to assess its terrain, soils, vegetation and flora in a local and regional context and to prepare guidelines for the design and management of the proposed subdivision. The terrain, soils and vegetation of the Study Area and the adjacent coastal dune system was described in seven landscape units, all of which are components of the Learmonth Land System (Payne et. al., 1987). Vegetation communities for each landscape unit were described on the basis of structural characteristics and common floristic composition. The Study Area was extensively inspected and searched for the purpose of preparing an environmental appraisal and identifying environmental development opportunities and constraints. Plant species were identified in the field and subsequently verified in the Herbarium of Western Australia.

Detailed environmental descriptions were obtained at 12 inspection sites (Figure 2). All inspection sites were photographed, the vegetation, soil and terrain were described and the site was searched for rare and priority listed flora. Extensive opportunistic vegetation sampling was undertaken throughout the Study Area to ensure that species which might have been missed at selected samples sites were located elsewhere. The entire Study Area was also extensively searched for rare and priority listed flora, introduced flora, interesting habitats and to confirm the mapping of landscape units. All opportunistic fauna sightings were noted during the field survey and specific searches were undertaken in interesting fauna habitats.

At each of the 12 inspection sites deep trenches were excavated by backhoe to permit the study of the soil profiles of the Study Area. The distribution of the landscape units within the Study Area was mapped with the assistance of 1:5000 colour aerial photographs and a map with contours at 0.5m vertical distance. The backhoe was also used to expose the various soil horizons of each soil profile for water infiltration tests. At each of these sites the soil was sampled and water infiltration tests were undertaken.

Soil samples were taken from each of the horizons of the profiles of the respective soil types and subsequently analysed by the Chemistry Centre (WA) of the Department of Minerals and Energy for their Phosphate Retention Index (PRI). The PRI was developed in Western Australia by Allen and Jeffrey (1990) as an indicator of the ability of a soil to fix phosphates. It is now widely used in Western Australia and PRI values are interpreted as follows:

- PRI < 2 Very weakly fixing.
- PRI 2 - 5 Weakly fixing.
- PRI 5 - 20 Moderately fixing.
- PRI 20 - 70 Strongly fixing.
- PRI > 70 Very strongly fixing.

The water infiltration rates of the different soil horizons of each soil type were measured in the field according to methods recommended by the Department of Health (The Treatment of Sewerage and Disposal of Effluent and Liquid Waste Regulation - under the Health Act of 1911). The method measures the time taken by a 25mm head of water to infiltrate soil with a moisture content of about field capacity. For sands this time is usually less than 5 minutes and for loams and clayey soils this can take 60 minutes and more. Soils which require more than 60 minutes are regarded as unsuitable for the use of leach drains or in need of special amelioration.

3.0 LANDUSE AND FUTURE DEVELOPMENTS

3.1 Present landuse

The Study Area is currently Vacant Crown Land with the title being transferred by the Department of Land Administration to the Shire of Exmouth. In the south the Study Area adjoins Exmouth Gulf Pastoral Station and to the immediate north is Reserve 118↑37664 (23.4ha) which is used as a rifle range.

The Study Area partly surrounds Recreation Reserve 109↑32946 (45.7ha). There is no obvious evidence of current usage of this Reserve.

An "Aerial landing ground support facility" is located within the Study Area on Reserve 73↑32867 which is 7738m² in size. Roads which will be constructed to serve the subdivision will also maintain access to this Reserve.

3.2 Future developments

The Exmouth Region is receiving considerable attention from wide ranging interests, especially tourism, fishing, mining, oil and gas exploration and associated service industries. There is a need to provide additional housing. This is recognised by the Shire of Exmouth and Greenough Holdings Pty Ltd. The latter assessed the market demand for housing and determined that there existed a considerable and immediate demand for the type of housing which is recommended for the proposed development. Discussions between the Shire of Exmouth, Greenough Holdings Pty Ltd, and the Department of Land Administration identified Lyndon Locations 222 and 223 as suitable for development to meet the identified demands. Consequently, the proponent is now anxious to meet this demand as soon as possible.

The Study Area is well removed from a proposed tourist development on the west coast of the Cape Range Peninsula and from a proposed limestone mining project which is currently being evaluated by the Public Environmental Review process. The proposed development of Lyndon Locations 222 and 223 is separated from the proposed tourist development along the west coast of Cape Range Peninsula by the Cape Ranges. It will not be affected by this tourist proposal and conversely it will not affect the proposed tourist development. In the event that the proposed limestone mining project is commissioned it is conceivable that the subdivision of Lyndon Locations 222 and 223 will assist in providing lots for housing for employees of the project.

The various development projects proposed for Cape Range Peninsula and which are likely to be assessed in the future will probably present a competing interest for available water resources. Negotiations with the Water Authority of Western Australia have already resulted in an agreement that water will be provided by the Water Authority for the proposed development of Lyndon Locations 222 and 223. It is expected that future projects will need to secure similar agreements following an assessment of their respective water needs by the Water Authority and possibly also the Department of Environmental Protection and the Environmental Protection Authority.

4.0 CLIMATE

The Study Area is located in a hot and semi-arid region. The mean monthly maximum and minimum temperatures recorded at Learmonth are given below:

MEAN MONTHLY MAXIMUM AND MINIMUM TEMPERATURES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MIN (°C)	23	24	24	21	16	13	11	12	14	16	19	21
MAX (°C)	38	38	37	33	28	25	24	26	29	32	35	37

Rainfall occurs mainly during the period of January to August as can be seen in the table below which was compiled from information recorded at Learmonth. Rainfalls generated by cyclones generally occur in February and March and reliable winter rains occur during May and June. Intense precipitation may occur and last up to 2 days with isolated records showing rainfalls of more than 250mm per day. The highest monthly rainfall of 361mm was recorded for Learmonth in January 1967. The mean monthly rainfall is given below for Learmonth:

MEAN MONTHLY RAINFALL (mm)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
27	22	27	21	51	50	29	16	3	2	2	2	252

Inspection of the rainfall events for the 80 year period from 1915 onwards (Station 5004, Exmouth Gulf) shows that on 26 occasions rainfall events in excess of 100mm per day were recorded. This is shown in the table below. Two of these were in excess of 200mm and one was greater than 300mm. The data also showed that during that period single rainfall events of greater than 100mm rarely occurred more than once per year. They occurred twice during the years 1918, 1927 and 1933 and on three occasions in 1923. On average, it appears that single rainfall events of 100mm or more can be expected once in three years.

Rainfall events which exceeded 100mm in a 24 hour period since 1915.

RAINFALL mm	NUMBER OF OCCASIONS
100 to 119	8
120 to 139	8
140 to 159	4
160 to 179	2
180 to 199	1
200 to 250	2
>250	1
TOTAL	26

Annual pan evaporation is 3150mm and this exceeds the annual precipitation of 252mm by about 2900mm.

The wind pattern is dominated by off-shore winds. During the morning southerly winds prevail with south to south-easterlies prevailing all year. From October to April south to south-westerly breezes become dominant in the afternoons. Strong winds from the north and north-east are infrequent and commonly associated with cyclones.

The average number of cyclones per annum for Cape Range Peninsula is 1.5, and the average frequency of severe cyclones with central pressures of less than 980 hPa is nearly one per year (Bureau of Meteorology).

5.0 ENVIRONMENTAL ASSESSMENT, POTENTIAL ENVIRONMENTAL IMPACTS AND THEIR MANAGEMENT

5.1 Geology, landforms, marine geomorphology, flooding by creeks, tides and oceanic storm surges

For the design and management of the proposed development it is important that the geological and landform characteristics of the Study Area are considered in order to address the following:

- impacts on sensitive landforms,
- flooding from creeks,
- impacts of oceanic storm surges.

5.1.1 Geology and landforms

5.1.1.1 Background

The geology of the Cape Range Peninsula has been reviewed by Wyrwoll et. al. (1993) and it is summarised below for the Study Area.

The Study Area is located within the Carnarvon Basin which encompasses the Cape Range Peninsula and extends inland for about 160km. The Carnarvon Basin is a low-lying sedimentary basin with exposed rocks of Permian to Recent origin. The Study Area abuts the coastal dune system which adjoins the beach and it includes the sandy outwash plain which extends to the Cape Range. Five geological formations occur within and adjacent to the Study Area, namely:

i. **Holocene coastal deposits:** These are the coastal dunes which consist of a complex of dune and beach sequences, and they are located to the immediate east of the Study Area.

ii. **Mowbowra conglomerate:** This consists of a Pleistocene shingle beachface or bar deposits in linear ridge forms and gravel conglomerate. Older units are often strongly calcretized with well developed solution pavements.

iii. **Quaternary alluvial sediment associated with creeks:** This consists of fans and well developed alluvial deposits which are dominated by coarse gravel conglomerate with moderately to well cemented calcrete development. These calcrete developments have been deposited on both sides of creeks to the south of Exmouth Airfield. A large alluvial fan surrounds the Shothole Canyon Creek in the south of the Study Area

iv. **Coastal plain deposits:** These are poorly defined alluvial and coastal units which have been locally reworked.

v. **Trealla Limestone:** This consist of dissected limestone terrain with karst development. This formation is found mostly inland of Murat Road, or inland of the Study Area.

The distribution of the above geological formations within the Study Area and its immediate surrounds is shown in Figure 3 as taken from Wyrwoll, et. al. This Figure provides general information on the region's geological features. More detailed information which is required for the environmental assessment is obtained from the contour and landscape mapping of Figure 2.

The Exmouth Coastal Strategy Document (DPUD, 1992) relates future landuse planning to sensitive elements of the landscape and to those elements which are likely to involve damage due to oceanic storm surges or stream discharge. Two of the five geological formations were considered to be environmentally sensitive and not suitable for a housing development. The remaining three geological formations of the Study Area were not rated as sensitive coastal elements. The two sensitive geological formations and comments from the Exmouth Coastal Strategy Document are given below:

i. **Holocene coastal deposits (coastal dunes).** These are rated as "least desirable" for development because they are unstable and prone to erosion. Development on this landform is also not encouraged due to the possibility of oceanic storm surges. In places oceanic storm surges have formed wave-wash deposits of coral bolder, and these deposits serve as a warning that such surges can recur.

ii. **Quaternary alluvial sediments associated with creeks.** These are rated as "least desirable" for development and the Coastal Strategy comments as follows:

- Alluvial fans are important indications of oceanic storm surge activity.
- The eastern part of the Cape Range has a well defined drainage net and flooding and surface ponding should not be a problem compared to the western part of the Cape Range.
- High to extensive rainfall events associated with cyclones can produce management problems due to extreme creek discharge.

5.1.1.2 Potential impacts on landforms

The housing of the proposed development will be located on three landforms which were identified in the Coastal Strategy as stable and capable of sustaining development. Consequently, their stability will not be adversely affected by the proposed development. The two sensitive landforms of coastal dunes and the gravel beds of creeks will be protected because the dunes are outside the Study Area and will be fenced to control beach access, and the major creeks will be included in Public Open Spaces.

5.1.1.3 Proposed design and management considerations

For the proposed subdivision the nominated management aims to prevent pedestrian access, off-road vehicles, motor cycles and other activities, such as horse riding, on coastal dunes outside of the Study Area. To achieve this it is proposed to erect a fence immediately inland of the coastal dunes and to direct all pedestrian access to the beach via natural creek entries. Damage to the creeks by pedestrians will be minimal and manageable because the creek beds consist of sand and stones which can sustain high rates of pedestrian use.

5.1.2 Marine geomorphology

5.1.2.1 Background

The western shore of Exmouth Gulf, from Bundegi Reef in the north to Point Lefroy to the south of Learmonth, is characterised by a wide flat intertidal limestone platform which is frequently exposed at low tide. Martinick and Associates (1992) studied the sea floor offshore of Badjirrajirra Creek which is approximately 5km to the south of the Study Area. In this area the limestone platform is about 200m wide and it slopes gently to the 5m depth contour before sloping more steeply to the 8m contour where it merges with the mixture of sands, coarse shells, mud and silt of the sea floor. This type of sea floor dominates from the 8 to 10m contour, and in isolated areas sand and seagrasses were observed to form a sparse cover. At the 8m contour the sea floor generally consists of coarse shells and sand, whilst mud and silt prevail at the 10 to 12m contour and uniform mud and silt occur at the 14m contour. The sea floor has been scared by extensive commercial trawling for prawns.

5.1.2.2 Potential impacts and proposed design and management considerations

The marine environment will not be affected by the proposed development. All domestic effluent will be disposed by means of septic tank systems. Evidence presented elsewhere in this Consultative Environmental Review indicates that none or very little of the phosphates and nitrogen of this effluent will leach into the sea. Consequently there is no need for special considerations in the design of the subdivision for the protection of the marine environment.

5.1.3 Creek flooding

5.1.3.1 Background

During floods the water level in creeks typically rise to the level of sand-bars which, within the Study Area, are usually located across creek entrances to the sea, before the sandbar is breached and ponding is rapidly discharged into the ocean. The height of the sandbars can vary, with a sandbar in the low-lying area in the north of the Study Area having been measured at approximately 1.5m AHD. This height appears to be typical for the sandbars of the various creeks. Ponding behind the sandbars is well contained within the creek beds and does not result in flooding.

The Water Authority of Western Australia has not conducted flood-level studies for the Cape Range Peninsula and no flood-risk guidelines are available for the Study Area. The Exmouth Coastal Strategy Document identified flooding as a risk for future developments and recommends detailed studies in the vicinity of creeks to quantify these risks. Nevertheless, the Exmouth Coastal Strategy Document concedes that creeks discharging into the sea to the east of the Cape Range, which includes the Study Area, are well defined and flooding and ponding should not present a risk.

For the planning for the proposed development, contours were mapped at vertical intervals of 0.5m to provide information for land capability constraints, especially potential flooding. This mapping provided the confidence for the correct siting of proposed housing lots and the selection of lot sizes which are appropriate for each landscape setting. The contour map of the Study Area shows that in most instances the plains are elevated 2m to 5m above the respective creek beds, and that for these areas flooding is not a high risk. This applies especially to Precincts D, E and F which are in the south of the Study Area.

The effects from extreme creek discharges will be minimised by sandbars being regularly inspected and, if deemed necessary, breached prior to each cyclone season. However, it is considered that this will be rarely, if ever, necessary.

5.1.3.2 Potential flooding problems and proposed design and management consideration to prevent or avoid flood damage

Inspection of the creekbeds and terrain suggests that flooding by the four large creeks of the Study Area is not likely to be a problem because of their well defined creek beds which are usually well below the surrounding terrain. Inspection of the terrain and vegetation immediately adjacent to the extremities of stream flow suggests that they very rarely if ever flood across the adjacent land. They certainly do not appear to flood with every single rainfall event of greater than 100mm. This concurs with the general observations of the Exmouth Coastal Strategy Document. In these four creeks the sandbars are estimated to be about 1.5m AHD and they will be readily breached by flood waters to prevent extensive ponding.

Two of the four large creeks are located within the proposed development areas of Precincts D, E and F, and they are all incorporated into Public Open Spaces. A third creek forms the southern boundary of the Study Area. Flooding of these precincts is considered to be highly unlikely because they are all located on land above 3.5m, and mostly above 4.0m, AHD.

Minor drainage lines in the north of the Study Area are included in Precincts A and B and they are not incorporated into Public Open Spaces. These drain small catchments and their fringing vegetation is an extension of that of the surrounds, thus providing excellent soil stability. These drainage lines are included in large lots with housing envelopes being removed from possible waterflow to ensure that drainage is not interfered with and the drainage vegetation is retained intact. No flood problems are anticipated from these drainage lines.

A fourth major creek between Precincts A and B in the north of the Study Area dissects some areas which lie below 2.0m AHD and which are likely to be inundated in the event of an extreme creek discharge which could occur during the passage of a cyclone. Inspection of the terrain and contours suggests that flooding is generally confined to areas below 2.0m AHD. Data given in Section 4.0 shows that since 1915 single rainfall events of greater than 100mm occurred on 26 occasions over an 80 year period. On three occasions rainfalls in excess of 200mm in a single day were recorded and these could have caused flooding of low-lying areas, probably less than 2m AHD, behind the coastal dunes.

The major creek between Precincts A and B is included in a Public Open Space. These precincts each includes small areas with elevations of marginally less than 2m AHD. In Precinct A two lots which adjoin the Public Open Space and in Precinct B three lots which also adjoin this Public Open Space have parts of their land below the 2m AHD contour. These low areas are subject to potential flooding. To address these concerns, the proposed subdivision has been designed so that each of these lots also includes substantial areas of higher terrain, up to 2.5m and possibly 3m AHD. For Precinct B this has further overcome by substantial increases in lot sizes. The higher areas within all of these lots are substantially less likely to be flooded and the proposal is to locate building envelopes in these lots onto these more elevated areas. It is recommended that the actual house pad be further elevated with infill material to 3m AHD. This will ensure that the risk of flooding in these areas is almost eliminated.

5.1.4 Tides, oceanic storm surges and potential impacts

Tides in Exmouth Gulf occurs twice a day and the tidal range increases towards the head of the Gulf. For example, at Point Murat to the north of the Cape the range of the Mean Spring Tide is 1.7m and at Neap Tide the range is 0.4m, whilst at Learmonth the range of the Mean Spring Tide is 2.1m and the range of the Neap Tide is 0.6m. At Badjirrajirra Creek the former Department of Marine and Harbours measured a Mean Spring Tidal range of 2m and the Highest Astronomical Tide was measured at Learmonth Jetty to be 3m above chart datum (Steedman and Russell, 1986). This translates to 1.6m AHD. The Mean High Water Spring Tide at Learmonth Jetty is 2.5m above chart datum (chart AUS 744) which is 1.1m AHD.

Tidal currents in Exmouth can exceed 0.5m/sec. The differences between the ranges of spring and neap tides result in considerable variations of tidal currents. The direction of the tidal current opposite the Study Area is approximately north to south, and it moves at an average speed of 0.1 knots at Neap Tide and 0.8 knots at Spring Tide.

Under prevailing conditions the swell of the Indian Ocean is strongly refracted into Exmouth Gulf, and reduced by shallow coastal waters. Consequently the swell influences only the east and extreme north coast of Exmouth Gulf. Wave action in the Gulf, especially along the western shore, is dominated by local winds. The Study Area is located on the western side where it is protected from oceanic storms by shallow waters and reefs. Steedman and Russell (1986) concluded that at Badjirrijarra Creek, and this would apply equally to the Study Area, cyclone risks are moderated by the following influences:

- Reefs and islands around the mouth of Exmouth Gulf which only allow narrow angular bands of swell to penetrate.

- Exmouth Gulf is rarely hit directly by a cyclone and consequently wind waves are smaller than would be expected if a severe cyclone passed directly over the Gulf.

- The shape and orientation of the northern opening of Exmouth Gulf.

Prevailing south-easterly and south-westerly winds will generate seas which are generally less than 1m in height and these will be directed off-shore of the Study Area. The most significant wave generation occurs during cyclones, and Steedman and Russell estimated that during cyclones wind waves up to 2m and swell waves of up to 5m with a 10 to 12 second period will be generated within Exmouth Gulf. They calculated that at Badjirrijarra Creek such conditions could give rise to a 1 in 50 year oceanic storm surge of 0.6m above existing conditions. This would result in a total water height of 1.7m AHD if superimposed on a Mean High Water Spring Tide. Steedman and Russell provided no probability for the

occurrence of such an event, but from calculations given below it is estimated to be a 1 in 4200 year event. Such an event could result in water entering some of the creeks but it would not result in any flooding. If a 1 in 50 year oceanic storm surge was to coincide with a Highest Astronomical Tide then according to Steedman and Russell the sea levels could rise to 2.2m AHD. The probability of such an event occurring is even less likely than the 1 in 4200 year event. Importantly, such an event is also unlikely to result in flooding within the Study Area except possibility the lower lying areas of Precincts A and B (see Figure 2).

To calculate the probability of different storm events occurring simultaneously the individual probabilities of the occurrence of each event are multiplied. Thus the probability of a 0.6m oceanic storm surge coinciding with a Mean High Water Spring Tide is calculated by multiplying the probability of a 0.6m oceanic storm surge (1 in 50 years) with the probability of a Mean High Water Spring Tide for the duration of the cyclone season. This is a probability of 1 in 84, and it is based on 8 High Spring tides occurring over 4 lunar months with each having a 4 hour duration for the peak of the tide {28 x 4 x 24) ÷ (8 x 4) = 84}. Thus the probability of a 0.6m surge occurring simultaneously with a Mean High Water Spring Tide is 1 in 4,200 years {50 x 84 = 4200}. It must be emphasised that probabilities will not prevent such an occurrence, they merely indicate the risk of such occurrences.

The parameters which increase during a cyclone are oceanic storm surges, wave height and wind speed. These events will not peak simultaneously and a period of several hours could pass between the occurrence of a maximum oceanic storm surge, wave height and wind speed. Steedman and Russell predicted that the water level at Badjirrijarra Creek would be 6.4m above chart datum (5.0m AHD) if a worst combination of these events was to occur. Such a combination would have severe consequences for the entire coastline, including most of the Study Area. No information was given on the probability of such an event occurring, but it will be a very low risk, and less frequent than the 1 in 4200 years event.

From an analysis of the effects on the sea of the most severe cyclones in the Exmouth Region between 1942 and 1985, it was estimated by Steedman and Russell that for the Badjirrijarra Creek area 19 oceanic storm surges of less than 0.1m, 11 of between 0.1 and 0.4m and 2 of greater than 0.4m had occurred. No information was given on whether any of these coincided with Spring High Tides.

The Coastal Strategy Document encourages development between the townsite of Exmouth and Wapet Creek to the south of the Study Area, with the following constraints which also apply to the Study Area:

- Meeting sound environmental principals.
- Develop foreshore management plans for proposed land developments.
- Locate development away from drainage lines and other flood-prone areas.
- Establish a reserve to include the coastal dunes and other environmentally sensitive areas.

Risks of oceanic storm surges which were identified in the Exmouth Coastal Strategy Document relate to developments which face the ocean or are located in low areas which could be inundated by oceanic storm surges. The probability of a 1 in 50 year oceanic storm surge of 0.6m coinciding with a Mean High Water Spring Tide would cause a total water height of 1.7m AHD. The probability of such an event is very low and substantially less frequent than a 1 in 50 years event. Consequently, the minimum floor levels for domestic dwellings should be determined by risks of creek discharges as these have a greater probability of occurring than oceanic storm surges.

5.2 Vegetation and flora

Vegetation and flora issues which need to be considered in the design and management of the proposed development relate to the:

- the conservation of plant communities with high conservation values, and
- protection of rare and priority listed plant species.

5.2.1 Description - terrestrial and marine

The terrain, soils and vegetation of the area inland of the coastal dunes consists of "scrub steppe on sandhill country" and it is representative of the Carnarvon Basin (Beard, 1975) and according to Payne et. al. (1984) it is part of the Learmonth Land System.

The Study Area adjoins the coastal dunes of Exmouth Gulf and it consists of six landscape units all of which are part of the Learmonth Land System of the coastal strip between the Cape Range and the ocean. A seventh Landscape Unit (Landscape Unit G) adjoins the Study Area. According to Payne, et. al., the Learmonth Land System (Figure 5) consists of approximately 255km² and occurs on 0.4% of the total Carnarvon Basin.

The seven landscape units are consistent with the description by Payne, et. al., and they include the following:

- Landscape Unit A: Sandy plain of widely scattered shrubs over a hummock grassland.
- Landscape Unit B: Sandy plain with a shrubland over a hummock grassland.
- Landscape Unit C: Outwash plain with moderately close and tall shrubland.
- Landscape Unit D: Low-lying plain with a mosaic of salt tolerant shrubs and hummock grasslands with scattered shrubs behind coastal dunes.
- Landscape Unit E: Drainage lines with trees and shrubs.
- Landscape Unit F: Calcrete plain with open shrubland over hummock grasses.
- Landscape Unit G: Beaches and coastal dune system.

The distribution of these Landscape Units is given in Figure 2. A detailed description of the terrain, soils, and vegetation of each landscape unit, and a list of all of the flora species identified in the Study Area is given in Appendix 4.

Rare and priority listed flora which are likely to be found in the greater region of the Study Area are tabled in Appendix 4. No such species were found during extensive searches. Of these species only *Scaevola acacoides* has been found on the coastal plain to the east of the Cape Range. All of the other species were found in the Cape Range National Park or to the west of the Cape Range. The Cape Range National Park represents a very different landsystem to that of the Study Area and consequently it is unlikely that many, if any, of the rare and priority listed species recorded within the Cape Range will occur in the Study Area and its immediate surrounds.

Introduced plant species which are widespread within the Study Area include *Aerva javonica, Aristida holathera, Cenchrus ciliaris, Cenchrus setigerus* and *Chenopodium morale. Cenchrus ciliaris* and *Cenchrus setigerus* are grasses and *Aerva javonica* is a bush which are valued by the pastoral industry of the North West.

Seagrasses do not form extensive meadows in Exmouth Gulf because there is a general absence of sufficient sand with most of the seabed consisting of a limestone surface. Seagrasses are generally expected in sandy areas at depth to 12m, although in Shark Bay extensive seagrass meadows have been discovered in clear water at a depth of 14m. Similarly good water quality exists in Exmouth Gulf, and sandy areas within Exmouth Gulf are likely to support seagrasses at a depth of 14m (Dr Hugh Kirkman, CSIRO, pers comm).

5.2.2 Potential environmental impacts and proposed design and management considerations to avoid or minimise such impacts

The Study Area and the adjoining dunes and beach system consists of two environmentally sensitive landscape units (E and G).

The major creeks (Landscape Unit E) within the Study Area are important habitats for the fauna of the region. These habitats include a variety of creek-bed structures, steep creek banks, tall and dense shrub layers and large trees. This landsystem has the potential of being adversely affected and is in need of protection. Such protection will be provided by incorporating most Landscape Unit E into Public Open Spaces except for minor drainage. The width of land adjacent to such Public Open Spaces depends on the terrain of each creek but generally the width will vary from 30 to 200m (see Figure 2).

The coastal dunes (Landscape Unit G) are outside of the Study Area but they could be affected by residents of the proposed development and are consequently in need of protection. Protection measures of fencing and controlled beach access are proposed.

The remaining Landscape Units of the Study Area are representative of extensive areas of the Learmonth Land System and the adjacent Cardabia Land System. Their vegetation communities and flora species are all very common and widespread. Apart from the major creeks, which will all be incorporated into Public Open Spaces, the Study Area does not have landscape units with local or regionally outstanding ecological values.

All of the plant species identified in the Study Area are common on the Cape Range Peninsula and the coastal plains of the Gascoyne Region. Consequently, the impact of the proposed development on these species will be negligible in a regional conservation context.

No gazetted rare or priority listed plant species were located during extensive searches of the Study Area and no such plants are likely to be affected by the proposed sub-division.

The marine ecosystems are unlikely to be adversely affected by the proposed development. Significant volumes of groundwater discharge into Exmouth Gulf and the presence in this water of nitrates, nitrites and phosphates from domestic effluent is considered to be negligible. This is discussed in section 5.3.

5.3 Groundwater, soils and the fate of phosphorus and nitrogen contained in domestic effluent

Groundwater parameters which need to be considered in the design and management of the proposed development include:

- possible contamination of groundwater by domestic effluent disposal from future home sites,
- activities of future residents which could pollute groundwater, and
- possible groundwater abstraction by residents.

The Water Authority of Western Australia will not permit the use of private bores within the proposed development. Hence private abstraction of groundwater will not be an issue for the proposed development and is not considered further in this Consultative Environmental Review.

No surface water bodies occur within the Study Area.

An assessment of the potential impacts of proposed septic tank systems on the quality of groundwater necessitates an appraisal of the groundwater and soils of the Study Area and a discussion on the likely fate of phosphates and nitrogen contained in domestic effluent water. This follows:

5.3.1 Background

5.3.1.1 Groundwater

The coastal plain is known to have an extensive aquifer from which water is abstracted by the Water Authority of Western Australia to supply the domestic and industrial needs of Exmouth. The quality of the groundwater is frequently brackish along the coast due to sea water intrusion. An extensive borefield has been established in and adjacent to the Cape Range by the Water Authority of Western Australia for the provision of potable water to residents of Exmouth. No bores exist within the Study Area.

Within the Study Area groundwater was located at a depth of 2.1m at Site 4 (Figure 2) which was one of the lower lying soil inspection sites. From the contour map for the Study Area it is estimated that the groundwater level at this site is at approximately 0.2m AHD.

The groundwater gradients of the Cape Range are steep with a maximum elevation of about 10m AHD, whilst those of the coastal plain are very flat (see Figure 4). This causes groundwater to flow rapidly from the Range to beneath the coastal plain and into the sea (Allen 1993). This flow rate is thought to be of the order of hundreds of metres per annum (pers.comm. Mr M Martin, Geological Surveys, Hydrology section). Forth (1972) estimated a daily through flow of groundwater into the sea for the length of the Cape Range of about 460 cubic metre per km of coastline.

The quality of the groundwater is monitored regularly by the Water Authority of Western Australia for a substantial range of chemical parameters. Inspection of data collected from 43 bores (SWRIS database, WAWA) over various periods indicates that the total sum of ions in the water ranges from 700 to 1673mg/l, the calcium content from 58 to 98mg/l and the total nitrogen present as nitrate and nitrite ranges from 1.3 to 2.1mg/l. No data is available for phosphates.

5.3.1.2 Soils

The soils of the Study Area are relatively uniform. They consist almost entirely of red/brown loamy sands which in most places are deep (2m plus), although there are occasional outcrops of calcrete and in these areas the soils are usually very shallow and soil depth is very variable over short distances. Typically, soil depth varies from 35cm to 225cm and deeper and it overlies calcrete, limestone gravel and stony colluvium. Only one location, Site 4, had a different soil. In this area red/brown loamy sand overlies friable brown clay. The description of the soils is given in Appendix 2 and the location of soil inspection sites is shown in Figure 2.

Important soil properties which need to be considered in the planning of the proposed development include:

a) **Phosphate Retention Index.** The results of the PRI analysis for the soils are given in Appendix 2 and they indicated that the PRI varies from 10 to 27, with most soils having a PRI in the range of 22 to 25. This suggests that the soils of the Study Area are moderately to strongly phosphate fixing. An interpretation of the PRI values is given in section 2.0.

b) **Water infiltration rates.** The water infiltration rates of the soils of the Study Area are given in Appendix 2, and from this it can be seen that water will infiltrate rapidly into all of the horizons of these soils.

5.3.2 Proposed septic tank systems: Potential environmental impacts of phosphorus and nitrogen on the quality of the groundwater; water infiltration; other pollutants; and marine considerations

Domestic effluent contains phosphorus, almost exclusively as phosphates, and nitrogen, mainly as nitrates and nitrites, and these chemicals are of environmental concern because they are plant nutrients which can stimulate algal blooms in open water bodies. Consequently, the potential impacts of phosphates and nitrogen on the quality of groundwater are assessed in the following.

5.3.2.1 Phosphates and nitrogen - impacts, discussion and recommended action

a) Phosphates

The PRI's of the soils of the Study Area confirm that most of the phosphates in effluent water will be readily fixed within the soils of the Study Area. Phosphates are expected to be further fixed by the calcium ions of the limestone and lime sands which underlie the soils of the Study Area. Phosphates are thus very unlikely to be leached from the respective septic tank systems into the wider surrounds. Instead, most of the phosphates will be fixed in the immediate vicinity of the septic tank systems.

Whelan and Titamnis (1982) estimate that on average each person annually contributes approximately 0.6kg of phosphorus, almost exclusively as phosphates, into septic tanks or sewerage systems. For an average family of 3.3 people this amounts to about 2kg per annum and for the entire proposed subdivision of 177 lots a total of 350kg of phosphorus as phosphates could be expected to be discharged annually into septic tank systems which will be scattered over 158ha. This is equal to about 2.2kg of phosphorus per hectare per annum distributed as point sources but which will then disperse very slowly at a rate which is determined by the saturation of phosphate sorption sites in the soil. The direction of dispersal will be in the general direction of groundwater flow but not at the rate of groundwater flow. Other studies indicate that the phosphate input to septic systems could be higher. Gerritse, *et. al.*, (1992) estimated that the average phosphorus input to a septic system in the Perth region was approximately 5kg per household per annum. For the proposed subdivision this would result in 885kg of phosphorus being discharged annually.

In most soils the leaching rate of phosphorus, in the most common form phosphate, is extremely slow and consequently very difficult to measure. The rate is dependant on the PRI of the soils surrounding a septic tank system. In a study in the hills to the east of Perth, Gerritse *et al* (1995) found that phosphates had only leached laterally 2m and 5m from septic systems that had been in place for 5 and 7 years, respectively. This shows that over the period of seven years the phosphates had dispersed at an average annual rate of less than 1m. Importantly, the leaching rate of the phosphate plume below a septic tank system will decrease with time and distance from the source due to the increasing area of the leaching front and the increasing volume of soil which this plume will traverse with increasing distance from the source. The uptake of phosphates by vegetation will further reduce the rate at which phosphates will disperse from the source.

For each septic tank system it is recommended that a dual leach drain system of 20m per leach pipe be used, with the pipes not being parallel to each other and each pipe being used for six months only per year. For such a disposal system the total annual phosphorus load per household will be discharged from 40m of leach pipe. For an average annual load of 5kg of phosphorus per septic tank system this amounts to 125g of phosphorus being released per linear metre into the underlying groundwater. This assumes that all of the phosphates are leached into the groundwater. If all of these phosphates are dispersed within the cubic metre of water beneath the linear metre of leach pipe, then this will result in an average and localised concentration of 125mg/l.

The rate of groundwater flow below the coastal plain is considered to be of the order of several hundred meters per year. This will result in the phosphates from the leach drains being drip-fed into the moving groundwater. For a very conservative groundwater flow of only 100m per year the concentration of 125mg/l would be diluted to 1.25mg/l, and for a possible flow of 1000m per year this would decrease to 0.125mg/l.

The above calculations are still gross over-estimates because they ignore the fixing of phosphates by the soil, limestone and lime sand through which the effluent water will leach.

Only a small percentage of the phosphates will leach, over time, into the groundwater and move any distance laterally in the direction of mass groundwater flow because of the relative good phosphate fixing properties of the soils. In addition, and very importantly, the high calcium content of the groundwater is highly likely to rapidly precipitate as insoluble calcium phosphate complexes all of the phosphates which do reach the watertable, thereby completely removing the phosphates from the groundwater.

When all of the above are considered, it is concluded that the proposed septic tank systems will have a very marginal impact on the phosphate concentrations of the underlying groundwater, and that these impacts are highly likely to be of minimal environmental consequence. This is shown in the table below for an average household for the proposed development and the assumption that the higher estimate of 5kg of phosphorus is annually released from a septic tank to the underlying groundwater.

ACTIVITY	RESULTANT CONCENTRATION OF PHOSPHORUS IN GROUNDWATER
Annual leaching of phosphates from 40m of leach drain to water table, in event of no soil fixation of phosphates and all of the phosphates being dissolved in the cubic metre of water below each linear metre of leach pipe, and there being no water exchange due to groundwater flow.	125mg/l
Annual dilution by groundwater flow at a conservative rate of 100m per year.	1.25mg/l
Fixation by soil, limestone and lime sand within, say 50m radius downstream of leach drain, uptake by plants and precipitation by calcium ions in groundwater. Almost 100% removal of phosphates.	Nil
Balance, say 50m downstream of septic tank.	Nil

b) Nitrogen

Nitrogen compounds are very soluble and unlike phosphates they are mobile and subject to losses in soils. These losses are in the form of gaseous losses to the atmosphere and leaching losses within soil profiles. Gaseous losses are temperature and moisture dependant, with high losses occurring from agricultural lands during warm and moist soil conditions.

Data presented by Gerritse *et al* (1992) shows that the annual nitrogen input to septic systems from an average household is approximately 22kg. Subsequent studies by Gerritse et. al. (1995) in the Darling Range east of Perth have shown that about 80% of the nitrogen applied to soils from effluent water is lost within 10m of lateral movements from the point of discharge. In the Exmouth region, with its higher temperatures, losses due to denitrification (natural breakdown of nitrogen compounds) are likely to be more rapid and greater. To further enhance such losses it is proposed that:

- Effluent water is discharged over a large area and close to the soil surface to enhance denitrification losses. For this reason it is recommended that dual leach drains are installed, and that they are extended from the standard length of 13m to 20m. They are also to be located as shallow as possible below the soil surface.

- A low housing density is planned to ensure that nitrogen is not concentrated in any one area,

- Deep rooted tree and shrub species be planted in the vicinity of leach drains to take up effluent water, complete with nitrogen and phosphates, which will then enter the plant/soil nutrient cycle.

It should be noted that the above three recommendations also address concerns with respect to phosphates.

For an average annual nitrogen load of 22kg per household and a discharge length of 40m about 550g of nitrogen will be discharged annually per linear metre of leach drain. A considerable portion of this nitrogen will be lost to the atmosphere within a short space of time, especially in the initial 48 hours. On the assumption that all of this annual nitrogen load leaches to the watertable immediately below the leach drain without the occurrence of losses and that all of the nitrogen load of each linear metre is dissolved in the surrounding cubic metre of groundwater, then the average nitrogen concentration in this water will be 550mg/l.

Gerritse et. al. (1995) observed that 80% of the nitrogen discharged from effluent disposal systems is lost within 10m of the point of discharge. Thus the maximum concentration of nitrogen from proposed septic tanks systems in groundwater some 10m horizontally from the leach drains is likely to be about 110mg/l. The annual rate of groundwater flow to the coast is thought to be of the order of hundreds of metres per annum. This will ensure that all of the water immediately below a leach drain will be continuously removed and discharged into the nearby sea. This high rate of groundwater flow prevents the accumulation of nitrogen in the groundwater immediately below each leach drain. A conservative groundwater flow of 100m per year will dilute the hypothetical concentration of 110mg/l to 1.1mg/l whilst a possible flow rate of 1000m per year will further decrease this to 0.11mg/l. The concentrates of 1.1mg/l approximates the concentration of background or natural nitrogen concentrations of the groundwater. This compares to the upper recommended concentration limit of nitrogen for safe human consumption of 10mg/l as listed in the Guidelines of the National Health and Medical Research Council in 1987 based upon the toxicity of nitrates in drinking water to infants. To put these concentrations further into perspective, they can be compared to the annual nitrogen release from pastures to creek systems in the south west of Western Australia which is in the vicinity of 100kg per hectare (Dr N T Barrow, pers. comm., 1994, CSIRO).

The likely fate of nitrogen released from an average household of the proposed lots is summarised in the table below which shows the annual mass balance of nitrogen inputs to the environment via domestic leach drains for 177 households.

SOURCE AND ACTIVITIES	NITROGEN	
	INPUT	OUTPUT
Leach drain.	22kg/household (3894kg for 177 lots)	
Natural losses within 10m of source (80% loss).		17.6kg/household (3115kg for 177 lots)
Discharge to groundwater and possible discharge to ocean assuming no further breakdown or uptake by vegetation and an annual groundwater flow of 100m.		4.4kg/household (779kg for 177 lots) 1.1mg/l concentration in groundwater for a conservative flow rate of 100m per year
TOTAL	**3894kg**	**3894kg**

5.3.2.2 Infiltration of effluent water discharged from leach drain - impacts and recommended action

A common problem affecting the function of septic tank systems is that anaerobic conditions within leach drains often cause the growth of anaerobic bacteria. This can form slimes within the leach drains which then block the holes in the leach drain and infiltrative soil surfaces, thereby restricting drainage of effluent water within the soils below the leach drain.

Blockages can be effectively prevented and/or removed by installing two separate leach drains per septic tank, not parallel to one another, with a stopcock to control the flow to either drain. Alternating on a six monthly basis the use of the two leach drains will result in aerobic processes removing such slimes and associated blockages. This method of effluent disposal is recommended and is a commitment by the Proponent. Residents will be reminded to switch the stopcock on the septic tank outflow every six months by the Shire including a reminder with their rates notices, and by suitable notification in the local

newspapers. An added benefit of two leach drains is the dispersal of nitrogen and phosphates over a larger area.

The efficiency of leach drains is often reduced where groundwater is close to the surface. In the Study Area the distance from the soil surface to the groundwater is greater than 2m for all proposed lots. For most of the building envelopes the distance to the groundwater will be 3 to 5m. This will ensure that groundwater levels will not adversely affect the functioning of leach drains.

5.3.2.3 Other pollutants - potential impacts and proposed management action

Future residents of the proposed development are likely to use garden fertilisers for lawns and other plants, and some of these plant nutrients could leach to the water table. An environmental pamphlet will be prepared by the Proponent and it will stress the importance of subterranean fauna habitats and other environmentally sensitive areas and issues and encourage the use of slow-release fertilisers and readily biodegradable pesticides. The use of local native plant species will also be encouraged as these generally require less watering and fertilising. Where potential groundwater pollutants have been applied to the soil surface, the high temperatures and solar radiation levels will accelerate the natural breakdown of these substances. This will minimise the leaching of such compounds into the groundwater.

5.3.2.4 Marine considerations - potential impacts and management considerations

It is concluded that most of the phosphates from the proposed septic tank systems will be fixed in the soils of the immediate vicinity of the respective septic tank systems with the balance being precipitated in groundwater as calcium phosphate complexes. Consequently, it is considered to be highly unlikely that phosphates will leach into the sea and they are therefore unlikely to affect the nearby marine environment.

Most of the nitrogen from the septic tank systems is expected to be lost by natural denitrification processes and uptake by plants. A very small volume of nitrogen may ultimately enter the marine environment adjacent to the Study Area. Coastal studies indicate that the moderate tidal range and currents will ensure mixing of in-shore waters and that the very small outflow of nitrogen will not result in an accumulation of nitrogen in the in-shore waters adjacent to the Study Area. Thus there is very little likelihood of marine algal growth being stimulated locally by domestic effluent.

From the above it is concluded that there is no need for special considerations of the marine environment in the design of the development.

5.3.3 Proposed design and management considerations

The following design and management considerations will be implementated to address potential impacts with respect to effluent discharge, water infiltration and the use of pollutants.

a) In proposed lots which adjoin Public Open Spaces which surround major creeks, septic tank systems will be located in the vicinity of the lot boundary which is furtherest removed from the respective Public Open Space. The final location for a septic tank system will be selected by site specific inspection.

   This will ensure that the septic tank system will probably be located some 80-100m or more from the various creeks of the subdivision. Drainage from these septic tank systems into the gravels beneath these creeks, and which are considered to be habitats for aquatic cave fauna will be avoided or minimised by this means.

b) Septic tank systems with dual leach drains rather than single leach drains are proposed, with each leach drain being 20m rather than 13m long. This will increase the length of leach drains from which effluent will be discharged from the conventional 13m length to 40m. Only one leach drain is to be used at a given time, and the use of leach drains is to be alternated at six monthly intervals. This is a commitment by the proponent. Residents will be reminded to switch the stop-cock on the septic tank outflows every six months by the Shire including a reminder with

rates notices and by suitable notification in the local newspapers. For a 12 month period effluent will thus be discharged from a length of 40m. The leach drains are to be installed close to the surface.

This is designed to:

- distribute effluent over a larger area and thereby expose nitrogen in the effluent to greater denitrification losses, and phosphates to more phosphate sorption sites. It is also designed to decrease nitrogen and phosphate concentrations in groundwater and expose them to greater volumes of groundwater mass flow,

- substantially increase evaporation losses of effluent water and thereby again considerably increase gaseous losses of nitrogen, and

- prevent blockages in the leach drains and surrounding soils and thereby maintain good water infiltration characteristics.

c) Prepare an environmental pamphlet for distribution to households and prospective buyers. The pamphlet newsletter will summarise environmental issues pertaining to the development and outline recommendations complete with justifications.

5.4 Fauna

The issues which relate to fauna include:

- The possible presence within the Study Area of habitats which are of importance to terrestrial species of vertebrates which are listed under the Wildlife Protection Act as rare or in need of special protection.

- The presence below the Study Area of aquatic habitats which may support fauna which are listed under the Wildlife Protection Act as rare or in need of special protection.

5.4.1 Terrestrial fauna - description, potential impacts and management considerations

The fauna of the Cape Range Peninsula has been reviewed in the 1993 Symposium of the Biogeography of the Cape Range Peninsula (Slack-Smith, 1993; Harvey et. al., 1993; Kendrick, 1993; Baynes and Jones, 1993). Fauna which have been extensively reviewed include the various cave fauna, including Arachnids (spiders), Myriapoda (millipedes and centipedes) and non-marine molluscs (land snails). The mammalian, amphibian and reptilian fauna have also been reviewed with an extensive fauna list having been established for the Cape Range Peninsula. These extensive lists have not been reproduced here. Many of the vertebrate fauna which have been listed could occur in the spinifex habitats of the Study Area. These species are widely distributed and the habitats of the Study Area are representative of vast areas of the region.

The Cape Range National Park provides a variety of ecosystems due to its rugged and complex terrain and provides water catchment in deep gullies and gorges where floral assemblages are found in sheltered areas that do not occur on the adjacent coastal plains. In contrast, the Study Area is composed of an extensive plain supporting a hummock grassland of predominantly *Triodia pungens* with scattered trees and shrubs, thus providing less diverse and more common habitats. The Study Area does not support any fresh water holes.

A large number of bat species occur in the coastal region but none of these are likely to roost in the Study Area due to the lack of roosting sites. Most of the bats roost in caves and trees which are common in the Cape Range National Park.

Vermin species which are likely to be found in the Study Area included cats, fox, goats, mice, rabbits and rats. Goats were seen in the Cape Range near the Study Area and fox and rabbit dung was frequently observed during the field survey.

Of the gazetted rare or endangered native mammals which might be found in the greater project region, only the Mulgara (*Dasycercus cristicaudata*) is known to favour sandy spinifex habitats which are found in the Study Area. The Mulgara is listed as one of the species which has been identified in cave remains in the Cape Range (Baynes and Jones, 1993) but it is not listed for the locality. There are no local records of sightings of the Mulgara and it is more likely to be found much further inland.

Characteristic pebble mounds of the Pebble-mound Mouse (*Pseudomys chapmani*) were discovered by Muir (1995) on the coastal plain inland of the Study Area and one of the mounds was thought to be active. This species has been gazetted (April, 1994) under Schedule 1 of the Wildlife Conservation Act, 1950, as rare and endangered. No pebble mounds were found within the Study Area during extensive searches and it is concluded that the proposed development is very unlikely to have any impact on this species.

Other larger endangered species endemic to the Pilbara, such as the Spectacled Hare Wallaby (*Largochestes conspicillatus*), the Burrowing Bettong (*Bettongia lesueur*) and the Bilby (*Macrotis lagotis*), which are all gazetted as rare and endangered have not been recorded locally nor have their remains been recorded in caves of the Cape Range. No evidence of these species was found within the Study Area during extensive field traverses.

Bird species which have been gazetted as rare and endangered, such as the Grey Falcon (*Falco hypoleucos*) and the Peregrine Falcon (*Falco peregrinus*) could be found within the Study Area. These species are wide-ranging in their daily and seasonal habits and they are very unlikely to be affected by activities within the Study Area. The habitats of the Study Area are thus of little consequence to the survival of these birds.

The are no habitats within the Study Area which could affect the survival of terrestrial mammals, birds or reptiles which have been gazetted as rare and endangered.

The general habitat values of the Study Area to the fauna of the greater region is appreciated and efforts are proposed for their preservation. This includes minimal clearing of vegetation on lots, especially larger lots, and the protection of all major creeks in Public Open Spaces.

5.4.2 Cave fauna

5.4.2.1 Description and potential impacts

Extensive subterranean habitats exist within the limestone cavities which honeycomb the Cape Range Peninsula and these are known to have a unique cave fauna. Other similar habitats are known for Barrow Island (Humphreys, 1993) but the distribution of individual species is not well understood. This fauna has been reviewed by Knott (1993), Harvey et. al. (1993), Adams and Humphreys (1993) and Humphreys (1993). Cave fauna is a simple term used to embrace several categories of animals (troglophiles, troglobites, trogloxenes, stygofauna and stygophiles) which utilise a range of underground habitats which vary in void size and habitat type, and from dry to fresh and brackish water (Humphreys, 1993). Void sizes may vary from the small spaces between gravel particles beneath stream beds to caverns in limestone of more than 20cm in diameter. The cave fauna include 121 to 34 species (pers comm Dr W Humphreys, WA Museum), including species of blind cave fish and eels and a large range of invertebrate groups. This cave fauna is believed to be a remnant of a diverse surface fauna which prevailed at a time when surface conditions were very wet. Such conditions are estimated to have existed more than 170,000 years ago (Wyrwoll, 1993). The total extent of the limestone cavities and gravel habitats is not known, with the known distribution of the cave fauna having been estimated mainly from wells or bores which lie along the coastal plain on the western and eastern sides of the Cape Range Peninsula (Knott, 1993). The extent of habitats and the distribution of species is further complicated by the interaction of salt and fresh water beneath the coastal plain with the aquatic species appearing to prefer habitats of fresh water (Knott,

1993).

Several species of cave fauna which are thought to occur only on the Cape Range Peninsula have been gazetted (April, 1994) under the Wildlife Conservation Act, 1950. These include the Cape Range Schizimid Spider (*Schizomus vinei*) and the Cape Range Blind Cockroach (*Nocticola flabella*) which occupy the dry caves beneath the Cape Range, the Blind Gudgeon Fish (*Milyeringa veritas*), Blind Cave Eel (*Ophisternon candidum*) and two cave-shrimp species (*Stygiocaris lancifera, Stygiocaris stylifera*) which occupy groundwater habitats beneath the coastal plain (Adams and Humphreys, 1993; Humphreys, 1993). Except for *Stygiocaris stylifera*, these species are all protected and restricted to the Cape Range Peninsula. *Stygiocaris stylifera* has been found in similar cave habitats on Barrow Island (Dr W Humphreys, pers comm). The cave spider and cave cockroach will not be affected by the proposed development because their habitats are located beneath the Cape Range and not the Study Area. The exact distribution of these habitats of the protected species is uncertain, but with respect to the Study Area and redevelopment of an adequate environmental management policy it is assumed that these animals occupy groundwater habitats beneath the Study Area.

The conservation value of the cave fauna, including aquatic cave fauna, has been reviewed by Humphreys (1993). He states that cave inhabiting species have a number of biological and geographical characteristics, especially limited distribution where species may be confined to small areas, which make them vulnerable to extinction. Humphreys states that "small disturbances to their physico-chemical environment can have a profound effect on the viability of the troglobite populations". The troglobites are terrestrial fauna species which only live in caves (Knott, 1993) and Humphreys' observations probably apply equally to stygofauna or aquatic cave fauna. Because of the interdependence of cave fauna species, Humphreys concluded that "the underground fauna needs to be treated as a separate component of any management plan, and the emphasis placed on the underground habitat rather than the species".

The potential impacts of phosphorus and nitrogen from domestic effluent on the quality of groundwater, in which aquatic cave fauna habitats may be found, is discussed in Section 5.3.2.1.

Cave fauna habitats which might be found in the Study Area include the spaces between gravel particles in gravel deposits beneath creeks and voids in limestone formations beneath the coastal plain (Humphreys, 1993).

No groundwater will be abstracted from the groundwater below the Study Area. Consequently, the development will not affect groundwater levels below the Study Area by abstraction of water. It is likely that the groundwater levels below the Study Area may be marginally increased by the importation of water to the Study Area. Any such potential increase is likely to be negligible because of the rapid rate at which the groundwater beneath the Study Area, in common with the remainder of the coastal plain, flows towards the sea.

No information is available on the sensitivity of the aquatic cave fauna to concentrations of nitrogen and phosphates, and determination of such sensitivities would require lengthy and costly studies.

From information given in Section 5.3.2.1 on the fate of phosphates and nitrogen leaching from proposed septic tank systems to the groundwater it is concluded that the resultant nitrogen concentrations in groundwater below the proposed septic tank systems are highly likely to be sufficiently low not to be harmful to this fauna because the concentration of nitrogen will be similar to, if not considerably less than, natural background levels. The nitrogen input to the groundwater could at worst double the background concentrations in a small plume of groundwater which passes beneath a leach drain to the ocean. However, within a short distance of the point of discharge this increased concentration would be quickly diluted. In addition, a doubling of concentrations could easily occur under natural conditions and is likely to be within the natural range of concentration variations.

The concentrations of nitrogen in the groundwater below septic tank systems is likely to be substantially less than 1.1mg/l, with 0.11mg/l being more realistic. The concentration of 1.1mg/l is well within the naturally occurring concentrations of nitrogen in ground and surface water, and it is about one tenth of the concentration which is considered to be the safe upper acceptable limit of drinking water for infants.

Equally important, these effects on the quality of groundwater are very localised and confined to the immediate surrounds of each proposed septic tank system. The effects will also not be cumulative because natural groundwater flows will continually remove and disperse nitrogen as it enters groundwater.

It is similarly postulated that phosphate concentrations of the groundwater will not be markedly affected by the proposed septic tank systems, with all effects being very localised. This is because most, and probably all, of the phosphates contained in effluent water will be fixed by the natural phosphate sorption sites of the soils, limestone and lime sands of the Study Area and precipitated within the groundwater as calcium phosphate complexes by the high calcium content of the groundwater. Consequently, it is concluded that it is highly unlikely that aquatic cave fauna will be adversely affected by phosphates contained in the effluent water of septic tank systems.

5.4.2.2 Proposed design and management considerations

Gravel deposits beneath the creeks are thought to provide habitats for the cave fauna of the Cape Range Peninsula. These habitats will be protected by including all of the major creeks into Public Open Spaces of various width to ensure that all of the creek habitats are included. To further preserve the gravel habitats below the creeks, all of the proposed housing lots have been set well back from these creeks. To provide additional protection, septic tank systems on lots facing such Public Open Space will always be located in the vicinity of the boundary furtherest from the respective Public Open Spaces. The final location for the respective septic tank site will be selected by site specific inspection and consultation with the Shire of Exmouth. This will result in the septic tank systems being generally removed at least 80 to 100m from the Public Open Space.

5.5 Archaeological sites

It was considered important to design and manage the proposed development without adversely affecting archaeological sites or material.

A search of the Register of Sites of the Heritage and Culture Division of the Department of Aboriginal Affairs showed that no archaeological sites were registered within the Study Area and its nearby vicinity, and that the Study Area had probably never been systematically searched for archaeological artefacts and sites.

An archaeological survey was subsequently undertaken (W G Martinick and Associates, 1995) and this located two artefact scatter sites which were considered to be of low archaeological and scientific significance. A few widely scattered artefacts were found in the coastal dunes adjacent to the Study Area but these were too widespread and isolated to constitute a specific site.

Permission was granted by the Minister for Aboriginal Affairs to incorporate the two archaeological sites into the design of the subdivision.

5.6 Sites of living cultural significance to Aboriginal people

To ensure that the proposed development will not result in the destruction of sites of living cultural significance to Aboriginal people a survey of such sites was undertaken within the Study Area and its immediate surrounds. A search of the Register of Sites of the Department of Aboriginal Affairs showed that no such sites had been registered for the Study Area. A subsequent survey by W G Martinick and Associates in April 1995 concluded that no such sites occur within the Study Area.

5.7 Exmouth Airfield

For the development of a subdivision adjacent to an airfield it is necessary to assess the following issues:

- aircraft noise which could be a nuisance to future residents, and
- could the presence of a residential development prevent future development of the airfield.

5.7.1 Background

Exmouth Airfield is located on the western side of Murat Road adjacent to the Study Area. Part of this airfield can be see in the aerial photograph (Frontispiece). The following information was provided by Mr Peter Arscott, the proprietor of Exmouth Air Charter Pty Ltd, a Company which operates from the airfield:

Exmouth airfield is vested in the Shire of Exmouth. It is not licensed and has not been surveyed. It is a separate entity from the airport at Learmonth which provides facilities for commercial air services to Exmouth, and is 27km to the south of the Study Area.

Exmouth Airfield has a 1500m bitumen runway which is oriented 20°N and provides a night-time landing and take off facility which is of importance to the Royal Flying Doctor Service.

Approximately 4,000 take-offs and landings, or movements, occur annually at this airfield. There are approximately 15 to 25 movements per week during October to January and up to 25 movements per day during the tourist season of February to September. This traffic consists of station owners travelling to and from Exmouth, Royal Flying Doctor Service flights, air-training and especially sight-seeing flights. Very few aircraft use the night landing or take-off facilities, with less than 20 such flights occurring per year.

Five aircraft are permanently located at the Exmouth Airfield and during the tourist season, especially during the whale-shark season from February to June, up to 10 aircraft may operate from the airfield.

Detailed records of aircraft movements for the Exmouth Airfield are not available. Available information indicates that most of the aircraft movements are undertaken by single engine aircraft with a maximum take-off weight of not more than 1040kg. Larger twin engine aircraft with a maximum take-off weight of 5,700kg only use the airstrip on a few occasions per year. Training flights are undertaken from this airfield and training circuits are flown.

5.7.2 Potential environmental impacts and proposed management considerations

Noise contours are not available for Exmouth Airfield, but they can be estimated from Australian Standard 2021. The smallest aircraft tabulated in Australian Standard 2021 are twin-engine propeller-driven craft with a maximum take-off weight of 5700kg. Using information provided in Table 3.24 of Australian Standard 2021, future lots within the proposed development located beyond the northern end of the runway and adjacent to Murat Road would be exposed to sound levels which are regarded as marginal (between acceptable and unacceptable - between 80 and 90dB(A)) if there were up to 20 such flights per day. Available information shows that there are only 10 to 15 such flights per year, with most flights being undertaken by single engine aircraft with a maximum take-off weight of 1040kg, with the largest being 2404kg.

Consequently, aircraft movements on Exmouth Airfield are not considered to be an environmental or social problem and no specific management criteria are recommended.

Most aircraft which take off from the airstrip fly to the west to avoid a nuisance to Exmouth residents and similarly approaches are mostly from the west before the final approach is made. Thus most air traffic will be directed away from the proposed development which lies to the east of the airfield.

All large commercial aircraft flying to Exmouth use the larger runway at Learmonth Airport. Hence any expansion of services which might require an expansion of facilities at Exmouth Airstrip are catered for by Learmonth Airport and will thus not be affected by the proposed development.

5.8 Water supply

Arrangements have been made with the Water Authority of Western Australia to reticulate water to the subdivision from a proposed water supply which is currently being assessed by the Environmental

Protection Authority via the Consultative Environmental Review process. In the event that this approval is not granted, arrangements have been made for water to be reticulated to the proposed subdivision from an existing and approved water supply which is owned and operated by the Water Authority of Western Australia.

No private bores will be allowed within the proposed development by the Water Authority of Western Australia.

5.9 Drainage

Stormwater run-off from the proposed subdivision carries a risk of sediment transport in the event of intense rainfall. This is addressed in the design and management of the proposed development, and is discussed in the following.

The large lot sizes of the proposed subdivision ensures that erosion risks associated with the subdivision are mainly confined to future road verges within the proposed subdivision. In housing developments with small lot sizes additional erosion risks are caused by the increase in the area of hard surfaces such as roof-tops, driveways, patios and other paved domestic areas. The proposed subdivision will utilise and encourage the implementation of recommendations contained in the document "Water Sensitive Urban Design" (Whelans et. al., 1994) where all drainage will be encouraged to recharge groundwater rather direct it to offsite areas. Water Sensitive Urban Design aims to retain run-off and stormwater close to its source to prevent the potential of carrying sediment and nutrients off-site. Home owners will be encouraged to direct all stormwater to swales or soak-wells within their properties.

Road drainage will be directed to wide and open drains to encourage infiltration to the groundwater beneath the Study Area. Proposed seeding of drains with locally native plant species will be encouraged to establish a groundcover which will provide increased surface stability.

5.10 Domestic animals

Domestic animals such as cats and dogs of the proposed development present the risk of contributing to the presence of such vermin animals on Cape Range Peninsula.

In common with large areas of Australia, the proposed subdivision is located in a region which has an indigenous population of native marsupials and mammals, reptiles and birds which have suffered predation from introduced animals such as foxes and cats. Cats from the proposed subdivision have the potential to increase the existing population of vermin cats which is likely to live in the Study Area and its immediate surrounds. The control of cats should be addressed on a regional basis.

It is recommended that land owners of the proposed subdivision are made aware of the impacts cats can have on native fauna and that the keeping of cats is discouraged. If domestic cats are kept, then they should be sterilised, kept in-doors at night and made to wear bells. If requested by the Shire of Exmouth, the subdivision could be declared a cat-free zone, but this would need to be supervised by the Shire. A decision on this should be deferred until the State government considers proposals to introduce State-wide legislation to control cats (Cats Advisory Committee, November 1994).

Dogs should not be allowed to roam freely, especially at night.

Improved public awareness within the proposed subdivision on the environmental impacts of stray dogs and cats may result in greater regional environmental awareness and a greater regional attempt to effectively address the environmental problems caused by straying dogs and cats.

The Shire should consider imposing guidelines on the ownership of livestock within the proposed development. These should consider potential environmental impacts and the need for satisfactory enclosures.

5.11 Fire

The large lot sizes and the predominant bushland of the Study Area will present a substantial fire risk to future dwellings unless preventative measures are undertaken by future residents.

It will be the responsibility of the Shire of Exmouth to enforce the regulations of the Bush Fire Control Board.

6.0 CONSULTATION WITH GOVERNMENT DEPARTMENTS AND COMMUNITY ORGANISATIONS

Representatives of various government departments and community organisations with environmental or planning interests were consulted to record and consider comments, concerns and recommendations which they may have with respect to the proposed development. In most instances this involved an assessment of an earlier draft of this Consultative Environmental Review. All of these comments were considered in this final Consultative Environmental Review, and where appropriate, necessary amendments were introduced. Where written submissions were received they are included in Appendix 6 and summarised in the following sections together with relevant replies/comments.

6.1 Museum of Western Australia

a) Contact

Dr W Humphreys. Expert in cave fauna.

b) Response

Dr Humphreys stated that the following issues need to be addressed:

- Constraints imposed by the limestone system. He stated that: "fissured and karst systems are considered to be very vulnerable to pollution. In karst the dispersion of pollutants can be very high, and the "filter" phenomenon can be deficient or even totally absent. Moreover, adsorption and sites for biological and chemical degradation are reduced in karst, giving these systems a limited self purification potential. Aquatic cave fauna is disrupted worldwide by sewage and very expensive remedial measures then fall on local authorities".
- Presence of caves and terrestrial cave fauna and what to do about them if found.
- The presence of aquatic fauna and monitoring.
- Groundwater abstraction.
- Adequacy of soil depth.
- Non-leach drain inputs of contaminants such as petroleum waste, garden waste, fertilisers and pesticides.

c) Reply/comment

The Study Area consists mostly of deep soils which are adequate for the establishment of leach drains, and these are to be installed as shallow as regulations permit to facilitate evaporation and denitrification losses.

Terrestrial cave fauna are confined to dry cave systems. Caves beneath the Study Area are likely to be located below the water table because of the proximity to the sea with the water table being above the sea level. Consequently terrestrial cave habitats and fauna are unlikely to occur beneath the Study Area.

The environmental assessment assumes that habitats for aquatic cave fauna exist beneath the Study Area and investigations for their presence are not required. The view expressed in this Consultative Environmental Review is that:

- all possible measure are being taken to ensure that nitrogen and phosphorus in effluent water are dispersed as widely as possible and that these are exposed to natural forces which will diminish their presence in groundwater, and

- the natural flow of groundwater is towards the ocean and this is likely to be rapid, of the order of hundreds of metres per year, hence any residual nutrients will be removed and discharged into the ocean where it will be dispersed rapidly.

No groundwater abstraction is permitted by the Water Authority of Western Australia within the proposed Study Area.

The relatively large block sizes, high cost of domestic water and arid climatic conditions are likely to ensure that only small applications of fertilisers and pesticides are used per lot and that only small quantities of garden wastes are produced. These materials will be exposed to high temperatures and together with occasional watering this will result in high rates of organic breakdown.

An environmental pamphlet will be issued to residents to outline the ecological importance of the region, discuss relevant environmentally sensitive issues and recommend minimal use of fertilisers and pesticides.

6.2 Department of Conservation and Land Management

Contact: Mr Frank Batini, CALM office, Como.

Response: Mr Batini requested that the managers of the Regional and District offices of CALM in Karratha and Exmouth be contacted.

Contact: Mr Doug Myers, District Manager, Exmouth.

Response: Mr Myers submitted his comments via the Regional Office of Karratha.

Contact: Mr Chris Muller, Regional Manager, Karratha. His submission is given in Appendix 1 and the recommendations and comments have been included in this Consultative Environmental Review.

6.3 Conservation Council of Western Australia

Contact: Ms Rachael Siewert.

Response: Ms Siewert made the following comments in an interview at the offices of the Conservation Council of Western Australia. The comments/questions are given in bold, followed by relevant replies. These comments were subsequently summarised by Ms Siewert in a letter to the Department of Environmental Protection. A copy is enclosed in Appendix A.

i. Has the proponent investigated the demand for housing in the Exmouth region?

The decision to develop the land was a commercial decision based upon considerable local knowledge by the Shire of Exmouth and a market appraised by Greenough Holdings Pty Ltd.

ii. Will there be any restrictions on the ownership of domestic animals such as pets, horses, cattle, pigs and goats which could be a source of pests and feral animals to the nearby Cape Range National Park?

This will be a matter for the Shire of Exmouth to decide. These concerns have been considered in the Consultative Environmental Review and noted by the proponent, the Shire of Exmouth. The Consultative Environmental Review contains recommendations for restrictions on domestic animals.

iii. Will there be any restriction on the use of private bores?

The Water Authority of Western Australia will not permit private bores within the proposed subdivision.

iv. Where will road-base for internal roads be sourced from?

A Mining Lease Application has been submitted to the Department of Minerals and Energy for the removal of gravel from an abandoned gravel pit which has not been rehabilitated. If gravel is obtained from this pit then it will be progressively rehabilitated. If this application is not granted then gravel will be obtained from an existing borrow pit or elsewhere subject to necessary approvals.

v. Are adequate precautions being undertaken to protect the cave fauna from groundwater pollution.

It is considered that the cave fauna is unlikely to be harmed by the proposed development if the recommended precautions for domestic effluent disposal are adopted. This is discussed in detail in the Consultative Environmental Review.

vi. What measures have been taken to protect the dunes?

The dunes are outside of the Study Area. They will be protected by a fence, appropriate signposting and direction access to the beach along well defined tracks along creeks which have created natural cuts through the dunes.

6.4 Ningaloo Preservation Association

Contact: Ms Sandra Wills, Exmouth. No response has been received.

6.5 Shire of Exmouth

On 21 June 1995 the Council of the Shire of Exmouth assessed the proposed subdivision of Lyndon Locations 222 and 223 as outlined in a draft of this Consultative Environmental Review. The proposal was approved unanimously.

7.0 CONCLUSIONS AND COMMITMENTS

7.1 Conclusions

It is concluded that septic tank systems will be environmentally acceptable within the proposed subdivision. This is because of the very large lot sizes and consequently low housing density, good water infiltration rates, good phosphate fixing properties of the soil types on which houses will be established, high nitrogen losses, rapid groundwater flow rates and the presence of calcium in groundwater to precipitate phosphates.

There is no need to ameliorate the soils or to consider alternative effluent disposal systems for residential lots to improve the phosphate retention abilities of these soils because of their naturally high phosphate fixing characteristics. Alternative effluent disposal systems will provide no additional benefits with respect to the management of phosphates in domestic effluent because they rely equally on the soils which surround the respective systems to fix the phosphates contained in effluent water.

Recommendations for the disposal of domestic waste water by means of shallow dual leach drain systems each with extended-length leach drains for the disposal of domestic wastewater will maximise the potential for nitrogen and phosphates to be dispersed into the environment and to enhance evaporation losses. This dispersal will be further enhanced by the recommendation for deep rooted shrubs and trees to be planted adjacent and on top of leach drains.

Small concentrations of nitrates and nitrites contained in domestic effluent will drain to the water table where they will be diluted rapidly by the flow of groundwater. Some of these nitrates and nitrites will be discharged into the ocean where tidal currents will ensure their rapid dispersal.

The coastal dune systems adjacent to the proposed development will be protected by fencing and controlled access to the beach. This will ensure the long-term stability of the dune systems.

Major creeks are protected by their inclusion into Public Open Spaces.

Recommended set-back distances of leach-drains from Public Open Spaces which surround creeks will minimise potential impacts of proposed septic tank systems on the underlying aquatic habitats.

7.2 Commitments

All development work to be undertaken and managed by Greenough Holdings Pty Ltd will be in compliance with the commitments given below. The work will be completed to the satisfaction of the Shire of Exmouth.

The following commitments are proposed:

i. Coastal dunes will be protected by restricting access to the beach. A north-south fence on the coastal side of the Study Area, inland of the hind-dune system, will be erected to discourage access across the dunes. Access to the beach will be directed via natural creek crossings of the dunes. This work will be carried out by the project manager, Greenough Holdings Pty Ltd, and completed to the satisfaction of the Shire of Exmouth.

ii. A brief environmental overview, complete with description of environmentally sensitive issues and appropriate environmental management action, will be prepared in the form of a pamphlet. This will aim to stimulate greater environmental awareness and improved environmental management by existing and future households. This pamphlet will include the following topics:

- A description of the environmental importance of Cape Range Peninsula in terms of the habitats of the Ranges and plains and the subterranean cave and aquatic fauna.

- Use of native plants in landscaping to minimise fertiliser, water use and use of insecticides and other poisons.
- Keep vegetation clearance to a minimum and manage the remaining native vegetation.
- Planting of shrubs and trees adjacent to leach drains to act as biological pumps of domestic effluent water.
- The importance of minimising the use of polluting substances which could enter groundwater via the leach drains or by surface drainage.
- Stormwater from roofs and other hard surfaces must be directed to soakwells or wide and open drains to minimise sediment transport off the respective property.
- A discussion of responsible pet ownership.
- Guidelines on stock ownership and management.
- The importance of controlled access to the beach.

Sufficient pamphlets will be printed for distribution to prospective buyers and display in the Offices and Public Library of the Shire of Exmouth.

iii. All major creeks and their adjoining riverine habitats will be included into Public Open Spaces to preserve these habitats and to ensure future housing is not endangered by flooding. This commitment is already part of the existing Structure Plan.

iv. Lot sizes within and adjacent to low-lying areas are increased to facilitate selection of homesites on elevated ground or suitable land for constructing appropriate pads to minimise flooding risks. This commitment is already part of the existing Structure Plan.

v. Domestic dwellings will not be permitted to be constructed on building pads of below 3.0m AHD. Land owners will be able to build appropriate housing pads to achieve this commitment. This provision will be enforced by the Shire of Exmouth.

vi. Leach drains will be set to a minimum length of 20m. This provision will be enforced by the Shire of Exmouth.

vii. Only one leach drain will be used at a given time, and the use of leach drains will be alternated at six monthly intervals. This will remove the build up of slimes due to bacterial growth and associated water infiltration problems. During the period of non use the slimes will be removed by microbial activities in the soil. This commitment will be enforced by the Shire of Exmouth.

viii. Dual leach drains, with each leach drain being at least 20m long and the respective drains not being adjacent to each other, will be used in each septic tank system. This provision will be enforced by the Shire of Exmouth.

ix. Leach drains will be constructed at the minimal depth required by Shire regulations. This provision will be enforced by the Shire of Exmouth.

x. On lots immediately adjacent to Public Open Spaces which incorporate major creeks, septic tank systems will be required to be located in the vicinity of the lot boundary which is furtherest removed from the Public Open Space. A site specific inspection will determine the location of each septic tank system. This provision will be enforced by the Shire of Exmouth.

xi. No private bores will be permitted within the proposed development. This is in keeping with the policy of the Water Authority of Western Australia for the Exmouth Town Region. This provision will be enforced by the Water Authority of Western Australia.

xii. Road drainage will be directed to wide and open drains. These drains will be seeded with local species to provide increased surface stability and encourage stormwater infiltration into the soils. This commitment will be included in the specifications for the construction of service roads and the wording will be to the satisfaction of the Shire of Exmouth.

xiii. Sandbars across the creek outlets to the ocean shall be inspected prior to the cyclone season and where necessary breached by the removal of sand. Breaching of sandbars will only be necessary if these have built to excessive height and could cause flooding. The inspection and breaching shall be the responsibility of the Shire of Exmouth.

xiv. Bush Fire Control Board regulations will be enforced by the Shire of Exmouth.

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9.0 GLOSSARY

Alluvial deposits*:	Deposits of fine mud, sand or gravel which have been deposited by the operation of modern rivers which includes sediments in river beds, lakes, fans at the foot of mountain slopes and estuaries.
Calcretized*:	Material which has been cemented together by calcium carbonate.
Calcrete*:	Gravel and sand cemented by porous calcium carbonate.
Chart Datum:	For each navigational chart all depths are referenced to this level which is the lowest possible tide which may occur locally under the influence of the moon and sun.
Colluvial deposits*:	Alluvial deposits in part and also containing angular fragments of the original rocks.
Conglomerate*:	Rounded water worked fragments of rock and pebbles cemented together by another mineral such as calcium carbonate.
Denitrification:	The process which results in the loss of nitrogen due to the formation of nitrates, nitrites, ammonia and ammonium. In soils this results in the loss to the atmosphere of gaseous nitrogen forms.
Dissected terrain:	Where the flow of water has eroded into hills and valleys or flat upland areas separated by valleys.
Highest Astronomical Tide:	Shown on marine charts with reference to Chart Datum. The highest possible tide which could occur locally due to the influence of sun and moon.
Holocene*:	The geological period from about 10,000 years ago to the present.
Karst:	Limestone landscapes where the dissolving influence of water is evident. Commonly honey-combed with caverns or tiny passages which water may flow through.
Mean High Water Spring Tide:	Used on navigational charts with reference to Chart Datum. To give the average height of the Spring High tide.
Neap Tide:	The smallest tidal range which occurs at half-moon. Thus there are two Neap Tides in every lunar month of 28 days.
Permian:	The geological age between 235 to 290 million years ago.
Pleistocene:	Geological period from about 10,000 to 1.8 million years ago typified by large changes in ocean levels due to periods of glaciation and thawing.
Quaternary:	The geological age including the Pleistocene and Holocene.
Reworked:	Where sediment is moved by water after preliminary deposition, commonly resulting in transportation and sorting of sediment.
Soil horizon:	A layer within the soil profile which has a distinct colour and/or texture.

Soil profile:	The different horizons which constitute a soil from the surface down to bedrock.
Solution pavement:	A hard limestone "pavement" or flat area formed by the precipitation of calcium carbonate.
Spring Tide:	The highest and lowest tides which occur at full moon and new moon. Thus there are two Spring Tides in each lunar month of 28 days.

The geological terms above (*) are taken from the "Dictionary of Geological Terms" by the American Geological Institute, published by Dolphin Books, Doubleday and Co Inc, New York, 1962.

10.0 STUDY TEAM

- Dr Wolf Martinick: Environmental Scientist.
- Dr Robert Holmes: Ecologist.
- Mr Ray Cranfield: Botanist.
- Mr Joe Mattner: Archaeologist.
- Mrs Glenda Martinick: Social Scientist.
- Ms Christine Mellersh: Word processing.

PLATE 1: LANDSCAPE UNIT A: SANDY PLAIN OF WIDELY SCATTERED SHRUBS OVER A HUMMOCK GRASSLAND

PLATE 2: LANDSCAPE UNIT B: SANDY PLAIN WITH A SHRUBLAND OVER A HUMMOCK GRASSLAND

PLATE 3: LANDSCAPE UNIT C: OUTWASH PLAIN WITH MODERATELY CLOSE AND TALL SHRUBLAND

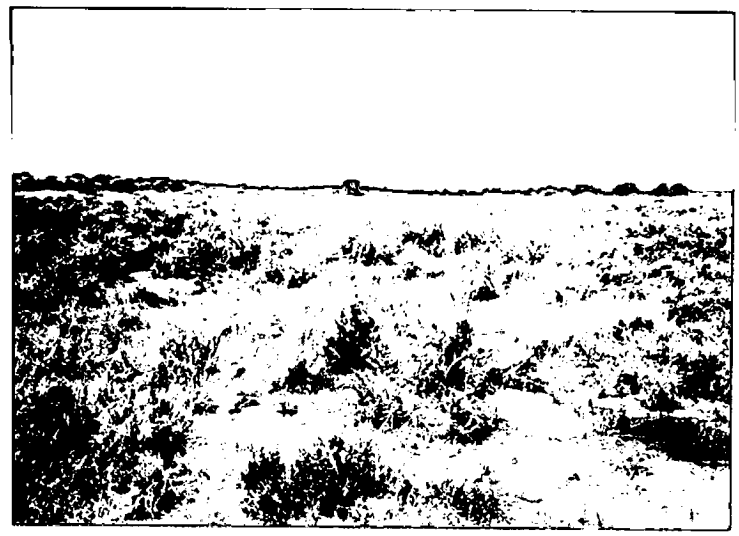


PLATE 4: LANDSCAPE UNIT D: LOW LYING PLAIN WITH A MOSAIC OF HALOPHYTIC SHRUBS AND HUMMOCK GRASSLANDS WITH SCATTERED SHRUBS BEHIND COASTAL DUNES

PLATE 5: LANDSCAPE UNIT F: CALCRETE PLAIN WITH OPEN SHRUBLAND OVER HUMMOCK GRASSES

PLATE 6: LANDSCAPE UNIT G: BEACHES AND DUNE SYSTEM; LEARMONTH LAND SYSTEM

RIFLE RANGE ROAD

PRECINCT A:
MIN. AVERAGE LOT
AREA 4000M² 20 LOTS

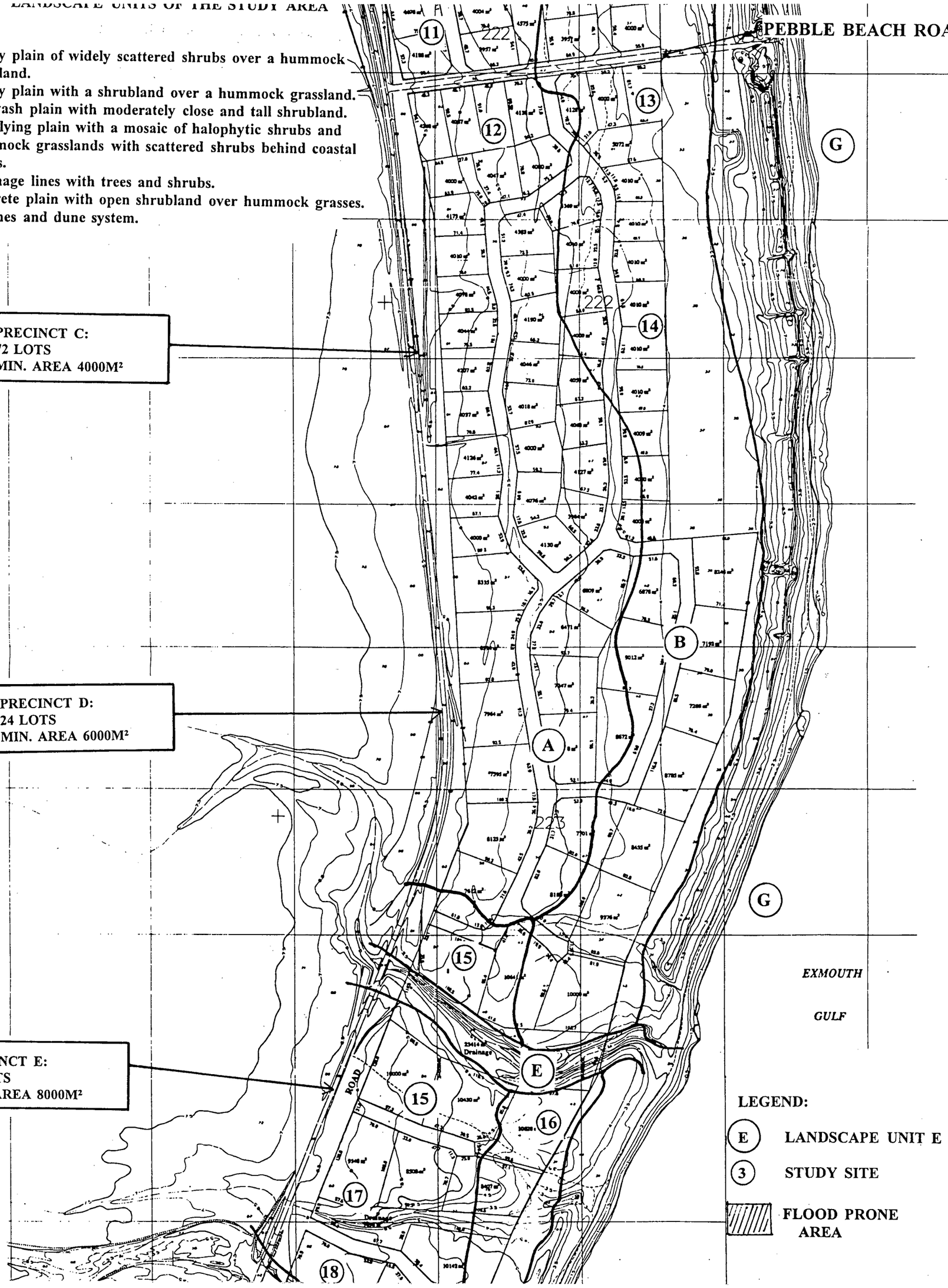
PRECINCT B:
18 LOTS
MIN. AREA 1.5HA

EXMOUT

GULF

LANDSCAPE UNITS OF THE STUDY AREA

A: Sandy plain of widely scattered shrubs over a hummock grassland.
B: Sandy plain with a shrubland over a hummock grassland.
C: Outwash plain with moderately close and tall shrubland.
D: Low lying plain with a mosaic of halophytic shrubs and hummock grasslands with scattered shrubs behind coastal dunes.
E: Drainage lines with trees and shrubs.
F: Calcrete plain with open shrubland over hummock grasses.
G: Beaches and dune system.



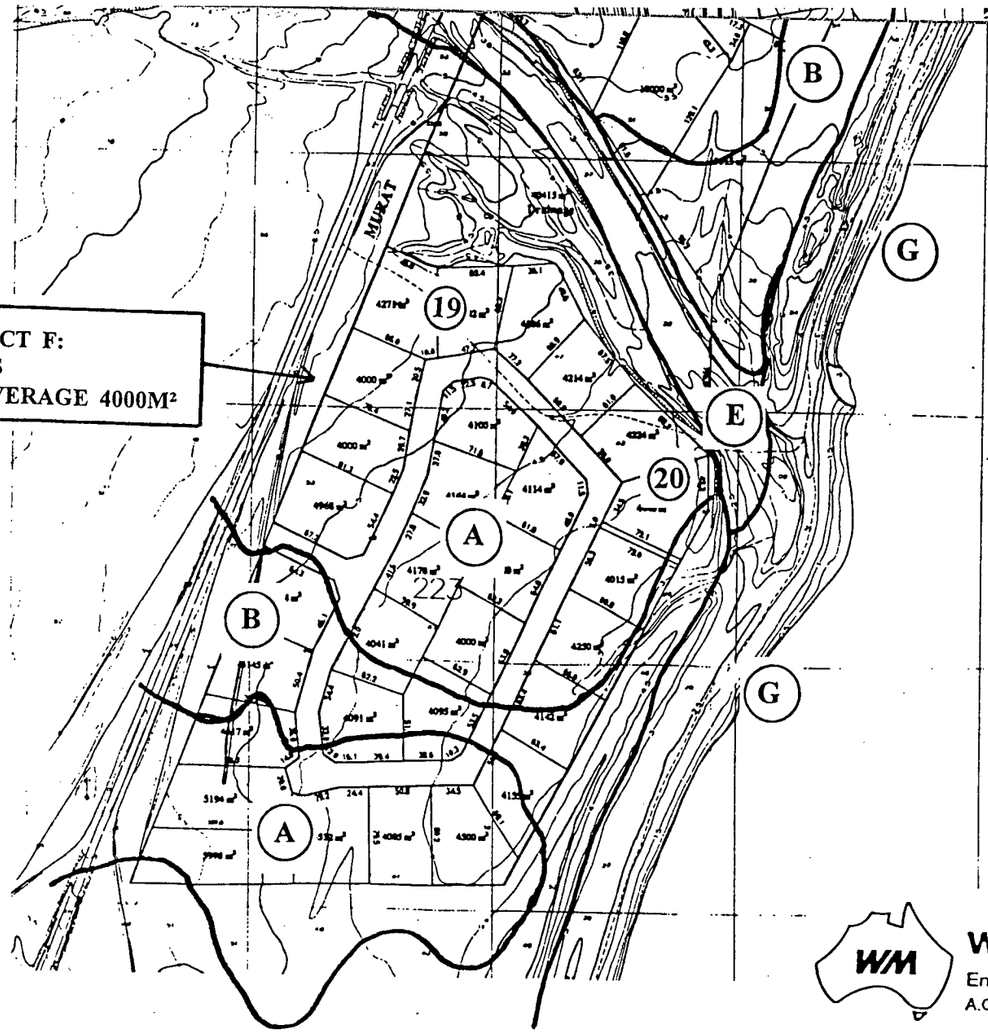


FIGURE 2: THE STUDY AREA SHOWING THE PROPOSED LOTS, TERRAIN, LANDSCAPE UNITS AND STUDY SITES

SPECIAL RESIDENTIAL DEVELOPMENT

PROPOSED SUBDIVISION LYNDON LOCATIONS 222- 223 EXMOUTH

prepared for : SHIRE OF EXMOUTH
prepared by : RUSSELL TAYLOR & WILLIAM BURRELL
Consultants in Town Planning & Civic Design

PLAN NO.94/85/4
DATE June 1995

W.G. MARTINICK & ASSOCIATES Pty Ltd
Environmental Consultants, Planners and Landscape Architects
A.C.N. 009 079 305

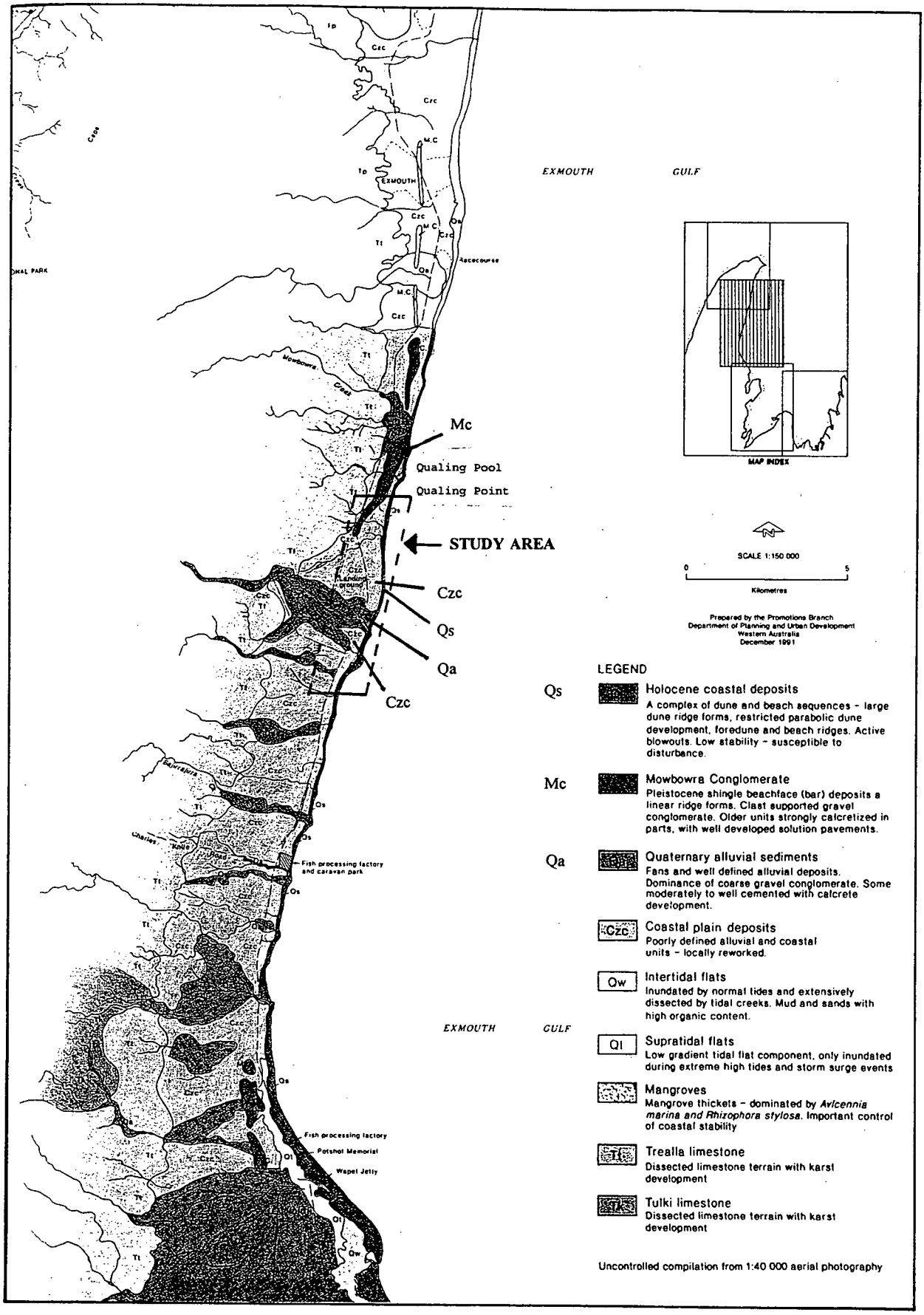


FIGURE 3: GEOMORPHOLOGY OF THE COASTAL PLAIN IN THE REGION OF THE STUDY AREA (FROM WYRWOLL ET. AL. 1993)

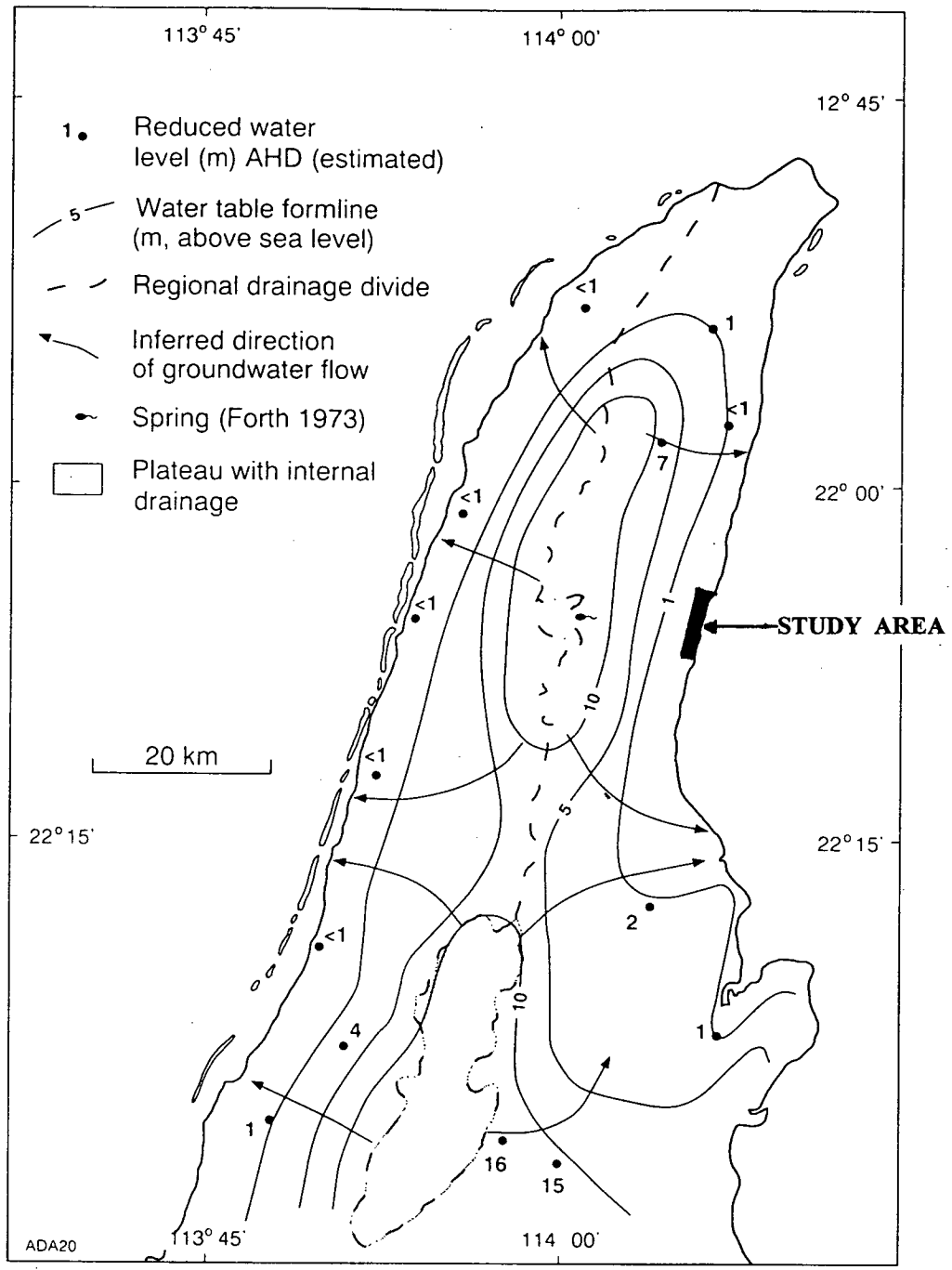


FIGURE 4: GROUNDWATER CONTOURS AND FLOW DIRECTION OF THE CAPE RANGE PENINSULA (FROM ALLEN, 1993)

Learmonth land system 285 km² (0.4% of survey area)

Sandy outwash plains marginal to the Cape Range, supporting mainly soft spinifex hummock grasslands with scattered acacia shrubs.

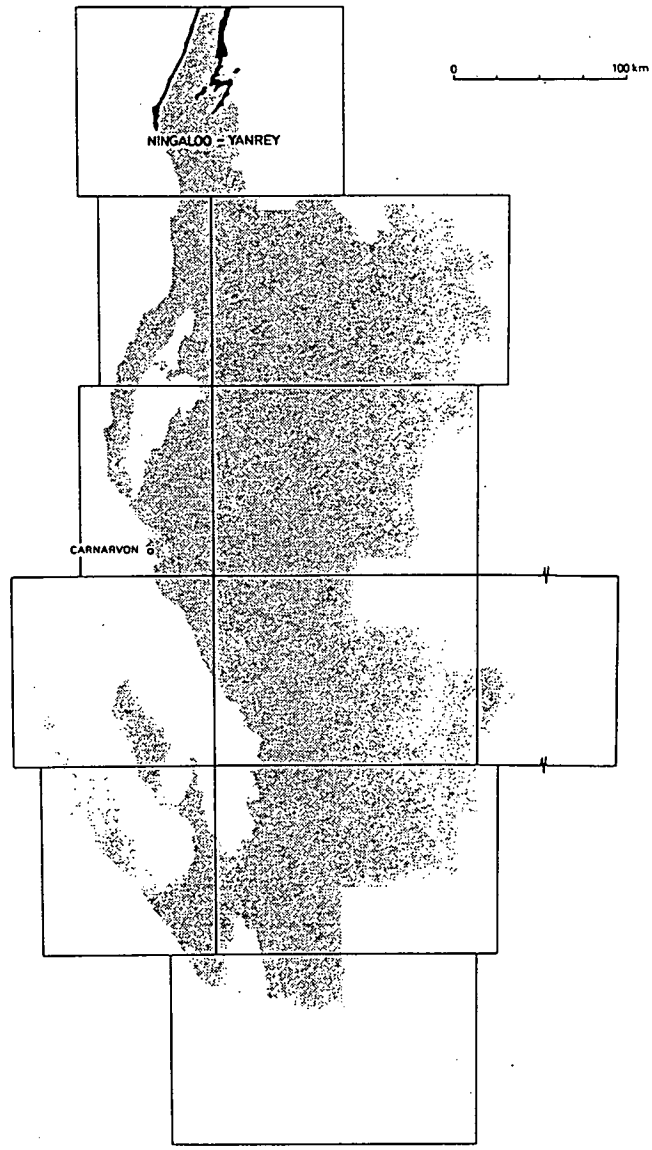
Geology: Tertiary Trella limestone, and Quaternary calcarenite, colluvium, alluvium and acolian sand.

Geomorphology: Erosional and depositional surfaces: Pediment-like footslopes and lower depositional colluvial plains with mainly sandy surfaces, dissected by parallel drainage lines of low density, ending in fan-shaped outwash plains fringed by coastal dunes and beaches.

Pastoral use: Mainly Soft Spinifex (SOSP) pastures interspersed with areas of Acacia Mixed Shrub (ACMS) pastures supporting a range of palatable shrubs and perennial grasses which confer good drought durability. The Soft Spinifex pastures require periodic burning, followed by a deferral of grazing, to rejuvenate this palatable hummock grass. The system is not normally susceptible to accelerated erosion.

Estimated carrying capacity, good condition: 7 ha/s.u.

Range condition summary: good 81%; fair 13%; poor 6%.



Unit
1. Stony footslopes
2. Outwash plains
3. Sandy plains
4. Coastal dunes
5. Saline plains
6. Drainage lines
7. Beaches and foredunes

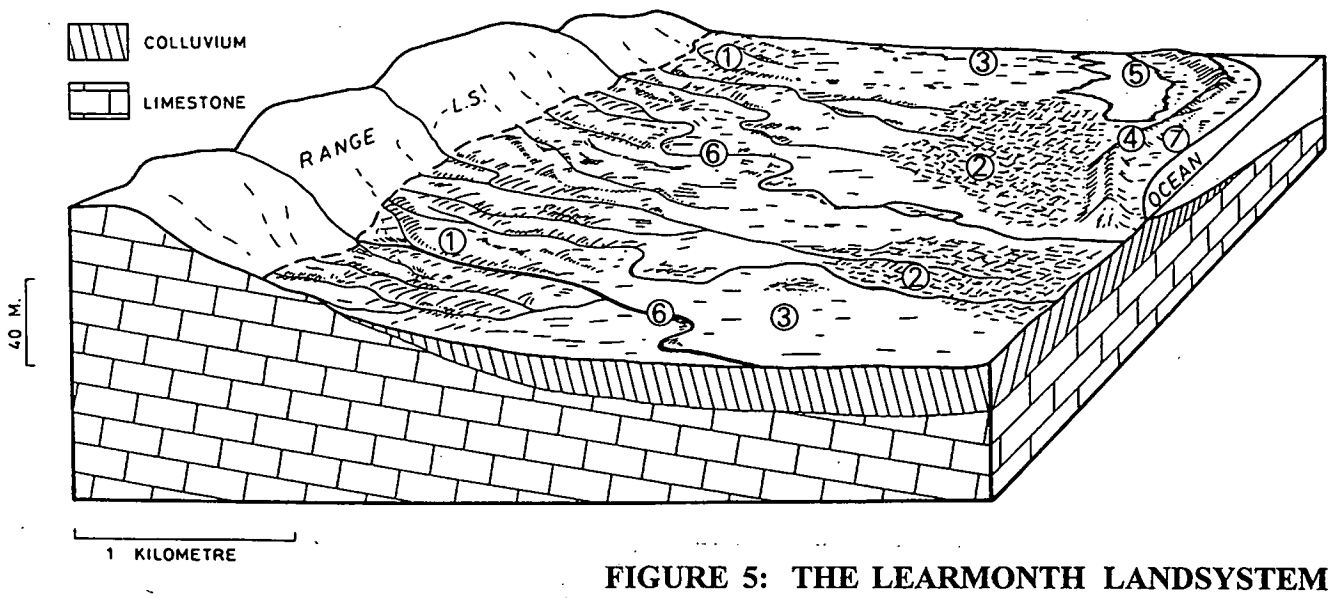


FIGURE 5: THE LEARMONTH LANDSYSTEM (FROM PAYNE ET. AL. 1987)

APPENDIX 1

CONSULTATIVE ENVIRONMENTAL REVIEW GUIDELINES

CONSULTATIVE ENVIRONMENTAL REVIEW GUIDELINES

The proposed Special Residential Subdivision was outlined in a Notice of Intent of July 1995 and submitted to the Department of Environmental Protection for assessment. The Environmental Protection Authority determined that the project be assessed at the level of a Consultative Environmental Review. The Department of Environmental Protection subsequently prepared the following guidelines for the preparation of this Consultative Environmental Review:

OVERVIEW

All environmental reviews have the objective of protecting the environment. The fundamental requirement is for the proponent to describe the proposal, receiving environment, potential environmental impacts and management of those impacts to ensure the environment is protected.

If the proponent can demonstrate that the environment will be protected then the proposal will be found environmentally acceptable; if the proponent cannot show that the environment would be protected then the Environmental Protection Authority would recommend against the Minister for the Environment approving the proposal.

Throughout the assessment process it is the objective of the Department of Environmental Protection to assist the proponent to improve or modify the proposal in such a way that the environment is protected. Nonetheless, the environmental review process in Western Australia is proponent driven, and it is up to the proponent to identify the potential environmental impacts and design and implement proposals which protect the environment.

PURPOSE OF A CONSULTATIVE ENVIRONMENTAL REVIEW

The primary function of a Consultative Environmental Review is to provide information about the proposal to the Environmental Protection Authority. Upon its assessment of the Consultative Environmental Review, the Environmental Protection Authority provides advice to Government on the environmental acceptability of the proposal.

An additional function of the document is to clearly communicate details of the proposal to the public so that the Environmental Protection Authority can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process.

OBJECTIVES OF THE CONSULTATIVE ENVIRONMENTAL REVIEW

The Consultative Environmental Review should have the following objectives:

- to place this project in the context of the regional environment and the progressive development of resources in the region, including the cumulative impact of this development,
- to explain the issues and decisions which led to the choice of this project at this place at this time,
- to set out the environmental impacts that the project may have, and
- for each impact, to describe any environmental management steps the proponent believes would avoid, mitigate or ameliorate that impact.

The Consultative Environmental Review should focus on the major issues for the area and anticipate the questions that members of the public will raise. Data describing the environment should be directly related to the discussion of the potential impacts of the proposal. Both should then relate directly to the actions proposed to manage those impacts.

The language used in the body of the Consultative Environmental Review should be kept simple and concise, considering the audience includes non-technical people, and any extensive, technical detail should either be referenced or appended to the Consultative Environmental Review. It is important to note that the Consultative Environmental Review would form the legal basis of the Minister for the Environment's approval of the proposal and, hence, should include a description of all the main and ancillary components of the proposal, including options.

KEY TOPICS

The critical topic for the proposal is likely to be the protection of subterranean fauna. The Consultative Environmental Review should show a detailed understanding of the conservation value of these fauna.

The key topics should be clearly identified in the Consultative Environmental Review and the content of succeeding sections determined by their relevance to these topics.

In this case the key topics should include:

1. Biological and physical environment and conservation

- Potential impacts on subterranean fauna via the groundwater:
  - management of sewage and waste water treatment,
  - protection of superficial groundwater quantity and quality, and
  - maintenance of surface water drainage patterns particularly overland flow.

- Other fauna, flora and ecosystems:
  - community ecosystem type and their secure representation in conservation reserves,
  - rare and poorly known flora and communities shown on distribution maps, and
  - inter-relationships of the biota and environment.

- Coastal management:
  - set backs from foreshore areas,
  - dune stability and landscape protection, and
  - management of public access,

- Water supply.

2. Pollution, its prevention and management

- Noise from the nearby airport:
  - ANEF contours.

Any other key issues raised during the preparation of the report should also be discussed. The reasons for selection of the preferred site and the alternatives considered should also be included.

PUBLIC PARTICIPATION AND CONSULTATION

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the Consultative Environmental Review. It should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management for the proposal which should clearly indicate how community concerns have been addressed. Where these concerns are dealt with through other departments or procedures, outside the Environmental Protection Authority process, these can be noted and referenced here.

DETAILED LIST OF ENVIRONMENTAL COMMITMENTS

The method of implementation of the proposal and all commitments made by the proponent in the Consultative Environmental Review would become legally enforceable under the Environmental Conditions set by the Minister for the Environment.

The commitments made by the proponent to protect the environment should be clearly defined and separately listed. Where an environmental problem has the potential to occur, there should be a commitment to rectify it. They should be numbered and take the form of:

a) who will do the work?

b) what the work is,

c) when the work will be carried out, and

d) to whose satisfaction the work will be carried out.

All actionable and auditable commitments made in the body of the document should be highlighted within the text and numbered and summarised in the list of commitments.

An electronic copy of the list of commitments should be provided to the Department of Environmental Protection.

APPENDIX 2

DESCRIPTION OF SOILS, PHOSPHATE RETENTION INDICES AND WATER INFILTRATION TIME

DESCRIPTION OF SOILS, PHOSPHATE RETENTION INDICES AND WATER INFILTRATION TIME (TIME FOR INFILTRATION OF 25CM OF WATER)

The location of sample sites is shown in Figure 2.

Site	Depth (cm)	Description	PRI	Infiltration time (minutes)	Phosphate [1] fixing characteristic
2	0-98	Red/brown loamy sand	10	7	moderate
2	98+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
4	0-35	red/brown sandy load	12	5	strongly
4	45-70	Friable light brown clayey sand	12	-	
4	70-200	Pale brown clay	29	-	
4	200+	Pale brown sandy clay with high gravel content (water table)	-	-	
8	0-180	Red/brown sandy loam	25	8	strongly
8	180+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
11	0-68	Red/brown sandy loam	27	13	strongly
11	68+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
13	0-65	Red/brown sandy loam	22	5	strongly
13	65+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
15	0-178	Red/brown sandy loam	24	5	strongly
15	178+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
18	0-170	Red/brown sandy loam	19	13	moderate
18	170+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
19	0-120	Red/brown sandy loam	19	7	moderate
19	120+	Red/brown sandy loam with limestone gravel and larger stones	-	-	
20	0-225+	Red/brown sandy loam	22	8	strongly

[1] Based on interpretations given in section 2.0.

APPENDIX 3

THE LANDSCAPE UNITS OF THE STUDY AREA

THE LANDSCAPE UNITS OF THE STUDY AREA

The distribution of these Landscape Units is shown in Figure 2.

Landscape Unit A: Sandy plain of widely scattered shrubs over a hummock grassland (Plate 1)

The soils are typically red brown loamy sands to sandy loams varying from 45cm to 2m in depth overlying a colluvium of limestone pebbles and larger stones. The terrain consists of a gently undulating plain. The vegetation consists of a hummock grassland of *Triodia pungens* with an overstorey of widely scattered shrubs, especially *Maireana georgei*, and small trees.

Very widely scattered trees up to 4m in height include *Acacia inaequilatera, Acacia murrayana, Grevillea stenobotrya, Gyrostemon ramulosus, Hakea preissii* and *Hakea suberea*, and occasional shrubs to 2.5m in height include *Acacia coriacea, Acacia tetragonophylla, Exocarpos aphyllus, Hakea* aff. *candolleana* and *Olearia axillaris*. Shrubs to 1.5m included *Corchorus sidoides, Corchorus walcottii, Crotalaria cunninghamii, Enchylaena tomentosa, Eremophila maitlandii, Gossypium robinsonii, Heterodendrum oleaefolium, Maireana georgei, Melaleuca* aff. *cardiophylla, Pimelea microcephala, Senecio lautus* and *Verticordia* sp.; and small shrubs to 0.5m include *Acacia ligulata, Acanthocarpus preissii, Crotalaria cunninghamii, Dampiera cinerea, Ptilotus polakii, Scaevola canescens, Scaevola tomentosa, Solanum lasiophyllum, Zygophyllum fruticulosum* and the annual *Sesbania cannabina.*

The introduced Kapok bush (*Aerva javonica*) is present on disturbed areas.

Triodia pungens is the dominant grass. Also present are the grasses *Eragrostis eriopoda, Eragrostis xerophila, ?Eriachne mucronata, Plectrachne schinzii, Triodia basedowii, Triodia secunda* and *Triodia wiseana.* The creeper *Mukia maderaspatana* is present, and *Tribulus terrestis* and *Chenopodium murale* are common groundcovers.

Landscape Unit B: Sandy plain with a shrubland over a hummock grassland (Plate 2)

The soils and terrain of this landscape unit are very similar to those of Landscape Unit A, but it supports a shrubland which is dominated by *Acacia bivenosa* over *Triodia pungens.* The species composition and their heights are as in Landscape Unit A, with the difference being the presence of more shrubs. This is likely to be due to differences in recent fire history. The creeper *Cassytha aurea* was common in some of the trees. In addition to the species identified in Landscape Unit A the following species were also identified:

Shrubs to 4m in height were *Acacia ampliceps, Acacia bivenosa, Myoporum acuminatum, Santalum acuminatum.* Shrubs to 2m in height include *Acacia pyrifolia, Aerva Javanica, Amaranthus pallidiflorus, Capparis spinosa, Ipomoea costata, Psoralea martinii, Ptilotus obovatus, Rhagodia preissii, Scaevola tomentosa, Senna glutinosa, Senna helmsii, Senna oligophylla* and *Stylobasium spathulatum.* Annual herbs included *Cleome viscosa, Flaveria australasica, Swainsona pterostylis, Tribulus occidentalis* and the woody annual *Trichodesma zeylanicum.*

The introduced Kapok bush (*Aerva Javonica*) is present on disturbed areas.

Landscape Unit C: Outwash plain with moderately close and tall shrubland (Plate 3)

The soils are red/brown sandy loams which vary in depth from 45cm to 185cm. The terrain is gently undulating and the surface is covered by a scatter of limestone gravel.

This landscape unit is dominated by a scattered shrubland up to 3m but most commonly to 2m in height. The most common shrubs are *Acacia bivenosa, Acacia tetragonophylla* and *Melaleuca ?cardiophylla.* Other common shrubs include *Acacia ampliceps, Acacia coriacea, Acacia gregorii, Acacia inaequilatera, Acacia pyrifolia, Acacia sclerosperma, Acacia xiphophylla, Corchorus sidoides, Dampiera cinerea, Heterodendrum oleaefolium, Pimelea microcephala, Pluchea* sp., *Pterocaulon sphacelatum* and *Stylobasium spathulatum.* Shrubs to 1.5cm include *Enchylaena tomentosa, Heliotropium undulatum, Indigofera georgei, Lepidium platypetalum, Lepidium strongylophyllum, Maireana planifolia, Olearia axillaris, Pileanthus* sp., *Pimelea microcephala, Psoralea ?pustulata, Ptilotus obovatus, Ptilotus villosiflorus, Scaevola tomentosa, Senna desolata, Senna helmsii, Senna notabilis, Solanum diversiflorum* and *Triumfetta leptacantha.*

Herbs and other annual plants included *Amaranthus pallidiflorus, Mukia maderaspatana, Rhynchosia minima* and *Swainsona pterostylis. Pluchea rubelliflora* is a common groundcover and *Cassytha* sp. is a common creeper. The creeper *Luffa sp.* occurs in some of the large shrubs and small trees.

The groundcover is dominated by the hummock grasses *Triodia pungens.* Also present are the grasses *Chrysopogon fallax, Plectrachne schinzii, Sporobolus ?virginicus, Triodia basedowii, Triodia wiseana,* and especially, the introduced grass *Cenchrus ciliaris.* The introduced the Kapok bush (*Aerva Javonica*) is present in disturbed areas.

Landscape Unit D: Low-lying plain with a mosaic of halophytic shrubs and hummock grassland with scattered shrubs behind coastal dunes (Plate 4)

The soils are red-brown sandy loams to a depth of 35cm over friable brown clays to a depth of 75cm and deeper. The terrain is gently undulating.

This landscape unit consists of a mosaic of low-lying saline flats dominated by low halophytic shrubs and slightly more elevated pockets of alluvial sand which support *Triodia pungens.* Some areas have been invaded by the introduced grass *Cenchrus ciliaris.*

On the saline flats scrubs to 30cm in height of the saline flats included *Atriplex amnicola, Atriplex inflata, Atriplex ?semilunaris, Chenopodium gaudichaudianum, Exocarpos aphyllus, Frankenia* aff. *pauciflora, Halosarcia auriculata, Halosarcia doleiformis, Halosarcia halocnemoides, Halosarcia pruinosa, Lawrencia spicatus, Maireana triptera, Neobassia astrocarpa, Rhagodia eremaea, Salsola kali, Streptoglossa* sp. and *Streptoglossa ?odora.* Herbs included *Hemichroa diandra* and *Trianthema triquetra.* Grasses included *Sporobolus virginicus* which in places has formed a dense lawn, and *Cenchrus ciliaris* and *Eragrostis pergracilis.*

In areas which are not salt affected the vegetation is dominated by a grassland of *Triodia pungens* with prolific stands of *Cenchrus ciliaris* and a very open shrubland to 2m consisting of the following common shrubs: *Acacia coriacea* subsp. *coriacea, Acacia victoriae, Alectryon oleifolius, Amyema ?preissii, Exocarpos aphyllus, Pimelea microcephala, Gymnema granitica, Rhagodia preissii* and *Sarcostemma viminalis* subsp. *australe.*

Landscape Unit E: Drainage lines with trees and shrubs

The soils of the minor drainage lines consist of alluvial red/brown sandy loams over gravel, with bare limestone gravel in the larger creek beds.

The drainage lines transect the landscape units of the Study Area from east to west, and most of the trees and shrubs of the surrounding landscape units, especially Units A, B and C, are also present in the drainage lines, but typically to a greater height. The drainage lines are distinct in that they frequently support *Eucalyptus* sp. trees which are absent from the surrounding plains.

Common trees within the drainage lines which attain about 6m in height include *Eucalyptus* sp. nr Euc. *polycarpa* and *Eucalyptus prominens*. Occasionally *Ficus platypoda* and *Brachychiton gregorii* are present to a height of 3m. Tall shrubs to 3 metres include *Acacia ampliceps, Acacia bivenosa, Acacia coriacea, Acacia sclerophylla, Acacia tetragonophylla, Acacia xiphophylla, Enchylaena tomentosa, Gossypium robinsonii* and *Stylobasium spathulatum*. Low shrubs include *Atriplex tetragonophylla, Capparis spinosa, Heliotropium undulatum, Indigofera georgei, Ipomoea costata, Lepidium platypetalum, Maireana planifolia, Olearia axillaris, Pileanthus* sp., *Psoralea martinii, Psoralea ?pustulata, Ptilotus obovatus, Scaevola tomentosa, Senna desolata, Senna notabilis, Senna oligophylla* and *Solanum diversiflorum, Solanum lasiophyllum* and *Tephrosia rosea.*

The dominant grass is *Triodia pungens*, with *Triodia basedowii, Triodia secunda* and *Triodia wiseana* also being present. The introduced grasses *Aristida holathera, Cenchrus ciliaris* and *Cenchrus setigerus* are also present. Herbs and other annuals include *Amaranthus pallidiflorus, Flaveria australasica*, and *Rhynchosia minima.*

Landscape Unit F: Calcrete plain with open shrubland over hummock grasses (Plate 5)

This landscape unit consists of shallow red/brown sandy loams over undulating calcrete terrain. Calcrete ridges with skeletal soil cover, and frequently no soil cover, are widespread and rise to 1m above the surrounding plain with deeper soils occurring in the depressions between these ridges. The soil surface of this landscape unit is variably covered by limestone gravel, with a denser cover of gravel along the slightly elevated ridges and less gravel on the depressions between ridges. The soils have a high content of gravel and larger stones.

The vegetation of the limestone ridges is dominated by *Melaleuca ?cardiophylla* to 1.5m in height over scattered hummocks of *Triodia pungens*. The depressions between ridges very occasionally support *Eucalyptus prominens* and *Eucalyptus sp. nr Euc. polycarpa* and *Ficus platypoda* to 3m in height. Common shrubs in this stratum include *Acacia bivenosa, Acacia lysiphloia, Acacia coriacea, Acacia tetragonophylla, ?Clerodendrum* sp., *Exocarpos aphyllus, Gossypium robinsonii, Hakea preissii, Hybanthus aurantiacus, Sarcostemma viminalis* subsp. *australe, Scaevola globulifera, Senna artemisioides* subsp. *oligophylla* and *Solanum lasiophyllum.*

The mistletoe *Amyema preissii* was found growing in a tall shrub of *Acacia victoria. Jasminum didymum* var. *lineare* is a common creeper in trees and shrubs.

Shrubs to 1m in height include *Abutilon otocarpum, Canavalia rosea, Corchorus* sp., *Corchorus parviflorus, Diplopeltis eriocarpa, Dipteracanthus australasicus* subsp.?, *Enchylaena tomentosa, Enneapogon caerulescens, Eremophila longifolia, Halosarcia halocnemoides, Indigofera monophylla, Jasminum didymum* subsp. *lineare, Ptilotus obovatus, Ptilotus schwartzii, Sarcostemma australe, Scaevola tomentosa, Scaevola spinescens, Senna artemisiodes subsp. oligophylla, Senna glutinosa, Senna helmsii* and *Solanum* aff. *phlomoides*. The creeper *Cynanchum floribundum* is also present.

Herbs and other annuals include *Abutilon* sp., *Tribulus occidentalis* and *Tribulus platypterus.*

The grass *Triodia pungens* is widespread and *Eriachne obtusa* and *Plectrachne schinzii* are scattered throughout this landscape unit. Other grasses included *Aristida holathera, Cenchrus ciliaris, Cenchrus setigerus* and *Chrysopogon fallax.*

Landscape Unit G: Beaches and dune system (Plate 6)

This landscape unit consists of the beaches and coastal foredunes over calcrete or limestone pebbles. In places coastal dunes rising to 10m or more above sea level.

The coastal dunes are generally stable with no large blow outs, and they support vegetation which provides good surface stability, although this would be easily eroded by trampling.

The sands of the coastal dunes and beach are white and of Recent origin. In the swale immediately behind the foredunes, the transition between the Recent coastal dunes and the older Quaternary alluvial soils is evident. Here red sand can be found at shallow depths below coastal beach sand deposits.

The beach above the high water mark supports a very sparse community of *Ptilotus* ? *villosiflorus* and *Salsola kali*. Higher up on the beach there are regularly spaced hummocks of *Spinifex longifolius*. Also present, but in very sparse are *Ipomoea brasiliensis, Ptilotus* ? *villosiflorus* and *Salsola kali*.

The dune consists of a hummock grassland with a scattered shrubland forming an overstorey of shrubs. *Spinifex longifolius* and *Triodia pungens* are equally common on the seaward slope, with *Triodia pungens* sometimes being dominant on the inland slope, together with the grasses *Eragrostis xerophila, Eriachne ?mucronata, Plechtrachne schinzii* and *Triodia secunda*. There appears to be no difference in the species composition of shrubs on the seaward and inland slopes, but there are height differences. Shrubs on the seaward slope and crest rarely exceed a height of 1.5m whilst shrub heights of 2.5m are common on the inland slope.

Common shrubs include *Acacia coriacea, Acacia translucens, Acacia tetragonophylla* and *Olearia axillaris*. The following shrubs are also present: *Commicarpus australis, Corchorus* sp. nr. *Corchorus sidoides, Dampiera cinerea, Grevillea stenobotrya, Hannafordia bissillii, Neobassia astrocarpa, Rhagodia preissii* var. *obovata, Scaevola* aff. *canescens, Senecio lautus, Sida rohlenae, Solanum horridum* and *Threlkeldia diffusa*. The mistletoe *Amyema* aff. *preissii* and the creeper *Cassytha* sp. are present, and the groundcovers *Heliotropium undulatum, Euphorbia australis, Euphorbia inappendiculata, Suaeda* sp. and *Swainsona pterostylis* are common.

APPENDIX 4

LIST OF FLORA SPECIES FOUND IN THE STUDY AREA, TOGETHER WITH INFORMATION ON GROWTH FORM AND LANDSCAPE UNITS IN WHICH THEY WERE OBSERVED

LIST OF FLORA SPECIES FOUND IN THE EXMOUTH PROJECT AREA, TOGETHER WITH INFORMATION ON GROWTH FORM AND LANDSCAPE UNITS IN WHICH THEY WERE OBSERVED

Landscape Unit A: Sandy plain of widely scattered shrubs over a hummock grassland.
Landscape Unit B: Sandy plain with a shrubland over a hummock grassland.
Landscape Unit C: Outwash plain with moderately close and tall shrubland.
Landscape Unit D: Low-lying plain with a mosaic of halophytic shrubs and hummock grasslands with scattered shrubs behind coastal dunes.
Landscape Unit E: Drainage lines with trees and shrubs.
Landscape Unit F: Calcrete plain with open shrubland over hummock grasses.
Landscape Unit G: Beaches and dune system.

The distribution of the above Landscape Units is given in Figure 2.

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Abutilon otocarpum	Shrub	1m						X	
Abutilon sp.	Herb							X	
Acacia ampliceps	Tree/shrub	4m		X	X		X		
Acacia bivenosa	Tree/shrub	4m		X	X		X		
Acacia coriacea	Tree/shrub	4m	X		X	X	X	X	X
Acacia gregorii	Shrub	4m			X				
Acacia inaequilatera	Tree/shrub	4m	X	X	X				
Acacia ligulata	Tree/shrub	4m	X						
Acacia lysiphloia	Shrub							X	
Acacia murrayana	Tree/shrub	4m	X	X					
Acacia pyrifolia	Tree/shrub	2m		X	X				
Acacia sclerophylla	Tree/shrub	4m					X		
Acacia sclerosperma	Shrub	4m			X				
Acacia synchronicia?	Tree/shrub	4m				X			
Acacia tetragonophylla	Tree/shrub	4m	X				X		X
Acacia translucens	Shrub	1m							X
Acacia xiphophylla	Tree/shrub	4m			X				
Acanthocarpus preissii	Small shrub	0.5m	X						
Aerva javanica	Shrub	2m		X					
Argrostis sp.	Grass							X	
Alectryon oleifolius	Shrub	2m				X			
Amaranthus pallidiflorus	Herb			X	X		X		
Amyema aff. *preissii*	Shrub	2m				X		X	

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Aristida holathera	Grass						X	X	
Atriplex amnicola	Saltbush	35cm				X			
Atriplex inflata	Saltbush	25cm				X			
Atriplex ?semilunaris	Shrub					X			
Atriplex tetragonophylla	Shrub	1m					X		
Brachychiton australe	Shrub	2m						X	
Brachychiton gregorii	Tree	4m					X		
Calytrix brevifolia	Shrub								X
Canavalia rosea	Shrub							X	
Cassytha aurea	Creeper			X				X	
Cassytha sp.	Creeper				X				X
Capparis spinosa	Shrub	1.5m		X			X		
Cenchrus ciliaris	Grass				X	X	X	X	
Cenchrus setigerus	Grass						X	X	
Chenopodium gaudichaudianum	Saltbush	1m				X			
Chenopodium murale	Groundcover		X						
Chrysopogon fallax	Groundcover				X			X	
Cleome viscosa	Annual herb	50cm		X					
?Clerodendrum sp.	Shrub							X	
Commicarpus australis	Shrub								X
Corchorus parviflorus	Shrub	80cm						X	
Corchorus sidoides	Shrub	1.5m	X		X				X
Corchorus sp.									
Corchorus walcottii?	Shrub	1m	X	X					
Crotalaria cunninghamii	Shrub	2m	X	X					
Cynanchum floribundum	Creeper							X	
Dampiera cinerea	Small shrub	0.5m	X		X				X
Diplopeltis eriocarpa	Shrub	1m						X	
Dipteracanthus australasicus subsp.?	Shrub	1m						X	
Enchylaena tomentosa	Shrub	1m	X	X	X		X	X	
Enneapogon caerulescens	Glass							X	
Eragrostis eriopoda	Grass		X						

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Eragrostis pergracilis	Grass					X			
Eragrostis xerophila	Grass		X						X
Eremophila longifolia	Shrub/tree	5m						X	
Eremophila maitlandii	Shrub	2.5m	X	X					
?Eriachne mucronata	Grass		X						X
Eriachne obtusa	Grass							X	
Eucalyptus prominens	Tree	6m					X	X	
Eucalyptus sp. nr Euc. *polycarpa*	Tree	6m					X	X	
Euphorbia australis	Groundcover								X
Euphorbia inappendiculata	Groundcover								X
Exocarpos aphyllus	Shrub	2m				X			
Ficus platypoda	Tree	3m					X	X	
Flaveria australasica	Annual herb			X			X		
Frankenia aff. *pauciflora*	Shrub					X			
Gossypium robinsonii	Shrub	3m	X	X			X	X	
Grevillea stenobotrya	Tree/shrub	4m							X
Gymnema granitica	Shrub	2m				X			
Gyrostemon ramulosus	Tree	4m	X		X	X	X	X	X
Hakea aff. *candolleana*	Tree	4m	X						
Hakea preissii	Tree	4m	X	X				X	
Hakea suberea	Tree	4m	X						
Halosarcia auriculata	Saltbush	30cm				X			
Halosarcia doleiformis	Saltbush	30cm				X			
Halosarcia halocnemoides	Saltbush	30cm				X		X	
Halosarcia pruinosa	Saltbush	30cm				X			
Heliotropium undulatum	Shrub	1.5m			X		X		X
Hemichroa diandra	Herb	30-50cm				X			
Hannafordia bissillii	Shrub								X
Heterodendrum oleaefolium	Shrub	1.5m	X	X					
Hybanthus aurantiacus, subsp. *australe*	Shrub							X	
Indigofera georgei	Shrub	1.5m			X		X		
Indigofera monophylla	Shrub	1m						X	

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Ipomoea brasiliensis	Creeper								X
Ipomoea costata	Creeping bush			X			X		
Jasminum didymum var. *lineare*	Shrub							X	
Lawrencia spicatus	Shrub	30cm				X			
Lepidium platypetalum	Shrub	1.5m			X		X		
Lepidium strongylophyllum	Shrub	1m			X				
Luffa sp.	Creeper				X				
Maireana georgei	Shrub		X						
Maireana planifolia	Shrub	1.5m			X		X		
Maireana triptera	Saltbush	30cm				X			
Melaleuca aff. *cardiophylla*	Shrub	1.5m	X		X			X	
Mukia maderaspatana	Climbing herb				X				
Myoporum acuminatum	Shrub	4m		X					
Neobassia astrocarpa	Shrub	30cm				X			
Neobassia astrocarpa var. *obovata*	Shrub								X
Olearia axillaris	Shrub	2.5m	X		X		X		X
Pileanthus sp.	Shrub	1.5m			X		X		
Pimelea microcephala	Shrub	2m			X				
Plectrachne schinzii	Grass		X	X	X		X	X	X
Pluchea rubelliflora	Groundcover				X				
Pluchea sp.	Shrub				X				
Psoralea martinii	Shrub	1m		X			X		
Psoralea ?pustulata	Shrub	1.5m			X		X		
Pterocaulon sphacelatum	Shrub				X				
Ptilotus exaltatus	Herb	30cm							
Ptilotus obovatus	Shrub	50cm		X				X	
Ptilotus polakii	Shrub	50cm	X	X					
Ptilotus schwartzii	Shrub	50cm						X	
Ptilotus villosiflorus	Shrub	50cm			X				
Rhagodia eremaea	Saltbush	2m				X			
Rhagodia preissii	Shrub	50cm		X					

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Rhagodia preissii	Shrub	50cm		X					
Rhynchosia minima	Perennial	30cm			X		X		
Salsola kali	Annual herb	1m				X			
Santalum acuminatum	Shrub	5m		X					
Sarcostemma australe	Shrub	50cm						X	
Sarcostemma viminalis	Shrub	2m				X		X	
Scaevola canescens	Small shrub	0.5m	X						X
Scaevola globulifera	Shrub							X	
Scaevola spinescens	Shrub	2m						X	
Scaevola tomentosa	Shrub	1.5m		X	X				
Senecio lautus	Shrub	1.5m	X						X
Senna artemisioides subsp. *oligophylla*	Shrub							X	
Senna desolata	Shrub	1.5m			X		X		
Senna glutinosa	Shrub	1m		X				X	
Senna helmsii	Shrub	1.5m		X	X			X	
Senna notabilis	Shrub	1.5m			X				
Senna oligophylla	Shrub	1.5m		X			X		
Sesbania cannabina	Annual	1.5m	X	X					
Sida rohlenae	Shrub								X
Solanum diversiflorum	Shrub	1.5m			X		X		
Solanum horridum	Shrub								X
Solanum lasiophyllum	Shrub	1m					X		
Solanum aff. *phlomoides*	Shrub	1m						X	
Spinifex longifolius	Grass								X
Sporobolus virginicus	Grass					X			
Streptoglossa sp.	Shrub	30cm				X			
Streptoglossa ?odora	Shrub	30cm				X			
Stylobasium spathulatum	Bush	2.5m		X	X				
Suaeda sp.	Groundcover								X
Swainsona pterostylis	Herb	30cm		X	X				X
Tephrosia rosea	Shrub	1.5m					X		
Threlkeldia diffusa	Shrub	1m							X

SPECIES	GROWTH FORM	HEIGHT	LANDSCAPE UNITS						
			A	B	C	D	E	F	G
Tribulus terrestis	Groundcover		X						
Trianthema triquetra	Herb	5-25cm				X			
Tribulus occidentalis	Herb	30cm		X				X	
Tribulus platypterus	Shrub	1m						X	
Trichodesma zeylanicum	Annual			X					
Triodia basedowii			X	X	X		X	X	
Triodia pungens	Grass		X	X	X		X	X	X
Triodia secunda	Grass		X	X			X	X	X
Triodia wiseana	Grass		X	X	X		X	X	
Triumfetta leptacantha	Shrub	50cm			X				
Verticordia sp.	Shrub	1.5m	X						
Zygophyllum fruticulosum	Small shrub	0.5m	X						

APPENDIX 5

DECLARED RARE AND PRIORITY LISTED PLANT SPECIES FOUND WITHIN THE GREATER REGION OF THE STUDY AREA

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
DECLARED RARE AND PRIORITY FLORA LIST
FOR THE CAPE RANGE PENINSULA

Species/Taxon	Code*	CALM Region	Distribution	Flower Period
Abutilon sp. Cape Range (A S George 1312)	2	P	Cape Range, Yardie Creek, Learmonth	-
Abutilon sp. Quobba (H Demarz 3858)	2	MW, P	Quobba, Cape Range, Minilya	July-October
Acacia alexandri	3	P	Cape Range, Exmouth	June-September
Acacia startii	3	MW, P	Cape Range, Rough Range, Minilya	July-August
Acanthocarpus rupestris	2	P	Cape Range	May-June
Brachychiton obtusilobus	4	P	Cape Range	August-September
Corchorus elachocarpus subsp. Cape Range (A S George 6671)	2	P	Exmouth, Ningaloo Station	May-September
Daviesia sp. [PLE] (A S George 10288)	2	P	Cape Range	September-October
Eremophila occidens ms	2	P	Cape Range	-
Eremophila youngii subsp. *lepidota* ms	4	P	S Cape Range, Roy Hill, N Mt Vernon, Paraburdoo	March, June
Livistona alfredii	4	P	Millstream, Cave Creek, Cape Range	November-December
Scaevola acacioides	2	P	Exmouth	-
Stackhousia umbellata (C Gardner and A S George)	3	P	North West Cape	-
Verticordia serotina	2	P	Cape Range N.P.	September

* Conservation code.

Key:

Conservation code: Rankings for priority flora.
P1: Critical - 1 location only.
P2: Critical - 1-2 locations only.
P3: Several populations.
P4: Still rare but not endangered

CALM region: P = Pilbara.
MW = Mid West (Carnarvon-Geraldton).

APPENDIX 6

WRITTEN SUBMISSIONS

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FACSIMILE

TO CONTACT	Rob Holmes ~~Halpern, Glick, Maunsell Pty~~ Ltd Mattruch cths
FACSIMILE NUMBER:	381 7061
FROM: NUMBER OF PAGES: SUBJECT	Dr W.F. Humphreys + 2 Exmouth subterranean fauna

Dear Rob

Thank you for the fax.

In my view the report does not adequately address the fauna issues specifically associated with the coastal plain (see Humphreys 1994). Between the Water Authority borefield and the coast a total of 21 (possibly 34) species of cavernicolous animals endemic to the coastal plain, distinct from those in Cape Range, could be affected by the proposed development.

The potential for this project to impact on the subterranean fauna is considerable owing to nutrient enrichment and other contaminants from domestic (wastewater, sewage, petroleum waste), garden waste and run-off (fertilisers, pesticides), and groundwater extraction. In this context it does not adequately address such issues as:-

- Constraints imposed by karstic landscape
- Occurrence, if any, of caves and troglobitic fauna and what to do about them if found
- The presence of aquatic fauna and monitoring
- Groundwater extraction
- Adequacy of soil depth
- Non-leach drain inputs of contaminants

You cite distances of 10 m between the leach drain and the groundwater. As the whole site is below the 10 m contour (on my maps) this is incorrect. You then refer to groundwater 2.1 m below the soil surface! This is a karst landscape and the soils are in places very thin and below which there is no effective filtering. You could provide a site map showing soil depth contours throughout and thus a rationalization of the proposed property boundaries and any recommended restriction on the siting of leach-drains.

Fissured and karst systems are considered to be very vulnerable to pollution. In karst the dispersivity of pollutants can be very high, and the "filter" phenomena can be deficient or even totally absent. Moreover, adsorption and sites for biological and chemical degradation are reduced in karst, giving those systems a limited self

purification potential. Another peculiarity of karst is the accumulation of sediment and polluted materials in lateral compartments. Stygofauna worldwide is disrupted by sewage and very expensive remedial measures then fall on local authorities. Anchialine systems are extraordinarily vulnerable to even slight organic pollution.

There is not 100 m of freshwater below the site (consideration of you own data with and Ghyben-Hertzberg principle tells you that), or even below the WAWA borefield. There is a very thin layer, if any, of freshwater to the east of Murat Road. Hence, some comment on the constraints on bores etc. would be useful.

Tidal movements are detected several km inland in the groundwater so there must be open conduit flow in the coastal plain; hence, contaminants would be widely dissipate in unpredictable directions through the superficial karst.

I hope this is of assistance. I will be on a course for the next two weeks. If urgent feel free to contact me before or after business hours on 09 382 2962.

Humphreys, W.F. 1993. Cave fauna in semi-arid tropical Western Australia: a diverse relict wet-forest litter fauna. *Mémoires de Biospéologie* 20: 105-110.

Humphreys, W.F. 1993. Stygofauna in semi-arid tropical Western Australia: a Tethyan connection? *Mémoires de Biospéologie* 20: 111-116.

Humphreys, W.F. 1994. *The subterranean fauna of the Cape Range coastal plain, northwestern Australia.* Report to the Australian Heritage Commission and the Western Australian Heritage Committee. 202 pp. Unpublished.

Humphreys, W.F. and Feinberg, M.N. 1995. Food of the blind cave fishes of northwestern Australia. *Records of the Western Australian Museum* 17: 29-33.

Humphreys ,W.F. and Blyth, J. 1994. Subterranean secrets: hidden treasure of the Cape Range. *Landscope*, 9(3): 22-27.

Harvey, M.S. and Humphreys, W.F. 1995. Notes on the genus *Draculoides* Harvey (Schizomida: Hubbardiidae), with the description of a new troglobitic species. *Records of the Western Australian Museum*, Supplement No. 52: 183-189.

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

To: C Muller
Regional Manager
Pilbara Region

Your Ref: B1(xv) exsub1
Our Ref: D Myers
Enquiries: (099) 491676
Phone:

Subject: **Comments on Proposed Subdivision of Lyndon Locations 222 and 223**

General
Before proceeding, it should be noted that the nature of the locality sketches provided in the subdivision and development proposal document make it difficult to readily locate the site on the ground.

In my view, it is unfortunate that this proposal is being considered before Town Planning Scheme No 3 is in place as it may conflict with the Scheme's basic philosophy and intent. Indeed, it is difficult to see any merit in providing basic services to land that is significantly removed from existing reticulation systems.

I also question the need to place this type of development next to a shoreline that attracts many local people and tourists for recreational purposes. It would be more appropriate to have this subdivision and development west of Murat Road, well away from coastal dunes and not interfering with existing pristine and attractive views of Exmouth Gulf. Views at the southern end of the proposed development will be specially affected because of the very flat terrain.

Rare Flora
The document states that no rare or priority listed flora were found in the study area yet I find no reference to any survey or study been carried out. The document seems to infer that all plants worthy of protection occur within Cape Range National Park but acknowledges that the Cape Range is a different land system to that of the study area.

Weeds
Once again, there is no reference to any survey or study been carried out in the study area.

Fauna
There is no reference in the document about specific studies being undertaken to determine the type and numbers of endemic animals that live within the study area. The statement that the subdivision area ecosystem contrasts those contained in Cape Range National Park lends weight to the concept of having the National Park extended eastwards to include some of these contrasting ecosystems.

Cave Fauna
While the well being of these animals a very much a concern for CALM, I believe that this aspect of the review of this document is being covered by the WA Museum.

Rare Fauna
Once again, the source of comments made in the document about rare fauna is not identified.

Heritage
The document does not demonstrate to me that a determined effort was made to ensure that there are no sites of cultural significance contained in the subdivision area. It would have been useful to have made known the identities of people making assessments about these matters.

Waste Water Disposal
The document acknowledges that there are concerns about the potential threat to cave fauna habitats via phosphorus and nitrogen discharge. Potential nutrient enrichment of Exmouth Gulf waters also needs to be considered, given the close proximity of the proposed development to the shoreline.

It would appear that the decision not to provide sewerage services to the proposed lots is being influenced by the excessive cost of providing that service. This should raise the question about the suitability of the development at this point in time.

Water Supply
The document states that all lots will be connected to scheme water reticulation from nearby borefields. Are these existing borefields, managed by the Water Authority or new ones yet to be developed? If they are new, have any studies been carried out to assess the likely impacts of the increased demand on groundwater?

In respect to development proposals of this nature on the shores of Exmouth Gulf, it should be remembered that there a couple of conservation and reservation proposals, yet to be fully addressed, in the vicinity of this particular development.

There is a body of opinion that recommends that the eastern extension of Cape Range National Park should contain a corridor extending to the shoreline of Exmouth Gulf. This would provide another representative ecosystem and habitat type within the local conservation estate. The proposal is signalled in the Cape Range National Park management plan.

A recommendation to similarly reserve a portion of Exmouth Gulf in the vicinity of the proposed development is contained in the draft report on ' A Representative Marine Reserve System For Western Australia'.

Please contact this office if you have any queries or require further information about this matter.

Doug Myers
District Manager
Exmouth

10 September 1995

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
SCIENCE AND INFORMATION DIVISION

To: Chris Muller
Regional Manager, CALM Pilbara

From: Stephen van Leeuwen, KARRATHA
Phone: (091) 431 628
Date: 19 September, 1995
File:

Subject: **Exmouth Residential Development**

PK asked me to have a quick look at the flora section of this CER and make any relevant comments. These comments are:

The botanist who identified plant specimens is credible and very competent, however, sampling strategy used in the field, person effort and personnel who undertook field sampling is not provided in the methods. Therefore, I am unable to assess how intense and comprehensive the field sampling program was. Also, April is probably not the best time of year to sample flora in this area.

Some of the plant species listed in Table Two appear to be incorrectly identified as current knowledge of their distribution suggests that they do not occur in this area. Examples include *Acacia victoriae* (probably *A. synchronicia*) and *Corchorus walcotii* (possibly one of three taxa, two of which are undescribed and one of which appears to be endemic to the eastern side of the Cape).

The treatment of Rare and Priority Flora is reasonable and the proponents conclusions appear to be legitimate as the vast majority of these species known from the Cape are restricted to limestone ridges or sands, particularly red, over limestone. Most Rare and Priority Flora also occur on top of the Range or on the western flanks.

The treatment of weeds is questionable. The proponent appears to assume that Buffel Grass is not a weed because it has now become naturalised. Conventional thinking in most conservation, land management and environmental protection agencies throughout Australia, as highlighted by ANCA in Environmental Weed publications, would categorise this species as a major environmental weed.

For you information

Cheers

Stephen van Leeuwen
Research Scientist
Science and Information Division

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
Pilbara Regional Office, Karratha

To: ROB HOLMES
MARTINICK & ASSOCIATES

Fax 09 381 7061

Your Ref:
Our Ref: 3320

Inquiries: C Muller
Phone: (091) 43 1488

Subject: EXMOUTH RESIDENTIAL DEVELOPMENT

To save time I enclose a copy of comments provided to me rather than incorporate them in an overall letter. I wish, however, to emphasise my concerns in a couple of areas.

Nutrients/Septic Tank Systems

A PRI of 20-70 is stated to indicate soils which are strongly phosphate fixing. Table 1 shows five of the eleven samples had a PRI <20, two were 22, and all were less than 30. On this basis it is incorrect to state that the soils are all strongly phosphate fixing, and raises the question whether the statement was designed to be deliberately misleading.

Spreading point loading data over the total area to provide a low average per hectare rate for comparison with broadacre fertiliser application is also misleading. A higher point source loading has a far greater potential to leach into waters.

The nutrient inputs from septic and from fertiliser application have been treated separately. The document acknowledges that residents will use fertiliser, and proposes an information sheet that will "encourage" the use of slow release fertiliser. The strategy proposed, of encouraging lawns and trees, is likely to encourage much greater inputs in order to maintain them. A "worst case' scenario of heavy fertiliser application combined with the maximum loading from a septic should be considered to determine potential impacts. It is irrelevant to consider "average" loadings spread over the total area.

I question the statement that there is "very little likelihood of marine algal growth being encouraged locally by domestic effluent". Insufficient data is provided to determine if adequate flushing exists at a local level. Effluent from septic discharges have caused recognisable changes elsewhere on the Cape with similar or greater macro level tidal flows. For example, to address the problem of nutrient discharge, sealed vault toilets have been installed in Cape Range National Park, and sewerage is being investigated for Coral Bay.

Storm Surge

The document states that the proposed developments are "well back" from potential flooding but does not provide any figures to substantiate this.

General

The document recognises some potential problems, but does not provide commitments to address these. For example (my emphases):

> "*Guidelines* for pet management *should* be provided...."

"the environmental information sheet.....will *encourage* the use of slow release fertilisers"

It is recommended a tabular summary of commitments be provided.

Chris Muller
REGIONAL MANAGER
19 Sept 1995

cc D Myers, CALM Exmouth

DEPT CONSERVATION AND LAND MANAGEMENT

To: Chris Muller
Regional Manager, CALM Karratha

Enquiries: Peter Kendrick, Ecologist, CALM Karratha
Your ref.:
Our ref. 33.20
Date: 18 September 1995

Chris,

Comments on CER for Proposed Residential Development, Lyndon Location 222 and 223.

General. The report is very wordy. For example, Section 5.7 begins 'No waterholes or other expressions of permanent or semi-permanent surface water occur within the study site'; this seems typical of many tracts within the document.

Weeds. The report is confused in its treatment of weeds. Section 5.11.3 implies that while two species of *Cenchrus* are introduced, they are not weeds because they are 'naturalised grasses which are widespread'. These species, and the other three introduced species mentioned are weeds precisely because they have become naturalised.

The report states that the study area is free of weeds; however, weed species are noted to occur in 6 of the 7 landscape units described. The statement that 'they are not currently a problem' is odd; no context within which they may or may not be a problem are identified. All environmental weeds are a problem to some degree, and their presence is of concern. The disturbances associated with housing development or subdivision will almost certainly favour weed species at the expense of native species.

Rare fauna. It appears that no systematic fauna survey was undertaken during the study. None of the four species of threatened mammals noted as 'endemic to the Pilbara' are currently endemic, or have in the past been endemic, to the Pilbara. The presence or otherwise of these large and relatively conspicuous species would be conclusively determined by field investigation.

Aquatic cave fauna is mentioned as being possibly present in the vicinity of the development (Section 5.12.3, para 3), but this is taken no further than to mention that it may occur up to 100 metres below the study area. The subterranean fauna is of considerable biological significance and deserves a thorough treatment. The report is deficient in this crucial aspect.

CONSERVATION COUNCIL
OF WESTERN AUSTRALIA INC.
79 Stirling Street, Perth 6000
Phone (09) 220 0652 Fax (09) 220 0653

13 September, 1995

By FAX: 322 1598

Karen Sanders
Department of Environmental Protection
8th Floor
141 St George's Tce
Perth WA 6000

Dear Karen,

RE: SPECIAL RESIDENTIAL SUBDIVISION, EXMONTH - GUIDELINES

The Conservation Council would like to submit the following comments on the draft guidelines.

The Council would like to see the following issues addressed in the CER.

- impact of domestic animals on surrounding area
- possible use of land eg. will horses etc be allowed?
- protection of creeks
- where will road and other construction materials be sourced?
- will there be restrictions on private bores?
- impacts of increased numbers in area?

If you have any questions please ring me at the office on 2200652.

Yours sincerely

Rachel Siewert
Co-ordinator