Public Environmental Review

Port Bouvard

Urban & Canal Development

Volume 2

Appendix 'A'

Groundwater Regime
Dames & Moore

Appendix 'B'

Coastal Dunes, Caddadup Reserve, Estuary Foreshore
Quilty Environmental Consulting

Appendix 'C'

Ocean Foreshore Stability, Canal Water Quality, Estuary Reclamation
Steedman Science & Engineering

PORT BOUVARD URBAN AND CANAL DEVELOPMENT
MANDURAH
POTENTIAL IMPACT OF DEVELOPMENT ON THE GROUNDWATER REGIME AND PROPOSALS FOR MANAGEMENT

for

Wannanup Development Nominees Pty Ltd

DAMES & MOORE

Dames & Moore Job No. 23641-003-074

August 1992

PORT BOUVARD URBAN AND CANAL DEVELOPMENT
MANDURAH
POTENTIAL IMPACT OF DEVELOPMENT
ON THE GROUNDWATER REGIME
AND PROPOSALS FOR MANAGEMENT

1.0 INTRODUCTION

nes & Moore has been commissioned to prepare this report on the groundwater aspects of proposed urban and canal development near Dawesville. This report also contains posals for groundwater and nutrient management and is to form part of a Public /ironmental Review report.

: project is being developed by Wannanup Development Nominees Pty Ltd and is referred to the Port Bouvard Urban and Canal Development. The project site (Figure 1) is ıroximately 10km southwest of Mandurah and occupies an area of land immediately to the th and south of the Dawesville Channel which is to be known as the "Dawesville Channel 'elopment Zone". The development will comprise of approximately 1,400 residential lots tred around a canal system, an 18 hole golf course, a resort and tourist development uding public recreation reserves and, a marina to be located on reclaimed land adjacent to Harvey estuary foreshore to the north of the Channel entrance (Figure 2).

2.0 EXISTING ENVIRONMENT

CLIMATE, PHYSIOGRAPHY AND DRAINAGE

area has a Mediterranean type climate, with warm dry summers and cool wet winters. average annual rainfall recorded at Mandurah is 895mm. Rainfall generally exceeds poration during the five months May to September. The annual average evaporation is ut 1,700mm. Histograms of monthly rainfall (Mandurah Station) and pan evaporation ·th Station) during the period 1983-1991 are given in Figures 3 and 4 respectively.

proposed development is located on a narrow belt of coastal dunes, 1,500 to 2,000m wide, ch separates the Peel Inlet from the Indian Ocean. The dunes are aligned parallel to the ;t and two dunal systems are recognised, namely, the Quindalup Dune System along the ın side, and the Spearwood Dune System on the inland side.

The coastal dunes are stabilised by natural vegetation and form a land surface with very steep slopes on the southern part of the site where surface elevations range from about 5 to 40m AHD. On the northern part, the site is characterised by more gentle slopes with surface elevations ranging from 5 to 25m AHD. Swamps occur in some of the low-lying interdunal depressions.

Drainage occurs predominantly by subsurface flow to the Indian Ocean and Peel Inlet. There are no major surface drainage features on the project site.

2.2 HYDROGEOLOGICAL SETTING

The project area is underlain by three main aquifers, namely, the superficial formations, the Leederville Formation and the Cockleshell Gully Formation. The superficial formations are underlain by the Leederville Formation, either directly or more likely with an intervening sequence of shales and siltstones of the Osborne Formation which has a total thickness of about 30 to 40m in this area. Low permeability sediments of the South Perth Shale form a major aquitard which underlies the Leederville Formation and separates it from the Cockleshell Gully Formation.

2.2.1 Superficial Formations

The project area is underlain by the superficial formations which extend from the ground surface to about -15m AHD and consist mainly of calcarenite and sand. The superficial formations comprise the Tamala Limestone and the Safety Bay Sand in this area. On the ocean side, the Tamala Limestone is overlain by the Safety Bay Sand which generally consists of unconsolidated calcareous sand forming the Quindalup Dune System. On the inland side, the Tamala Limestone is exposed and consists of calcarenite and sand which form the Spearwood Dune System. These sediments form an inhomogeneous unconfined aquifer of generally high permeability.

The groundwater system in the superficial formations comprises a thin freshwater lens overlying saline groundwater in the lower part of the aquifer. The freshwater lens is only about 5m thick and it is separated from the saline groundwater by an interface zone which contains brackish groundwater.

The superficial aquifer is recharged by percolating rainfall which maintains the freshwater lens. The annual average rainfall surplus (excess of rainfall over evaporation during winter) is 336mm at Mandurah. Allowing for runoff and evapotranspiration losses, the maximum available recharge is expected to be about 250mm per annum. The water table reaches a maximum level in August to September of about 0.5m AHD in response to winter rainfall and declines to slightly below 0m AHD in the summer.

Groundwater flows away from the central part of the peninsula westwards towards the Indian Ocean and eastwards towards the Peel Inlet. Groundwater discharge occurs across seawater interfaces along the shores of the ocean and the inlet.

The freshwater lens in the superficial formations is currently exploited by means of a number of shallow private bores. Yields are low as higher pumping rates result in upconing of the underlying saline groundwater.

An operational domestic refuse disposal site is located about 800m south of the Dawesville Channel (Figure 2). Leachates generated by percolating rainfall are likely to be causing contamination of the superficial aquifer.

2.2.2 Leederville Formation

The Leederville Formation is a major regional aquifer, consisting of interbedded sandstone, siltstone and clay. In the Mandurah area, the Leederville Formation contains a distinct marker horizon, 3 to 6m thick known as the "green clay". This horizon is readily identifiable on natural gamma logs, enabling correlation between boreholes. In the Dawesville area the green clay appears to be downthrown about 90m to the south, along an east-west trending fault line. The general dip of the Leederville Formation is about half a degree, to the west-southwest.

In the vicinity of Mandurah, groundwater in the Leederville Formation is generally saline above the green clay horizon, and fresh, becoming brackish with depth, below it. At Dawesville, however, borehole logs indicate that fresh groundwater occurs both above and below the green clay, which is at a depth of about 265m in Bore Miami 2/75, just south of Dawesville (Figure 1). The general groundwater flow direction is westwards, so the occurrence of freshwater above the green clay, downgradient of saline groundwater east of the Peel Inlet itself, is anomalous. The fresh groundwater may be derived from below the green clay, either by upward leakage, or laterally from the north, across the inferred fault. Alternatively, it may represent fossil groundwater remaining from a previous period of lower sea level, which has not as yet been flushed out by subsequent more saline recharge from the east.

The groundwater in the Leederville Formation is artesian, with hydraulic heads generally 3 to 4m above AHD in the strata above the green clay, and 7 to 8m AHD in the strata below it.

Groundwater in the Leederville Formation probably has a salinity in the range of 400 to 3,500mg/L TDS and may contain significant concentrations of dissolved iron.

2.2.3 Cockleshell Gully Formation

The Cockleshell Gully Formation consists predominantly of sandstone and shale in the Dawesville area and occurs at a depth of about 250 to 300m below ground surface. It is unconformably overlain by the South Perth Shale which forms a major aquitard between the Leederville Formation and Cockleshell Gully Formation. The Cockleshell Gully Formation contains only brackish to saline groundwater in this area.

3.0 DEVELOPMENT OF WATER SUPPLIES FOR GOLF COURSE IRRIGATION

Development of the groundwater resource in the Leederville Formation is planned for irrigation of the 18-hole golf course and the recreational reserve. Treated residential wastewater may be a supplementary source in the long-term, but will not be available for the first few years during the construction and establishment phase.

3.1 WATER REQUIREMENTS

Preliminary estimates of the water requirements for the irrigation of the golf course are given in Table 1. These estimates will be revised as final detailed design of the golf course proceeds.

TABLE 1

IRRIGATION WATER REQUIREMENTS

Month	*Rainfall* *(mm)*	*Pan Evaporation* *(mm)*	*Net Pan Evaporation* *(mm)*	*Water Requirement* *(kL)*				*Abstraction*	
				Greens (2.0ha)	*Fairways and Tees* (34.0ha)	*Reserve* (6.0ha)	*Lakes* (2.0ha)	*Total* *(kL)*	*Ave Daily* *(kL/d)*
January	10	253.79	243.79	6338.54	66310.88	11701.92	4875.80	89227.14	2878.29
February	13	225.76	212.76	5531.76	57870.72	10212.48	4255.20	77870.16	2781.08
March	19	195.08	176.08	4578.11	47894.12	8451.90	3521.63	64445.77	2078.90
April	46	120.60	74.60	1939.72	20292.48	3581.03	1492.09	27305.32	910.18
May	128	83.01	-44.99	0	0	0	-899.83	-899.83	0
June	192	61.79	-130.21	0	0	0	-2604.26	-2604.26	0
July	176	63.65	-112.35	0	0	0	-2247.03	-2247.03	0
August	126	79.21	-46.79	0	0	0	-935.87	-935.87	0
September	88	107.16	19.16	498.17	5211.65	919.70	383.21	7012.73	233.76
October	63	155.93	92.93	2416.26	25277.78	4460.78	1858.66	34013.48	1097.21
November	22	192.02	170.02	4420.49	46242.16	8160.91	3400.38	62226.94	2074.23
December	12	234.71	222.71	5790.37	60576.17	10689.91	4454.13	81510.59	2629.27
TOTAL	895	1772.71	877.71	31513	329679	58179	17554	436925	1197

Source: Department of Administrative Services, Bureau of Meteorology.

Note: Based on monthly rainfall data (1889-1991), Mandurah Station and monthly Epan (1967-1990), Perth Station.

Projected Application Rates:

Greens	:	130% Net Epan
Fairways, tees	:	80% Net Epan
Recreation Reserve	:	80% Net Epan
Lakes	:	Net Epan

The water requirements have been calculated using the projected application rates which are based on long-term daily evaporation rates for Perth and monthly rainfall data for Mandurah.

The total water requirement for the irrigation of the golf course and recreation reserve is estimated to be 440,000kL/annum with a peak demand of 2,900kL/day. Additional supplies may be required during initial phase for the re-establishment of vegetation in areas disturbed during golf course construction.

3.2 GROUNDWATER SUPPLY AND TREATMENT

Abstraction of a significant supply of groundwater of suitable quality from the superficial formations would be difficult and expensive, because of the depth to water (20 to 40m) and the presence of only a thin freshwater lens. It is therefore not an economic source of water for golf course irrigation.

The water supply will be obtained by groundwater abstraction from a borefield completed in the Leederville Formation aquifer. It is anticipated that the borefield will be located to the south of the project site, in the vicinity of the proposed golf course.

The Leederville Formation is known to contain a substantial resource of fresh groundwater at Dawesville but the long term sustainable yield is unproven. The resource is presently under-utilised, although there has been substantial abstraction further north in the vicinity of Mandurah for more than 20 years. Current abstraction for both public and private use totals 1.7 x 10^6kL/annum. In the Dawesville area, there are only four current licences issued by the Water Authority for small abstractions from the Leederville Formation, with a combined total of 75,000kL/annum. The Water Authority has no plans to use the resource in the Dawesville area for public water supply.

Abstraction from the Leederville Formation can therefore be supported on the following grounds:

- known fresh groundwater resource;
- minimum usage at present;
- no planned use for public water supply; and

o abstraction of about 2 x 10^6kL/annum from the Leederville Formation has been sustained since 1965 without any adverse effects on regional groundwater levels or water quality.

Abstraction from the Leederville Formation for irrigation in the development area has been approved by the Water Authority of WA and a licence will be issued when water requirements have been finalised and bores have been drilled and tested. Groundwater from the Leederville Formation will be pumped into lakes which will be lined and will form temporary water storage facilities from which the reticulated water supplies will be drawn. These lakes will be located at selected sites around the golf course to facilitate the distribution of water across terrain where differences in surface elevation of up to 30m are encountered. If necessary, the irrigation supply will be treated by aeration for iron removal.

3.3 TREATED WASTEWATER

The Perth Urban Water Balance Study showed that the average annual in-house consumption of water is 173kL. When the 1,400 residences have been established, this will provide an estimated aggregate wastewater volume of 242,200kL/annum.

If half the wastewater could be recovered and recycled for irrigation, it would provide a useful supplementary source, particularly as a proposed water treatment plant is to be located adjacent to the golf course.

However, the residential areas will only be fully established after a period of 10-15 years and therefore this supplementary source could only be available in the long term. The recycled water would require treatment to appropriate standards defined by the Health Department.

4.0 EFFECTS OF DEVELOPMENT ON THE GROUNDWATER REGIME

4.1 ENHANCED RECHARGE

Land clearing and urban development will result in a rise in water table levels due to the following factors:

- reduced evapotranspiration losses following removal of vegetation;
- enhanced recharge from roofed and paved areas which have higher runoff potential than uncleared land; and
- enhanced recharge as a result of losses from domestic and irrigation water reticulation systems and discharge to ground of stormwater drainage.

Enhanced recharge to the superficial aquifer will potentially increase the thickness of the freshwater lens. However, the construction of the Dawesville Channel and also the canals will reduce the thickness of this lens in the immediate vicinity of the development.

4.2 EFFECT OF DEVELOPMENT ON PEEL-HARVEY CATCHMENT BOUNDARY

It is difficult to accurately define the pre-development position of the Peel-Harvey groundwater catchment boundary since it migrates seasonally and the maximum difference in the elevation of the water table across the peninsula is only about 0.5m.

The construction of the Dawesville Channel will alter the hydrology of the surrounding area and change the position of the Peel-Harvey Catchment Boundary. Currently, groundwater discharges to the Indian Ocean and the Peel Inlet. The proposed development will create additional groundwater discharge areas which comprise the Dawesville Channel and also the proposed canal system and marina. The positions of the groundwater catchment boundaries following development (Figure 2) are difficult to predict accurately. The positions shown on Figure 2 were predicted using preliminary design information for the development to assess the impact on the groundwater flow regime. These positions can only be regarded as approximate since the factors which make it difficult to define the pre-development catchment boundary affect the post-development boundary positions and in addition, the accuracy to which it is possible to make predictions is limited at this stage.

4.3 EFFECTS OF ABSTRACTION

The proposed borefield will be at least 2,000m from the nearest existing user of groundwater from the Leederville Formation. Groundwater exploration and aquifer testing are planned prior to golf course construction to obtain aquifer parameters and to enable the borefield to be designed to minimise the effects of abstraction on existing users. Abstraction from the Leederville Formation is unlikely to have any measurable effect on the superficial aquifer.

4.4 EFFECTS ON GROUNDWATER QUALITY

Stormwater drainage systems will be designed to prevent the introduction of oils and other noxious chemicals into the superficial aquifer. Consequently, the only effect of the development on groundwater quality which is potentially of significance is the addition of nutrients to the shallow groundwater system in the superficial aquifer. The sands and limestones in the unsaturated zone underlying the development area have a high capacity to remove phosphorus by absorption due to the nature of the sediments (high phosphorus retention indices are likely, based on previous testing of similar materials at other locations) and the thickness of the unsaturated zone (5m to 40m). Attenuation of any phosphorus reaching the saturated zone will also occur by absorption and dilution as groundwater flows through the aquifer.

4.4.1 Effluent Discharge from Sewage Treatment Works

The development is to be serviced by a reticulated sewerage scheme constructed, operated and maintained to Water Authority of Western Australia standards. The sewerage scheme will be connected to the proposed treatment plant which will be located adjacent to the golf course and constructed and operated by the Water Authority.

Treated effluent from the plant may be utilised in 10-15 years time for the irrigation of some areas of the golf course using a low pressure irrigation system. The golf course is underlain by Tamala Limestone which is highly permeable. Consequently, high infiltration rates can readily be maintained without generating surface runoff of treated effluent. Attenuation of nutrients by absorption is also likely to occur as discussed above.

4.4.2 Golf Course and Turfed Areas

Fertiliser applied to the golf course and turfed areas is a potential source of nutrient loading to the shallow groundwater system.

Application rates will form part of a detailed fertiliser programme which will be drawn up when soil analyses are carried out. Key components of the programme will be the use of slow release fertilisers, tissue testing and foliar feeding to minimise the leaching of nutrients to the water table.

4.5 IMPACT OF CANAL CONSTRUCTION ON THE GROUNDWATER REGIME

The construction of the canals will alter the groundwater flow regime in the upper section of the superficial aquifer. Construction of the canals will result in groundwater discharge to the canal systems as well as the ocean and inlet. The directions of groundwater flow following development are shown on Figure 2. The original design for the development included two canal systems and groundwater inflows into each of the canals have been evaluated. Preliminary estimates based on the limited data available are presented below:

- Southern Canal - 170,000m^3/annum; and
- Northern Canal - 190,000m^3/annum.

Because of the proximity of the southern canal to an existing domestic refuse disposal site, there would be a high potential for serious contamination of the southern canal system to occur via groundwater throughflow from beneath the tip. Based on Darcy's equation, the groundwater throughflow from the tip to the southern canal would be approximately 76,000m^3/annum. Due the highly permeable nature of the underlying sediments, any leachate emanating from the tip would be rapidly transported to the southern canal. A 'typical' composition for leachate from landfill sites is summarised in Table 2. The concentration of each constituent in groundwater discharging into the canal would depend on the following factors:

- composition of the landfill;
- rainfall infiltration rate within and around the landfill;
- permeability of the aquifer;

- thickness of the unsaturated zone; and
- attenuation of contaminants in the aquifer.

Because of the potential problems and risks associated with the construction and operation of a southern canal system, it is proposed that the southern canal will not be constructed and that the golf course will be extended into this area.

4.6 IMPACT OF MARINA CONSTRUCTION ON THE GROUNDWATER REGIME

A marina complex is to be constructed on the Harvey estuary foreshore on reclaimed land adjacent to the north of the Dawesville Channel entrance. This land will be created by the disposal of spoil associated with excavation of the Channel. The reclamation of land will enhance aquifer recharge locally and cause the seawater interface present in the basal section of the superficial aquifer to migrate eastwards to a new equilibrium position. The impact on the groundwater regime is expected to be localised and confined to the immediate vicinity of the marina because of the moderate to high permeability and low hydraulic gradient of the superficial aquifer.

Groundwater inflow to the marina is estimated to be about 44,500m^3/annum. The development and management of the marina is the responsibility of the Department of Marine and Harbours.

TABLE 2

TYPICAL LEACHATE COMPOSITION FROM LANDFILL SITES

Parameter	*Concentration*
pH*	2.5 - 7.5
BOD5*	10,000
COD	6,000
Total Suspended Solids	500
Total Dissolved Solids	15,000
Alkalinity	3,000
Total Hardness	3,500
Organochlorine Pesticides	<0.002
Organophosphate Pesticides	<0.02
Total PAH	<0.02
Total Petroleum Hydrocarbons	<2
Ammonia Nitrogen*	2,500
Nitrate	370
Total Phosphorus	30
Ortho Phosphate	20
Copper*	15
Lead*	15
Zinc*	130
Total Iron*	400
Cadmium	<0.1
Total Chromium	3
Dissolved Manganese	<14
Arsenic	<0.01
Selenium	<0.01
Mercury	<0.1
Sodium	2,200
Potassium	1,400
Calcium	1,000
Magnesium	250
Chloride	6,000
Sulphate*	900
Free Cyanide	<0.1

Note: * Exceeds primary seven target concentrations.

All units in mg/L except pH.

5.0 MANAGEMENT AND MONITORING

5.1 NUTRIENT MANAGEMENT PLAN

A staged nutrient management programme has been designed to minimise the impact of the development on the environment and to address the major nutrient inputs and the potential export. A schematic nutrient flux diagram for the resort is presented on Figure 5.

Sources of nutrient input to the site are summarised below:

- fertiliser application to the 18 hole golf course - both for establishment and maintenance;
- disposal of sewage effluent;
- fertiliser application to turfed areas and gardens; and
- leachate from the existing rubbish tip.

The nutrient management programme aims to minimise nutrient export from the site by the following methods:

- Golf Course Management
  - minimise fertiliser application through the use of slow release fertilisers and foliar feeding; and
  - regular soil sampling and tissue testing to assess soil and plant nutrient levels.

- Management of Sewage Effluent Disposal
  - to be undertaken by the Water Authority of WA.

- Management of Fertiliser Application to Turfed Areas and Gardens
  - annual soil testing of resort lawns to monitor soil nutrient levels and hence minimise fertiliser usage; and
  - private lot owners to be encouraged to cultivate native species and to use slow release fertilisers on turfed areas.

- Management of Existing Rubbish Tip
  - to be undertaken by the Shire of Mandurah.

The overall nutrient management plan is shown schematically on Figure 6.

5.2 GOLF COURSE MANAGEMENT IN TERMS OF NUTRIENTS AND GROUNDWATER CONSERVATION

5.2.1 Establishment of Turf

Planting will be undertaken in stages to minimise the additional water required in excess of normal operating requirements.

A fertiliser program will be drawn up to achieve the following results:

- o to establish a deep root system to obtain maximum benefit from the water applied and assist in maintaining the turf against wear stress; and
- o to avoid excessive leaf growth which would cause turf maintenance problems and result in the use of more water.

5.2.2 Turf Management Programme

A turf management programme will be designed to achieve a turf coverage, which is adequate for the anticipated wear stress and is of satisfactory appearance, using the minimum quantities of water and nutrients.

The application of too much water and/or nutrient results in the development of excessively succulent leaves and heavy thatching. This causes maintenance costs to rise and ultimately requires the removal and replanting of the grass. Overwatering can also lead to temporary waterlogging, reduced soil oxygen levels, a restricted root system, increased disease development and an overall reduction in turf-grass vigour and quality.

Regular de-thatching of fairways, tees and greens, including removal of grass clippings, is a prime management objective. This will allow maximum benefit to be obtained from the water applied in that it facilitates rapid infiltration to the root zone and minimises evaporation losses. Other measures to facilitate and maintain water movement to the root zone include coring of the turf and the application of products such as Wetta Soil.

Irrigation scheduling is important and will be given careful consideration in terms of the soil water retention characteristics and the soil infiltration rates. Irrigating too frequently can cause excessive leaf growth at the expense of root development.

It is planned to operate the irrigation system as necessary between 6pm and 6am to lessen wind interference and minimise evaporation losses. This will also avoid disturbance of players during daylight hours.

There is some variation in soil type across the golf course and the irrigation system will be designed to accommodate this variation in terms of head to head coverage, sprinkler coverage, sprinkler size and quantity applied.

5.2.3 Monitoring

A monitoring programme will be designed to allow the determination of the plant water balance and the nutrient requirements on a regular basis. This will allow the growth and maintenance of satisfactory turf.

The installation of soil-moisture level-sensing units is under consideration and this would greatly assist in the determination of appropriate water application rates.

Regular monitoring of the soil nutrient levels and tissue testing is also planned.

5.2.4 Operational Water Usage

Operational water usage will be based on the evaporation of a free water surface measured at the Perth Meteorological Station and calculated on a weekly basis.

The golf course superintendent will adjust application rates for each hole on a daily basis after consideration of the condition of the grass, the nature of the soil, the soil-moisture levels and the local weather conditions.

Maintenance of top quality turf is a necessary aim of the developer in order to attract tourists and the proposed golf course management strategy is designed to achieve this aim whilst minimising the water and fertiliser requirements.

The monitoring programme will enable accurate assessment of turf water and nutrient requirements on a regular basis and, allow efficient operation of the golf course.

5.3 GROUNDWATER MONITORING PROGRAMME

It is understood that the Water Authority of WA is managing a programme to monitor the effects of construction of the Dawesville Channel on the superficial aquifer. This programme will be reviewed to confirm that it provides adequate coverage for monitoring the effects of canal and marina construction on the groundwater system.

The efficient maintenance of the golf course and associated facilities requires a considerable commitment by the developer in terms of the operation of the water supply scheme. Routine groundwater monitoring will be undertaken by the golf course maintenance personnel who will receive appropriate training for this work.

The water supply monitoring programme proposed for the long-term operation of the system is described in three parts:

- water level monitoring;
- discharge, lake storage and irrigation monitoring; and
- water quality monitoring.

5.3.1 Water Level Monitoring

Water levels in all bores will be measured before the commencement of the seasonal pumping and every month thereafter.

5.3.2 Discharge, Lake Storage and Irrigation Monitoring

Volumes of water abstracted from each bore will be recorded monthly using cumulative flow meters installed on each bore main. Lake levels will be monitored by staff gauge and, the irrigation rates and distribution of irrigation throughout the resort will be recorded.

5.3.3 Water Quality Monitoring

An annual sample from each production bore will be taken at the end of summer and submitted to an approved laboratory for chemical analysis to ensure that the water-quality is not declining significantly.

5.3.4 Monitoring Reviews

Annual reviews of borefield performance will be undertaken to the satisfaction of Water Authority requirements. It is anticipated these reviews could be prepared during the winter low-pumping period each year. This will ensure that the aquifer is maintaining the required abstraction without any adverse hydrogeological and environmental effects, and will enable pumping schedules to be adjusted if necessary to avoid such effects.

6.0 SUMMARY AND CONCLUSIONS

The quantitative assessment of the existing groundwater regime presented in this report and the prediction of changes which may be caused by the development are based on limited data and on comparisons with similar projects in the Perth area.

The development site is underlain by the superficial formations which extend from the ground surface to about -15m AHD and consist mainly of calcarenite and sand. The aquifer contains freshwater lens overlying saline groundwater in the basal section. Abstraction of useable supplies of groundwater from the superficial aquifer would be difficult and uneconomic because of the depth to water and the presence of only a thin freshwater lens.

The Leederville Formation underlying the superficial formations is the most prospective source of a water supply for the golf course irrigation. The formation is known to contain a substantial resource of fresh groundwater but the long-term sustainable yield has yet to be proven. The resource is currently under-utilised in the Dawesville area and there are no plans by the Water Authority to use it for public water supply. Abstraction from the Leederville Formation aquifer has been approved by the Water Authority and a licence will be issued following the construction and testing of bores and the finalisation of water requirements.

Groundwater will be pumped into lined lakes which will form temporary water storage facilities from which the irrigation water supplies will be drawn. Treated wastewater may be a supplementary source in the long-term but will not be available for the first 10 to 15 years following construction.

The total water requirement for irrigation of about 38ha of golf course and 6ha of public reserve area is estimated to be 440,000kL/annum with a peak demand of about 2,900kL/day. This preliminary estimate will be revised as detailed design of the development proceeds.

Potential impacts of development on the shallow groundwater system include:

- enhanced recharge;
- change in the position of Peel-Harvey Catchment Boundary;
- canal and marina construction; and
- sources of nutrients.

The main sources of nutrients associated with the development are discussed and proposals for nutrient management are provided. In general, the impacts of the proposed development on the groundwater regime are minor and not significant in comparison to the effects of the development of the Dawesville Channel.

7.0 REFERENCES

Dames & Moore, 1990. Eglinton Beach Resort. Predicted Impact of Development on the Groundwater Regime and Proposals for Management. Appendix 5 of Public Environmental Review Report. Prepared for Eglinton Resort Development Pty Ltd.

Dames & Moore, 1992. Assessment of Water Storage Options for Proposed Golf Course and Recreational Reserve at Dawesville. Unpublished Report for Wannanup Development Nominees Pty Ltd.

National Health and Medical Research Council (NH&MRC)/Australian Water Resources Council (AWRC) 1987. Guidelines for Drinking Water Quality in Australia.

Water Authority of Western Australia, 1987. Perth Urban Water Balance Study.

* * *

Respectfully submitted
DAMES & MOORE

pp J. Ding
Project Engineer

LIMITATIONS OF REPORT

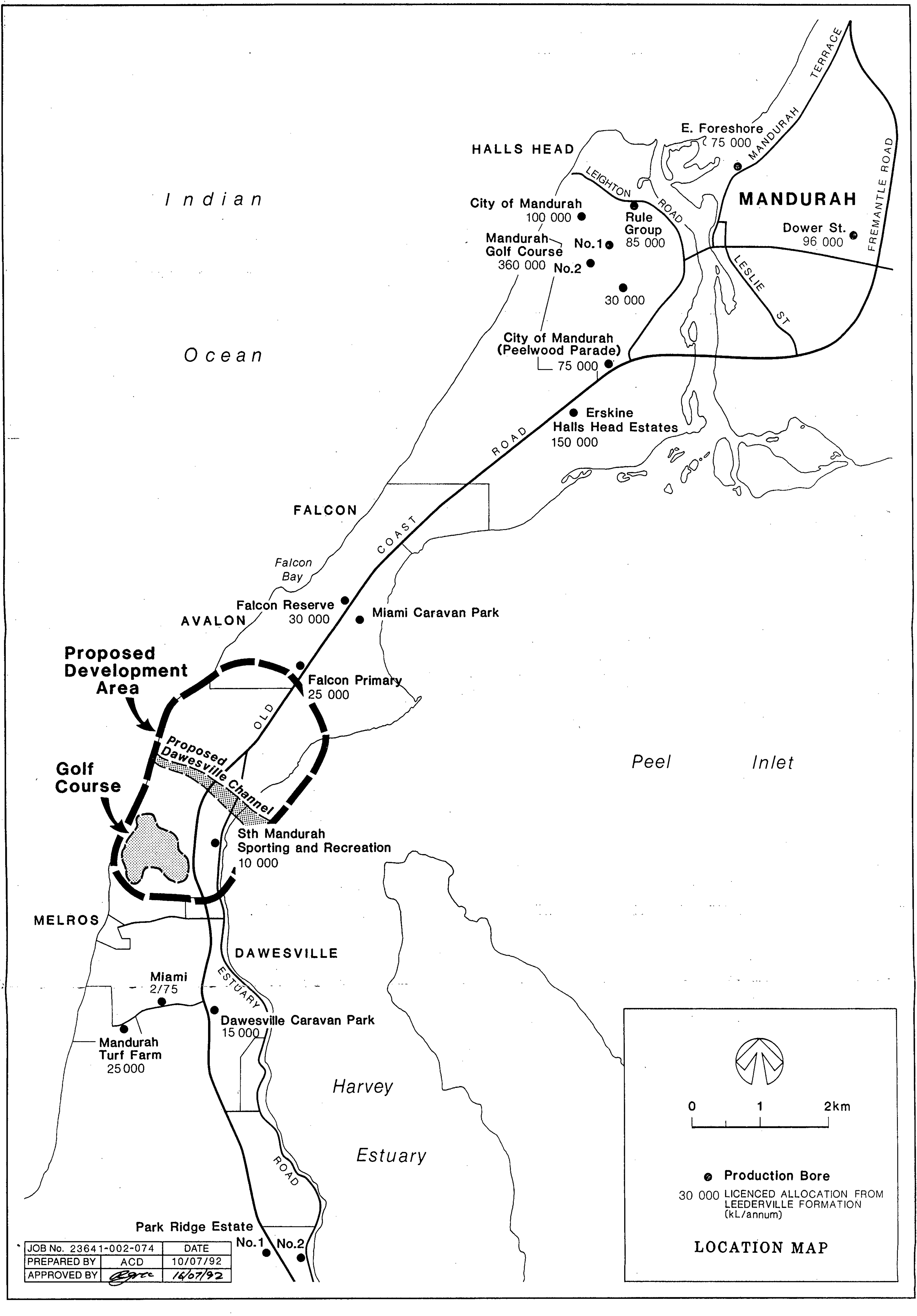
We have prepared this report for the use of Wannanup Development Nominees Pty Ltd in accordance with generally accepted consulting practice. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has not been prepared for the use by parties other than the client, the owner and their respective consulting advisors. It may not contain sufficient information for purposes of other parties or for other uses.

It is recommended that any plans and specifications prepared by others and relating to the content of this report or amendments to the original plans and specifications be reviewed by Dames & Moore to verify that the intent of our recommendations is properly reflected in the design.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels and contaminant concentrations, can change in a limited time. This should be borne in mind if the report is used after a protracted delay.

There are always some variations in subsurface conditions across a site which cannot be fully defined by investigation. Hence it is unlikely that the measurements and values obtained from sampling and testing during the investigation will represent the extremes of conditions which exist within the site.

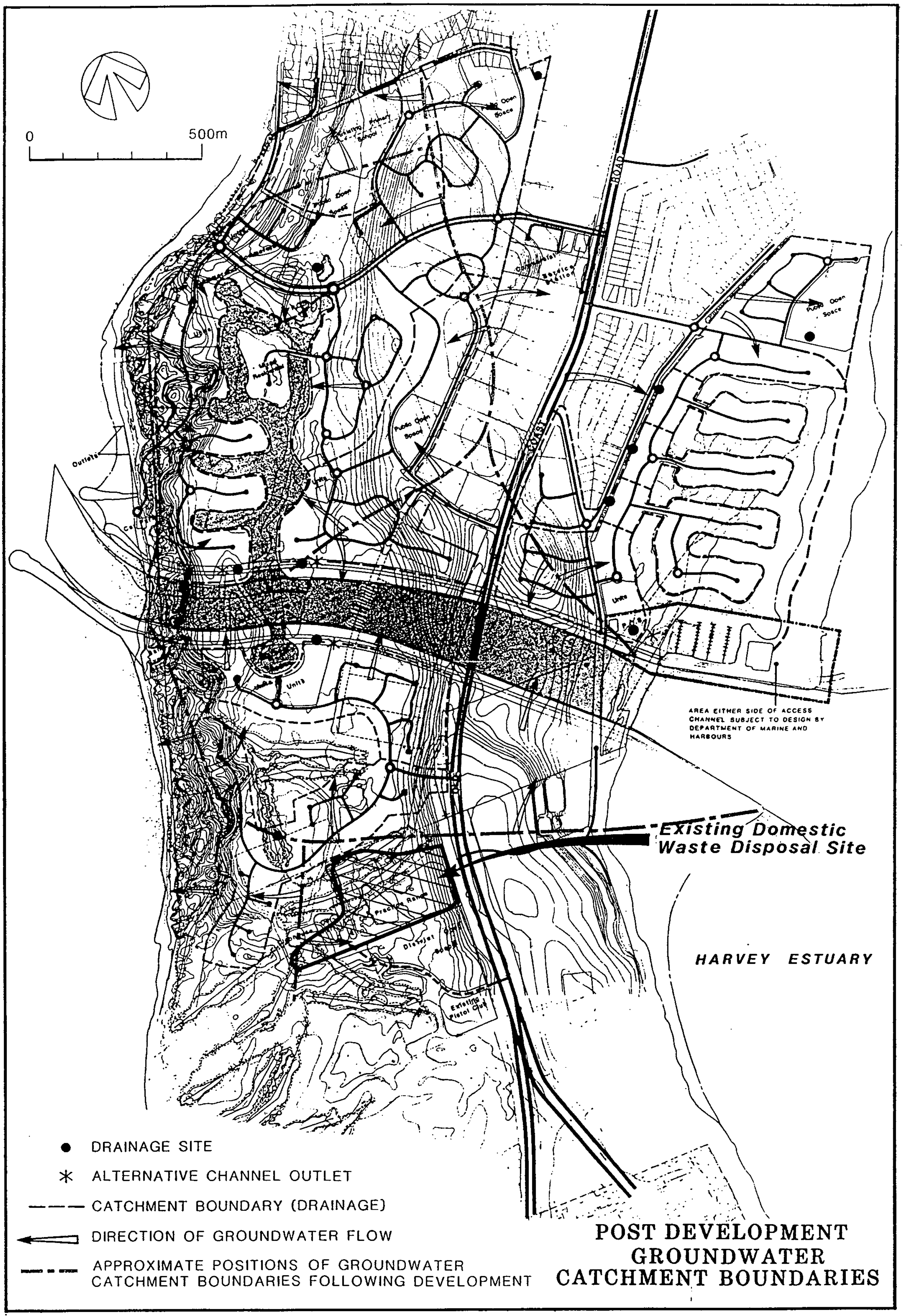
Figures



LOCATION MAP

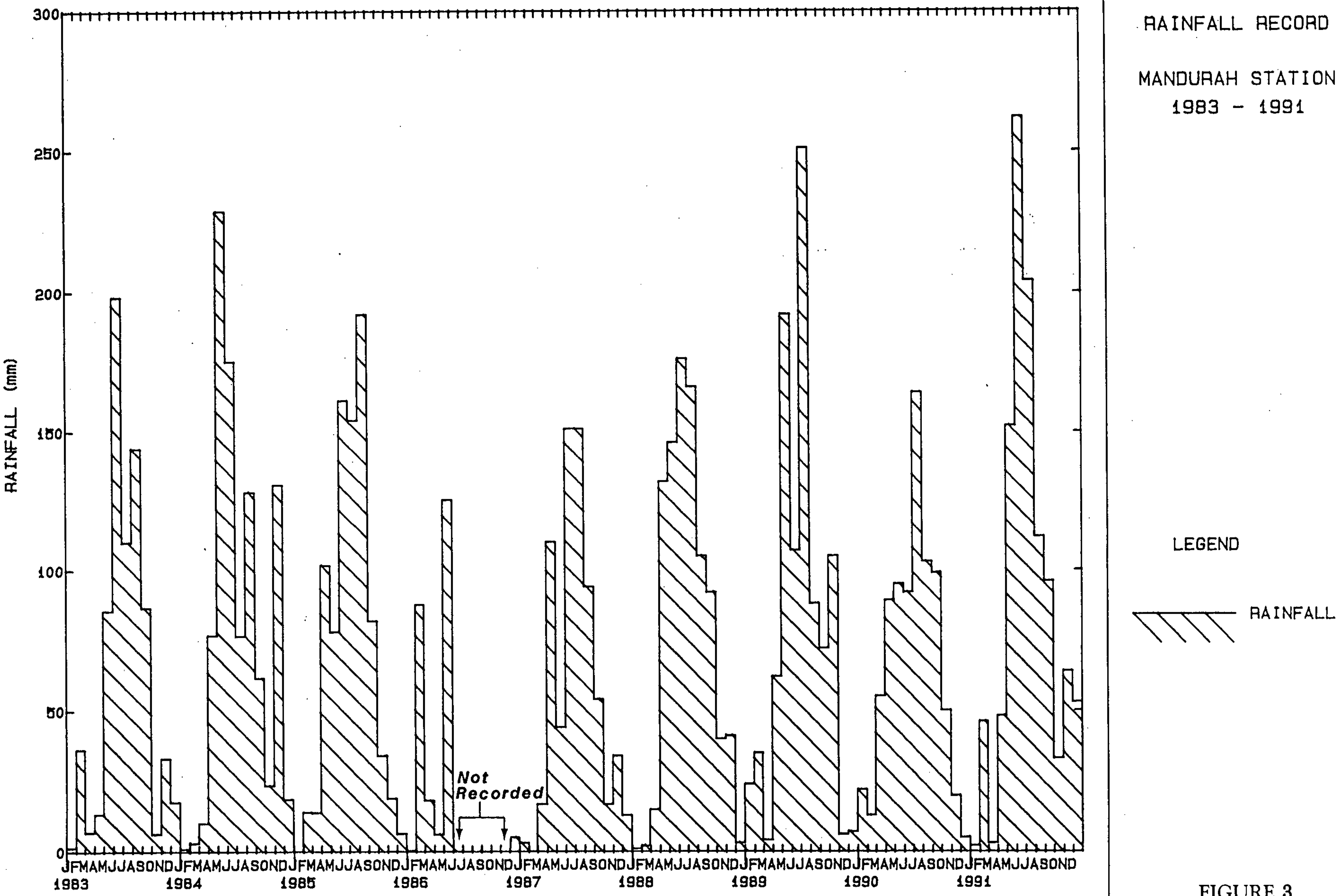
JOB No. 23641-002-074	DATE
PREPARED BY ACD	10/07/92
APPROVED BY	16/07/92

FIGURE 1
DAMES & MOORE



POST DEVELOPMENT GROUNDWATER CATCHMENT BOUNDARIES

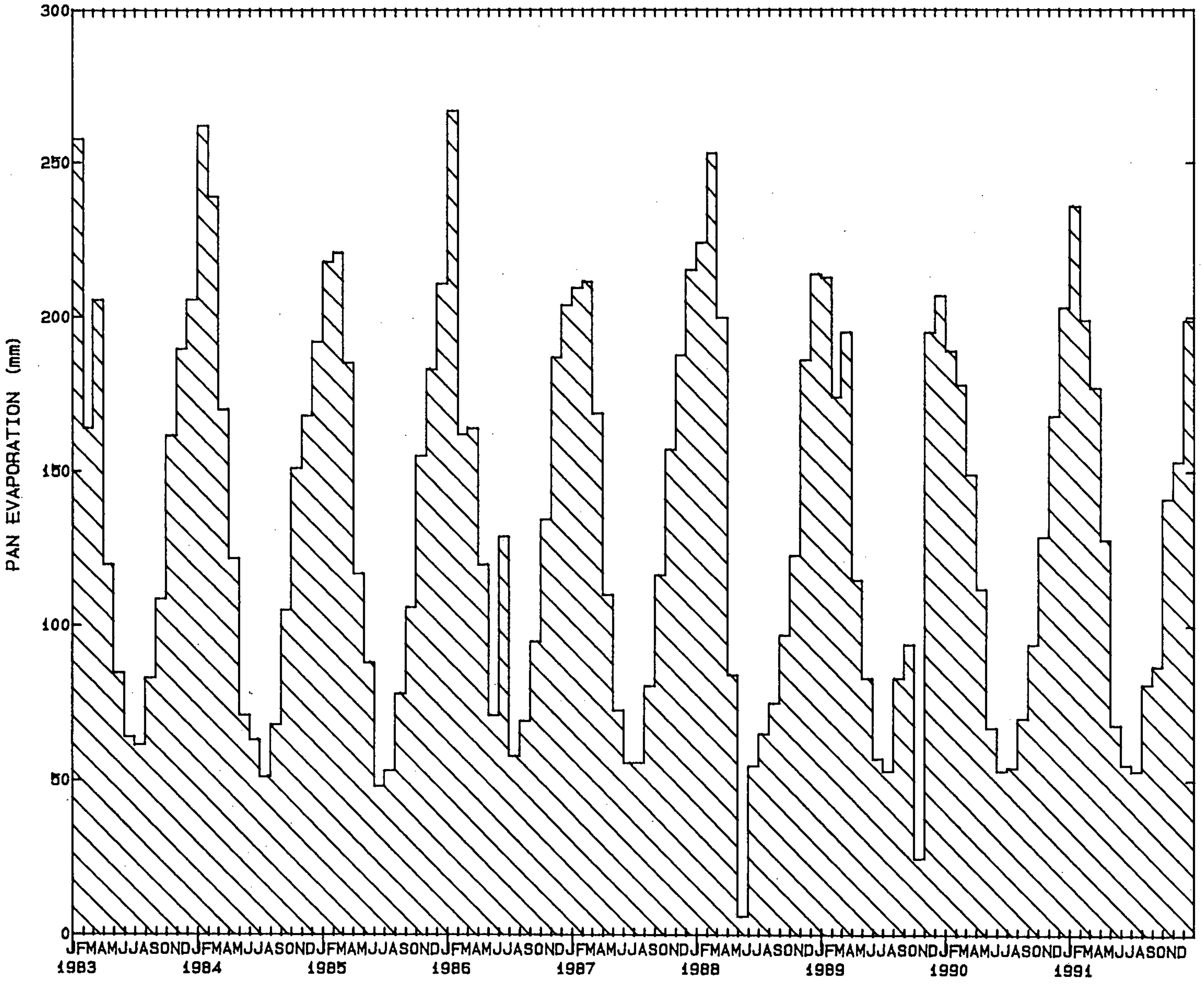
FIGURE 2
DAMES & MOORE



RAINFALL RECORD

MANDURAH STATION
1983 - 1991

FIGURE 3
DAMES & MOORE



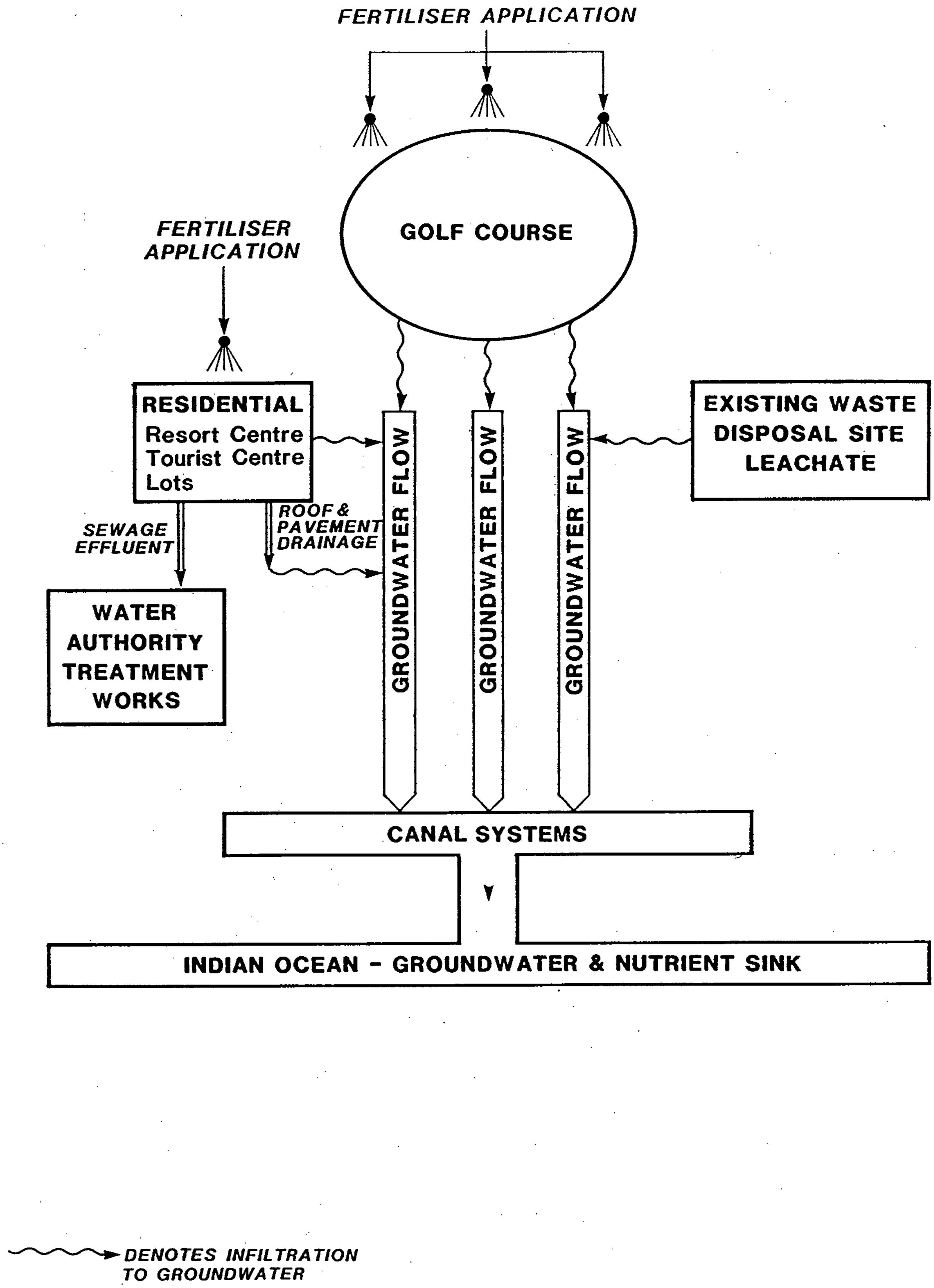
PAN EVAPORATION
RECORD

PERTH STATION
1983 - 1991

LEGEND

▨ EVAPORATION

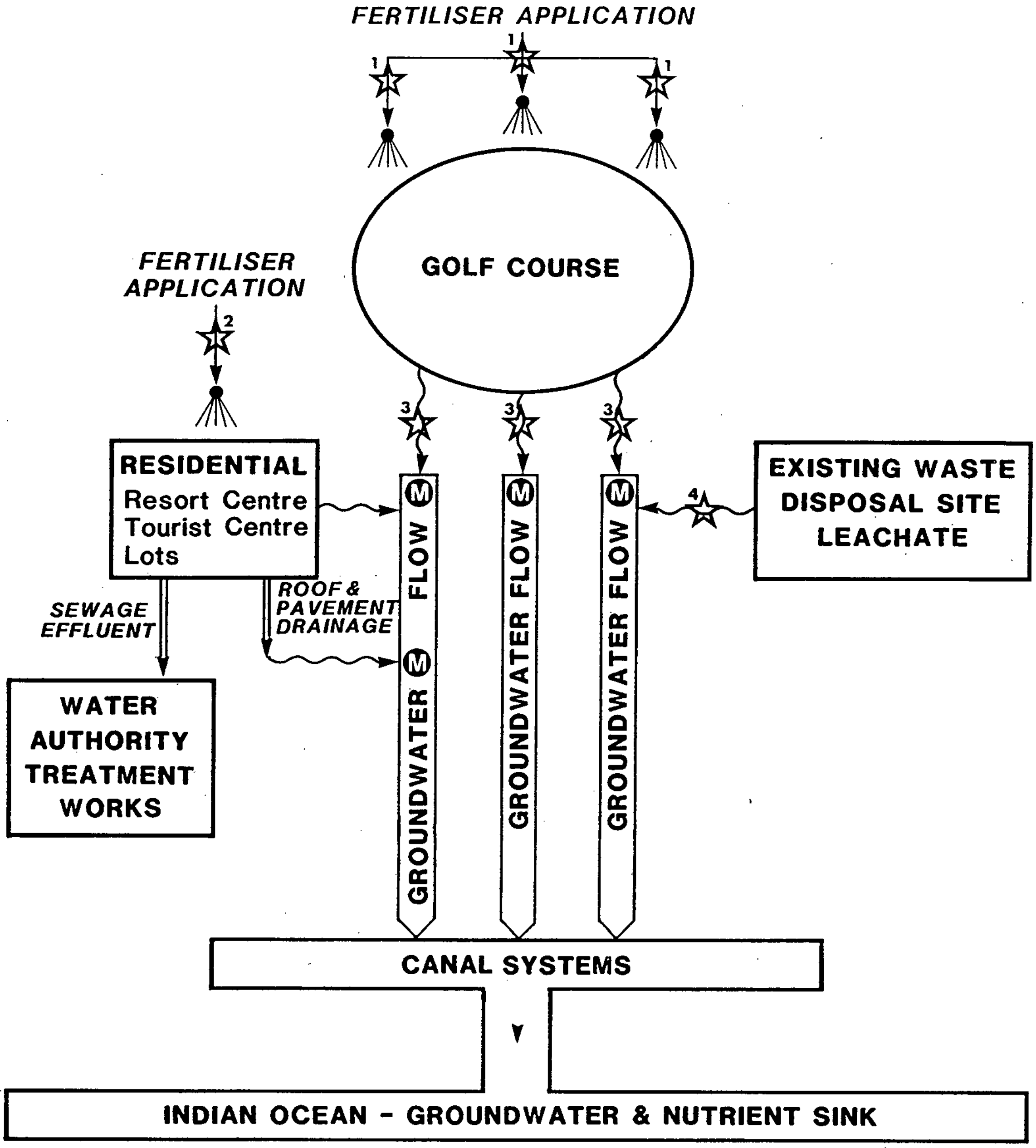
FIGURE 4
DAMES & MOORE



JOB No. 23641-002-074		DATE
PREPARED BY	ACD	10/07/92
APPROVED BY		16/07/92

NUTRIENT FLUX DIAGRAM

FIGURE 5
DAMES & MOORE



☆1	USE OF SLOW RELEASE FERTILISERS, TISSUE TESTING AND FOLIAR FEEDING. DETAILED FERTILISER PROGRAM, MANAGEMENT TO AVOID EXCESSIVE LEAF GROWTH
☆2	SOIL NUTRIENT MONITORING AND CULTIVATION OF NATIVE SPECIES
☆3	SOIL NUTRIENT MONITORING
☆4	ABSORPTION IN UNSATURATED ZONE AND ATTENUATION SATURATED ZONES

Ⓜ *DENOTES GROUNDWATER MONITORING*

〰→ *DENOTES INFILTRATION TO GROUNDWATER*

JOB No. 23641-002-074		DATE
PREPARED BY	ACD	10/07/92
APPROVED BY		16/07/92

NUTRIENT MANAGEMENT PLAN

FIGURE 6
DAMES & MOORE

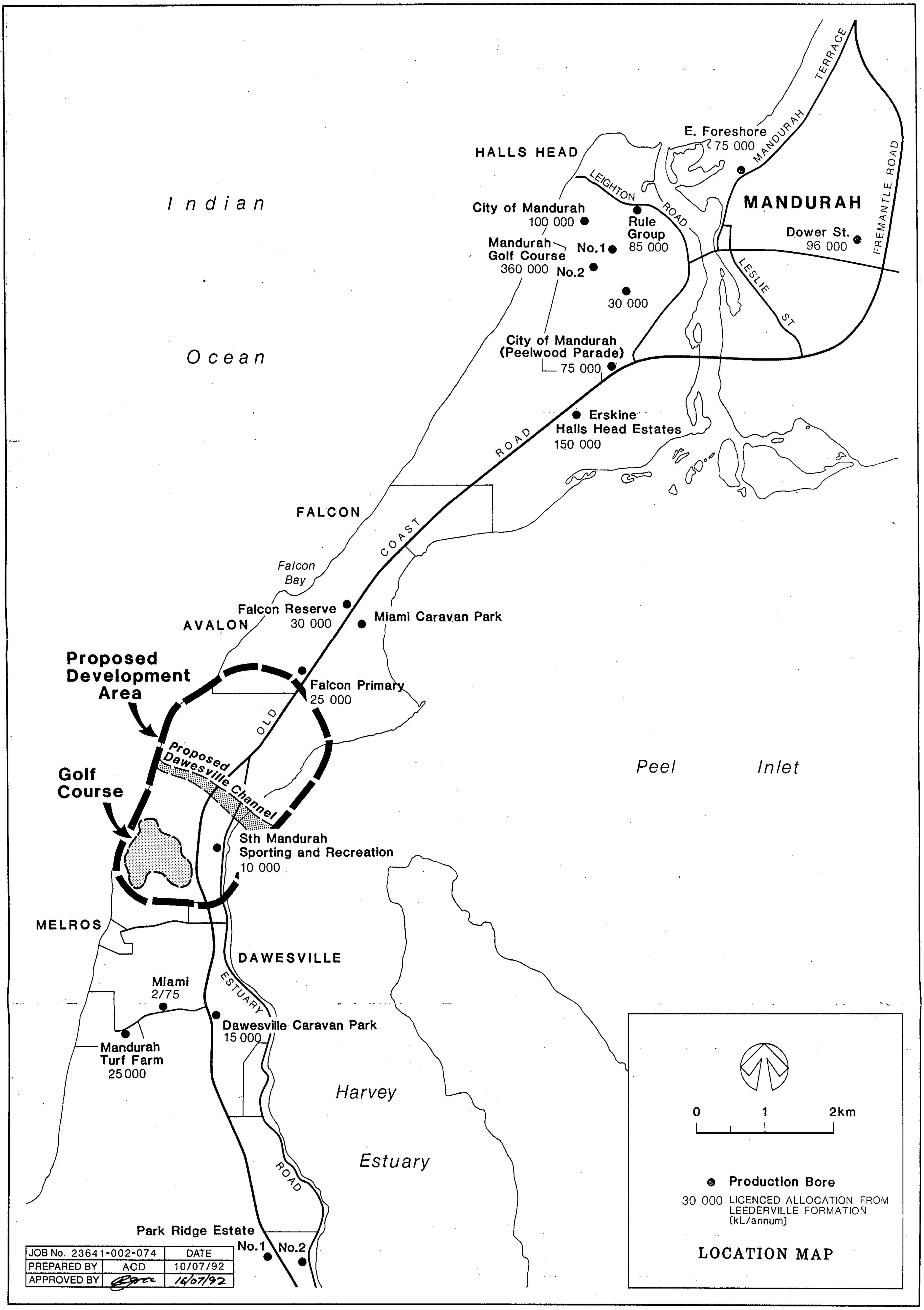
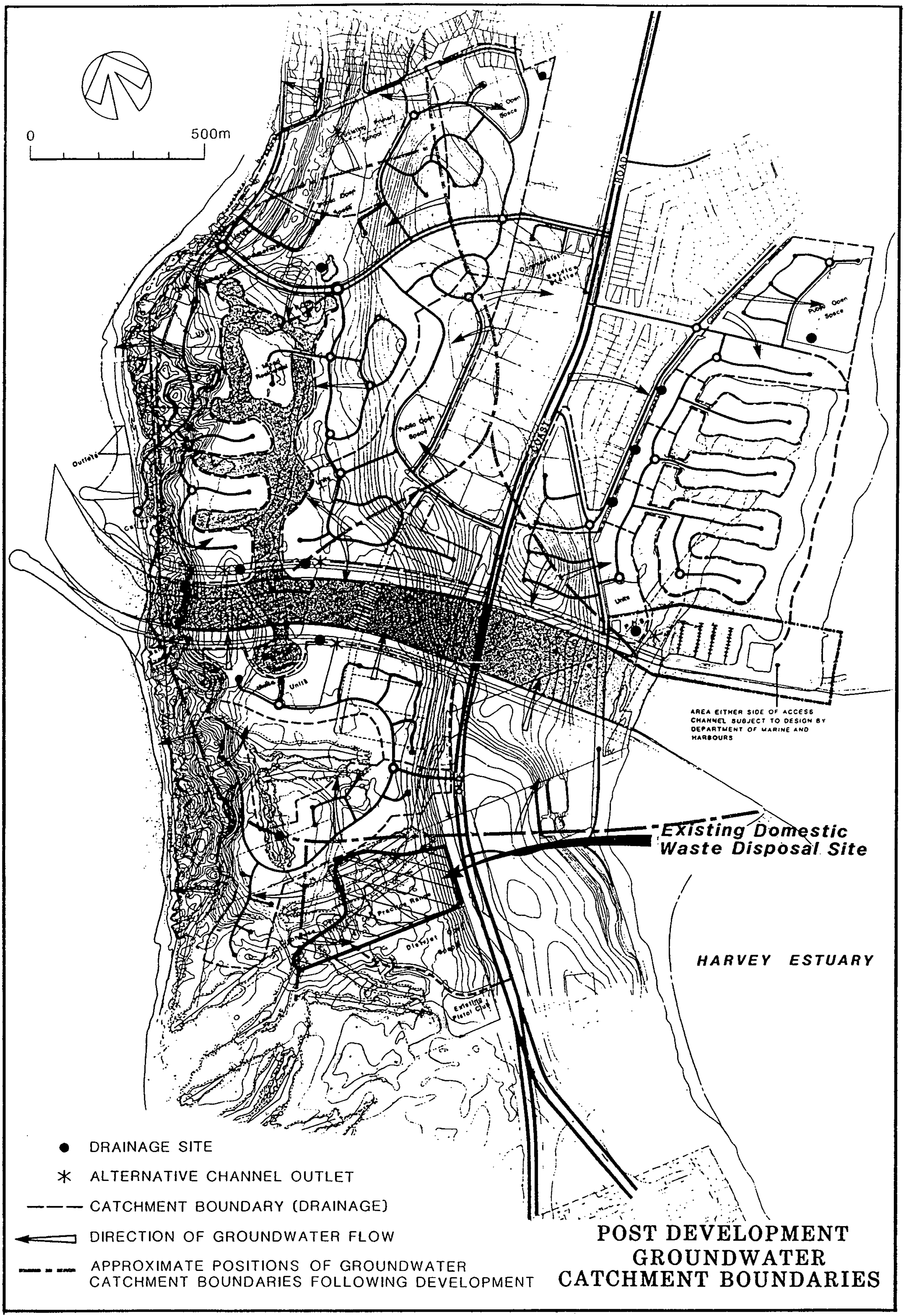


FIGURE 1
DAMES & MOORE



POST DEVELOPMENT
GROUNDWATER
CATCHMENT BOUNDARIES

FIGURE 2
DAMES & MOORE

RAINFALL RECORD

MANDURAH STATION
1983 - 1991

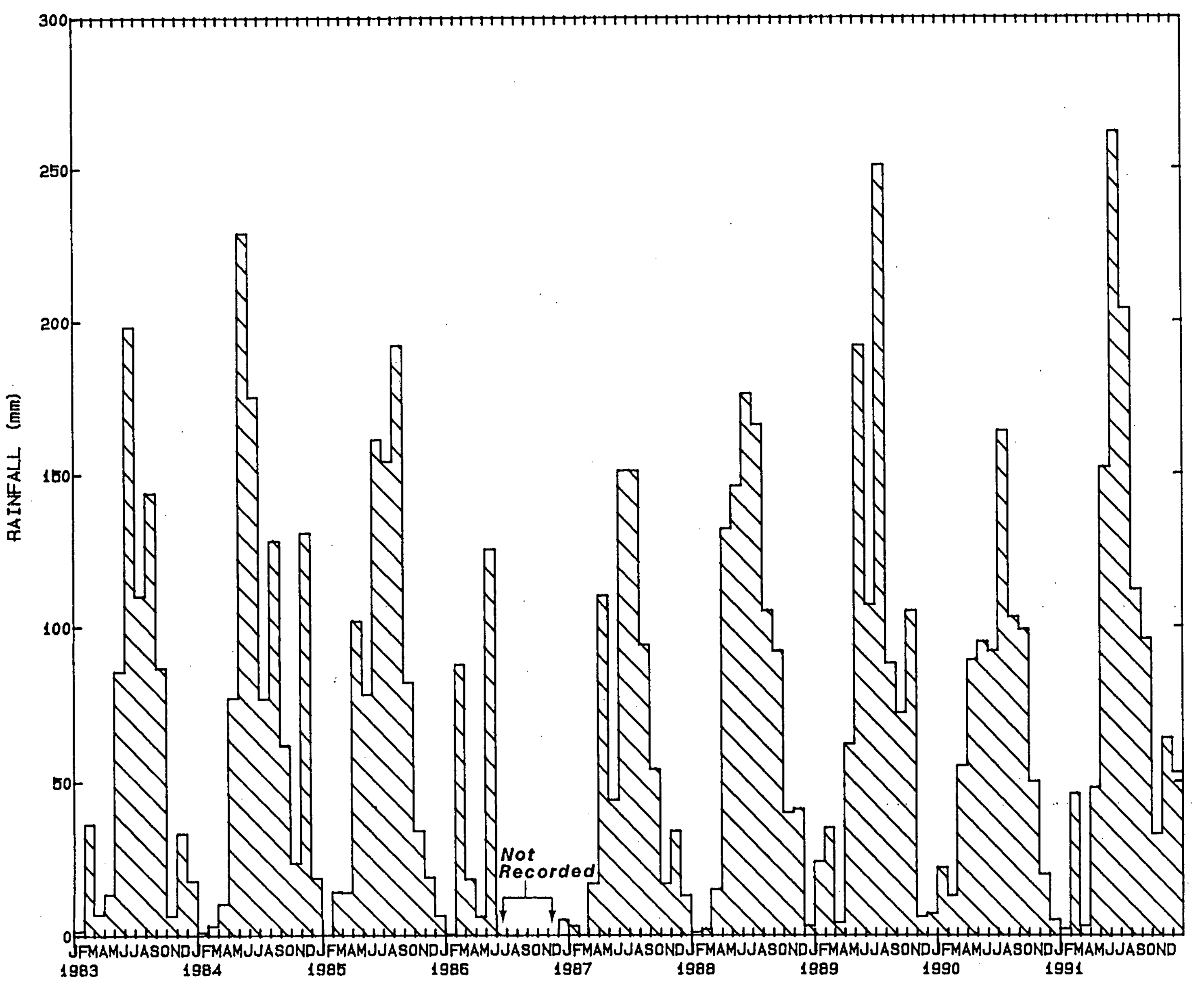
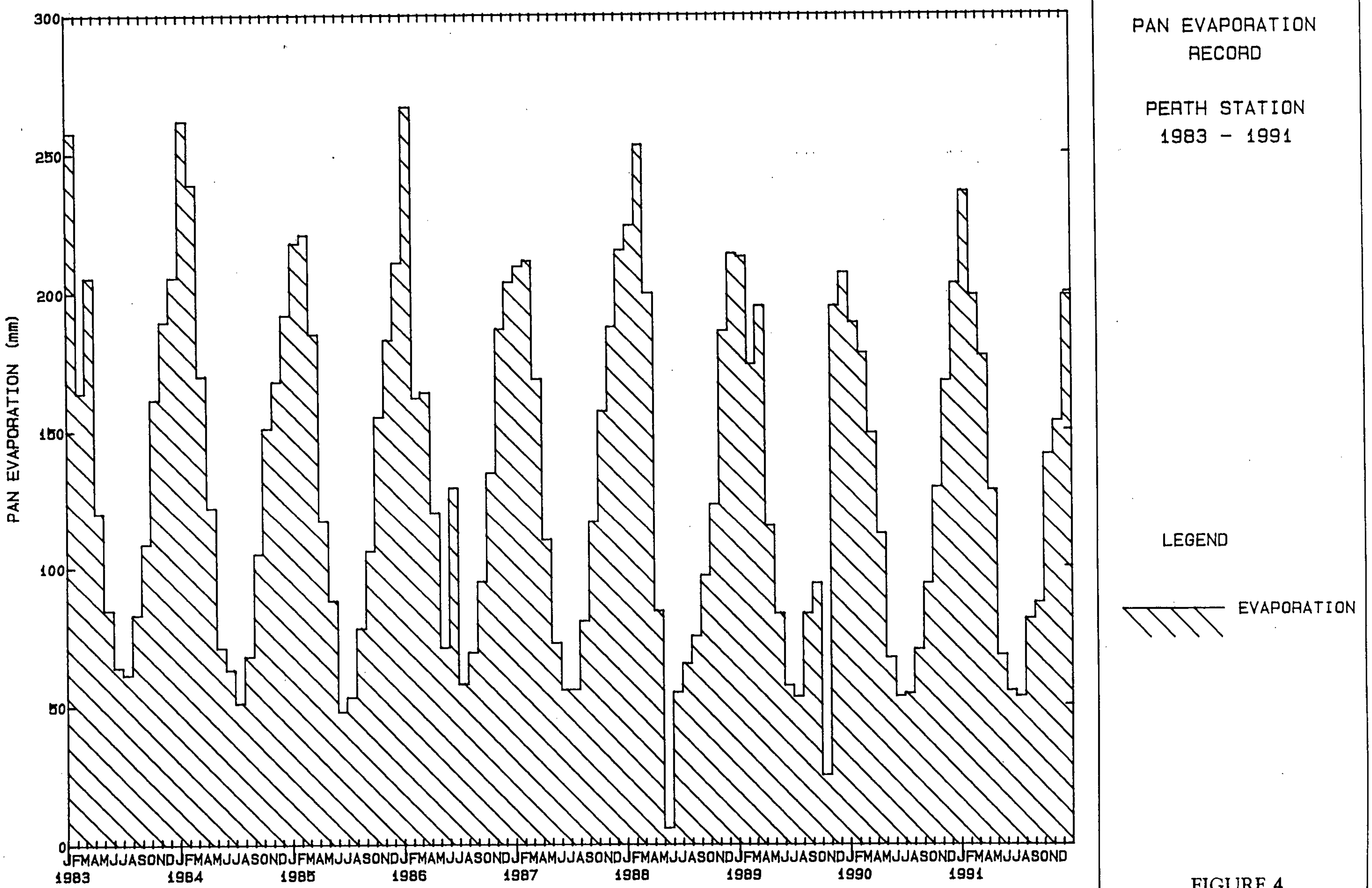


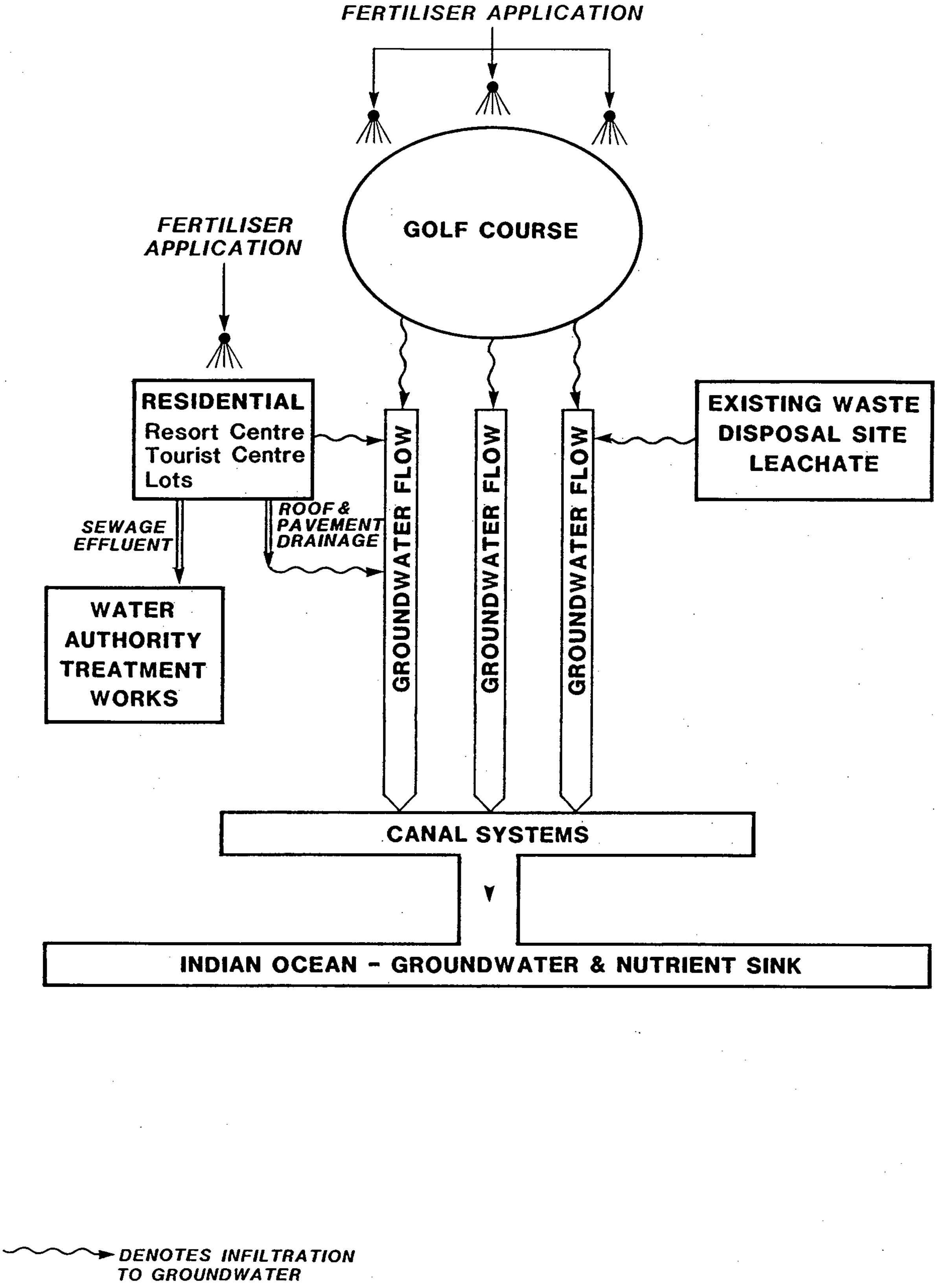
FIGURE 3
DAMES & MOORE



PAN EVAPORATION
RECORD

PERTH STATION
1983 - 1991

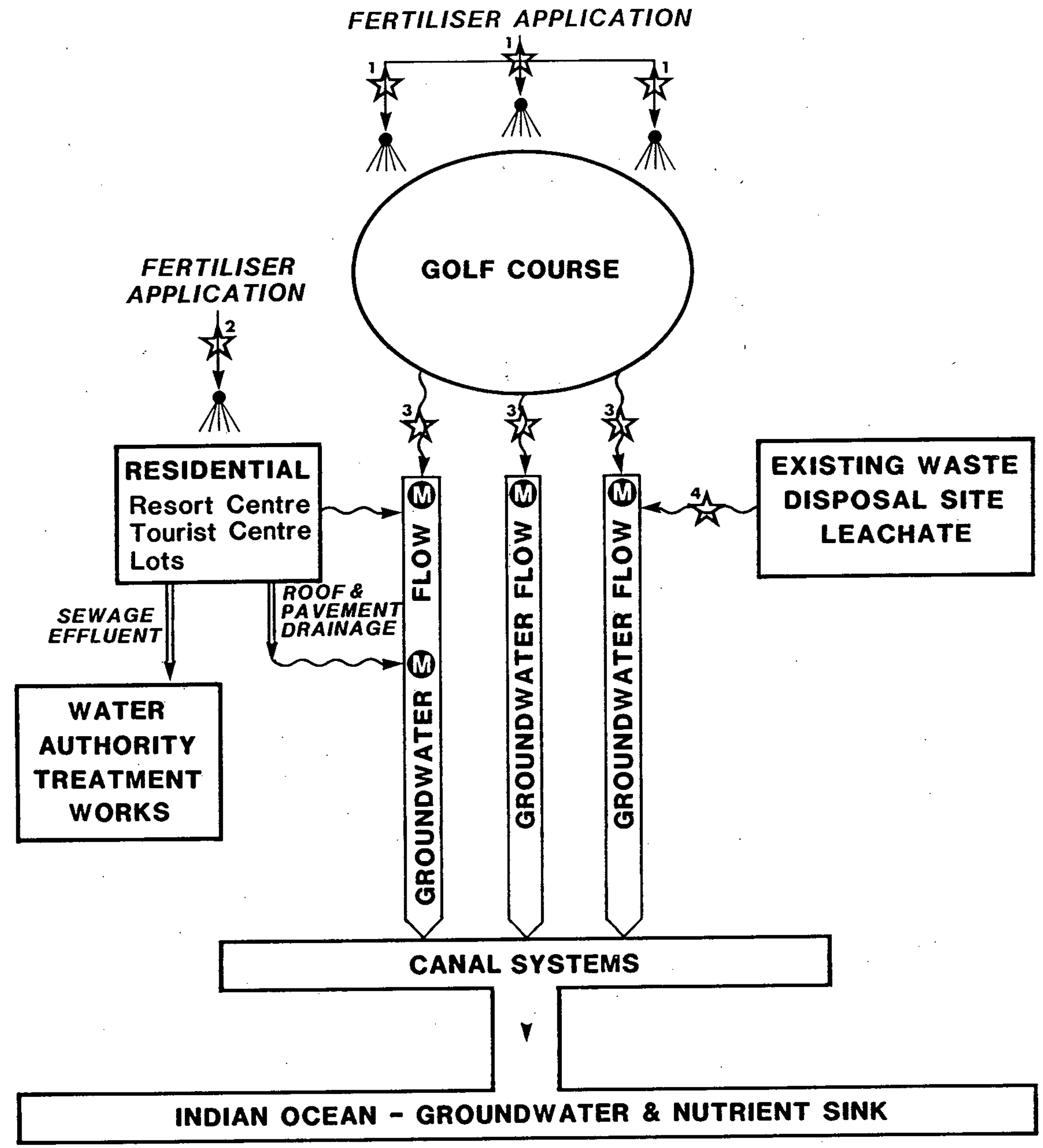
FIGURE 4
DAMES & MOORE



JOB No. 23641-002-074		DATE
PREPARED BY	ACD	10/07/92
APPROVED BY		16/07/92

NUTRIENT FLUX DIAGRAM

FIGURE 5
DAMES & MOORE



Ⓜ *DENOTES GROUNDWATER MONITORING*

〰→ *DENOTES INFILTRATION TO GROUNDWATER*

☆1	USE OF SLOW RELEASE FERTILISERS, TISSUE TESTING AND FOLIAR FEEDING. DETAILED FERTILISER PROGRAM, MANAGEMENT TO AVOID EXCESSIVE LEAF GROWTH
☆2	SOIL NUTRIENT MONITORING AND CULTIVATION OF NATIVE SPECIES
☆3	SOIL NUTRIENT MONITORING
☆4	ABSORPTION IN UNSATURATED ZONE AND ATTENUATION SATURATED ZONES

JOB No. 23641-002-074		DATE
PREPARED BY	ACD	10/07/92
APPROVED BY		16/07/92

NUTRIENT MANAGEMENT PLAN

FIGURE 6
DAMES & MOORE

PORT BOUVARD
IMPACTS ON COASTAL DUNES
AND
ESTUARINE FORESHORE

Prepared for:

Feilman Planning Consultants Pty Ltd

By:

Quilty Environmental Consulting

JUNE 1992

CONTENTS

1. INTRODUCTION

CP Developments Pty Ltd is planning a canal and dry lot development at Wannanup associated with the construction of the Dawesville Channel linking Harvey Estuary to the ocean. The development will impose environmental pressures on the area, including potential impacts on the fragile coastal dunes and on the estuary foreshore which is to be relocated eastwards by fill derived from excavation of the channel.

Purpose of the present report is to consider the environmental values potentially impacted in these areas and design and management avenues to attenuate these impacts.

2. EXISTING ENVIRONMENT

The areas to be impacted by the development and which are of relevance to the present study are:

- the coastal dunes,
- portion of Caddadup Reserve, and
- the estuary foreshore.

2.1 Coastal Dunes

The coastal dunes in the project area are unconsolidated Holocene sands of the Quindalup System overlying Tamala limestone. They are covered by a healthy and vigorous community of diverse coastal vegetation.

2.1.1 Stratigraphy

The dunes are divided into four phases, Q1 to Q4, by McArthur and Bartle. Q4 is the youngest and the predominant type along the foreshore frontage, with Q3 and Q2 appearing immediately east of the frontal crest and the Q2 type also evident as low dunes behind the frontal zone in the north.

South of Dawesville Channel the foreshore dunes are particularly large, rising to a height of over 20 metres, with a width of up to 150 metres. North of the channel they are of similar dimensions as far as Avalon Point before dropping to a lower elevation of 5 to 8 metres and a width of about 50 metres beyond the Point towards Falcon.

The dunes are underlain by three distinct pre-Holocene limestone units deposited during separate marine phases. The stratigraphy is discussed in the appendix which presents the findings of a recent drilling program, but a brief summary is provided here.

South of the channel the uppermost of these three limestone units rises to 5 metres AHD within 80 metres of the vegetation line on the beach. The second limestone unit rises to 0.5 metres AHD beneath the beach, extending seawards to outcrop as a wave-cut platform.

North of the channel as far as Avalon Point the uppermost limestone unit outcrops as a cliff along the back of the beach and is at about 4 metres AHD beneath the dunes. Beyond the Point the stratigraphy changes, with the uppermost unit rising from below or close to sea level at the shoreline to an elevation of 0.5-0.75 metres AHD 70 to 80 metres from the vegetation line. Here the second unit is removed offshore, separated from the beach by a protected lagoon.

Examination of 80 years' data on shoreline movement indicates that over this period the shoreline in this portion of the coast has been stable apart from short term fluctuations associated with particular storm sequences. Should serious erosion of the foreshore dunes occur at some stage in the future, however, the uppermost limestone unit mentioned above is sufficiently indurated to offer some resistance to such erosion as evidenced by the cliff outcrop at Avalon Point.

2.1.2 Vegetation

The vegetation sequence across the foreshore dunes is a reflection of the comparative exposure of their different sectors: the strand immediately behind the beach, the intermittent berm at the toe of the frontal dune, the steep face of that dune and its more gentle upper slopes, the crest and the protected hind slopes.

Within the strand fleshy annual succulents are found: *Cakile maritima, Salsola kali* and *Arctotheca populifolia*. This is the AC open heathland as classified by Trudgen in his vegetation map of the Mandurah coastline.

Where it is present, the berm is colonised by a healthy cover of grasses and succulents - predominantly *Spinifex hirsutus* and *Tetragonia decumbens*, with some *Spinifex longifolius* also present.

Behind this the exposed face of the frontal dune is dominated by these three species with the herbaceous *Carpobrotus virescens, Pelargonium capitatum* and the shrubs *Olearia axillaris* and *Scaevola crassifolia* also appearing.

Behind the immediate frontal face in the sometimes broken and semi-sheltered terrain rising to the crest a wider variety of dune species is evidenced. A well developed shrub storey in the substantial dunes south of Avalon Point has *Olearia axillaris* , *Scaevola crassifolia, Acacia rostellifera* and *Spyridium globulosum* as the dominant species amongst a diverse range which includes all of the species mentioned previously together with the groundcovers and creepers *Hardenbergia comptoniana, Isolepis nodosus, Hemiandra pungens, Lepidosperma gladiatum, Conostylis acculeata,* various native and invasive grasses and the weed *Euphorbia peplus* .

Apart from the dominant species already mentioned, the shrub storey here also contains *Santalum accuminatum, Myoporum insulare, Threlkeldia diffusa, Jacksonia furcellata, Acanthocarpus preissii, Helichrysum cordatum, Rhagodia* *baccata*, *Exocarpos sparteus*, *Diplolaena dampieri*, *Alyxia buxifolia* and *Acacia saligna* .

The berm and frontal face vegetation described above are the Sh as classified by Trudgen. The more varied communities covering the rising slopes of the frontal dune behind this are Trudgen's OA and SO open to closed heath to open scrub. These vegetation types dominate the foreshore dunes from here south into Yalgorup National Park.

To the north of Avalon Point the lower dunes carry a lesser diversity of vegetation, with the spinifexes and *Tetragonia decumbens* the most prominent groundcovers and *Olearia axillaris* and *Acacia rostellifera* the predominant shrubs in a narrower band of Trudgen's SO and OA vegetation types.

On the protected eastern slope of the high frontal dunes *Acacia rostellifera* tends to dominate. *Spyridium globulosum*, *Olearia axillaris* and *Scaevola crassifolia* are also prominent amongst a wide variety of shrub species, with *Melaleuca huegelii* dominating in some lower slope situations which lead into low-lying *Melaleuca huegelii* and *M. viminea* scrub behind the dunes - the MM and Mv vegetation types of Trudgen.

2.2 Caddadup Reserve

Within Caddadup Reserve the areas to be affected by the proposed development are the more mature Q1 dune type, with some Q2 in a central valley. Vegetation on these is dominated by the EAf forest and the As woodland of Trudgen.

The EAf type has been degraded in the north of the reserve where a rubbish tip, rifle range and miscellaneous vehicle tracks have impacted on it. Across a ridge to the south, however, this vegetation type is in good condition. Here healthy and attractive *Eucalyptus gomphocephala/Agonis flexuosa* forest towards the east changes to *Agonis flexuosa* forest to closed forest westwards, with *Acacia saligna*, *A. truncata*, *A rostellifera*, *Olearia axillaris*, and *Spyridium globulosum* the most prominent shrubs amongst the rather open understorey.

The As vegetation type occurs in a wide valley south of the EAf type. Here there is more open scrub dominated by a shrub storey in which *Acacia saligna*, *A. truncata* and *A. rostellifera* are most prominent with *Spyridium globulosum*, *Melaleuca huegelii*, *Acacia lasiocarpa* and *Jacksonia furcellata* also prominent. Within this low woodland some clumps of *Agonis flexuosa* are still to be found as pockets of Af type vegetation.

To the west of the reserve the frontal dunes have a vegetation assembly similar to that previously described. These dunes are, however, degraded in numerous places by blowouts which are advancing eastwards into the reserve.

The worst of these blowouts have been partly stabilised by marram (*Ammophila arenaria*) which, judging by its extent and growth status, was presumably introduced some years ago to attempt to check the sand advance.

2.3 Estuary Foreshore

The estuary foreshore at the development site comprises marshy flats and depressions interspersed by minor beach ridges.

2.3.1 Foreshore Vegetation

In the tidal zone on the estuarine edge *Sarcocornia sp.* predominates with *Sporobolus virginicus* and *Juncus kraussii* dominant on slightly higher ground immediately behind it. The marshy ground beyond is a low melaleuca forest dominated by *Melaleuca rhaphiophylla* and *M. cuticularis* with *Juncus kraussii* and patches of *Gahnia trifida* prominent beneath them.

Beach ridge scrub interspersed amongst the melaleuca woodland includes dense growth of *Jacksonia furcellata, J. sternbergiana, Kunzea vestita, Regelia ciliata, Anthocercis littorea* and occasional *Acacia saligna* and *Casuarina obesa.*

Behind the marshy flats and intervening sand ridges on slightly elevated Karakatta Sands the vegetation changes to a tuart-marri woodland. *Eucalyptus gomphocephala* and *Eucalyptus calophylla* dominate the overstorey, but with widespread *Agonis flexuosa* also present. *Acacia saligna* and *Jacksonia furcellata* are prominent amongst an understorey which also includes *Melaleuca cuticularis, Jacksonia sternbergiana* and *Xanthorrhoea preissii* as some of the more prominent shrub species.

2.3.2 Estuarine Biota

Estuarine fauna to be found in the shallows are dealt with in the Stage 2 ERMP for the Dawesville Channel. A summary derived from this is presented below.

The seagrasses *Ruppia megacarpa* and *Halophila ovalis* which originally grew in these areas have declined as a result of epiphytic diatoms reducing available light and smothering by macroalgae.

Large faunal communities are however to be found here, their composition varying according to salinity. These include large numbers of foraminiferans, over 30 species of molluscs, large numbers of the snail *Hydrococcus brazieri*, and abundant bivalves including *Arthritica semen, Tellina, Sanguinolaria, Spisula* and *Anticorbula amara.*

The most abundant polychaete worms found in the estuary are *Ceratonereis, Haploscoloplos, Prionospio* and *Capitella.*

Small crustaceans found amongst the seagrasses and algae include the amphipods *Paracorophium, Melita* and *Corophium*, the shrimp *Palaemonetes australis*, copepods and mysids.

Estuarine detritus and the rich assemblage of estuarine invertebrates are a bountiful food source for fish, crabs and prawns which use the estuary as a nursery habitat and/or a rich feeding ground.

The shallows are also bountiful feeding areas for a wide range of waterfowl which also find refuge in the marshy habitats around the foreshore.

3. DEVELOPMENT IMPACTS AND THEIR MANAGEMENT

Impacts on the above areas will derive from both site changes and structural measures associated with the development, and subsequent people usage, particularly in a recreational sense, which will flow from that development.

3.1 Coastal Dunes

Developments that will impact on the coastal dunes include:

- the establishment of R20 residential development impinging on their eastern slopes and associated reshaping of the mid and lower slopes of this face;
- establishment of a carpark at the protected beach immediately north of the channel mouth and of road access to that carpark;
- development of pedestrian access pathways through and within the dunes;
- possible development of a limited number of fairways within the dunes.

3.1.1 Residential Subdivision

R20 residential subdivision will extend onto the backslopes of the high dunes north and south of the channel mouth. This will involve some cutting into the mid and lower slopes of these dunes and associated filling to establish satisfactory gradients for development.

The location of this residential development is believed to be consistent with the objectives of SPC Coastal Planning Policy in that:

- A substantial foreshore reserve is to be retained between the residential development and the beach.
- Setback of buildings from the vegetation line behind the beach is about 100 metres over most of the length of affected coastline, although it reduces to 70 metres north of Avalon Point. Here the foreshore road at Falcon is to be extended south to link with the new development, following an existing track which lies 40 to 50 metres east of the vegetation line.

- Location of the boundary line for development has also ensured that it does not encroach onto the crest of the foreshore dunes, thereby maintaining the aesthetic value of the natural dune landform and its cover of native vegetation along the western skyline. This approach has entailed widening the foreshore reserve beyond 100 metres in certain locations.

Considering the substantial and well vegetated nature of the dunes, the presence beneath them of an erosion barrier in the form of limestone as discussed at 2.1.1 above and the stable nature of the coastline in this area, this setback indicated above is considered to leave an adequate buffer between the development and the ocean. The adequacy of same will, however, hinge on retaining adequate stabilising cover on the dunes and on maintaining sand feed past the Dawesville Channel to the beaches to the north.

A sand bypass operation proposed in the stage 2 ERMP for the Dawesville Channel should ensure that sand feed is maintained. Rehabilitation and protection measures proposed for the dunes at 3.1.4 below should ensure the continued retention on these of adequate vegetative cover.

3.1.2 Carparks, Roads and Pathways

The SPC Coastal Planning Policy also advocates provision of public access to the foreshore at suitable locations. The development plan addresses this through provision of one carpark immediately behind the beach at the northern breakwall, with a further carpark at Avalon Point with a pedestrian path from it through the dunes to the beach.

From a stability viewpoint, locations behind the dune are preferred for car parking. The one to be located immediately adjacent to the beach is, however, in a situation which is protected by two breakwalls and which is therefore not expected to be at risk. Its situation here recognises that this beach is likely to be very popular because of the shelter from the afternoon sea breeze and swell provided by the breakwaters to the south.

The carpark at Avalon Point will serve the beach here which is popular with surfers and for which a surf club has been proposed with the support of Council. This area offers the options of safe swimming to the north in a lagoon protected by an offshore reef, and good surfing conditions to the south where waves break onto the reef.

South of the channel surfing and fishing are currently popular, with access to the beach provided along a number of sand tracks. Disposition of access paths through the dunes to the beach here will ensure easier and formalised access to these areas to accommodate the increasing use which development of the land behind will occasion.

3.1.3 Fairways

Development of a golf course at the southern end of the estate extending into Caddadup Reserve will see several fairways located in the foreshore dunes. Exact location of these will be determined on the ground at a later stage of planning, but the objective will be to site them in areas where they will not detract from the rich assemblage of foreshore vegetation.

Thus preferred locations will be degraded areas associated with the numerous blowouts in the south. Fairway development here will provide a basis for stabilising and rehabilitating these blowouts for a use that is consistent with retention of vegetative cover and thus protection of their stability.

3.1.4 Dune Management and Rehabilitation

The most significant impact of development will be the increased recreational pressure which it places on the foreshore dunes and the beach as increasing numbers of residents and visitors use it for fishing, surfing and relaxation.

Development per se will also remove some dunal vegetation for establishment of roads, access paths and residential allotments and the hind slopes of the dunes will be reshaped by cutting and filling to accommodate residential development which extends onto these.

As previously mentioned, the development allows an adequate foreshore reserve within the dunes to accommodate any long term erosion, bearing in mind the size and stability of these dunes and the underlying limestone basement. Building allotments are generally to be located on the rear slopes of the high frontal dunes, thereby ensuring that the natural skyline is retained for aesthetic benefit when viewed from both the beach on the one side and the subdivided land on the other.

Where development activities do enter the dunes, the area of disturbance will be minimised to ensure that the majority of existing vegetation cover is retained. Such vegetation as is cleared for roads and pathways through the dunes and for residential development on their rear slopes will be stockpiled. This can be used later as stabilising brush cover on areas which are to be rehabilitated.

Topsoil will also be stripped and stockpiled for use in subsequent rehabilitation. Such rehabilitation will follow completion of roads and pathways through the dunes, to reinstate any adjacent ground disturbed during their construction. It will also extend to existing areas of instability along the berm and frontal face over the length of the development site, to numerous minor blowouts encroaching into the dunes over this same length and to larger blowouts to the south, in Caddadup Reserve, where these affect the proposed golf course development.

This rehabilitation will entail earthworks within the blowouts, establishing a continuous berm and frontal dune where these have broken down to provide a stable landform for revegetation. Subsequently brush and mulch will be spread to provide temporary stability over the bare surface. The native and naturalised groundcovers and shrubs of the dunes will be propagated by planting and seeding beneath this temporary cover to afford permanent vegetation cover for long term protection.

Formal beach access pathways through the dunes will be carefully sited, particularly where they emerge through the frontal face or berm onto the beach, to ensure they are not prone to wind scour or sand deposition.

All pathways within the dunes will be surfaced with concrete or limestone as appropriate. They will also be fenced, as will the perimeters of carparks and the eastern edge of the foreshore reserve where this abuts public land. Temporary fencing may also be appropriate on the western side of the dunes, immediately behind the berm, to protect stabilisation and revegetation work until this is well established.

Signs will be installed at key points to direct pedestrians to pathways through the dunes and to request cooperation in respecting dune vegetation and rehabilitated areas.

High quality treatments will be used throughout for fencing, signage, surfacing of paths, rest areas along these and associated benches, etc. If a high standard is adopted initially , there is a greater tendency by the general public to respect the work so that vandalism and indiscriminate access through vegetated and rehabilitated areas is minimised.

As a basis for the foregoing work, a foreshore management plan will be developed detailing:

- areas to be treated;
- the nature of such treatment including earthworks, temporary stabilisation measures, revegetation species and techniques;
- location, design and management of accessways;
- ongoing maintenance requirements to preserve the stability and vegetative cover of the dunes.

3.2 Caddadup Reserve

The golf course proposed at the southern end of the estate will be partly within private land owned by the developer and partly within Caddadup Reserve to the south. In the former it is on land which is to be filled with spoil from the channel development. In the latter a majority of the fairways will be in the disturbed northern sector of the reserve but some may extend into the well vegetated central portion of the reserve and westwards into the foreshore zone.

Caddadup Reserve is an A Class reserve for recreation and camping vested in the Local Authority. Present uses within the northern portion of this reserve - the part most affected by the golf course development - include the Mandurah City rubbish tip, a sand quarry and a motocross circuit within same, a pistol range and various informal access tracks to the coast.

Random bike and 4WD tracks traverse the dunes and swales of the balance of the reserve to the south. These are a source of damage to the area, although the most degraded land is in the north where the more intensive uses have occurred.

The area is recognised by the EPA in its advice on the Dawesville Channel Strategy Plan as "likely to become the only significant area of regional open space containing representative woodland vegetation species on the land joining the ocean and the estuary." In this context they consider it to be important as a potential faunal corridor between the ocean and the estuary and to be significant also to the visual character of the estuarine precinct. They therefore suggest that the suitability of the reserve for a golf course be studied carefully.

Fairways within the private development land and the northern sector of the reserve will have little adverse impact because these areas have already been grossly disturbed. Their development is a sound approach to rehabilitation of these areas to a productive recreational use which will reinstate vegetative cover and enhance the visual amenity of a degraded landscape.

Further south, fairways within areas of the reserve which are now disturbed only by bike and 4WD tracks have the potential to impact on tuart woodland and peppermint forest of higher conservation value. Siting of these fairways will accordingly be determined carefully on the ground to contain deleterious impacts.

Those fairways which are located towards the west will, as mentioned in Section 3.1.3, be preferentially located to minimise their impact on better vegetation assemblages and to capitalise on areas of dunal erosion where native vegetation is being inundated by sand drift. This is an attractive option as it affords the opportunity to reinstate a degraded dunal area whilst providing an attractive ocean frontage environment for users of the course.

A substantial natural link between the ocean and the estuary will remain through the southern-most portion of the reserve which will be unaffected by the golf course. Furthermore, aesthetic values will be protected: the terrain is such that a high ridge following Old Coast Road will hide the golf course development from the estuary, while to the west of this ridgeline the perspective over the southern end of the reserve remains unchanged and to the north judicious siting of fairways, as previously mentioned, will contain impacts on the tree storey in particular.

Along the fairways themselves amendment with bauxite residue will be considered to improve nutrient and moisture retention. This concept is consistent with one of the policy provisions for open space recreation areas of the Peel Harvey Catchment Planning Policy.

3.3 Estuary Foreshore

The estuary foreshore on either side of the Dawesville Channel entry is to be filled with spoil excavated from the channel and the estuary floor beyond its mouth. Landscape and rehabilitation plans for this fill and for the channel banks are being prepared by the Department of Marine and Harbours.

The plans for the area of fill north of the channel mouth include development of a canal estate and a marina, with a peninsular of land east of the estate which might serve as a foreshore reserve for public recreation. In this context it could be effectively rehabilitated as recreational parkland, interspersed by nodes of natural foreshore vegetation.

2.3.1 Demands and Objectives for Foreshore Use

The recently released Peel Inlet Management Programme advocates that the subdivision of any land along the estuary foreshore be accompanied by dedication of adjoining land to the Crown as a foreshore reserve. The design indicated above is consistent with this objective.

The Management Programme further advocates a priority on development of recreational nodes to accommodate future demands, with such nodes providing for a broad range of recreational opportunities compatible with the estuarine environment and having well planned and appropriate facilities established within them. Such facilities could include launching areas, barbecues, toilets, shelters, tables and seating, play equipment, fresh water supply, rubbish disposal facilities, vehicular and/or pedestrian access, car parking, nature interpretation facilities and beaches.

With respect to the last, the possibility of creating areas of deeper water suited to swimming is canvassed. Development of dual use paths to provide and encourage linear access for cyclists and pedestrians to the foreshore is also advocated.

The emphasis on recreational use of the estuary and its foreshores is reinforced by surveys conducted in the area - notably one carried out for the Mandurah Tourism Development Plan in 1984 which indicated that the largest single tourist attraction at Mandurah was fishing and crabbing (29% of responses), followed by beaches (17.4%) and the inlet/estuary/boating (16.4%).

That the demand for these and other recreational activities within the area will increase is axiomatic, deriving not only from the intended development adjacent to the Dawesville Channel but also from increasing visitation pressure from Mandurah and Perth.

Thus the suggested dedication to recreational use of 1.5 kilometres of foreshore created by fill from the Dawesville Channel would be a sound response to a well documented need and would be consistent with priorities indicated in the Peel Inlet Management Plan.

3.3.2 Impacts on Foreshore Vegetation and Estuarine Biota

The environmental impact of the channel development on foreshore vegetation and estuarine biota as dealt with in the Stage 2 ERMP for the Dawesville Channel will apply equally to this particular section of the foreshore at the channel entry. Accordingly those impacts are simply summarised here.

The filling operation on either side of the channel mouth will bury the fringing vegetation along the foreshore. This vegetation does not have a high conservation value in its own right but is nonetheless a valuable buffer between the estuary and urban development.

In the estuary itself creation of the channel will lead to increased tidal fluctuation, a reduction in salinity variation through the year and a reduction in macroalgae in the long term after a possible initial increase. Foreshore erosion may increase, with such erosion possibly greatest in the vicinity of the channel mouth where tidal variation will be greatest.

The reduction in macroalgae will see an improvement in clarity and dissolved oxygen levels, and there will be a likely recruitment of seagrasses to the shallows with the better light penetration.

There is unlikely to be any major adverse impact on the biota, with benthic fauna persisting as the dominant species, increased species diversity overall, but possibly a reduced population of true estuarine species.

Elimination of *Nodularia* will create a more favourable environment for certain fish species and there is likely to be further recruitment of blue manna crabs and a greater variety of marine fish. There may, however, be a reduction in the numbers of sea mullet and also of the Western King prawn which favours the hypersaline summer conditions of the estuary.

Overall the decline in macroalgae together with a reduction in the area of shallows permanently underwater may reduce the productivity of the estuary as a fishery.

The increased tidal variation is also likely to see less roosting sites available for waterfowl, although predictions of the effect on these are speculative.

3.3.3 Foreshore Rehabilitation and Development

Rehabilitation and development of the foreshore strip created north of the channel entry should aim to ameliorate some of the impacts on the estuarine flora and fauna. This rehabilitation could, at the same time, capitalise on the radical disturbance of this area to develop a frontage to the estuary which can accommodate much of the increasing recreational pressure on its foreshore.

In forming, rehabilitating and developing this area particular attention might be paid to the importance of establishing a stable foreshore, providing an aesthetically pleasing environment and servicing diverse recreational demands.

Contouring of the fill along the estuary interface should be designed to match the anticipated shoreline form which natural erosion and accretion will otherwise establish in time. Engineering measures should be adopted, as and where appropriate, to protect this form from serious erosion, with concurrent attention to any impacts such measures may have on the neighbouring shoreline to the north.

Modest variations might be provided in surface levels of fill to break the continuity of what would otherwise be a flat plain and to provide micro-environments within which different foreshore plant species can be established.

Once the fill has been placed, topsoil which has been pre-stripped from the original foreshore should be respread to provide a satisfactory surface medium for plant regeneration.

In areas which are to be grassed for recreational use, amelioration of the surface soil with bauxite residue could be considered to improve nutrient and water retention and thus aid development and maintenance of healthy grass cover, the more so as these areas are unlikely to be irrigated. These areas should then be sown or sprigged to an appropriate turf species - kikuyu (*Pennisetum clandestinum)* and, at least near the estuary edge, saltwater couch (*Sporobolus virginicus*) are likely to be most suitable. Establishment of sandy beaches would then be focused along the frontages to these recreational areas.

Trees might be planted for shade, shelter and aesthetic enhancement, drawing upon endemic species such as tuart (*Eucalyptus gomphocephala*), peppermint (*Agonis flexuosa*), swamp oak (*Casuarina obesa*) and paperbark (*Melaleuca rhaphiophylla*).

In time facilities could be introduced as warranted to meet progressive demands - barbecues, tables and seating, play equipment, toilets and possibly a kiosk.

For diversity, aesthetic enhancement and restoration of some of the pre-existing ecological values, pockets of native foreshore vegetation might be established to break up the recreational area, occupying up to 50% of this frontage. With the proposed variation in surface contours this vegetation could provide a continuity from tidal sedgeland on the estuary edge through tea tree and paperbark woodland/forest behind to beach ridge scrub and possibly tuart-marri woodland on higher ground.

Because this area will initially be an extensive tract of bare ground adjacent to the open expanse of the estuary, exposure to wind may interfere with plant establishment and may generate surface erosion. Should this prove a problem, brushing/mulching of the surface, use of wind fences and/or cover cropping with cereal rye might be considered to afford temporary protection to developing plant cover.

To provide public access to this area a road is to be constructed along its length leading to a carpark at its southern end, adjacent to the proposed marina. Further carparks could be provided adjacent to any recreational segments developed along the length of this peninsular of land.

A dual use path might also be constructed along its length. This would desirably follow an irregular route, weaving amongst the vegetation and at times approaching the foreshore, to provide visual diversity and interest to pedestrians and cyclists.

3.4 Channel Banks

The channel banks offer a golden opportunity for developing a major recreational and access resource linking the estuary to the ocean. Periodic access will be required by Marine and Harbours to permit repairs to canal walling or dredging, and this will in turn demand temporary dumping areas for dredge spoil and rocks. This access requirement need not, however, preclude public use of the channel banks and development of facilities suited to this.

Establishment of a promenade for use by strollers, cyclists, anglers, etc is the primary development suggested here. This will not demand more than the 15-metre width presently within the public domain behind the channel walls, but intermittent increases in this width are proposed to accommodate areas of grassed parkland with play equipment and space for picnicking.

The promenade will be improved by planting of trees in clumps and as individual specimens to provide shade, shelter and aesthetic enhancement. Emphasis in species selection for this purpose will attach to the horsetail oak (*Casuarina equisetifolia*) and the peppermint (*Agonis flexuosa*) which are well suited to such an environment.

At the western end of the promenade there will be limited access only to the breakwaters extending into the ocean. Current plans foreshadow the southern breakwall being armoured with granite rock from a point 60 metres from the shoreline, the central one being similarly armoured from a point 90 metres from the shore and the northern-most being armoured from a point 100 metres from the shore. This armouring will preclude public use beyond the point where it commences.

REPORT ON DRILLING IN COASTAL ZONE ADJACENT TO DAWESVILLE CHANNEL

BY

PETER J WOODS & ASSOCIATES

JUNE 1992

Report to QUILTY ENVIRONMENTAL CONSULTING

INDEX

1 INTRODUCTION

In order to provide some data on the potential for coastal erosion as a basis for determining the width of the coastal reserve adjacent to the Dawesville Channel, a drilling programme has been carried out to determine the stratigraphy of the coastal zone within 100-150m of the shoreline.

Because of the size of the drilling rig provided, and lack of suitable access along the coast, drilling was limited. However, the information obtained from this programme correlated well with information logged in 1986 from cores provided by the Department of Marine and Harbours and reported in Woods (1986). Thus while further drilling would have provided more data, the consistency of the data gained has allowed the stratigraphy in areas between drill lines to be predicted with some confidence.

1.1 THE STUDY AREA

The study area is shown in Figure 1. It lies immediately north of the Shire of Mandurah rubbish tip and extends to the southern boundary of residential housing.

1.2 REVIEW OF PREVIOUS DATA

A report by Woods (1986) contains details of Marine and Harbour's cores logged by Peter Woods and Vic Semeniuk in 1986.

Very briefly, previous drilling along a transect immediately north of the proposed Dawesville Channel, revealed that the area is underlain by three distinct limestone units (Units 1, 2 and 3) with a fourth presently being deposited along the modern coast (Unit 4). Due to the presence of calcrete and soils on the upper surface of the three limestone units it is clear that these three units were deposited during three separate marine phases.

The first (ie. oldest) two units underlie the narrow neck of land between the Harvey Estuary and the modern coast. The third (ie. younger) unit, however, abuts a ridge of yellow sand which unconformably overlies the eastern part of the second unit. The youngest or fourth unit, which is being deposited today, unconformably overlies the western part of the third limestone unit. This fourth unit is clearly Holocene. As the third unit has been calcreted it is likely to be pre-Holocene in age.

In general the oldest two limestone units are more cemented and have thicker calcrete cappings than the Unit 3 limestone. The Holocene (Unit 4) dune sands are unconsolidated.

The stratigraphy along the drilled section has been repeated here as Cross section 2 (see also Figure 2). Of significance to this report is the occurrence above sealevel (0.0m AHD) of the Unit 2 limestone beneath the modern beach, in Holes L6/84 (+0.9m) and Sites 10, 11 and 12 (±1m), and Unit 3 limestone beneath the modern dunes.

2 METHOD

2.1 DRILLING

Nine holes were drilled using a Wallis Mantis 500 rig (see Figure 1 for locations). Holes were logged continuously with special note taken of grain size, colour, composition and degree of cementation. In general, holes were drilled through the Holocene sand dunes (Unit 4) into the underlying weakly to well cemented Unit 3 limestones. The uncomformity between Units 3 and 4 is generally marked by a brown sandy soil where the contact is above sea level, or a thin layer of course shells and round lithoclasts (the Rocky Shore Unit) where the contact is below sea level. In some holes drilling continued until a very dense hard calcrete layer prevented further penetration. This surface marks the contact between Unit 3 limestone and the underlying and older Unit 2 limestone.

2.2 MAPPING

The coastal area was mapped using a 1:5,000 scale air photograph. Special note was taken of:

(a) the location of the most seaward outcrops of calcrete-capped Unit 3 limestone,

(b) the location of calcrete-capped Unit 3 limestone cliffs behind the beach.

(c) the presence, or not, along the coast of a platform cut into Unit 2 limestone.

The distribution of the Holocene Unit 4 sands and the pre-Holocene Unit 2 and 3 limestones is shown in Figure 1.

2.3 SURVEYING

Holes, calcrete outcrops and the Vegetation Line were surveyed in and natural surface Cross sections produced from previous surveying data by McMullen Nolan & Partners (Table1).

3 NOMENCLATURE

In order to be consistent with Woods (1986) the following simplified nomenclature has been adopted:

(a) Dune/Beach Ridge Unit - Sediments formed behind the beach which typically comprise well sorted fine to medium quartzose shelly sands.

(b) Beach Unit - Sediments formed in the beach zone which typically comprise well laminated, medium to coarse quartzose shelly sands. Swash zone sediments typically are coarse, seaward-dipping laminated shelly sands whilst backshore zone sediments typically comprise alternating horizontal laminae of medium to coarse sand.

(c) Rocky Shore Unit - Sediments, formed on a rocky wave-cut shore, which typically comprise coarse, shelly material with large pelecypods and gastropods and coarse quartz and rounded lithoclasts.

(d) Soil Unit - Brown quartzose sands developed during weathering over the calcreted surface of an underlying limestone.

(e) Yellow Sand Unit - Sediments formed in the subaerial environment which are typically medium to coarse yellow-stained quartz sands.

(f) Limestone - Any pre-Holocene sediments (ie. includes Unit 2 and 3 limestones).

4 RESULTS

The results of both current and previous drilling indicate that the coast adjacent to the Dawesville Channel cut is underlain by three pre-Holocene limestone (Units 1, 2 and 3).

Unit 2 limestone outcrops as wave cut platforms along the coast and forms a reef in the northern part of the study area. This well cemented unit was not penetrated during the current drilling, however, it is 2 - 5m thick based on previous drilling.

The uppermost limestone unit (Unit 3) which is 2 - 5m thick outcrops as:

(a) a low lying plain behind the modern dune and beach ridge system,

(b) underlies the modern dunes and beach ridges, and

(c) outcrops in places behind the beach as resistant cliffs.

The Unit 3 limestone which has a calcrete capping and is poorly - moderately cemented rests on the heavily calcreted surface of the underlying Unit 2 limestone.

The unconsolidated Holocene dunes and beach ridges (Unit 4) rest unconformably on the underlying limestone units.

In the southern part of the study area it is evident that the Holocene dunes rest upon a pre-existing low dune of limestone with its overlying brown sandy soil. In Hole 5, 80m from the Vegetation Line, yellow sand was encountered at 6m AHD and well cemented limestone at 5.2m AHD. A weakly cemented limestone was found at 6.5m AHD. This may be part of Unit 3 limestone however for the purposes of this report it is classed as Unit 4 (see Cross section 1). Thus in this area unequivocal limestone (Unit 3) lies at 5.2m AHD within 80m of the Vegetation Line.

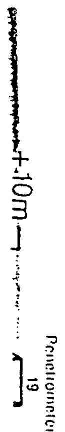
In the vicinity of the Dawesville Channel, Unit 3 limestone outcrops as a cliff behind the beach. The Holocene dunes overlie the pre-existing Unit 3 limestone dune which rises to 5m AHD within 50m of the Vegetation Line (see Cross section 2). This section also shows that the Unit 2 limestone rises above sea-level (0.5m AHD) beneath the beach - presumably it extends seawards as the wave-cut platform.

In the vicinity of the prominent point, the upper surface of the Unit 3 limestone outcrops behind the beach as a cliff. The Holocene dunes overlie the Unit 3 limestone which occurs at around 4m AHD (see Cross section 3).

Thus the stratigraphy of the strip of coast from the southern end of the study area to the point is generally consistent, with the calcreted surface of the Unit 3 limestone occuring at 4-5m AHD below the Holocene dune system.

North of the point, the coast and the offshore reef are separated by shallow lagoon. This part of the study area is characterised by a series of curved Holocene beach ridges which basically parallel the current shoreline. The Holocene sequence comprises dune sands which overlie a sandy beach and a rocky shore unit composed of coarse shelly grit, shells and rounded pebbles of calcreted limestone. This unit rests upon the gently seaward-sloping calcreted surface of the Unit 3 limestone.

In Cross section 4 the upper surface of Unit 3 limestone rises from 0.0m AHD at 45m in from the Vegetation Line to 0.75m AHD at about 70m. In Cross section 5 the upper surface of the Unit 3 limestone rises from -1m AHD at 50m in from the Vegetation Line to 0.5m AHD at 85m. The Unit 3 limestone in turn rests on the heavily calcreted surface of the underlying Unit 2 limestone at around -1 to -2m AHD (see Cross sections 4 and 5).



Thus the stratigraphy north of the point differs from that to the south in that he calcreted surface of the Unit 3 limestone rises from below or close to sea level at the current shoreline, to reach an elevation of about 0.5 - 0.75m AHD t 70 - 80m in from the Vegetation Line.

5 CONCLUSION

The results of current and previous drilling provide evidence that the unconsolidated Unit 4 Holocene dune and beach ridge units are underlain by wo pre-Holocene limestone units whose upper calcreted surfaces are above present sea level near the current shoreline. This implies that should conditions which induce loss of sand from the coast occur, erosion will proceed until the underlying limestone units are sufficiently exposed to offer resistance. The more cemented Unit 2 limestone outcrops along the coast as a wave-cut platform which to some extent appears to be determining the shape and location of the current shoreline south of the point. North of the point the ridge of Unit 2 limestone is detached from the coast.

The Unit 3 limestone while not strongly cemented, is sufficiently indurated to offer some resistance to erosion as evidenced by the cliffs along the coast south of the point, and the buried rocky platform north of the point.

Given data from drilling it is likely that only limited erosion will occur south of the point as the Unit 2 limestone currently outcrops as a resistant wave-cut platform and rises to above sea level beneath the modern beach and dune system. In places the beach is backed by a cliff of Unit 3 limestone. Elsewhere the Unit 3 limestone consistently occurs at 4 - 5m AHD within at least 50 - 80m of the Vegetation Line. While no drilling was possible between the southern transect and the Dawesville Channel, it is likely that the Unit 3 limestone exists above present sea level within 10 - 50m of the Vegetation Line.

CROSS-SECTION THROUGH DAWESVILLE

North of the point the Unit 2 limestone outcrops as a reef which is detached from the shore. Beneath the current coast the calcreted surface of this Unit occurs at around -1m AHD within 60m of the shoreline (Cross section 4). The Unit was not encountered in Cross section 5. Erosion will therefore be controlled by the presence or absence of the Unit 3 limestone. Based on drill data on Cross sections 4 and 5, erosion is likely to be limited to around 80m as the Unit 3 limestone occurs at 0.75m AHD within 80m of the Vegetation Line in Holes 2 and 7 (Cross sections 4 and 5).

REFERENCES

Woods, P.J., 1986, Interpretation of geological history from Dawesville, Western Australia: Report to Department of Marine and Harbours.

+10m

Penetrometer 19

CROSS-SECTION THROUGH DAWESVILLE

McMULLEN NOLAN AND PARTNERS SURVEYORS PTY LTD
A.C.N. 009 363 311
Consulting Surveyors • Land Development • Mining • Engineering

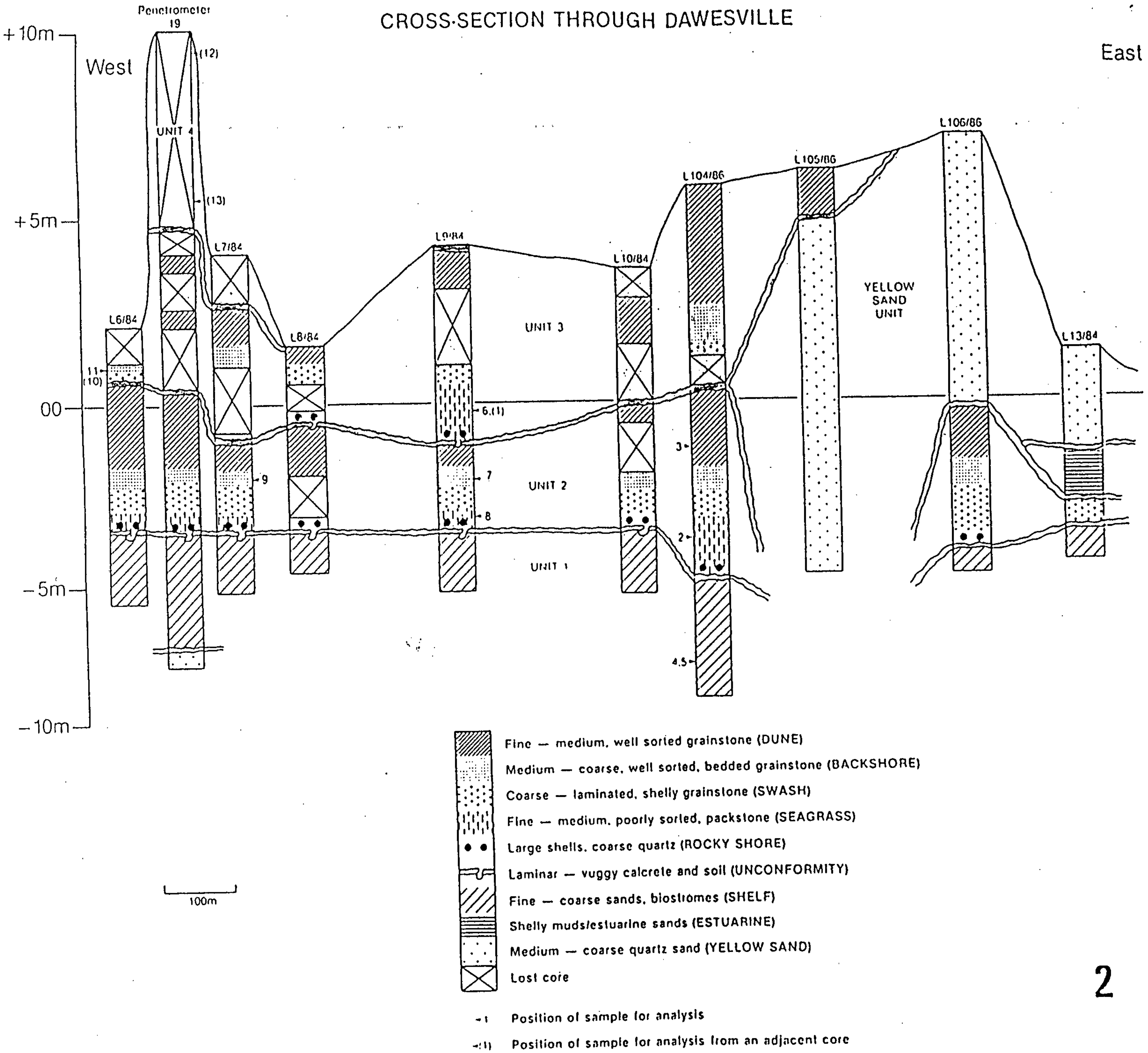
TABLE 1

DAWSEVILLE - 05/06/92

BOREHOLE & ROCK OUTCROP LOCATIONS

No	East	North	RL
1	21408.7	192106.4	1.55
2	21414.35	192080.0	2.85
3	21473.4	192072.7	3.10
4	21145.9	191927.7	12.65
R/Outcrop	21236.6	191927.8	5.15
Vegetation	20594.3	190345.8	6.35
5	20681.7	190345.7	16.45
6	20709.2	190341.8	17.05
R/Outcrop	20821.75	190343.2	4.95
7	21708.55	192228.5	5.05
8	21738.7	192224.35	5.0
9	21689.2	192227.95	4.05

9 Lyall Street,
South Perth, W.A. 6151.
Phone: 474 1099 Fax: 474 1093


CROSS-SECTION THROUGH DAWESVILLE
West
East
+10m
+5m
00
-5m
-10m
Penetrometer 19
(12)
(13)
UNIT 4
UNIT 3
UNIT 2
UNIT 1
YELLOW SAND UNIT
L6/84
L7/84
L8/84
L9/84
L10/84
L104/86
L105/86
L106/86
L13/84
11
(10)
9
6,(1)
7
8
3
2
4,5
100m
Fine — medium, well sorted grainstone (DUNE)
Medium — coarse, well sorted, bedded grainstone (BACKSHORE)
Coarse — laminated, shelly grainstone (SWASH)
Fine — medium, poorly sorted, packstone (SEAGRASS)
Large shells, coarse quartz (ROCKY SHORE)
Laminar — vuggy calcrete and soil (UNCONFORMITY)
Fine — coarse sands, biostromes (SHELF)
Shelly muds/estuarine sands (ESTUARINE)
Medium — coarse quartz sand (YELLOW SAND)
Lost core
Position of sample for analysis
Position of sample for analysis from an adjacent core

2

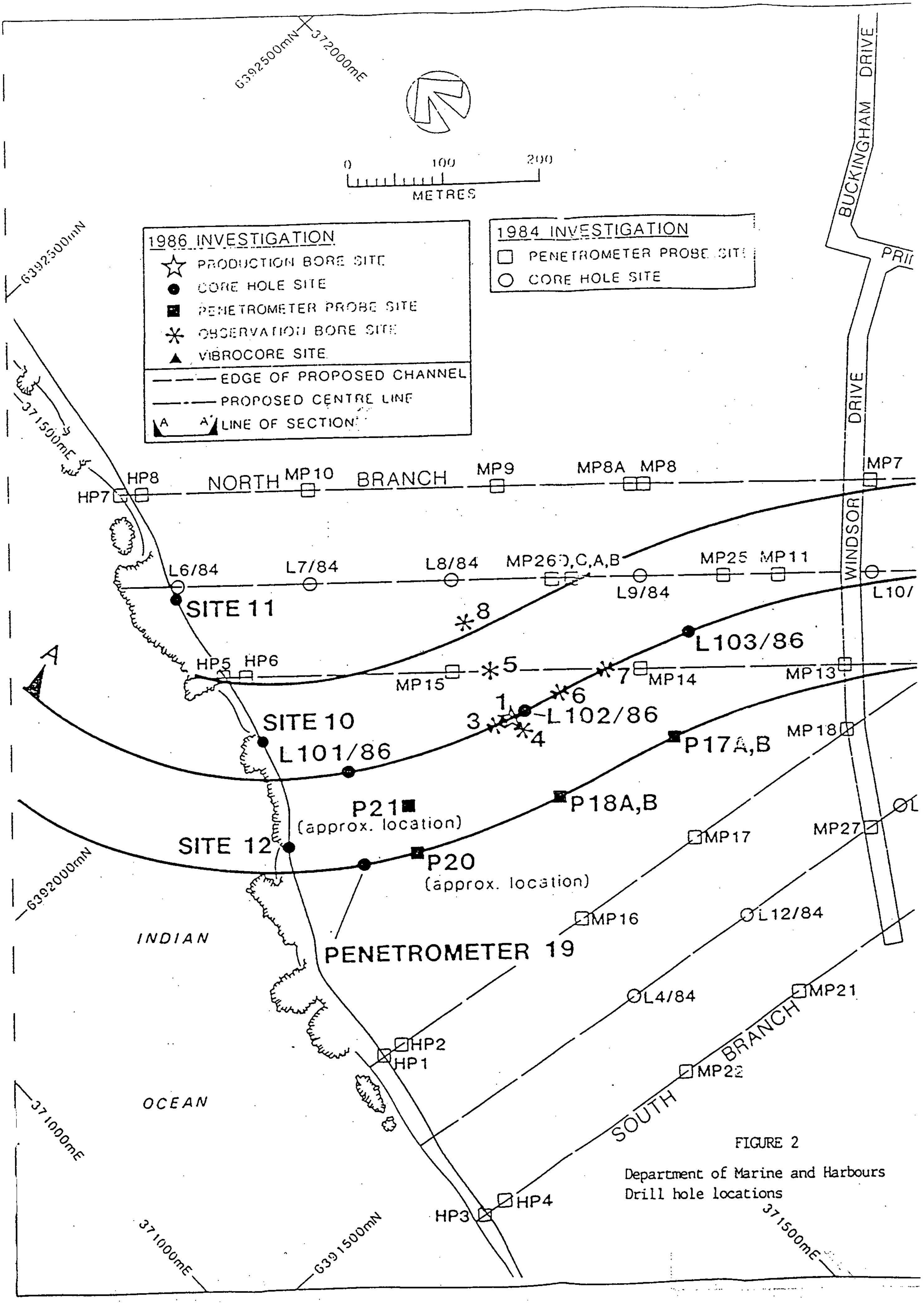
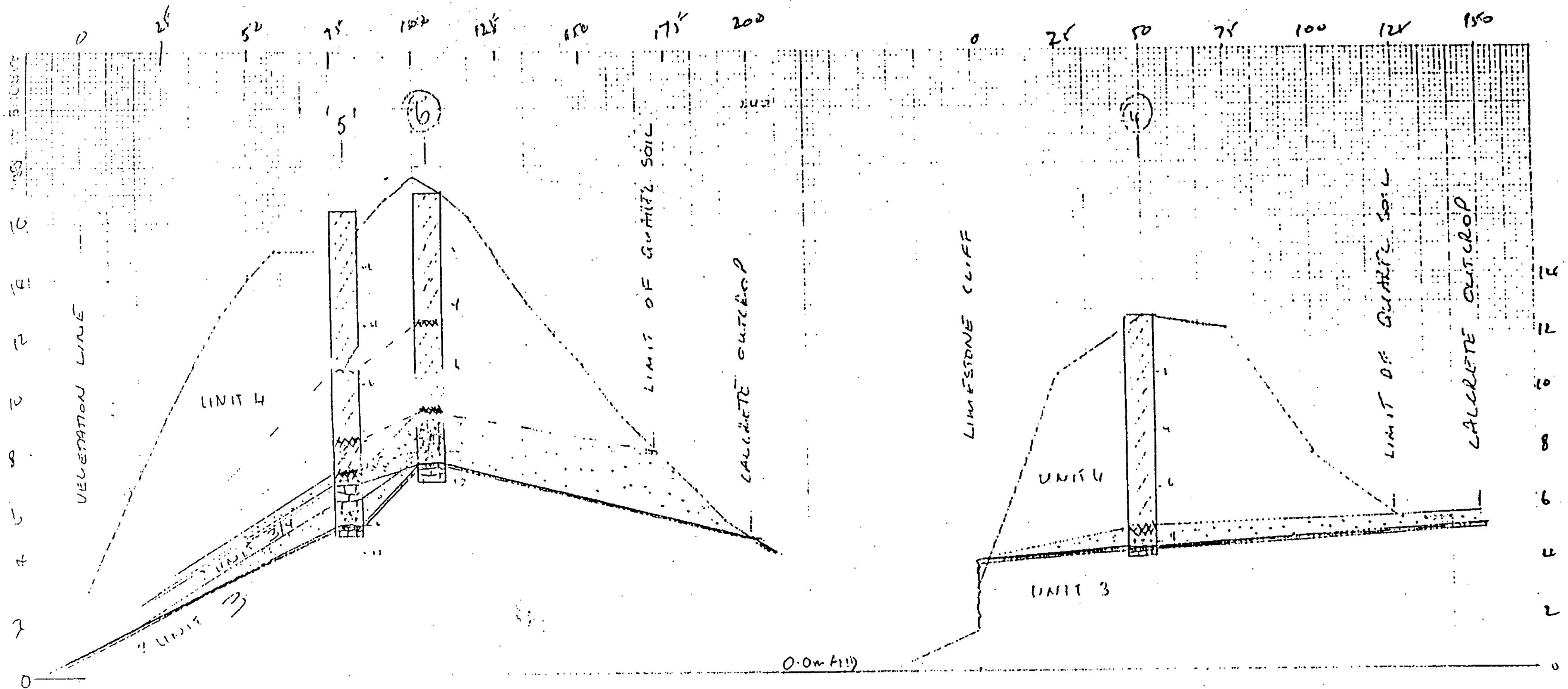
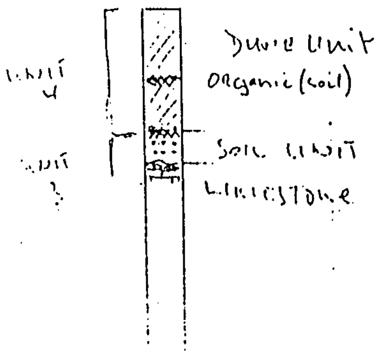


FIGURE 2

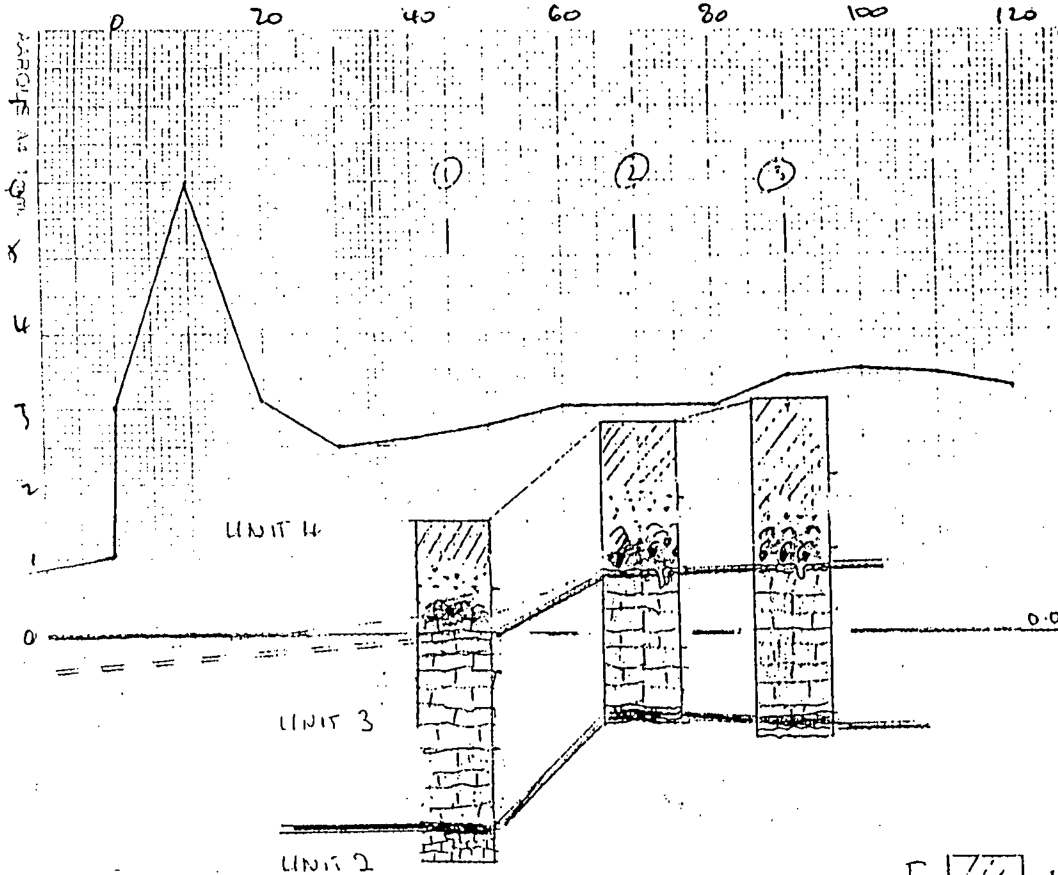
Department of Marine and Harbours
Drill hole locations



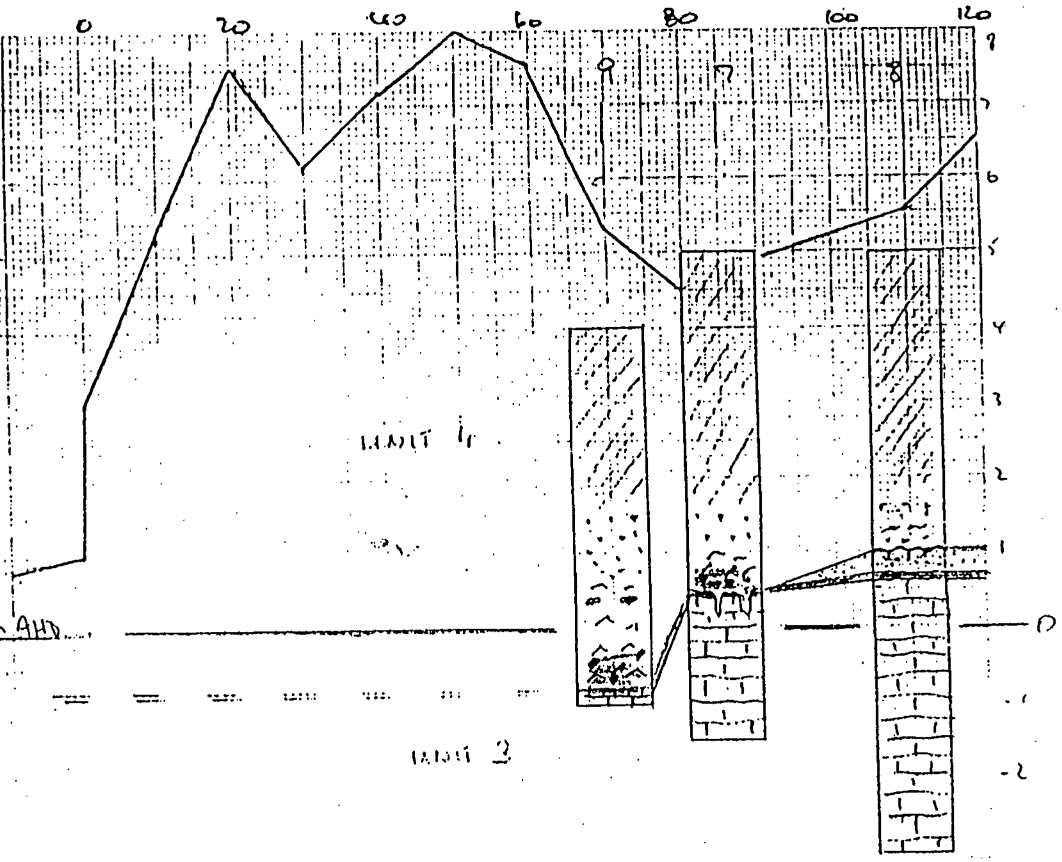
CROSS SECTION 1



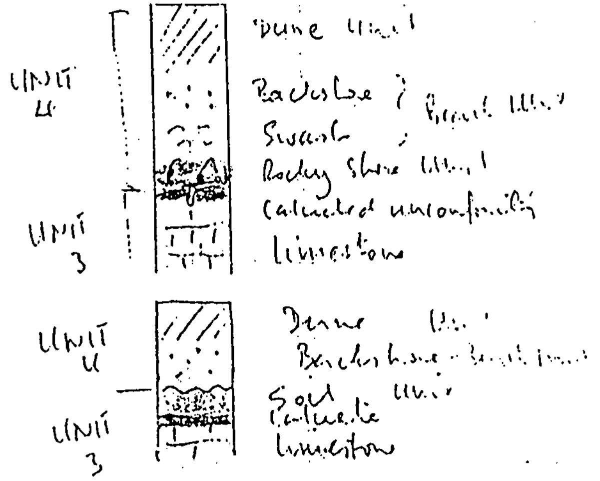
CROSS SECTION 3.



CROSS SECTION - 4



CROSS SECTION 5



Port Bouvard
Coastal and Hydraulic Engineering Study

Prepared for
Wannunup Development Nominees Pty Ltd

Prepared by: Michael Rogers
Reviewed by: Steve Buchan

Steedman Science & Engineering
July 17, 1992
Job No. C1350
Report No. R556
Copy No. **12**

STEEDMAN SCIENCE & ENGINEERING
A Division of Oceanroutes (Australia) Pty Ltd
A.C.N. 008 885 998

31 Bishop Street, Jolimont, Western Australia, 6014
Ph. (09) 387 7955, Telex AA93934, Fax (09) 387 6686

July 17, 1992

CP Developments Pty Ltd
C/- Development Strategies International Pty Ltd
62 Colin Street
WEST PERTH WA 6005

Attention: Mr Ed Turner

Dear Sir

PORT BOUVARD
COASTAL AND HYDRAULIC ENGINEERING

As per your letter of March 16, 1992 we have prepared the attached 3 unbound copies of our report R556 titled "Port Bouvard, Coastal and Hydraulic Engineering Study" for your use in the PER.

We have sent bound copies of the report to both Mr Merv Warren of Wannunup Development Nominees Pty Ltd and Mr Erwin Roberts of Fielman Planning Consultants.

If you have any queries on this work, please do not hesitate to contact us.

Yours faithfully
STEEDMAN SCIENCE & ENGINEERING

M P Rogers

Michael Rogers
Manager, Coastal & Ocean Engineering

MPR:CEW:C1350:92426

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF APPENDICES

Appendix 1	Water Quality Criteria for Beneficial Uses Nos. 1 and 3, taken from Bulletin 103, Department of Conservation and Environment, 1981.
Appendix 2	Groundwater report by Dames and Moore.

1. INTRODUCTION

Over the past 20 years the Peel Harvey Estuarine System has suffered significant biological deterioration. This has been due to excessive algal growth that has been linked to the high levels of nutrients in the inflows to the estuary. In the 1980's, the State Government completed numerous studies into the problem and possible solutions. A comprehensive review is provided in the Stage 2 Environmental Review and Management Programme prepared by Kinhill, 1988.

The Dawesville Channel was adopted by the State Government as part of the overall management strategy and is presently under construction. The channel is some 12 km south west of the City of Mandurah as shown in figure 1.1. When completed it will significantly improve the exchange of water between the Indian Ocean and the Peel Harvey Estuarine System. As outlined in the ERMP (Kinhill, 1988), the channel will not only remove nutrients from the estuarine system but also provide social benefits in the form of new recreational opportunities.

Wannunup Development Nominees Pty Ltd (Wannunup) owns a large proportion of the land adjacent to the Dawesville Channel. It wishes to develop both dry lot and canal subdivisions on this land and where practicable create a variety of recreational opportunities. The development will be known as Port Bouvard.

As part of its studies for the development, Wannunup has engaged Steedman Science & Engineering (Steedman) to investigate the following aspects.

- Water quality in the proposed canal estates.
- Stability of the ocean foreshore and recommended set back to buildings.
- Reclamation and stability of the estuary foreshore immediately north of the channel with the aim to create safe swimming beaches.
- Recommend appropriate building levels inconsideration of river flooding, ocean storm surge and possible "greenhouse" effects.

The results of this work are presented in this report.

2. WATER QUALITY IN THE PROPOSED CANAL ESTATES

2.1 General

The developer initially put forward the concept of 3 separate canal estates as shown on figure 2.1. The proposal was to develop the naturally low lying areas behind the coastal dunes, both north and south of the Dawesville Channel as well as the low lying area north of the channel adjacent to the Harvey Estuary. The canal estates were called North Port, South Port and East Port.

The proposed South Port canal estate south of the channel abuts the existing open tip used by the City of Mandurah for more than the last decade. As will be explained in section 2.3, ground water containing high levels of both nutrients and pollutants would flow from the tip area into the proposed South Port canal estate. This would result in unacceptable water quality in this canal estate and consequently, the developer amended the concept plans and deleted the proposed South Port canal estate. The development concept that is now proposed, has only the 2 northern canal estates, North Port and East Port, as shown on figure 2.2.

In line with the Recommendations for the Development of Canal Estates produced by the Steering Committee on Canal Developments, 1984, the beneficial uses of the proposed canal waterways are proposed as follows:

- occasional human immersion;
- boating;
- adjacent residential development; and
- passive recreation.

The Department of Conservation and Environment, 1981 put forward various categories of beneficial use for marine and estuarine waters of WA. The above uses are subsets of Beneficial Use No. 1 - Direct Contact Recreation. A copy of the Marine and Estuarine Water Quality Criteria for Direct Contact Recreation is included in appendix 1. In addition to these criteria, a copy of the more stringent criteria for Beneficial Use No. 3 - Harvesting Molluscs for Food has also been included in appendix 1. Except where limited by the source water, the canal waterways will be designed and managed in order to meet not only the requirements for Direct Contact Immersion but also the more stringent requirements appropriate to Harvesting Molluscs for Food.

The resultant water quality in the canals is dependent upon the following:

- the quality of the source water;
- the management of nutrient and pollutant inflow; and

- the mixing and exchange processes.

Each of these items and the resultant canal water quality will be discussed in the following sections.

2.2 Source Water

The source water for the proposed canal estates will be clean ocean water during incoming tides and Harvey Estuary water for outgoing tides and significant river flows. As outlined in the ERMP - (Kinhill, 1988), the outgoing water from the estuary will be a mix of the ocean water from the previous flood tide and the residual estuary water. The source water will be suitable for canal development and is expected to further improve over time because of the longer term influences of the Dawesville Channel and the catchment management strategies being implemented by the State Government.

2.3 Management of Nutrient and Pollutant Inflow

Minimisation of nutrient and pollutant inputs to the canals will be achieved by careful design and management of the water bodies. The design elements comprise the following.

- The site selection will avoid inflow of polluted groundwater from the tip site.
- The development will be serviced with a reticulated sewerage system.
- All road runoff will be collected and allowed to soak into the groundwater aquifer. This drainage system will have an overflow into the canals for flood events with return periods greater than 1 year.
- Only runoff from roofs will be allowed to be discharged directly into the canals.

The ongoing management of nutrient and pollutant inputs will comprise the following:

- Rubbish disposal and effluent discharge into the canal will be banned and policed by the appropriate authority.
- The use of slow release fertilizers and vegetation species that require minimal fertilizing will be encouraged.

All of these design and management features are important to minimise the inflow of nutrients and pollutants to the proposed canals. With respect to the site selection, the original proposal was to develop all 3 canal estates as shown on figure 2.1. During the initial investigations, the groundwater inflow rates and quality were estimated by Dames and Moore. Its report is included as appendix 2. It was estimated that the average groundwater inflow rates would be as follows:

*	North Port canal estate -	450 - 500 m^3 day^{-1}
*	South Port canal estate -	450 - 500 m^3 day^{-1}
*	East Port canal estate -	100 m^3 day^{-1}

In addition, the groundwater flowing into the southern canal estate would be greatly influenced by the tip site which is less than 0.5 km away. The estimated composition of the leachates from the tip is presented in table 2.1. The leachate is believed to exceed the target concentrations for primary sewers for the following items. For comparison the criteria given for Beneficial Use No. 3 - Harvesting Molluscs for Food are also listed.

Item	Tip Leachate	Beneficial Use No. 3
pH	2.5 - 7.5	6.5 - 8.5
biological oxygen demand$_5$	10,000 mg L^{-1}	not applicable
ammonia nitrogen	2,500 mg L^{-1}	600 μg L^{-1}
copper	15 mg L^{-1}	5 μg L^{-1}
lead	15 mg L^{-1}	8 μg L^{-1}
zinc	130 mg L^{-1}	20 μg L^{-1}
total iron	400 mg L^{-1}	not given
sulphate	900 mg L^{-1}	not given

The tip leachate concentrations are expressed in mg L^{-1} (one-thousandth of a gram per litre) and the Beneficial Use in μg L^{-1} (one millionth of a gram per litre). Consequently dilutions in the order of 2,000 to 10,000 would be required to make the tip leachate acceptable in the canal water body, This magnitude of dilution is not attainable without extraordinary mechanical effort. Such mechanical assistance is not practicable for these sorts of developments.

Another approach to this issue would be to use flow minimisation techniques such as barrier membranes and capping of the tip site. These were briefly assessed to be very expensive and not without attendant risks. Given the above, the developer decided to delete the South Port canal estate from the development concept and adopt the configuration shown in figure 2.2.

Another potential source of nutrients and pollutants would be from vessels using the canal estates. There would be inputs of copper from the antifouling paints, a variety of nutrients and pollutants from bilge water and oils, fuels and greases from maintenance and refuelling activities.

In 1991, a new regulation was added under the Environmental Protection Act of WA that now totally prohibits the use of Tributyl Tin Oxide antifouling paints on vessels less than 25 m in length. Consequently, virtually all antifouling paints now used on vessels less than 25 m contain copper as the toxin.

The amount of copper released from well maintained antifouling paint for pleasure craft has been estimated to be in the order of 5 to 10 $\mu g/cm^{-2}/day$ (Taubman Australia, pers comm). On the basis of the typical vessel being a power boat 10 m long, the average daily release of copper is estimated to be in the order of 0.5 to 1.0 g per boat. Given the large volume of water in the canal estates and good mixing and exchange characteristics, this is a manageable load.

Bilge water would not be permitted to be discharged into the canals. Nevertheless it is reasonable to anticipate a small amount of leakage and some infrequent accidental discharge. This is normal for any marine facility. The composition and discharge rate of bilge water varies greatly from boat to boat, region to region and season to season.

Public Works Department-NSW, 1987 presents a reasonable analysis of the impact of bilge water. Table 2.2 has been prepared on the basis of this analysis. This table shows that the leakage and accidental discharge of bilge water accounts for only minor inputs of nutrients and pollutants into the canal. With good mixing and exchange characteristics, these levels are readily manageable.

Inputs of oils, fuels, and greases into the canal waters would occur primarily as minor accidents during refuelling and maintenance activities. Although hydrocarbons can be quite toxic to marine organisms, there has been virtually no reported problems in the existing canal developments at Mandurah. This is probably due to the following factors.

* Spillage is believed to be very small, probably less than 20 mL during most refuelling or maintenance operations.

* Only a small proportion of vessels would be refuelled or maintained in the canals, and such activities would be infrequent.

* Fuels are very volatile and quickly evaporate so there is little chance for the soluble portions to enter the water in large concentrations.

Given the above, and good water mixing and exchange, hydrocarbons would not be present in concentrations greater than the recommendations for Beneficial Use No. 3 except in significant accidents which would rarely occur.

2.4 Water Mixing and Exchange

The canal water bodies will be mixed by winds, waves, advecting currents as well as boat traffic. All of these would ensure that the canal waters are regularly mixed.

There are several mechanisms that will cause water exchange between the canals and the source waters (the ocean and the Harvey Estuary). The dominant mechanisms are:

- wind induced currents; and
- density currents.

Secondary mechanisms are:

- astronomical tidal fluctuations;
- meteorological effects on water levels; and
- groundwater inflow.

All of these mechanisms will be discussed in the following sections.

2.4.1 Wind Induced Currents

Winds blowing over closed-end canals are known to create water motions that are important for water mixing and exchange. McKeehan, 1975 specifically studied the effects of wind on water motion in canals. This work included a theoretical approach as well as presenting extensive measurements taken in existing residential canal estates. This study shows that wind blowing over a closed-end canal water body causes:

- a slope of the water surface, raising the level at the down-wind end of the canal; and
- down-wind water motion in the upper levels of the water profile and a reverse motion in the bottom layer.

These features are shown on figure 2.3. The expression for the water velocity as a function of depth and surface velocity was given as:

$$U(z) = U_s\,(1-4z/h + 3(z/h)^2) \qquad (2.1)$$

where $U(z)$ = water velocity at depth z

U_s = water velocity at the surface

z = distance below the surface

h = the total depth of water.

The water flow at the surface is usually taken to be in the range of 2 to 5% of the wind speed, refer to Wu, 1973, Bishop, 1979 and McKeehan, 1975. The above suggests that the water speed decreases rapidly with depth and reaches zero at about ⅓ of the total depth. Underneath this level there is the reverse flow in order to satisfy the conservation of mass law.

Fortunately there have been good quality wind records taken at Mandurah from 1965 to 1985. As there is a significant "sea breeze" effect in the region, the Bureau of Meteorology took a recording each morning at 9:00 am and a second in the afternoon at 3:00 pm. These data have been separated into the four seasons and a separate wind rose produced for each of the morning and afternoon readings. The 8 wind roses are presented as figures 2.4 to 2.11.

Figures 2.4 and 2.5 are for summer. In the summer mornings the winds come from the easterly quadrant about 50% of the time with speeds in the range of 5 to 30 kph. Typically the speeds would be 10 kph. For 25% of the time the summer morning winds come from the south and southwest. Again the typical speed is 10 kph.

In the summer afternoons the pattern is significantly different with over 55% of the winds coming from the south and southwest. The wind speed tends to be marginally stronger with typical values of 10 to 20 kph. For about 20% of the time the wind speed comes from the southeast of east, with speeds typically 10 kph.

The wind roses for other seasons show different patterns but do show that the most common wind directions are along the southwest/northeast and east/west axes.

The canals have been aligned to take full benefit of these wind patterns. During southerly winds, the winds will flow along the main canals which are oriented north northeast/south southwest. Local topography effects and the layout of the buildings along the canals will ensure that the southerly winds funnel down the main canals causing strong wind-induced currents and associated water exchange with the source water.

The secondary or branch canals have been aligned east/west to take full advantage of the easterly and westerly winds. These winds will funnel down the secondary canals and cause good water exchange between the secondary canals and the main canals.

These commonly occurring winds are important in the exchange of water between the canal water body and the source water. Using the method outlined in McKeehan, 1975 and equation 2.1 above it was calculated that a wind of 10 kph would cause the top one-third of the water column to move at an average of 0.04 m s^{-1}. This would be accompanied by a return flow of equal mass in the bottom two-thirds column. This is shown diagrammatically in figure 2.12 for southerly winds.

As the main canals are about 800 m long, the wind-induced current of 0.04 m s^{-1} in the top third of the water column would take about 5 to 6 hours to travel the length of the main canals. This would result in exchange of about one-third of the volume of the main canals with the source water. Such a scenario would be representative of the sea breeze events experienced during most summer afternoons.

2.4.2 Density Currents

In the ERMP (Kinhill, 1988) it is predicted that the Harvey Estuary will be less saline than the ocean during winter and early spring. During these seasons the water from the Harvey Estuary is predicted to have salinities in the range of 15 to 25 p.p.t. Under these conditions it would be possible to have the canals full of ocean water at 35 p.p.t. at the start of the ebb tide and during the ebb tide, the less saline and less dense Harvey Estuary water would flow past the canal entrances. Provided there are not mechanisms to suppress vertical stratification (e.g. strong winds), then density currents may form and cause exchange of canal waters.

McKeehan, 1975 and Turner, 1973 provide a description and calculation methods for density or gravity currents. Figure 2.13 shows the mechanisms for mutual intrusion of fluids of different densities.

McKeehan, 1975 gives the speed of the advancing front as follows.

$$U_f = 0.46 \left[\frac{\Delta\rho g h}{\bar{\rho}} \right]^{1/2} \qquad (2.2)$$

where U_f = speed of the advancing front

$\Delta\rho$ = the difference in density of the two fluids

$\bar{\rho}$ = the near density of the two fluids

g = the acceleration due to gravity

h = depth of the water column.

For a difference in the salinity of 15 p.p.t. the $\Delta\rho = 10.7$ kg m^{-3}. Such a difference would cause the fronts to advance at $U_f = 0.26$ m s^{-1}. This would cause 50% of the canal waters to exchange about 1 hour and total exchange in about 2 hours.

From this analysis it can be seen that density currents can be a very powerful exchange mechanism. Unfortunately they are only likely to exist during winter and early spring and could be readily suppressed by strong winds.

2.4.3 Astronomical Tidal Fluctuations

Steedman Limited, 1986, took tidal measurements in the ocean near Dawesville from early September 1985 to early January 1986. Figure 2.14 shows the measured tidal level, the predicted astronomical tidal level and the residual. The residual is the difference between the measured tide and the predicted astronomical tide.

As shown in figure 2.14, the tides at Dawesville are diurnal and have a daily range of about 0.3 m during neap tides and about 0.6 m during spring tides.

Dufty, 1983 numerically modelled the hydraulic effect of the Dawesville Channel and predicted that the Harvey Estuary adjacent to the channel would experience about 70% of the daily tidal range of the ocean. It should be noted that this level of daily tidal fluctuation would not necessarily be felt further away from the channel.

The consequence of this is that the North Port canal estate would experience the full diurnal ocean tide and the East Port canal estate would experience an attenuated diurnal ocean tide. Dufty, 1983 suggests that it would be about 70% of the daily tide range. The anticipated astronomical tidal daily ranges are as follows.

Tidal Cycle	Daily Tidal Range (m)	
	North Port	East Port
Neap Tides	0.3	0.2
Spring tides	0.6	0.4

This indicates that the typical daily fluctuation in canal water levels would be about 0.3 m or greater.

The tidal prism ratio (TPR) is defined as the ratio of the volume of tidal flow entering the waterway from low to high tide to the total volume of water in the waterway. For the proposed developments the tidal prisms ratio has been calculated to be about 15% for a 0.3 m tidal range.

Falconer, 1980 indicates that under some conditions not all of the incoming source water mixes with the canal water. The geometry can have a significant effect on the efficiency of mixing and exchange. Falconer, 1980 defines an exchange coefficient as follows.

Exchange coefficient = Tidal prism ratio x Efficiency coefficient.

Based on work by Falconer, Nece, et al, 1976 the "Efficiency coefficients" in table 2.3 were estimated for various parts of the canals. These factors have then been multiplied by the typical tidal prism ratio of 15% to obtain an estimate of the daily tidal exchange caused by the astronomical tides alone.

Locations 1 to 4 in table 2.3 are shown on figure 2.15. Table 2.3 shows that the astronomical tide is expected to have a good flushing effect for the canal entrances as well as the proposed DMH marina in East Port. Unfortunately the astronomical tide is expected to cause little flushing of the northern portions of the canals.

2.4.4 Meteorological Effects

Long period water level variations are commonly experienced along the southwest coast of Western Australia. Provost and Radok, 1979 studied these variations by removing the astronomical tide from water level records taken at Fremantle. The resultant residuals were water level fluctuations with periods of 1 to 20 days (typically 3 to 10 days) and 20 to 265 days (seasonal fluctuations). The 3 to 10 day fluctuations can be seen in the plot of residuals shown on figure 2.14.

Several factors are believed to cause these long period water level fluctuations. They include the following:

* response to high and low pressure synoptic features moving from west to east across the Indian Ocean and Australia at intervals of 3 to 10 days;

* wind and wave setup from storms moving across the coast at intervals of 3 to 10 days during winter;

* oscillations of the water over the shallow continental shelf.

In order to roughly gauge the effect of these long period fluctuations a typical height of 0.2 m and a period of 7 days will be taken. Because the incoming source water has a long time to mix with the canal water body, this mechanism is very efficient and the entire "meteorological tidal prism ratio" will be effective water exchange. This has been calculated to be an exchange about 10% of the canal volume and would occur about every 7 days. This is a persistent mechanism that would occur throughout the year. Consequently it is an important adjunct to the other mechanisms.

2.4.5 Groundwater Inflow

Canals and marina with significant inflows of less saline groundwater can experience significant water flushing due to density currents. As outlined in the Dames & Moore report in appendix 2, there is expected to be only small inflow of groundwater to the proposed canals. The estimated inflow rates for North Port and East Port are only 500 and 100 m^3 day^{-1} respectively. These are too small to cause a major water exchange mechanism. Nevertheless, they will add a minor contribution to the flushing of the canals.

2.5 Resultant Water Quality

As outlined in the previous sections the canals have been designed and will be managed to achieve minimal inflow of nutrients and pollutants. Of the various sources of nutrients and pollutants the only significant inflows would come from the antifouling treatment on the boats and severe but infrequent accidents which may release fuel and oil.

It was estimated that the typical 10 m boat would probably release about 0.5 to 1.0 g day^{-1} of copper from its antifouling treatment. East Port would have the higher density of boats. The DMH marina would have up to 70 boat moorings and there would be about 170 canal lots each with a mooring. Even with 100% occupancy, which is unlikely to occur, the inflow of copper would be about 120 to 240 g day^{-1}. As there would be a good distribution of the load, it is reasonable to assume that it would be well mixed throughout the entire waterway volume. The volume of water has been estimated to be about 430 x 10^6 L. Consequently the daily inflow of copper would equate to a concentration of about 0.3 to 0.6 $\mu g\ L^{-1}$.

The water quality criteria for Beneficial Use No. 3 requires that the 6 month median concentration be less than or equal to 5 $\mu g\ L^{-1}$. Even with no flushing it would take about 10 days to reach the limiting concentration. However, as outlined in section 2.4, the DMH marina and East Port canals would have significant and persistent flushing. The estimates of flushing are summarised below.

Mechanism	Water Exchange	
	% of Canal Water Volume	Time Scale
Strong winds along the canals	10 to 30%	< 1 day
Density currents during low winds in winter and early spring	100%	<< 1 day
Astronomical tidal effects at northern end of the canals	< 1%	1 day
Meteorological tidal effects at northern end of the canals	10%	5-10 days
Groundwater inflow	minor	1 day

Given these good flushing characteristics and a daily input of 0.3 to 0.6 $\mu g\ L^{-1}$ of copper, the resultant concentration of copper is anticipated to always be less than 2 $\mu g\ L^{-1}$. This is substantially below the acceptable limit of 5 $\mu g\ L^{-1}$. Consequently the water quality in the canals will be better than the limits set down in Beneficial Use No. 3 - Harvesting Molluscs for Food.

3. OCEAN SHORELINE STABILITY AND RECOMMENDED SET-BACK FOR DEVELOPMENT

3.1 Description of the Ocean Beaches

The ocean beaches either side of the Dawesville Channel are generally narrow sandy beaches between a rocky shore and well vegetated and high primary sand dunes. These dunes are generally 15 to 20 m high. About 1 km north of the Dawesville Channel is the sandy embayment at Avalon. This beach is backed with well vegetated sand dunes 6 to 8 m high. These features are shown on figure 3.1.

Various boreholes were drilled in the 1980's as part of the engineering investigations for the Dawesville Channel. Woods, 1992 reports on the relevant results of these boreholes together with additional boreholes drilled in June 1992 as part of this present study. Figures 3.2 and 3.3 have been taken from this report and show the geological cross sections through the common situation with the 15 to 20 m high dunes and a section through the sandy beach in the Avalon embayment. Both sections show the presence of significant pre-holocene limestone units. Figure 3.4 has photographs of the limestone (Unit 3) outcropping from the high dunes and the limestone (Unit 2) outcropping as the rocky shore.

The presence of these limestone units will significantly restrict any extensive erosion of this entire shoreline.

3.2 Historical Records

There are two reliable sources of historical record on the stability of the ocean shoreline at Dawesville. One source is the coastline movements plan, DMH 067-5-1 produced by DMH. This plan has been reproduced as figure 3.5. It shows the waterline and the vegetation line plotted from aerial photographs taken in January 1955 and December 1982. The plan shows the extensive nearshore reef along the coast near the Dawesville Channel. In addition it indicates that the coast about 800 m either side of the channel has been very stable over the 27 year period between photographs. The movement of the vegetation and water lines was virtually nil. This is undoubtedly due to the extensive presence of rock along this shore.

To the north, the sandy embayment at Avalon has experienced some movement. The main vegetation line has retreated about 10 m over the 27 years. However, the water line has advanced some 30 m over the same period. This accretion is confirmed by the presence in 1982 of light vegetation west of the water line of 1955. It would be possible that there had been periods of both erosion and accretion in this embayment over the 27 years. Significant erosion events such as Cyclone Alby in 1978 could have caused the retreat of the vegetation line between 1955 and 1982. Subsequent accretion could have occurred causing the westerly movement of the water line and the presence of the light vegetation in 1982.

The other source of information is the surveys of High Water Mark (HWM) taken in March 1909 and February 1992. The earlier survey was taken as part of the regional cadastral surveys. The later survey was taken by McMullen, Nolan and Partners as part of the present studies. The results of both HWM surveys are plotted on figure 3.6.

With HWM surveys there is only limited accuracy as the actual HWM is selected by the surveyor of the day. Given that there is likely to be seasonal variations in HWM, it is likely that the HWM lines are only accurate to ±10 m. Nevertheless, figure 3.6 does indicate that this coastline has been basically stable over the 83 years between surveys.

The indication is that most of the coastline had little movement or small accretion. The largest indicated retreat of the HWM is in the sandy embayment at Avalon. Here the two surveys indicate a retreat of 30 to 40 m. This is quite contradictory to the DMH shoreline movement plan.

Considering all of the historical evidence it would seem likely that this sandy embayment experiences cycles of erosion and accretion. The amount of fluctuation appears to be up to 30 to 40 m.

3.3 Longshore Drift

As part of the investigations into the Dawesville Channel, DMH studied the coastal processes along the coastline at Dawesville, refer DMH 1987. This work showed that the area is subjected to moderately high wave energy that is attenuated to some extent by offshore reefs.

The above study included a review of the following features along the coastline between Bunbury and Mandurah:

* analysis of aerial photographs;
* field inspections;
* DMH shoreline movement plans;
* detailed aerial photogrammetry;
* suspended sediment measurements;
* mathematical modelling of sediment movement along the shore;
* the behaviour of the Mandurah Ocean Entrance.

This work provided a range of estimates of the longshore drift at Dawesville. DMH adopted a value of 80,000 m^3 $year^{-1}$ for average conditions with the expectation that the actual amount may vary from season to season and year to year. Using this figure, DMH developed the concept of sand bypassing system to avoid any siltation problems at the ocean entrance of the Dawesville Channel and maintain the down drift beaches to the north.

In the ERMP (Kinhill, 1988) it was stated that:

> "As the bypassing system would simulate the natural passage of littoral drift, it is not anticipated that there would be adverse effects on beaches to the north and south of the channel entrance".

Most of the beaches north of the Dawesville Channel have a protective rocky base that can be exposed by winter storm activity. However, the sandy embayments, such as at Avalon, don't have such effective protection and are subject to a greater amount of seasonal fluctuation. These sandy embayments would quickly show the deleterious effects of ineffective or partial sand bypassing at the Dawesville Channel. To avoid such an adverse impact it is essential that the sand bypassing system at the Dawesville Channel be designed and operated in a way that bypasses all of the littoral drift.

3.4 Recommended Set-back to Buildings

The ocean foreshore has been studied and assessed to be generally quite stable. The historical evidence consistent of the following:

- shoreline movement plans prepared by DMH based on aerial photographs taken in 1955 and 1982; and
- HWM surveys in 1909 and 1992.

Both data suggest a generally stable coastline but with some fluctuations in the embayment at Avalon. This is supported by the coastal engineering assessment and by the fact that a large proportion of the shoreline in question has natural protection in the form of extensive rock on the beach. The natural protection is in fact generally more extensive as the higher primary dunes have substantial areas of limestone to generally 2 to 2.5 m above the AHD and the lower dunes at the Avalon embayment have limestone to AHD only 40 to 60 m from HWM.

In the ERMP (Kinhill, 1988) it was stated that the littoral drift along the beach would be trapped and mechanically bypassed across the Dawesville Channel. Provided that the bypassing is suitably designed and managed, there is not expected to be adverse impacts on the beaches to the north of the Dawesville Channel. Naturally, there will be seasonal and interannual changes on the beaches. However, provided there are adequate buffers there would be no impact on buildings in the development.

In view of the above assessment, the proposed development line is generally 100 m behind the vegetation line. To the north of the proposed development, the setback has been proposed to marry up to the existing development at Avalon Beach. Nevertheless, the minimum building setback is 70 m which would be adequate on this coast.

4. ESTUARY SHORELINE AND RECOMMENDED RECLAMATION AREA

In the ERMP (Kinhill, 1988) there was significant emphasis placed on the recreational opportunities which would result from the construction of the Dawesville Channel. The developer wishes to pursue these opportunities to create the best possible water based recreation facilities.

Presently, there are only limited and modest swimming beaches in the district near the Dawesville Channel. The South West Development Authority, the Department of Planning and Urban Development and the City of Mandurah have jointly funded a study into the issue of recreational beaches in the area. With the increased population resulting from the proposed development there will be increased demand for good, safe swimming beaches. This demand would come from local residents and the numerous visitors that would be attracted to the area.

Unfortunately, much of the ocean coastline is not suitable for swimming because of the presence of rock and nearshore reefs coupled with reasonably high levels of wave energy. The best swimming beach would be the sandy embayment at Avalon. Realistically there is little scope for improving the remaining beaches. With this in mind, the estuary shoreline was examined. The estuary shoreline immediately north of the Dawesville Channel is ideal from planning and water quality points of view to create safe beaches for swimming, wading and windsurfing in addition to passive recreation.

As shown in figure 3.1 this area has substantial and very shallow sand and mud flats that widen to the north. The bathymetry of the area is shown on figure 4.1. To the north, the -0.5 m AHD contour is about 200 m from the current shoreline.

As part of the DMH engineering investigations into the physical effects of the Dawesville Channel, numerical modelling of the hydraulics was done. Some of the work is reported in Dufty, 1983. Figure 4.2 has been taken from this report. This clearly shows that the Dawesville Channel will have a significant impact on the daily tidal range experienced in the Harvey Estuary. The biggest changes will be experienced in the areas nearest to the channel.

During summer, it is expected that about half of the time the water level would be -0.2 m AHD or lower. There would also be many episodes when the water would be 0.5 m or more below AHD. This would result in the mud flats being totally exposed for 150 to 200 m. In addition there would be a further 200 to 500 m of mud flat with less than 0.5 m of water at low tide. These areas are shown on figure 4.3.

In order to create useable swimming beaches it is essential to reclaim some of the mud flat area. The proposed reclamation is shown on figure 4.4. The proposed reclamation widens to the north to follow the general shape of the mud flats. Such reclamation would create about 1 km of safe swimming beaches.

Naturally, it is important to ensure that the resultant beaches are stable. The wind patterns and fetches for wave generation are such that some seasonal fluctuation would be inevitable. Nevertheless, by providing two headlands and orientating the beaches to face the dominant southerly wave direction the beaches would be stable. These features are shown in figure 4.4. The two headlands could be made using small rocks or the pine pole walling commonly used by the Peel Inlet Management Authority.

The proposed reclamation would enable the creation of safe swimming beaches that could form an important part of the recreational facilities of the Dawesville Channel area.

5. RIVER FLOOD AND STORM SURGE LEVELS AND RECOMMENDED MINIMUM BUILDING LEVELS

5.1 Possible Greenhouse Effects

Although the so called "Greenhouse Effects" receive much publicity there is still no definitive evidence available that proves that the Greenhouse changes are occurring or will occur. There is certainly clear evidence that the amount of Carbon Dioxide and other "Greenhouse Gases" has increased dramatically over the last century and is continuing to rise. However, the link to global warming and associated sea level rise is still largely based on predictive numerical models of the global atmospheric and oceanic processes. These general circulation models are currently run on coarse grids and have rather rudimentary treatment of ice melting, cloud cover and albedo feed back links and impacts. Pielke, 1991 presents a good review of the scientific uncertainty with the present "Greenhouse" predictions.

Some of the possible impacts on the southwest coast of WA of Greenhouse Gas Warming could be:

- increase in cyclone frequency;
- increase in sea level; and
- change in position of synoptic features causing a changed wave climate.

The current knowledge about such possible changes is extremely limited. This coupled with the uncertainty about Global Warming, has lead to many organisations and authorities to take a low key approach to the issue until more definitive proof is available.

The Institution of Engineers, Australia 1991, put forward a draft document for assessing the impacts of possible climate change on coastal engineering projects. The paper is aimed at ensuring that a responsible review of the possible impacts is made. Designs should be robust and minimise future risk. This document does not say that climate change will happen but merely it may happen and engineering design should take this risk into consideration.

The issue of minimum building levels for the proposed developments is fundamentally linked to the mean sea level. The Institution of Engineers, Australia, 1991 presents three scenarios for possible (not necessarily probable) changes in the Global Mean Sea Level. These are reproduced in table 5.1. Considering the uncertainty of these scenarios, the design life of buildings and the frequency and impact of flood inundation, it is appropriate at this stage to make an allowance of 0.3 m for the affects of the possible climate change. This is believed to represent a reasonable compromise between present day costs and future risk.

5.2 River Flood Levels

Public Works Department, 1984 presents calculations of river flood levels in the Peel/Harvey Estuary System with the existing catchment and ocean outlet conditions. The 100 year return period river flood level was calculated to be 1.6 m AHD in the estuary. One of the studies in the investigation of the Dawesville Channel examined the effect of the proposed channel on flood levels in the estuary. Dufty, 1983 calculated that the Dawesville Channel would reduce the 100 year return period river flood level in the estuary by 0.35 m.

Given the above, the appropriate minimum floor level for buildings near the Harvey Estuary end of the Dawesville Channel is estimated as follows:

Existing 100 year river flood level	+ 1.60 m AHD
Reduction due to Dawesville Channel	- 0.35 m
Climate change allowance	+ 0.30 m
Freeboard for wind and wave set-up, seiching and wave run up, etc	+ 0.40 m
Recommended Minimum Floor Level	= 1.95 m AHD

The recommended minimum floor level for permanent buildings near the Harvey Estuary end of the Dawesville Channel is 2.0 m AHD.

During this extreme river flood event the ocean end of the Dawesville Channel would be controlled by the water level in the adjacent ocean and not the estuary level. The ocean water level is likely to be less than 1.0 m AHD.

5.3 Ocean Storm Surge

Given the proximity of Dawesville to Fremantle and the similar offshore bathymetry, it is reasonable to use the extensive storm surge record available at Fremantle for estimating the ocean storm surge versus return period at Dawesville.

The measured ocean water levels or "tides" consist of the sum of deterministic astronomical tides and non-tidal residuals due to other effects including long waves and storm surges. The astronomical tide can be decomposed using harmonic analysis techniques into tidal constituents, each possessing a distinct amplitude, frequency and phase.

Tide measurements have been taken by the Fremantle Port Authority for over 90 years, However, accurate tide data are presently only available from March 1967. These data are to an assured datum of 0.756 m below AHD.

Using the calculated tidal constituents, astronomical tidal predictions for Fremantle have been done by the Tidal Laboratory of the Flinders Institute for Atmospheric and Marine Sciences (FIAMS). The predicted astronomical tides have been subtracted from the total measured water levels to give "residual tides" which include any storm surges. These were supplied by FIAMS for the 17 year record 1967 to 1981 and 1984 to 1985. The 17 years of tide height residual for Fremantle Harbour represents combined wave setup, storm surge and the effect of any flooding due to the outflow of the Swan River into the harbour. The effect of flooding is believed to be minor due to the closeness of the harbour to the ocean. The 17 years record includes Tropical Cyclone Alby in April 1978 with an estimated surge of 1.0 m.

Extreme surges corresponding to return periods up to 100 years have been estimated using the technique of Petrauskas and Aagaard, 1971. Extreme values were obtained in the following way; a threshold of 0.5 m was selected and a total of 52 independent surge events exceeding this level were identified from the 17 year record. A Weibull distribution was then fitted to the exceedence probabilities associated with the 52 surge values.

Return period storm surge values are shown on table 5.2 and figure 5.1. It should be noted that these values do not include an allowance for wave runup which is dependent on the size of the wave and the nature and slope of the surface that the wave is impinging upon. Finally it is noted that generally, reliable extreme values can be obtained by extrapolation of the fitted distribution for return periods up to twice the length of the available record. Therefore, extreme values for 50 and 100 year return periods will be less certain than those for shorter return periods. The extreme surge for a 100 year return period is estimated to be 1.1 m.

Based on the above, the appropriate minimum floor level for buildings near the ocean end of the Dawesville Channel is estimated as follows:

Mean Sea Level	+ 0.0 m AHD
Climate change allowance	+ 0.3 m
100 year return period ocean surge	+ 1.1 m
Freeboard for wave runup, etc	+ 0.4 m
Recommended Minimum Floor Level	= 1.8 m AHD

The recommended minimum floor level for buildings near the ocean end of the Dawesville Channel is 1.8 m AHD. Given the fill that is available from the excavation of the Dawesville Channel and the natural topography, it would be reasonable to simply adopt a minimum floor level of 2.0 m AHD throughout the proposed development.

6. SUMMARY AND RECOMMENDATIONS

This study into the coastal and hydraulic engineering aspects of the proposed development can be summarised as follows:

6.1 Water Quality in the Proposed Canal Estates

* The existing tip south of the Dawesville Channel is a source of significant nutrients and pollutants. Because of the deleterious impact of the leachates from the tip, the South Port canal estate has been removed from the concept plans.

* The North Port and East Port canal estates have been designed and will be managed to ensure minimal inflow of nutrients and pollutants.

* The North Port and East Port canal estates will experience strong and persistent water mixing and exchange through the physical processes of :

- wind induced currents;
- density currents;
- astronomical tidal current; and
- meteorological tidal currents.

* The resultant water quality in the North Port and East Port canal estates is expected to be better than the requirements for Beneficial Use No. 3 - Harvesting Molluscs for Food.

6.2 Ocean Foreshore Stability and Recommended Set-Back for Development

* The ocean beaches near the proposed development have significant natural protection from erosion in the form of limestone beneath the sand dunes.

* The historical evidence of DMH shoreline movement plans and HWM surveys from 1909 and 1992 suggest that the coast is basically stable. Nevertheless, some fluctuations can be expected in the embayment at Avalon.

* DMH has made a commitment to mechanically bypassing the littoral drift across the Dawesville Channel to ensure that the northern beaches are not affected.

* The ocean coast adjacent to the proposed development has been assessed as being stable. The proposed development line is generally 100 m behind the vegetation line. To the north of the proposed development, the set-back to buildings is proposed to be 70 m. This is sufficient from a coastal

engineering point of view and will enable the new development to marry up to the existing development at Avalon.

6.3 Estuary Shoreline and Recommended Reclamation

* The ERMP for the Dawesville Channel highlighted that there would be opportunities for increased water related recreation once the channel was constructed.

* There are only limited safe swimming beaches in the district. The ocean beaches are restricted due to rock and nearshore reefs and the high wave energy regime.

* The estuary shoreline immediately north of the Dawesville Channel would be ideal for safe swimming beaches because of its location and anticipated water quality.

* This area of the estuary has extensive sand and mud flats that widen to the north.

* The construction of the Dawesville Channel will greatly affect the daily tidal range in the adjacent Harvey Estuary. Much of the mud flats will be dry or very shallow at low tide.

* In order to create safe swimming beaches it is recommended to reclaim and stabilise an area of the mud flats immediately north of the Dawesville Channel.

6.4 River Flood and Storm Surge Levels and Recommended Minimum Building Levels

* There is still some uncertainty about the so-called "Greenhouse Effect". No definitive evidence that it is occurring or will occur is presently available.

* An allowance of 0.3 m for possible increase in sea level has been adopted for the design of the development.

* The hydraulic effect of the Dawesville Channel will be to reduce the 100 year river flood level at Dawesville by 0.35 m.

* The extreme ocean storm surge level will be experienced all along the Dawesville Channel.

* Considering all of these issues, it is recommended that the minimum finished floor level be set at 2.0 m AHD for the entire development.

7. REFERENCES

Bishop, J.M., 1979. A note on surface wind driven flow. Ocean Engineering Vol. 6, 273-284.

Department of Conservation and Environment, 1981. Water Quality Criteria for Marine and Estuarine Waters for WA. DCE Bulletin No. 103, April 1981.

DMH, 1987. Peel Inlet and Harvey Estuary Management Strategy, Dawesville Channel engineering investigations. Department of Marine & Harbours Report No. DMH 5/88, May 1987.

Dufty, P., 1983. Modelling of the proposed Harvey to ocean channel and its effect on estuary levels and Mandurah Channel flows. Environmental Dynamics, Centre for Water Research, University of Western Australia, Paper No. WP-83-008.

Falconer, Nece, et al, 1976. Plan form influence and flushing circulation in small harbours. Proc. 15th Int. Coastal Eng. Conf., 1976.

Falconer, R.A., 1980. Modelling of plan form influence on circulation in small harbours. Proc. 17th Int. Coastal Eng. Conf., 1976.

Institution of Engineers Australia, 1991. Climate Change and Coastal Engineering Draft No. 3. National Committee on Coastal and Ocean Engineering.

Kinhill, 1988. Peel Inlet and Harvey Estuary management strategy - Environmental Review and Management Programme - Stage 2. Prepared by Kinhill Engineers Pty Ltd for the Department of Agriculture and the Department of Marine & Harbours.

McKeehan, D.S., 1975. Water motion in closed-end canals. RSMAS, Technical Report 75-1. University of Miami, USA.

Petrauskas, C. and P.M. Aagaard, 1971. Extrapolation of historical storm data for estimating design wave heights. Soc. Pet. Engr. J., Trans. AIME, Vol. 251, pp. 23-37.

Pielke, R.A., 1991. Overlooked Scientific Issues in Assessing Hypothesized Greenhouse Gas Warming. Environmental Software, 1991, Vol. 6, No. 2.

Public Works Department of Western Australia, 1984. Murray River Flood Study. ISBN 0 7244 6909 5.

Public Works Department-NSW, 1987. Environmental Impact Statement for the Proposed Rozelle Bay Marina and Bicentennial Park - Stage 1, May 1987.

Steedman Limited, 1986. Directional wave measurements offshore Dawesville, Western Australia, September 5, 1985 of January 9, 1986. Steedman Limited Report R314 prepared for the Department of Marine and Harbours, May 12, 1986.

Steering Committee on Canal Developments, 1984. Recommendations for the Development of Canal Estates.

Turner, J.S., 1973. Buoyancy Effects in Fluids. Cambridge University Press.

Woods, P., 1992. Report on drilling in the coastal zone adjacent to Dawesville Channel. Report to Quilty Environmental Consultants by Peter J. Woods and Associates, June 1992.

Wu, J., 1973. Prediction of near surface drift currents from wind velocity. ASCE HY9, September 1973.

Tables

Tables

pH^2	2.5 - 7.5[1]
BOD_5	10,000 mg/L
COD	6,000 mg/L
Total Suspended Solids	500 mg/L[1]
Total Dissolved Salts	15,000 mg/L
Organochlorine Pesticides	<0.002 mg/L[1]
Organophosphate Pesticides	<0.02 mg/L[1]
Total PAH	<0.02 mg/L[1]
Total Petroleum Hydrocarbons	<2 mg/L[1]
Ammonia Nitrogen[2]	2,500 mg/L[1]
Nitrate	370 mg/L[1]
Total Phosphorus	30 mg/L
Ortho Phosphate	20 mg/L
Alkalinity	3,000 mg/L
Total Hardness	3,500 mg/L
Copper, Lead[2]	15 mg/L
Zinc[2]	130 mg/L
Total Iron[2]	400 mg/L
Cadmium	<0.1 mg/L
Total Chromium	3 mg/L
Dissolved Manganese	<14 mg/L[1]
Arsenic	<0.01 mg/L[1]
Selenium	<0.01 mg/L[1]
Mercury	<0.1 mg/L[1]
Chloride	6,000 mg/L[1]
Sulphide[2]	900 mg/L[1]
Sodium	2,200 mg/L[1]
Potassium	1,400 mg/L[1]
Calcium	1,000 mg/L[1]
Magnesium	250 mg/L[1]
Cyanide-free	<0.1 mg/L-[1]

NOTES:
1. Based on available test data.
2. Exceeds primary sewer target concentrations.

Table 2.1 Estimated composition of leachate from the Mandurah tip (taken from the Dames and Moore report, appendix 2).

	Daily Load/boat
Bilge water discharged	2 L
Suspended solids	159 mg
Grease and oils	11 mg
Ammonia-nitrogen	1 mg
Total nitrogen	15 mg
Total phosphorous	2034 mg
Zinc	0.8 mg
Lead	0.8 mg
Copper	1.3 mg

Table 2.2 Estimated load of nutrients and pollutants discharged in bilge water.

Location	Estimated "Efficiency Coefficient"	Estimated Daily Tidal Exchange
1. Canal entrance to the Dawesville Channel	0.8	12%
2. DMH Marina	0.8	12%
3. 400 m north of the entrance	0.05	< 1%
4. 800 m north of the entrance	< 0.05	< 0.5%

NOTE: Locations 1 to 4 are shown on figure 2.15.

Table 2.3 Estimated daily tidal exchange in the canals.

Year	2030 (m)	2050 (m)	2100 (m)
Low Scenario	0.10	0.16	0.32
Medium Scenario	0.20	0.32	0.68
High Scenario	0.32	0.51	1.13

Table 5.1 Scenarios for possible rise in global sea levels due to possible climate change (taken from Institution of Engineers, Australia, 1991).

Return Period (years)	Fremantle[1] Surge (m)
1	0.62
2	0.69
10	0.86
25	0.95
50	1.02
100	1.10

NOTE: 1. Values for Fremantle are calculated from a Weibull (k = 1) distribution, following Petrauskas and Aagaard (1971). Based on 17 years of tide recorded 1967 to 1981 and 1984 to 1985.

Table 5.2 Extreme surge values for Fremantle Harbour. Surge levels for Dawesville identical. (Note, the surge is additional to the astronomical tide).

Figures

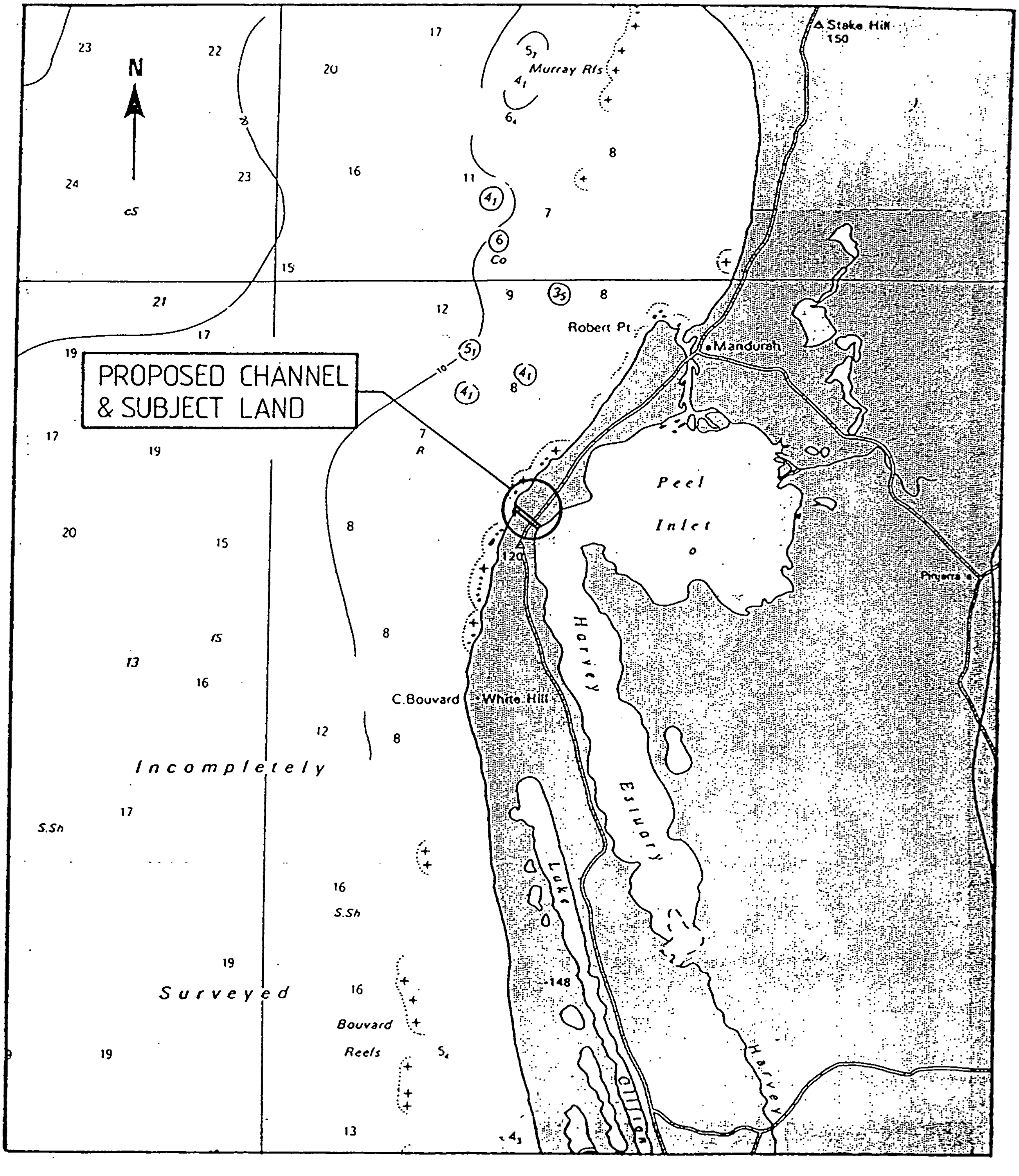


Figure 1.1 Location map.

Figure 2.1 Initial concept for 3 canal estates.

Figure 2.2 Proposed concept for 2 canal estates.

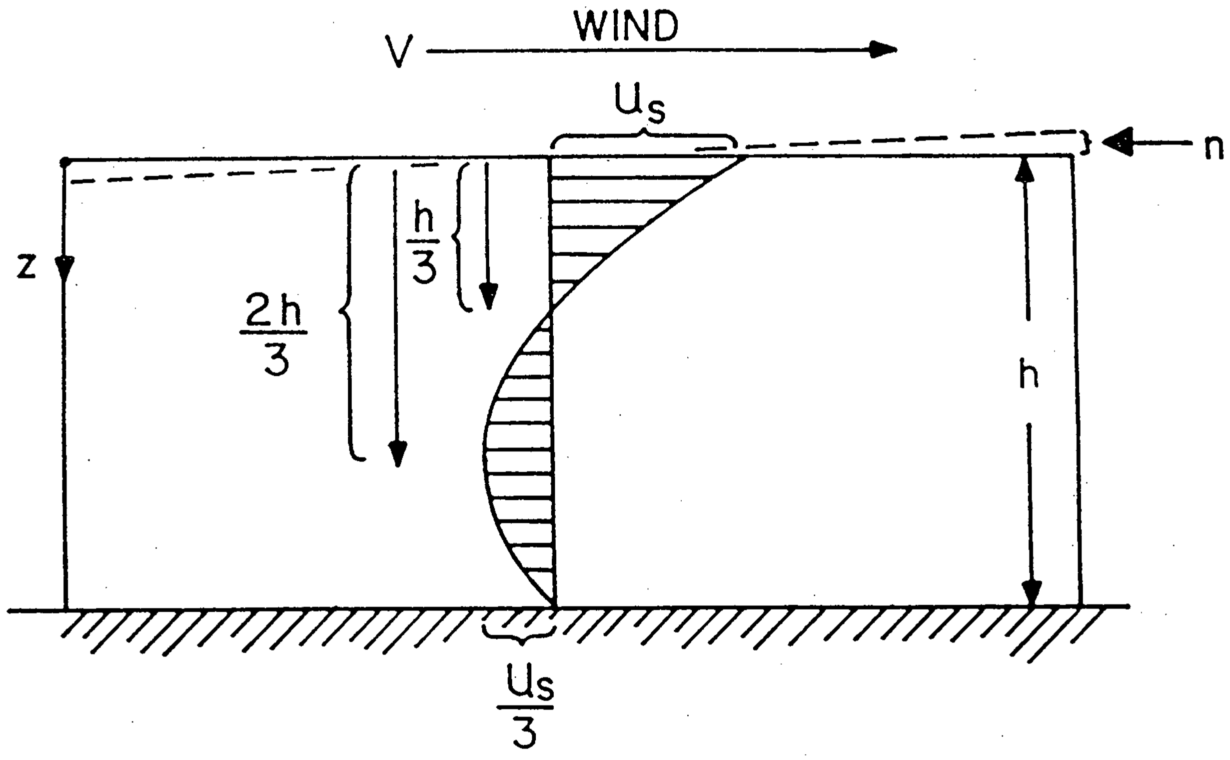


Figure 2.3 Wind induced currents in a closed end canal.

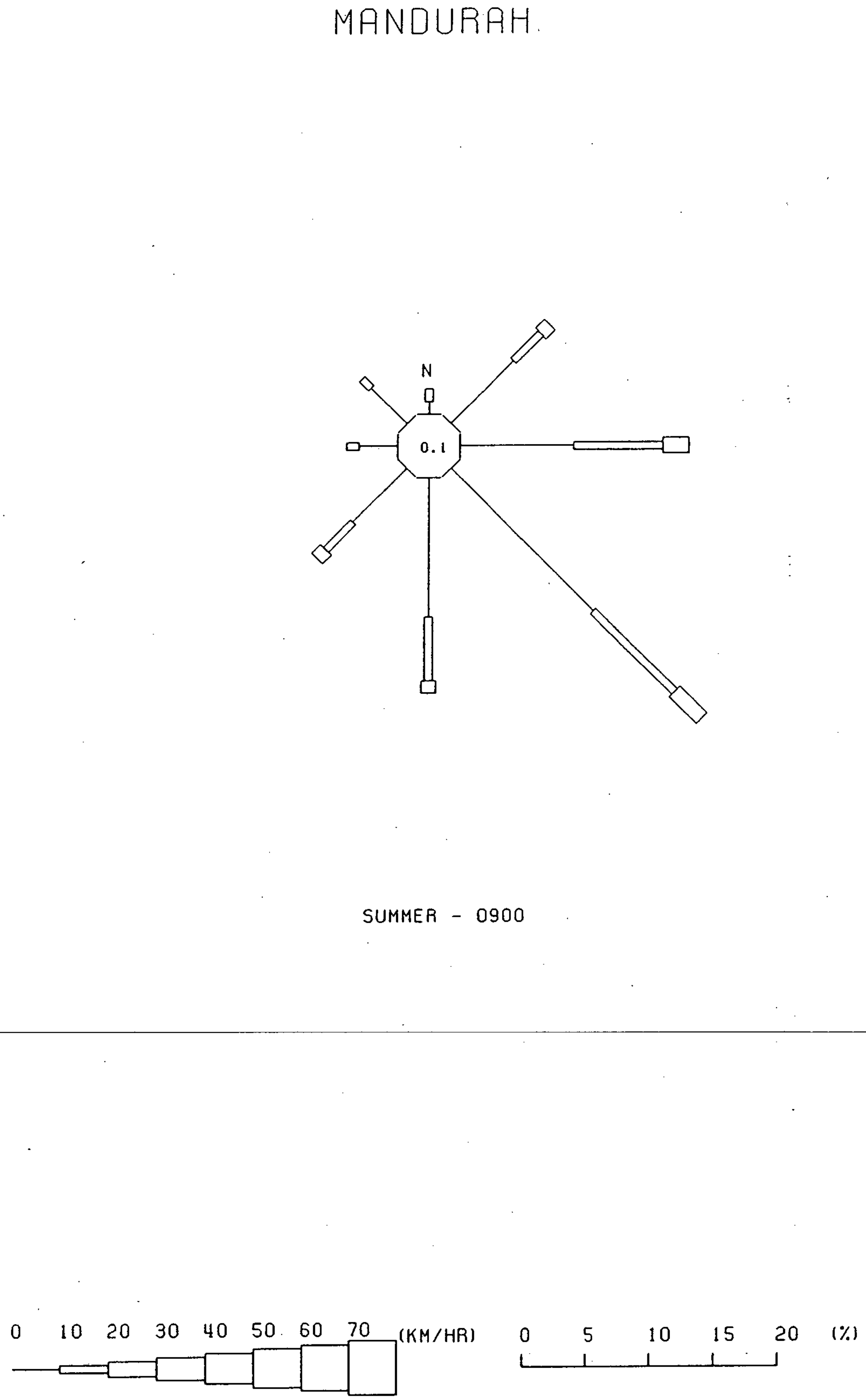


Figure 2.4 Wind rose for summer mornings at Mandurah.

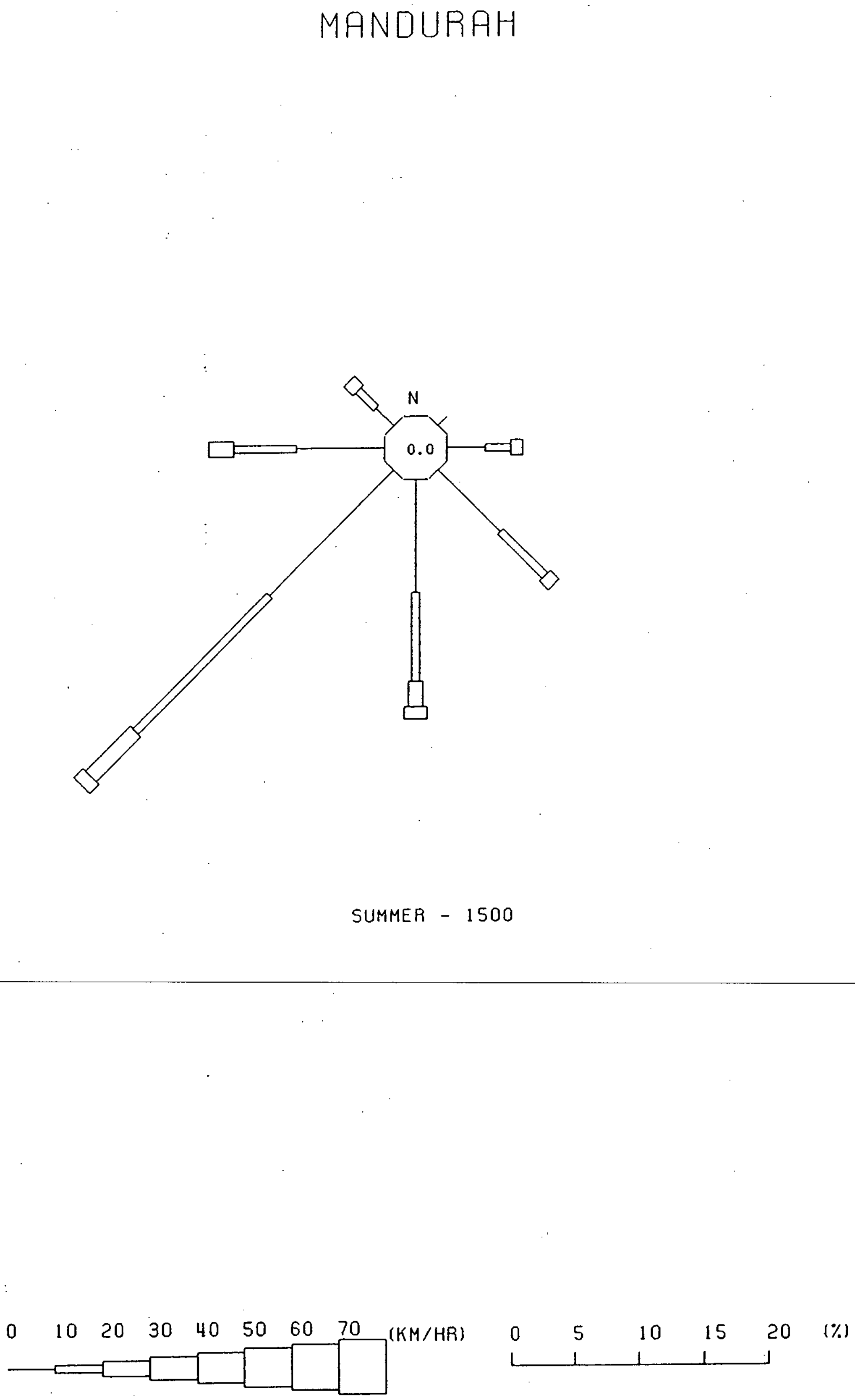


Figure 2.5 Wind rose for summer afternoons at Mandurah.

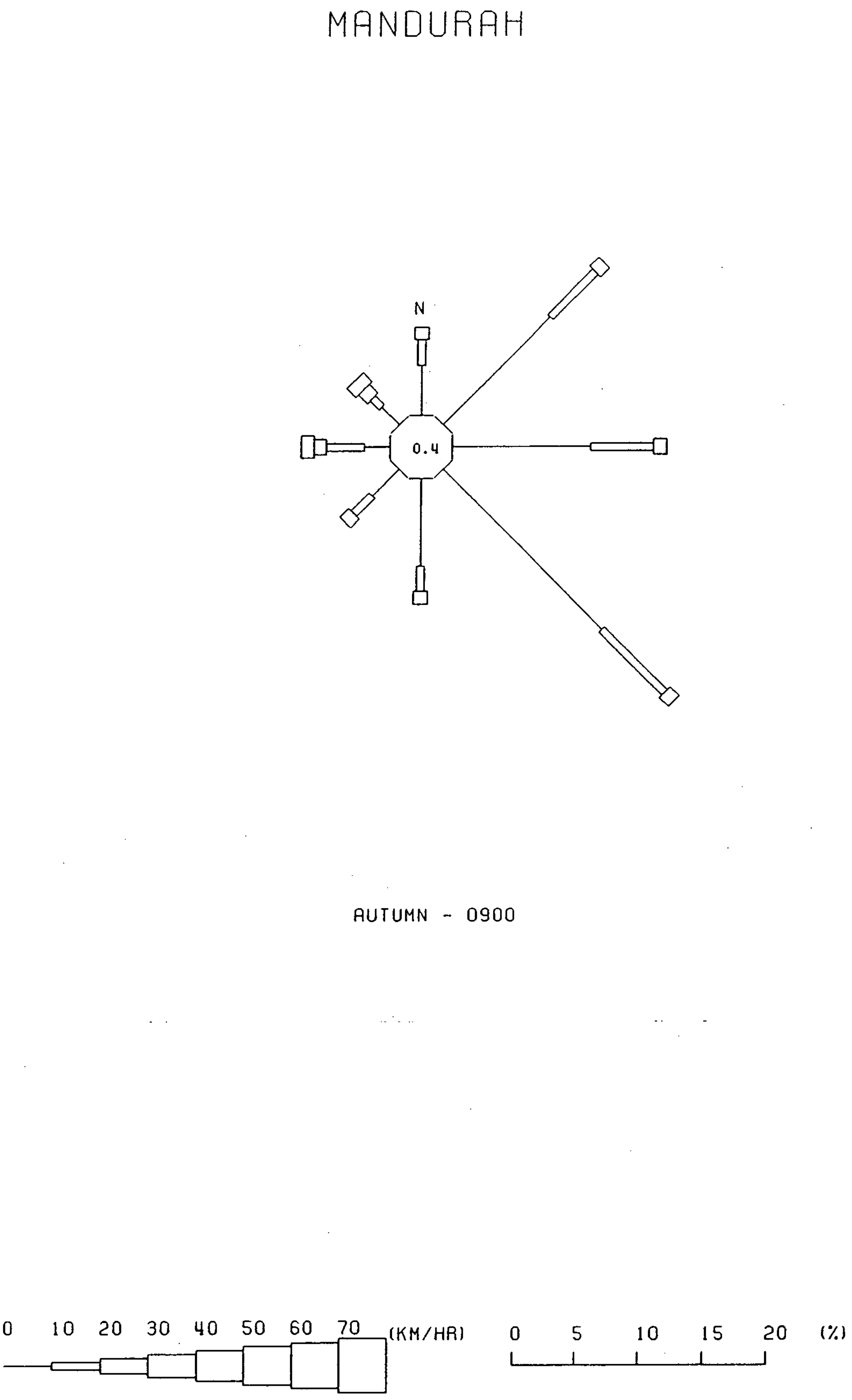


Figure 2.6 Wind rose for autumn mornings at Mandurah.

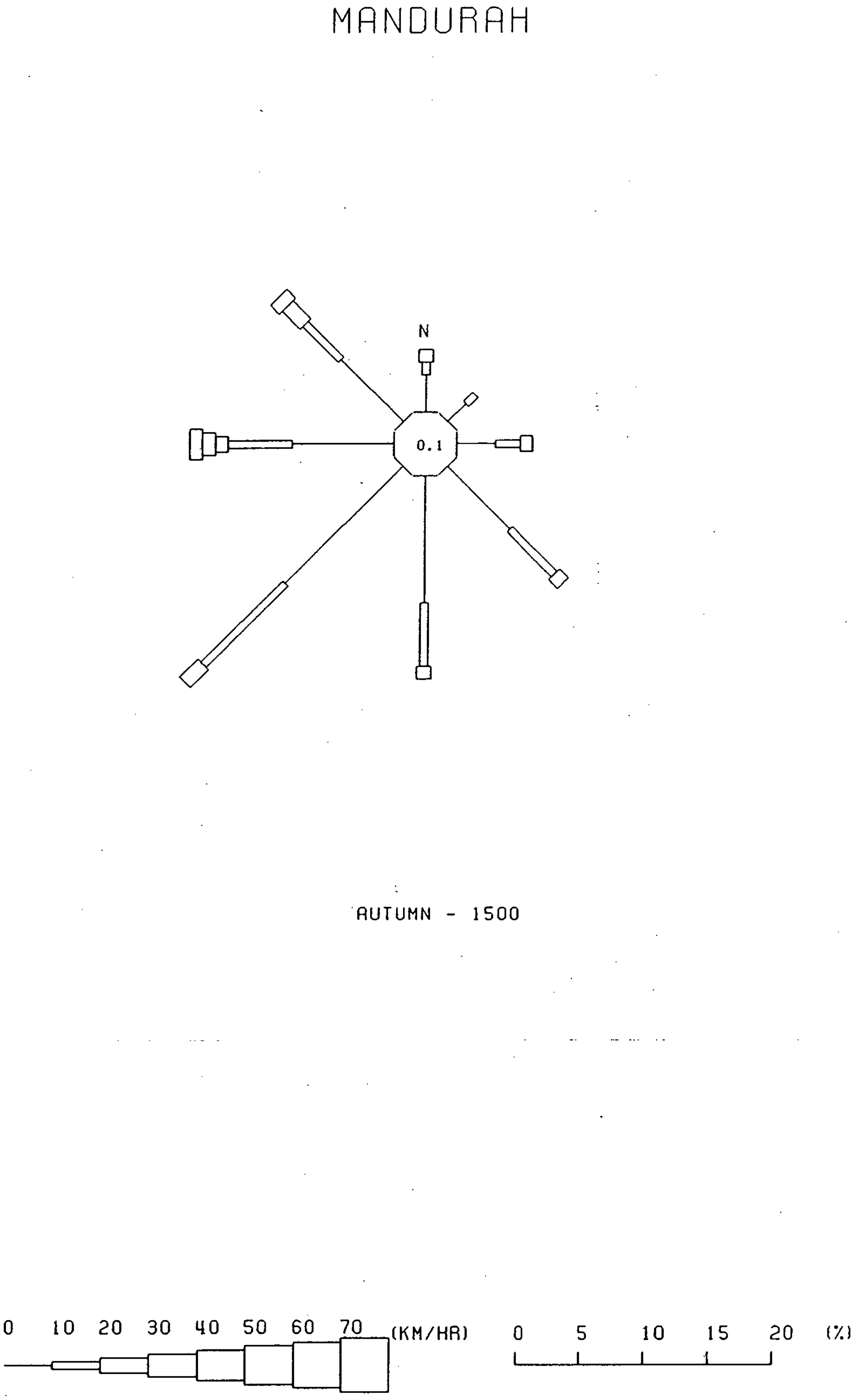


Figure 2.7 Wind rose for autumn afternoons at Mandurah.

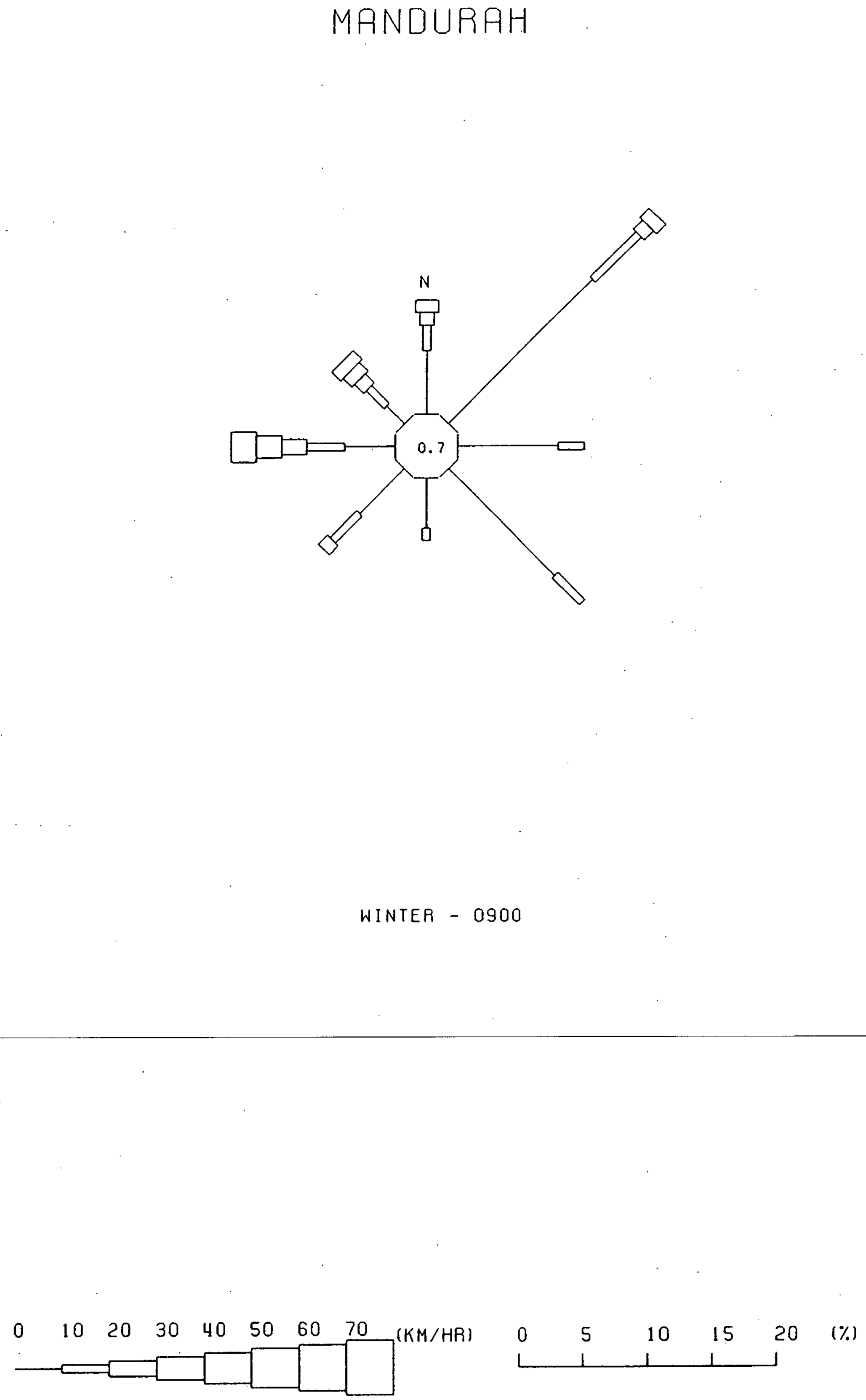


Figure 2.8 Wind rose for winter mornings at Mandurah.

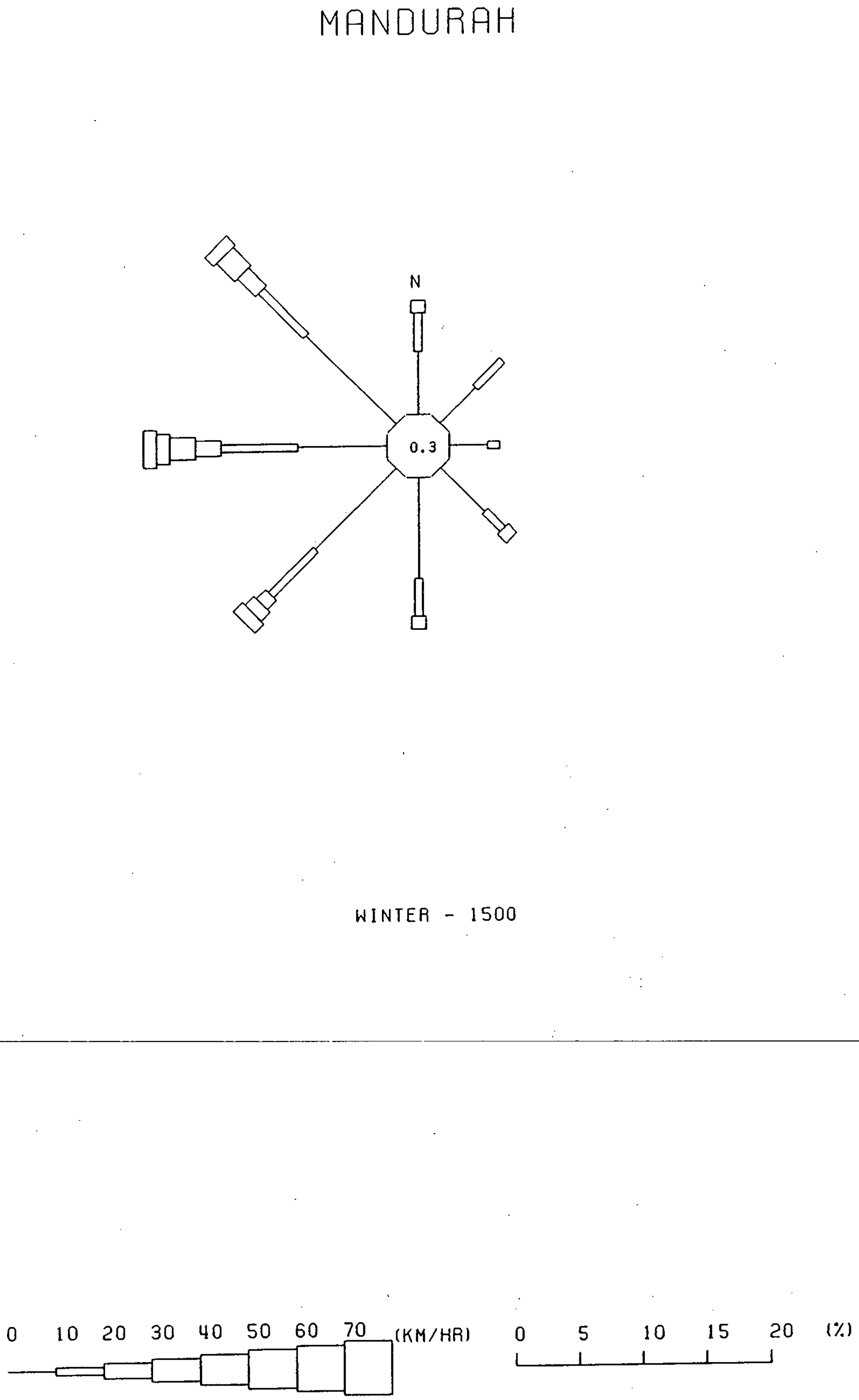


Figure 2.9 Wind rose for winter afternoons at Mandurah.

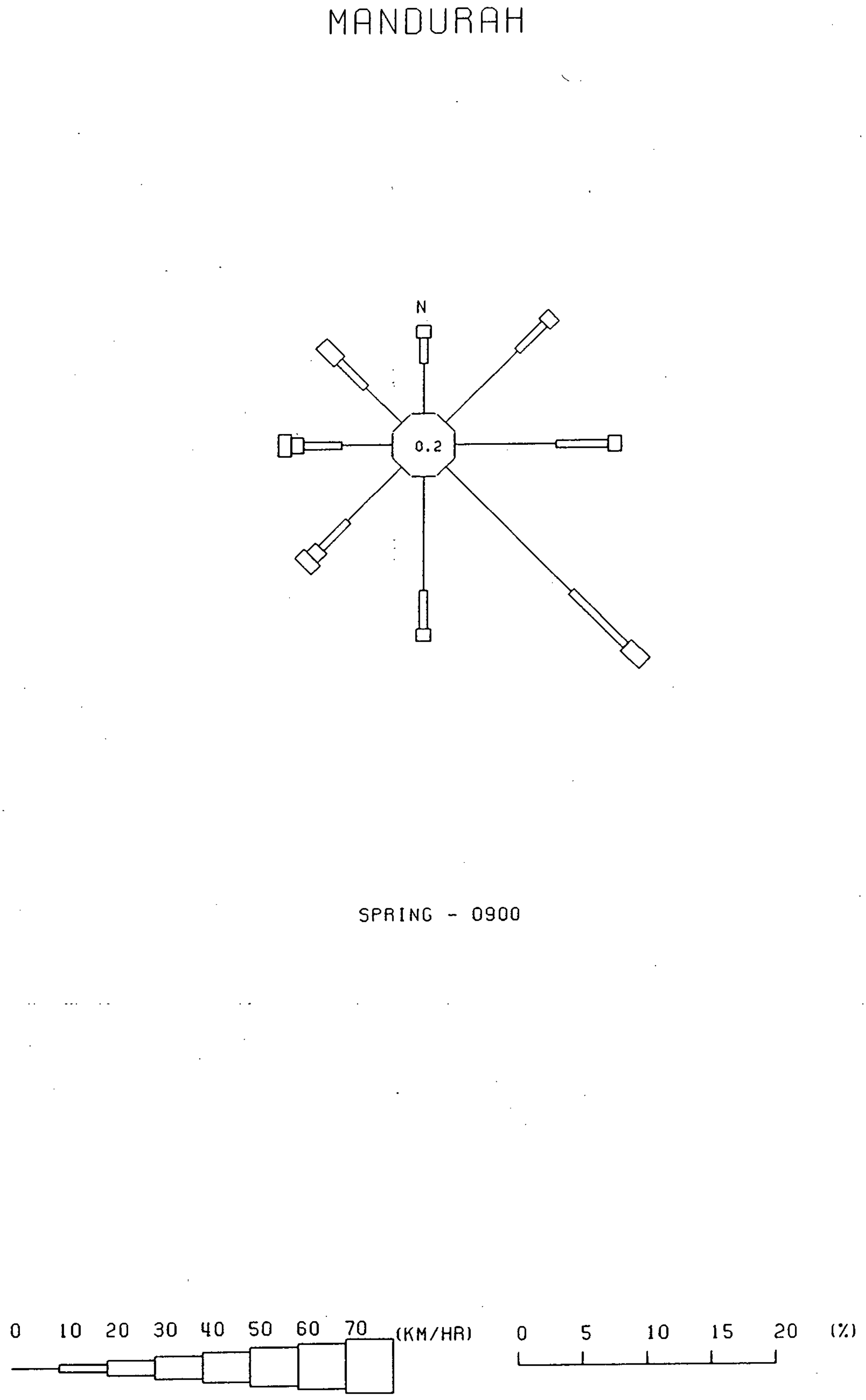


Figure 2.10 Wind rose for spring mornings at Mandurah.

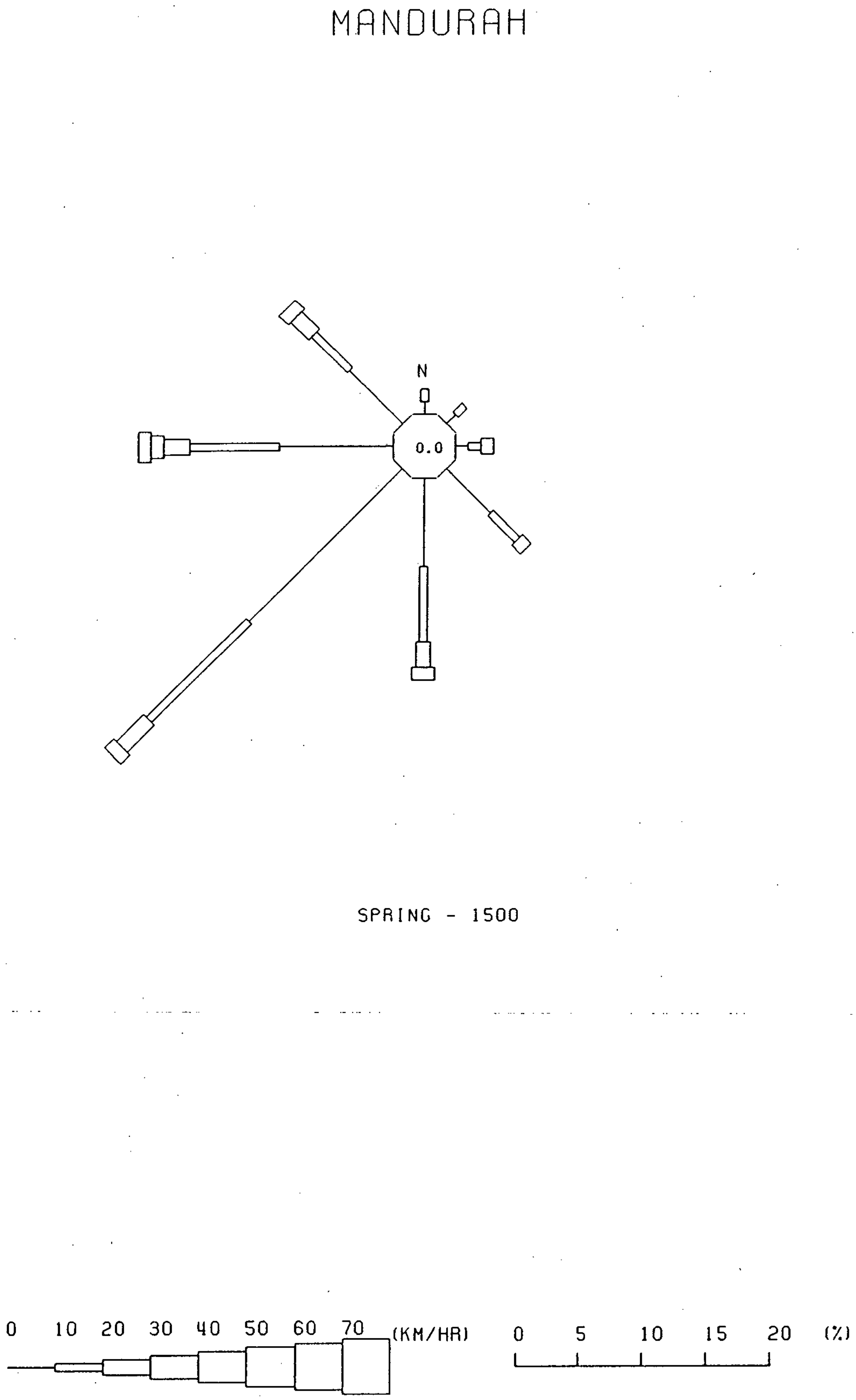


Figure 2.11 Wind rose for spring afternoons at Mandurah.

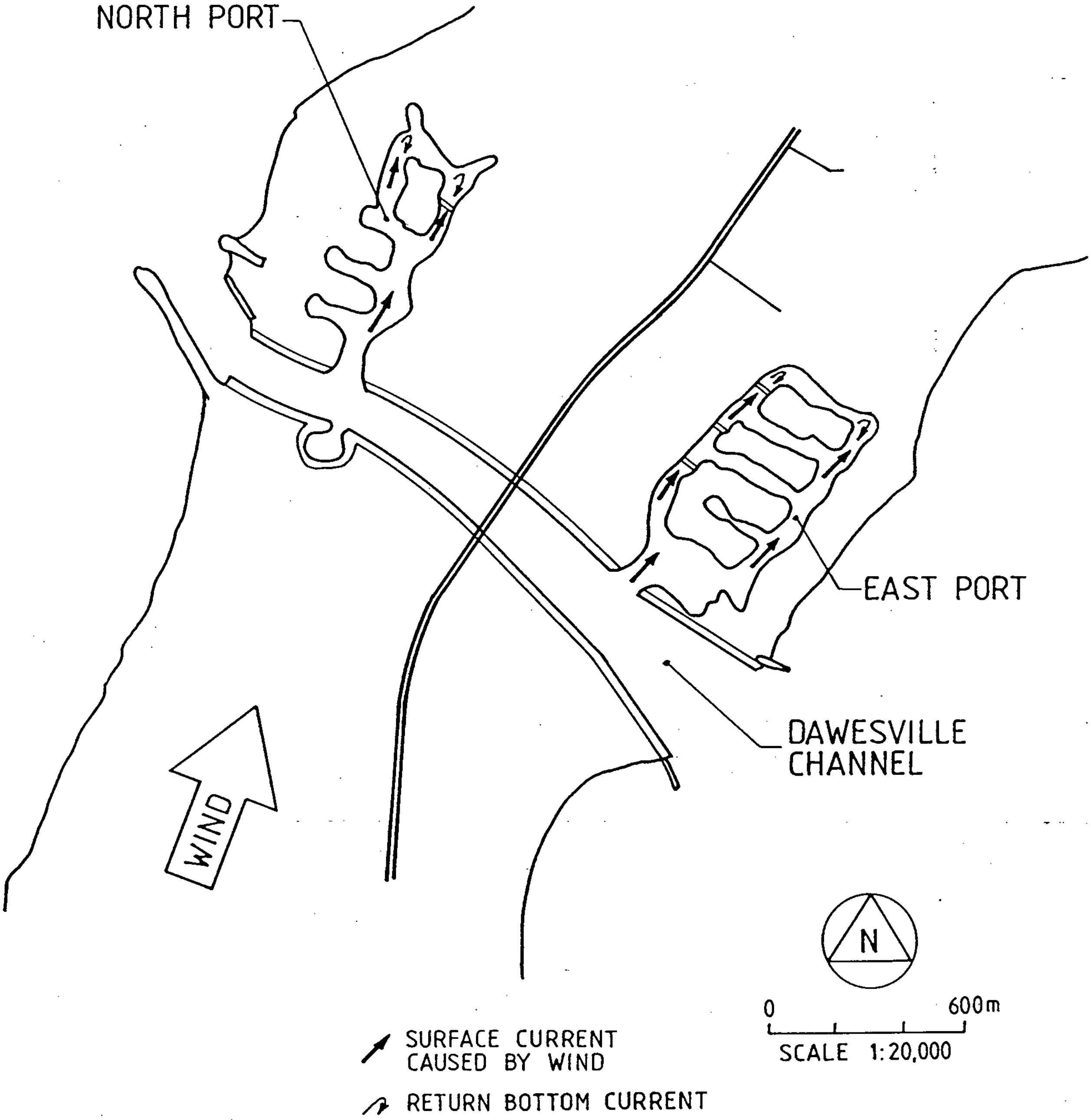


Figure 2.12 Wind induced currents in the main canals.

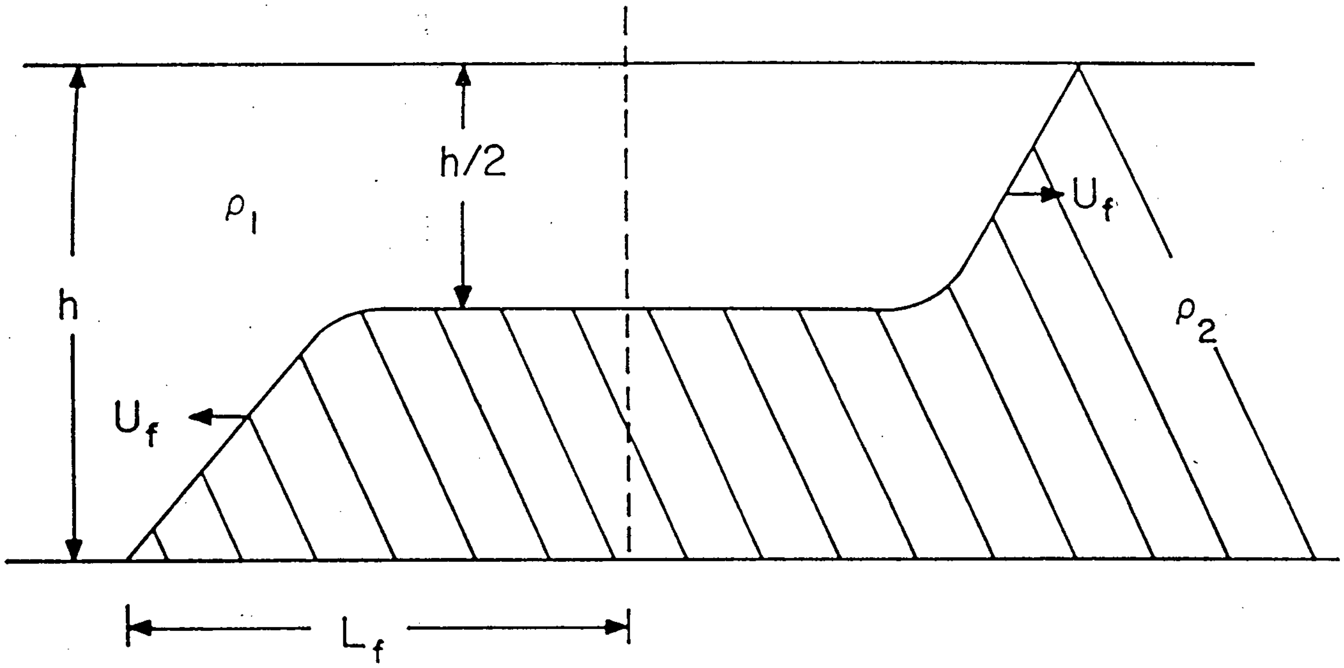


Figure 2.13 Schematic diagram of the action of density currents.

STEEDMAN SCIENCE & ENGINEERING

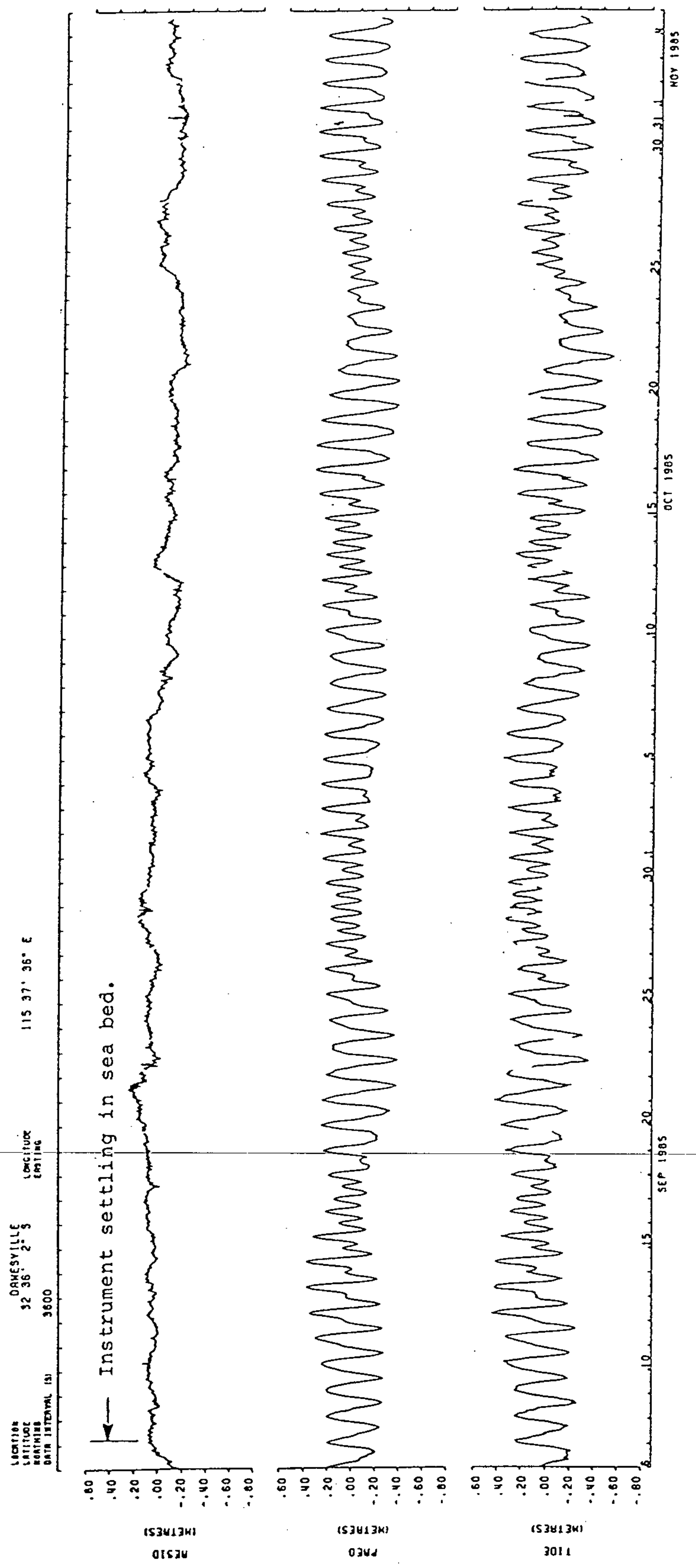


Figure 2.14 Tidal record taken offshore from Dawesville (taken from Steedman Limited, 1986).

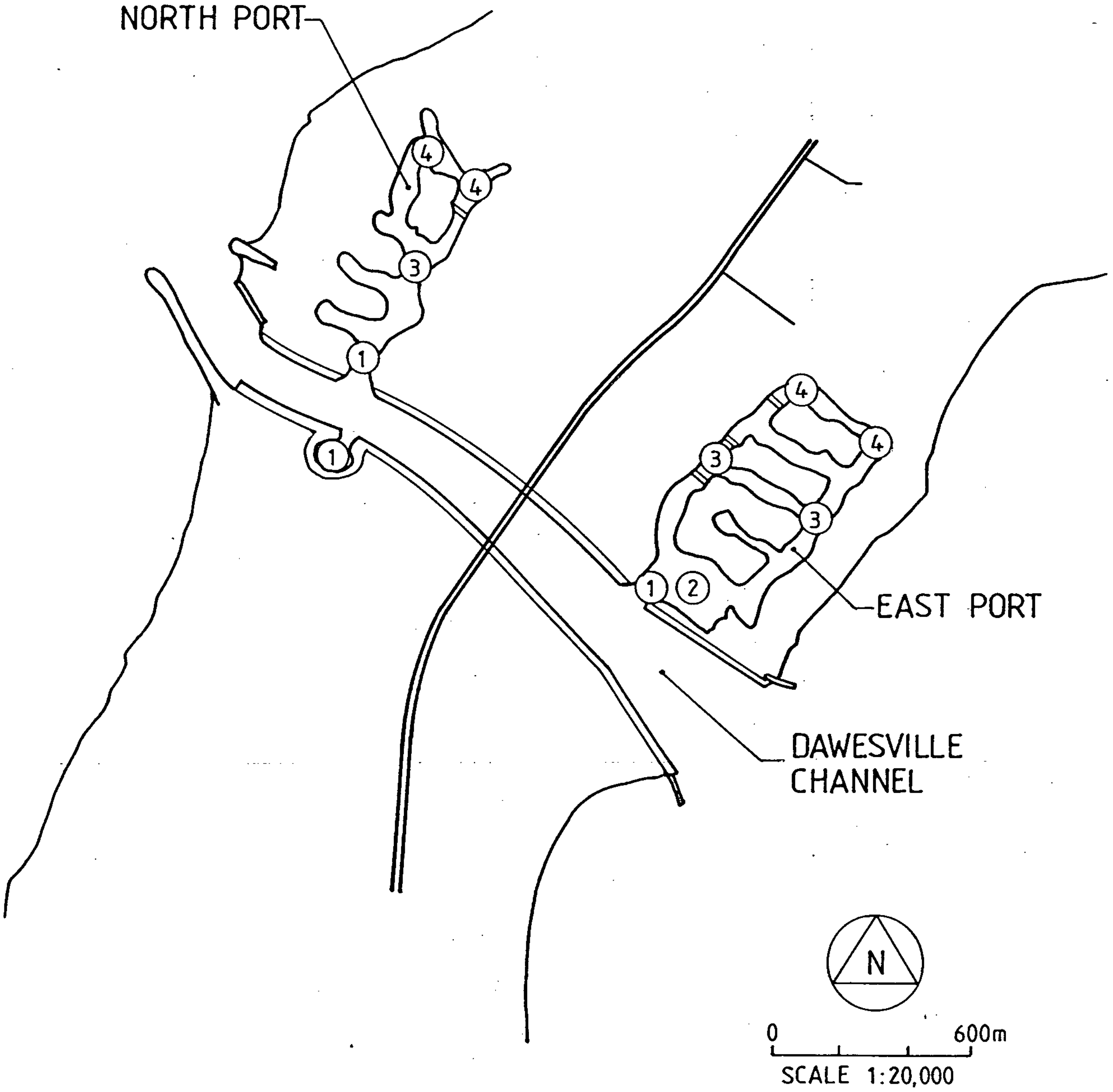


Figure 2.15 Position of locations 1 to 4 from table 2.3.

Figure 3.1 Ocean beaches near the Dawesville Channel.

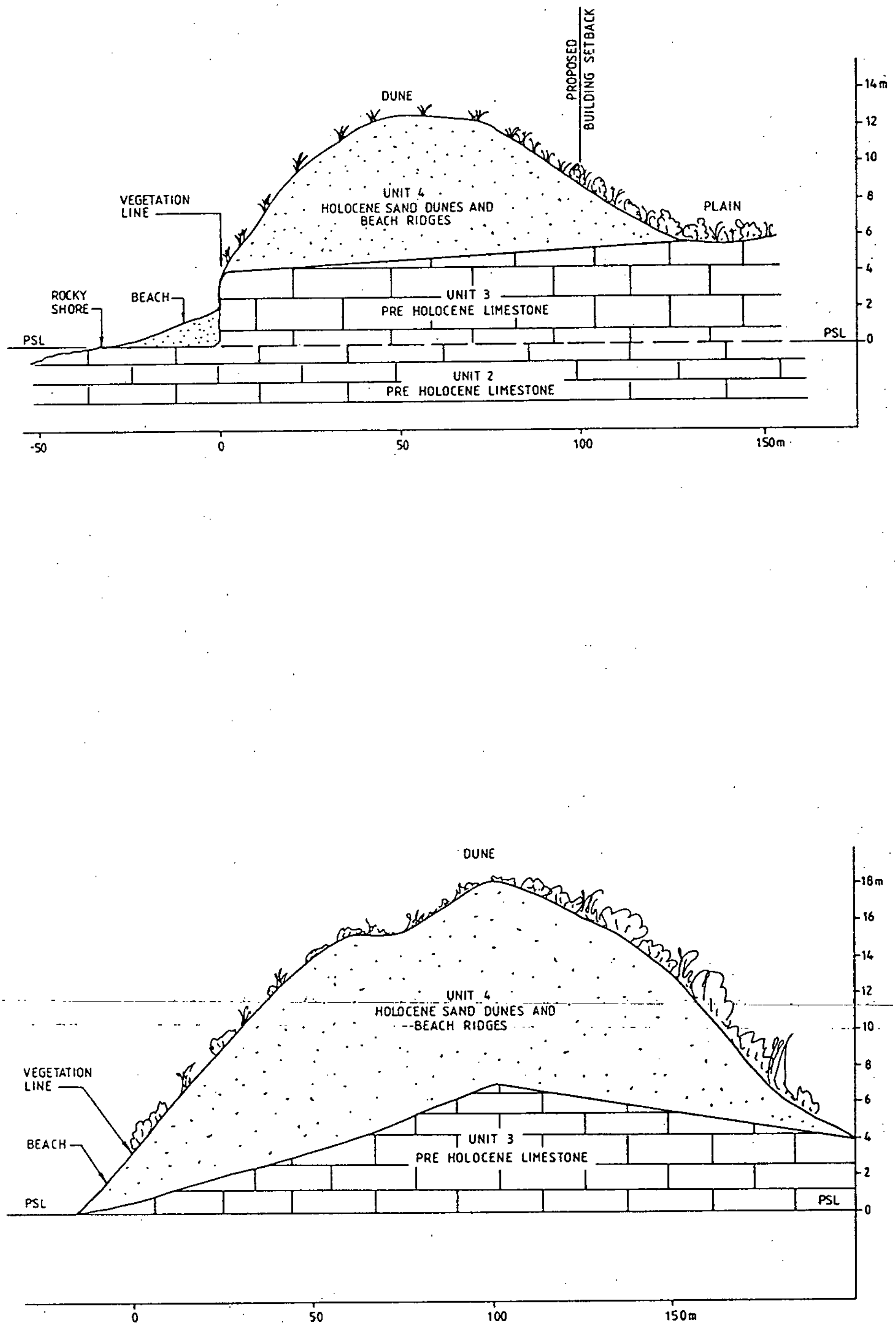


Figure 3.2 Geological sections through the beach backed by high dunes.

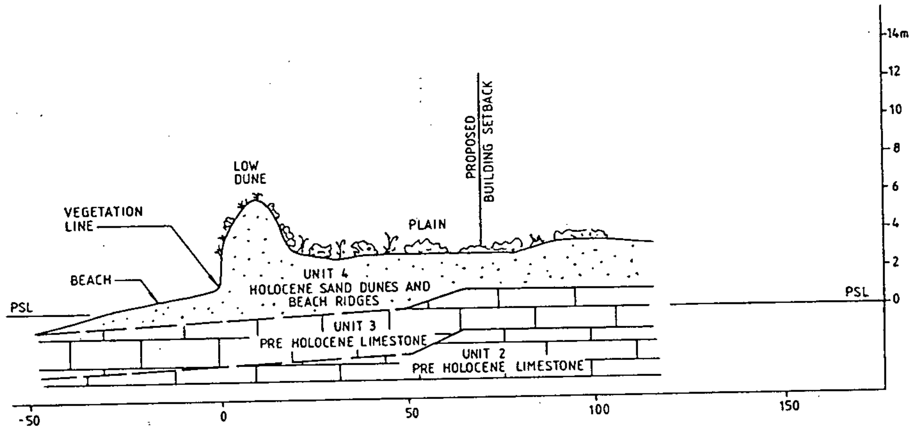


Figure 3.3 Geological section through the sandy embayment at Avalon.

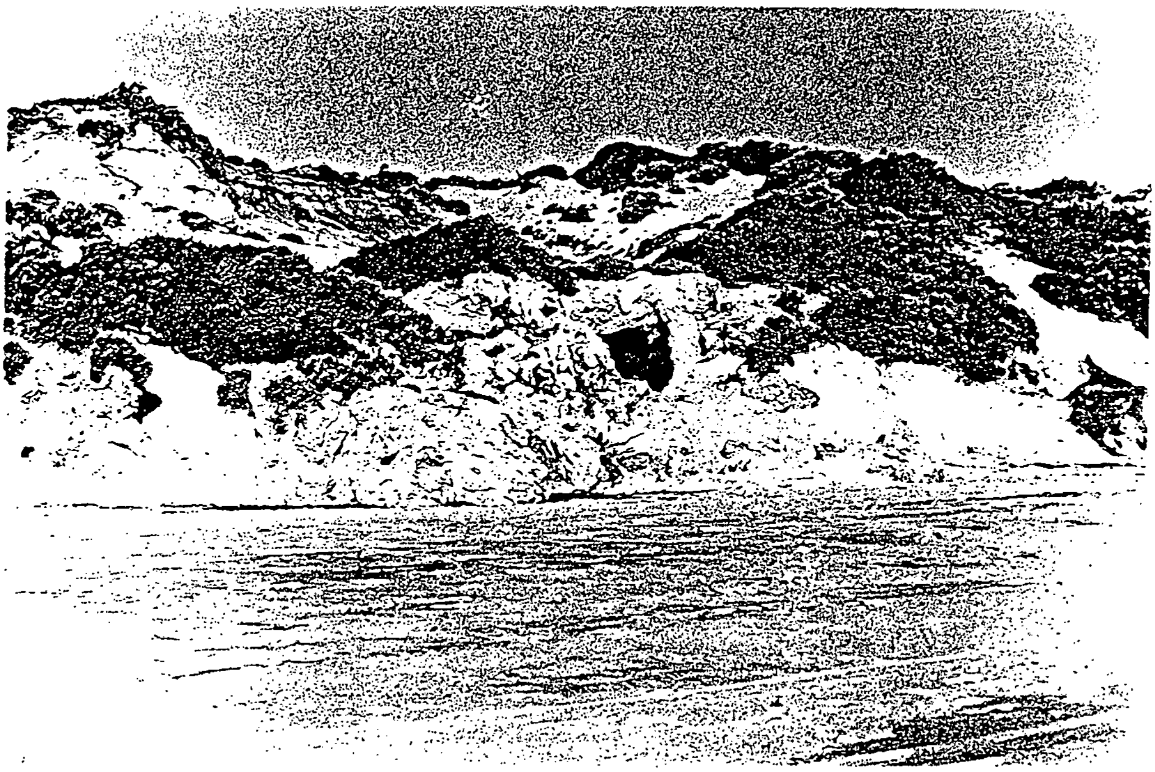


Figure 3.4 Photographs of limestone outcropping from the dunes and beaches near the Dawesville Channel.

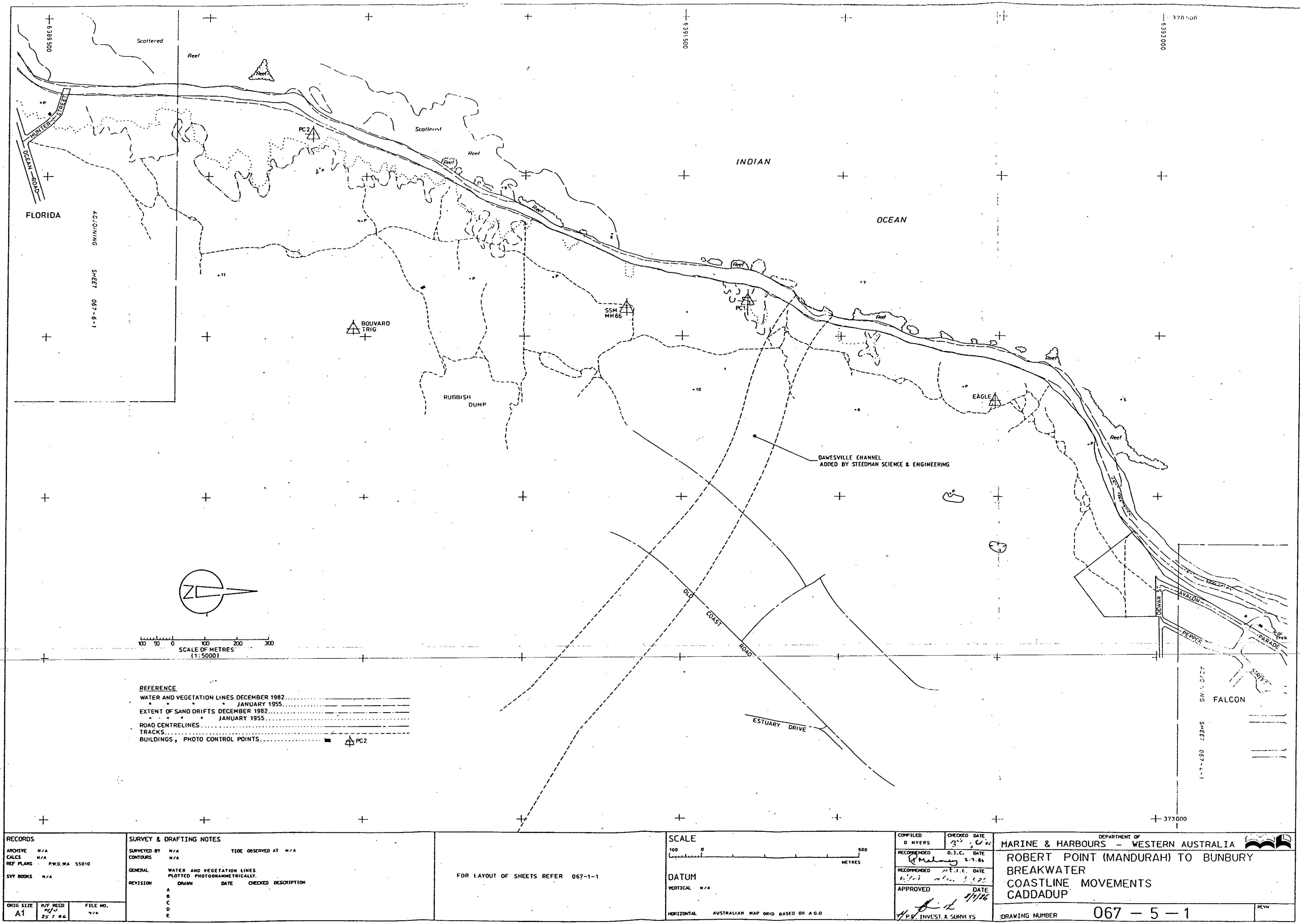


Figure 3.5 DMH shoreline movement plan for the area near the Dawesville Channel.

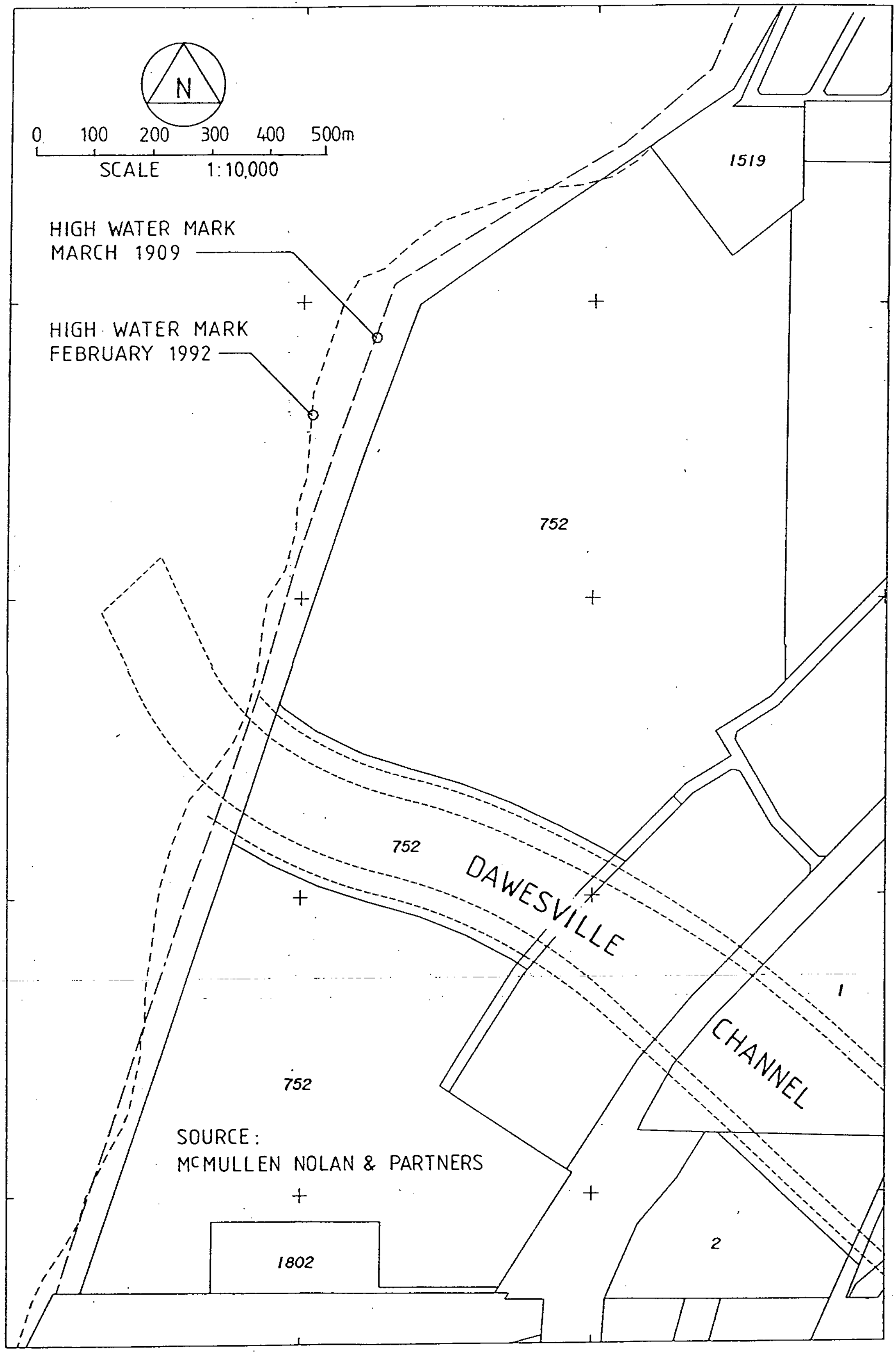


Figure 3.6 Comparison of High Water Mark Surveys taken in March 1909 and June 1992.

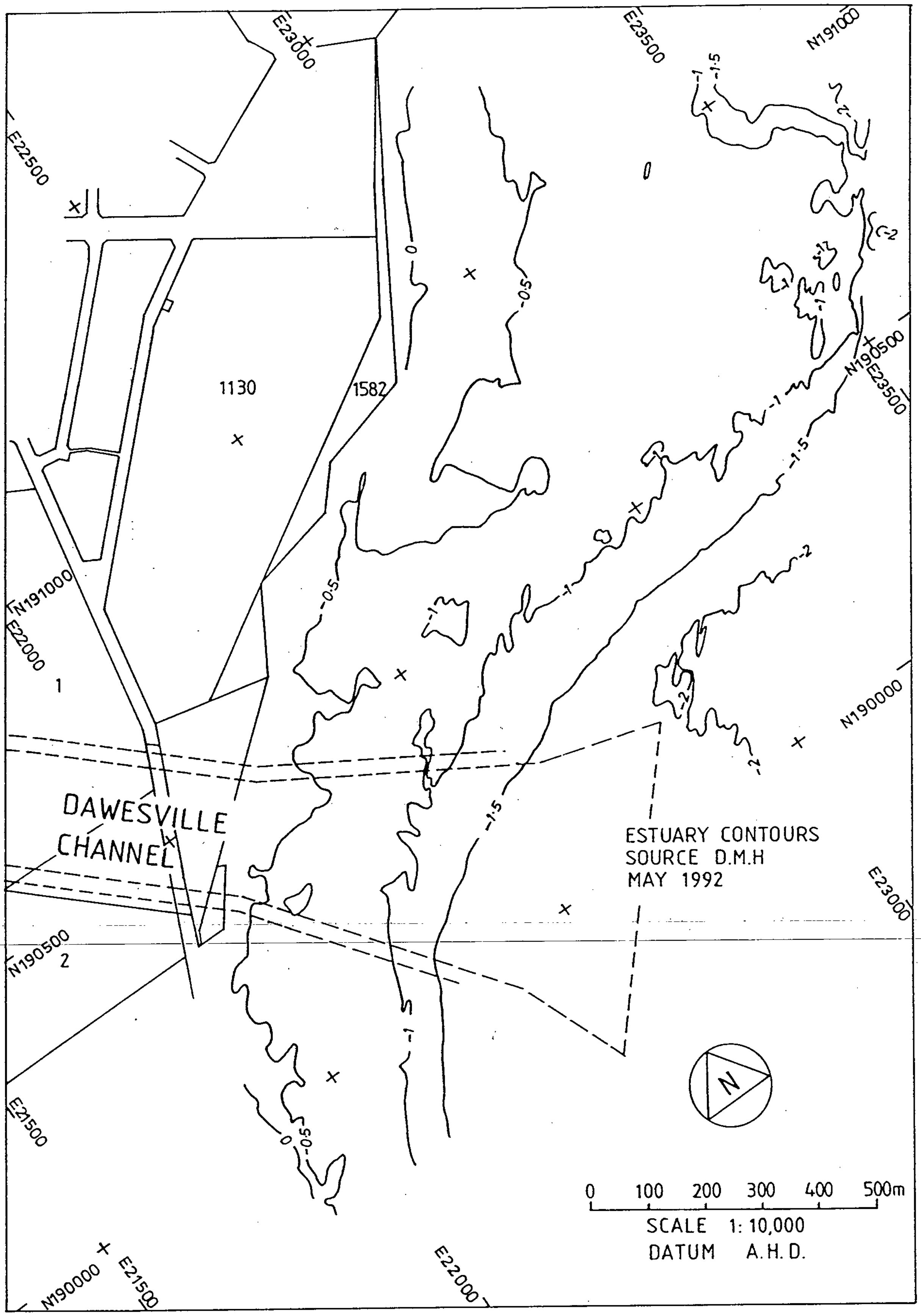
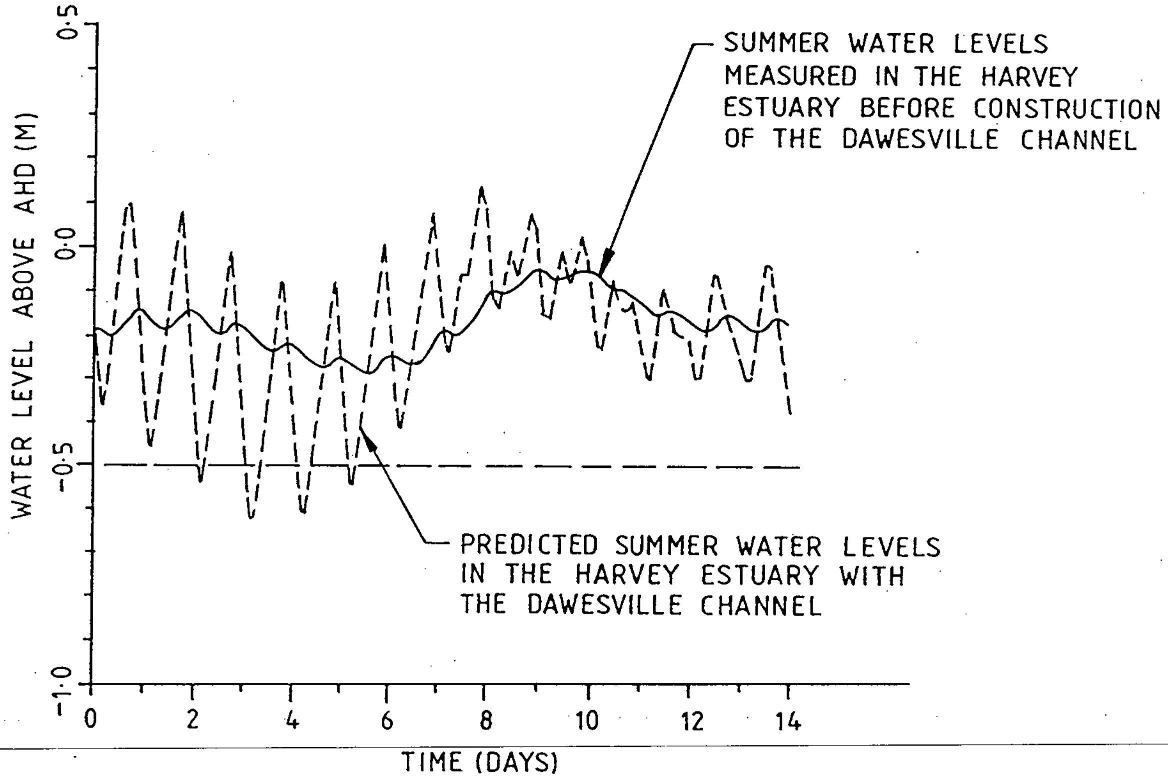


Figure 4.1 Bathymetry of the Harvey Estuary near the Dawesville Channel.



SOURCE : DUFTY, 1983

Figure 4.2 Summer water levels in the Harvey Estuary with and without the Dawesville Channel.

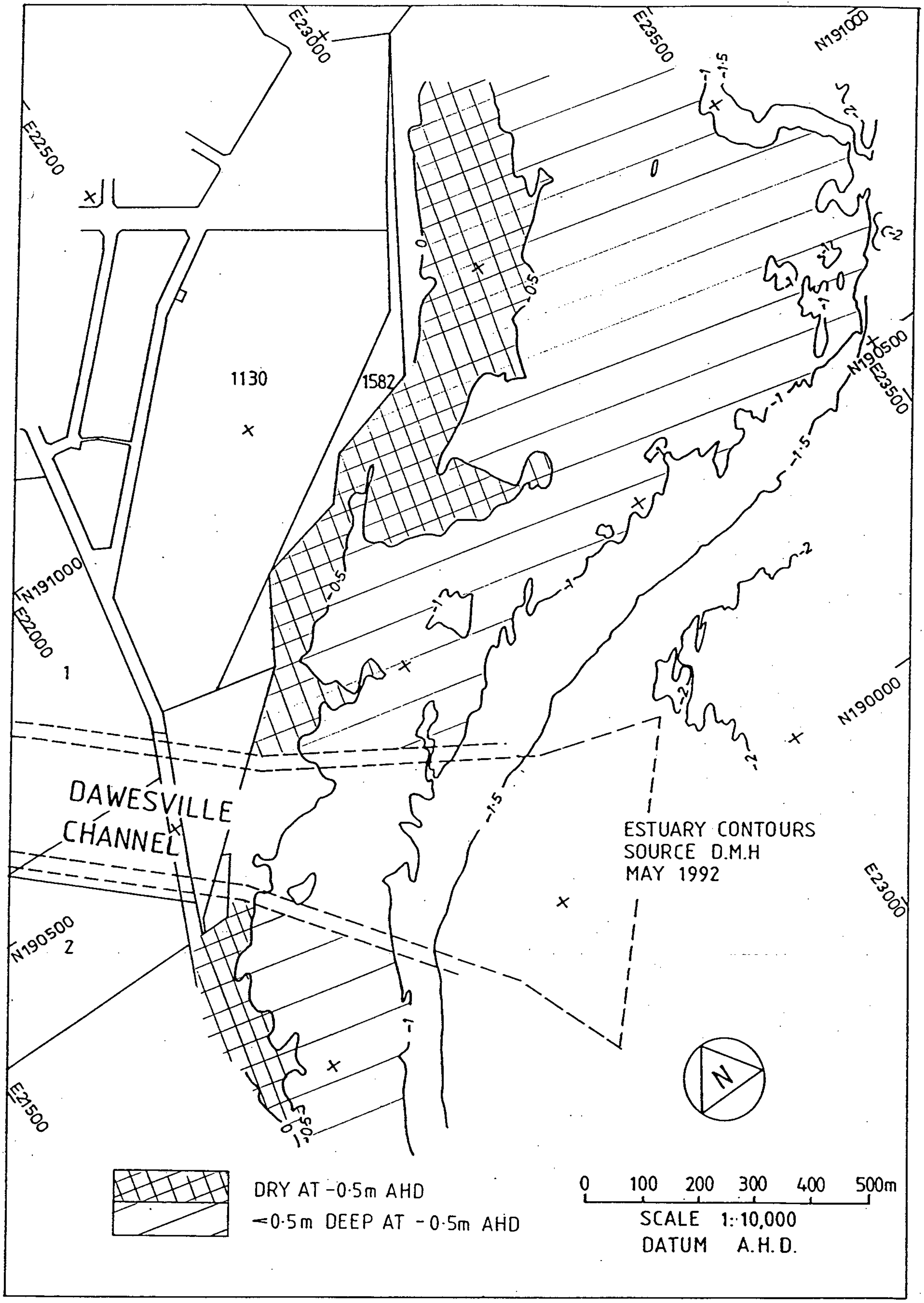


Figure 4.3 Extent of shallow water and drying mud flats at low tide after the construction of the Dawesville Channel.

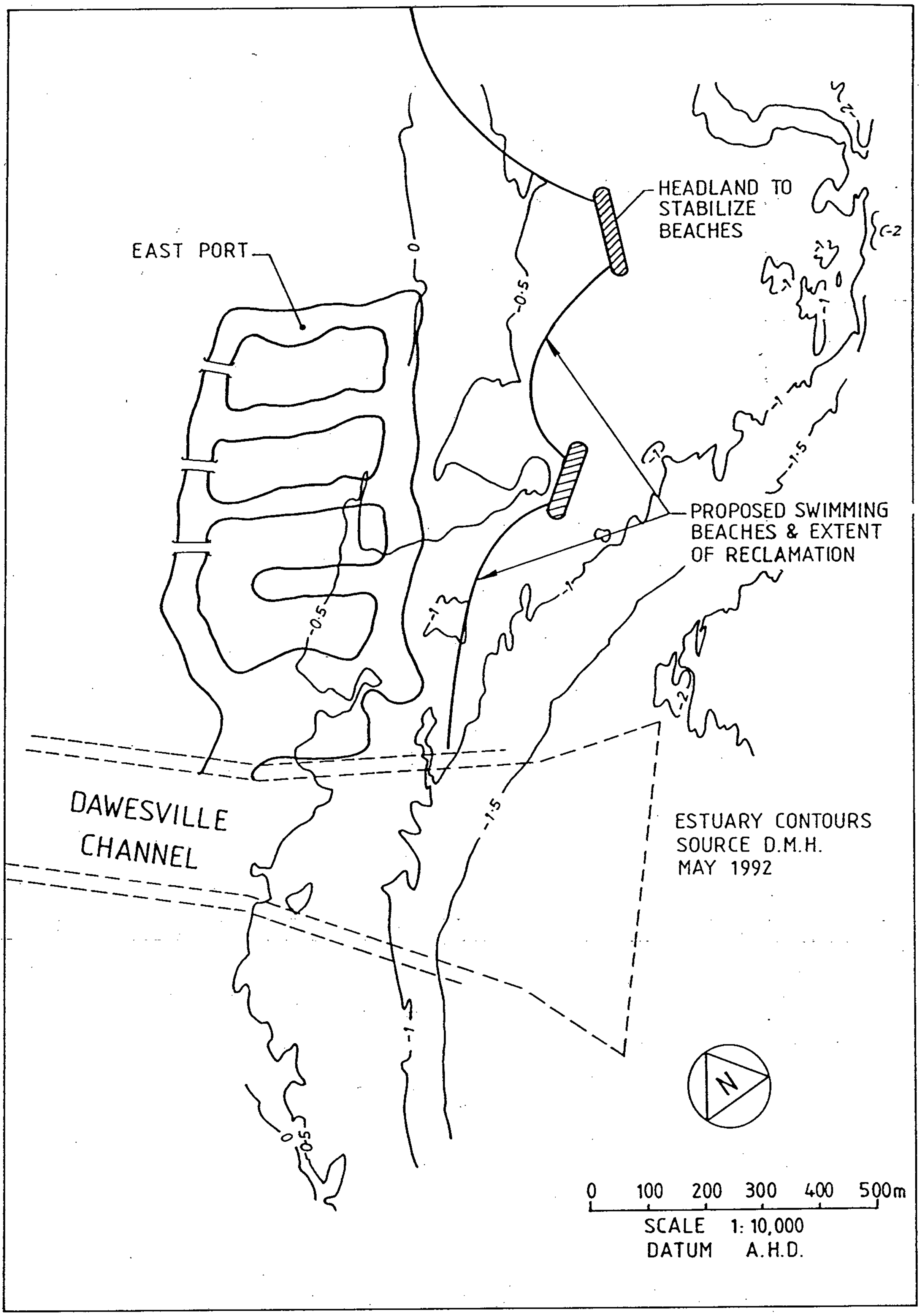


Figure 4.4 Proposed extent of reclamation of the mud flats north of the Dawesville Channel.

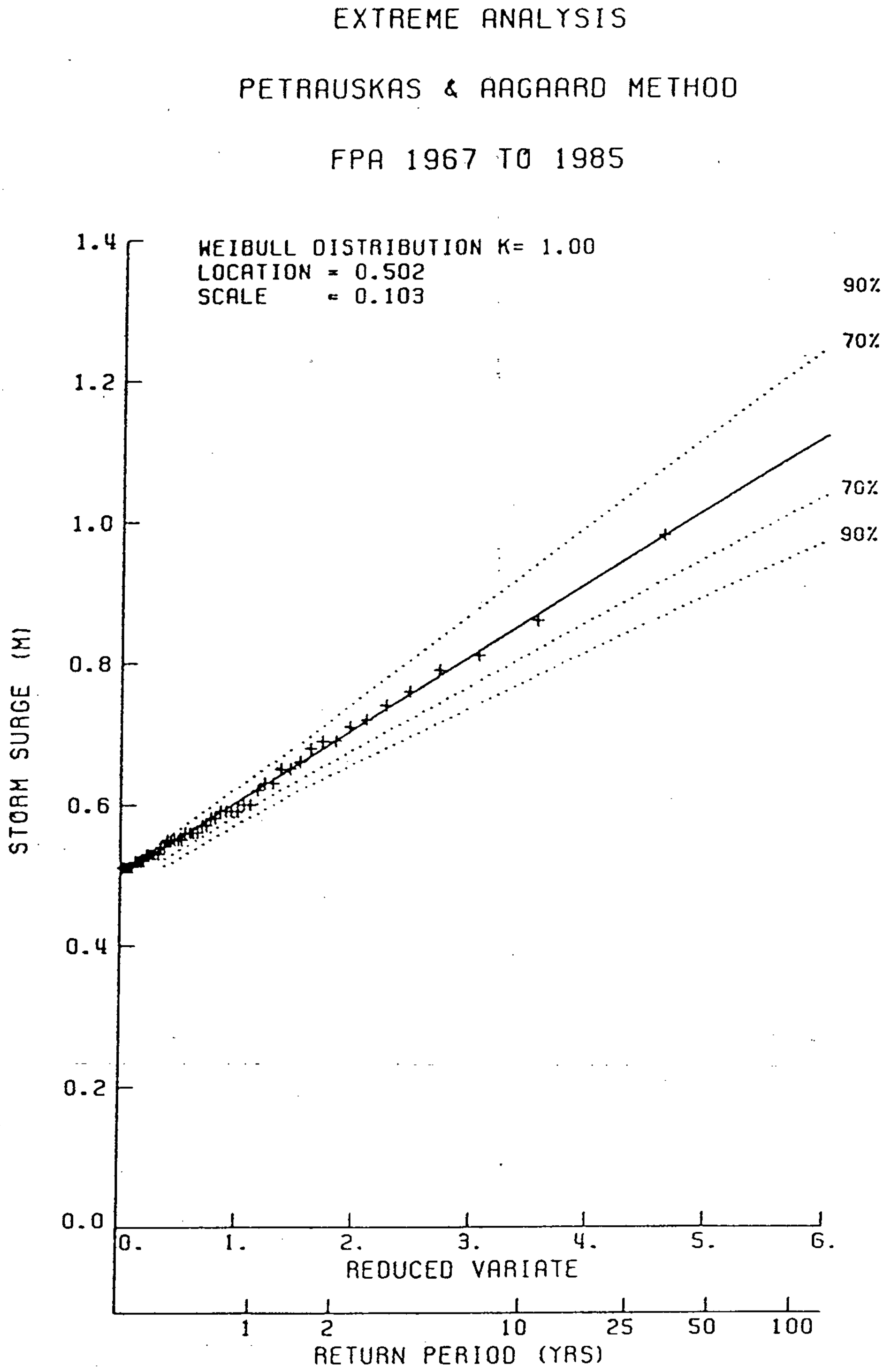


Figure 5.1 Storm surge values, Fremantle, based on 17 years of tide residuals from Fremantle Harbour tide gauge over the periods 1967 to 1981 and 1984 to 1985.

Appendices

Appendix 1

Water Quality Criteria
for
Beneficial Uses Nos. 1 and 3

taken from Bulletin 103,
Department of Conservation and Environment, 1981.

WATER QUALITY CRITERIA
for
MARINE AND ESTUARINE WATERS OF WESTERN AUSTRALIA

REPORT

of the

MARINE AND ESTUARINE WATER QUALITY CRITERIA

WORKING GROUP

established by the

ENVIRONMENTAL PROTECTION AUTHORITY

April, 1981

Department of

Conservation and Environment

Western Australia

Bulletin No. 103

BENEFICIAL USE NO. 1

DIRECT CONTACT RECREATION

The criteria in Schedule 1 are intended to protect marine and estuarine waters for direct contact recreation including bathing, diving, water-skiing and other activities in which the human body may come into direct contact with the water to the point of complete immersion.

The waters should conform to the general aesthetic criteria for marine and estuarine waters. They should also be protected against loads of nutrients and other biostimulants capable of causing excessive or nuisance growths of algae or other aquatic plants.

It should be pointed out that for a complete understanding of the criteria in Schedule 1, especially as far as "health investigation levels" are concerned, the relevant passages in the Introduction should be read (see pages 3 and 4).

SCHEDULE 1

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR DIRECT CONTACT RECREATION

Parameter	Criterion	Source
Aesthetic Considerations	As on page 9	USA EPA (Comp)
Physical Hazards	The water in designated bathing and swimming areas should be free of submerged bodies and other subsurface hazards.	NH&MRC
Light Penetration	A Secchi disc should be visible to a depth of 2 m except in "learn to swim" areas where a Secchi disc should be visible on the bottom.	NH&MRC
pH	6.5 - 8.5, except for waters with a low buffer capacity where a range of pH between 5.0 and 9.0 may be tolerated.	NH&MRC
Chemicals and Biological Materials	The waters should not contain chemicals and biological materials in such concentrations as to be irritating to the skin or mucous membranes of the human body upon brief immersion. In addition, they should not contain chemicals and biological materials in such concentrations as to be toxic to man if small quantities are ingested.	NH&MRC
Faecal Coliforms	A health investigation level for water in open and unenclosed bathing and swimming areas may be established on the basis of a minimum of five samples taken over not more than a 30-day period under conditions representative of the water quality to which users are commonly exposed, and is reached either when the median reading of such samples exceeds 150 organisms/100 mL, or when more than 20% of the total samples during this period exceed 500/100 mL. For this purpose samples during the wettest quarterly interval may be omitted if users are not commonly exposed during that interval. The water in designated bathing and swimming areas in which the median reading ordinarily exceeds 50/100 mL and/or in which more than 20% of samples ordinarily exceed 150/100 mL, should be protected against any degradation in that quality from a new or increased source of pollution. Water of higher quality should be similarly protected against degradation beyond the levels mentioned in this paragraph.	WG

Parameter	Criterion	Source
Faecal Material	The water in designated bathing and swimming areas should be protected against direct contamination with fresh faecal material of human or domesticated animal origin.	WG
Radioactive Substances	The waters should not contain radioactive substances in such concentrations as to be deleterious to man if small quantities are ingested.	DH&MS

SCHEDULE 3

MARINE AND ESTUARINE WATER QUALITY CRITERIA FOR HARVESTING OF MOLLUSCS FOR FOOD

Parameter	Criterion	Source
Aesthetic Considerations	As on page 9.	USA EPA (Comp)
Floating and Submerged Litter	No materials should be present which directly or indirectly have an adverse effect upon molluscs or which interfere with normal fishing or harvesting practices or damage fishing equipment.	WG
Barriers	No barrier should be constructed, substances added nor alterations made to the marine or estuarine environment which will prevent the normal movement and migratory patterns of molluscs to the detriment of their populations or cause changes in the normal water movement pattern which will lead to adverse effects upon them.	WG
Light Attenuation	The combined effects of turbidity and colour should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonal background value.	USA EPA
Settleable Matter	Unnatural inputs of settleable material should not cause the formation of deposits which are harmful to aquatic organisms.	VIC EPA (M)
Suspended Solids	Upper limit of 80 mg/L and depth of compensation point for photosynthetic activity should not be reduced by more than 10% from the natural seasonal norm.	Hart/USA EPA
Temperature	The maximum acceptable variation in the weekly average temperature due to artifical sources is 1°C for waters north and 2°C for waters south of latitude 27°S during all seasons of the year, provided that no single value exceeds the highest summer maximum recorded over the previous five years inclusive.	USA EPA
Salinity	Unnatural influences should not change the seasonal mean salinity, measured preferably over not less than five years, by more than 0.25 of the standard deviation, nor change the salinity beyond the range recorded	WG/VIC EPA (G)

Parameter	Criterion	Source
Ionic Ratio	The ratio of major ions should not be altered such that this beneficial use is affected.	WG
pH	6.5-8.5 and no change in excess of 0.2 units from normal. For waters of salinity below 5 000 mg/L (5°/oo) the pH range should be 6.0 to 9.0 and no change in excess of 0.5 units.	USA EPA/ WG/Hart
Dissolved Oxygen	Not to fall below 4.0 mL/L (5.7 mg/L) for more than 6 consecutive hours, and never to fall below 3.5 mL/L (5.0 mg/L)	WG
Arsenic	6 month median not to exceed 8 µg/L. No more than 20 per cent of readings to exceed 80 µg/L. No single reading to exceed 500 µg/L.	Calif(K&S)
Cadmium	6 month median not to exceed 3 µg/L. No single reading to exceed 8 µg/L.	Calif(K&S)
Chromium (total)	6 month median not to exceed 2 µg/L. No single reading to exceed 7 µg/L.	Calif(K&S)
Copper	6 month median not to exceed 5 µg/L. No single reading to exceed 40 µg/L.	Calif(K&S)
Lead	6 month median not to exceed 8 µg/L. No more than 20 per cent of readings to exceed 80 µg/L. No single reading to exceed 200 µg/L.	Calif(K&S)
Mercury	6 month median not to exceed 0.14 µg/L. No more than 20 per cent of readings to exceed 1.4 µg/L. No single reading to exceed 3 µg/L.	Calif(K&S)
Nickel	6 month median not to exceed 20 µg/L. No more than 20 per cent of readings to exceed 200 µg/L. No single reading to exceed 450 µg/L.	Calif(K&S)
Silver	6 month median not to exceed 0.45 µg/L. No more than 20 per cent of readings to exceed 4.5 µg/L. No single reading to exceed 10 µg/L.	Calif(K&S)

Parameter	Criterion	Source
Zinc	6 month median not to exceed 20 µg/L. No single reading to exceed 200 µg/L.	Calif(K&S)
Aldrin	Not to exceed 0.003 µg/L	USA EPA
Azinphosmethyl	Not to exceed 0.01 µg/L	USA EPA
Camphechlor	Not to exceed 0.005 µg/L	USA EPA
Chlordane	Not to exceed 0.004 µg/L	USA EPA
2,4-D	Not to exceed 4 µg/L	NAS/NAE
DDT	Not to exceed 0.001 µg/L	USA EPA
Dieldrin	Not to exceed 0.003 µg/L	USA EPA
Endosulfan	Not to exceed 0.001 µg/L	USA EPA
Endrin	Not to exceed 0.004 µg/L	USA EPA
Heptachlor	Not to exceed 0.001 µg/L	USA EPA
Lindane	Not to exceed 0.004 µg/L	USA EPA
Maldison	Not to exceed 0.1 µg/L	USA EPA
Methoxychlor	Not to exceed 0.03 µg/L	USA EPA
Parathion	Not to exceed 0.04 µg/L	USA EPA
Other Pesticides	Not to exceed 0.01 of the 96-hour LC_{50} value for the selected test species.	WG
Ammonia (expressed as Nitrogen)	6 month median not to exceed 600 µg/L. No single reading to exceed 2000 µg/L.	Calif (K&S)
Chlorine (Total Residual)	6 month median not to exceed 2 µg/L. No single reading to exceed 10 µg/L.	Calif (K&S)
Cyanide	6 month median not to exceed 5 µg/L. No single reading to exceed 10 µg/L.	Calif (K&S)
Fluoride	6 month median not to exceed 2 mg/L. No single reading to exceed 10 mg/L.	WG
Hydrogen Sulphide	Not to exceed 2 µg/L	USA EPA

Parameter	Criterion	Source
Total Hydrocarbons	Not to exceed 10 μg/L	WG
Aromatic Hydrocarbons	Not to exceed 1 μg/L	WG
Phenolic Compounds	6 month median not to exceed 300 μg/L.	Calif. (K&S)
Polychlorinated Biphenyls (PCB)	Not to exceed 0.001 μg/L	USA EPA
Surfactants	Not to exceed 0.01 of the 96-hour LC_{50} value for the test organisms.	WG
Other Toxic Substances	No material should be present in an amount exceeding 0.01 of the 96-hour LC_{50} value for the test organism.	WG
Metals Accumulation	In addition to the criteria set out above for individual metals in water, a health investigation level may be established for any given metal on the basis of samples of the edible portion of a particular mollusc species, and is reached when more than 10% of such samples exceed the maximum permissible level prescribed for that metal in the Food and Drug Regulations, 1961, as amended, made under the Health Act, 1911-1978.	DH&MS
Tainting Agents	Taste- or odour-producing substances should not be present at concentrations that lead to undesirable tastes or odours in fish flesh or other edible products of aquatic origin. For examples of levels and types of compounds known to taint aquatic organisms see Table 1. These are not intended to be criteria.	Calif.
Radioactive Substances	Radioactive substances should not be present in concentrations that are deleterious to human, plant, animal, or aquatic life or that result in the accumulation of radioactive substances in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.	Calif.

Parameter	Criterion	Source
Nutrients and other Biostimulants	The loads of nutrients and other biostimulants to receiving waters should not cause excessive or nuisance growths of algae or other aquatic plants or deleterious reductions in dissolved oxygen concentrations in those waters.	VIC EPA (M)
Faecal Coliforms	A health investigation level for water in areas designated for mollusc harvesting may be established on the basis of a minimum of five samples taken over not more than a 30-day period under circumstances in which faecal contamination is most probable, and is reached either when the median reading of such samples exceeds 15 organisms/100 mL, or when more than 20% of such samples exceed 50/100 mL.	NSSP/Maine
Faecal Material	The water in areas designated for mollusc harvesting should be protected against direct contamination with fresh faecal material of human or domesticated animal origin.	DH&MS

Appendix 2

Groundwater report by Dames and Moore.

DAMES & MOORE
SOUTH SHORE CENTRE
85 THE ESPLANADE, SOUTH PERTH, W.A. 6151

TELEPHONE:(09) 367 8055
FACSIMILE:(09) 367 6780

FACSIMILE TRANSMISSION SHEET

NO. OF PAGES 4

TO: Mick Rogers FAX NO. 387 6686
FROM: Alan Deeney JOB NO. 09074-074
DATE: 18 May 1992
SUBJECT: DAWESVILLE CHANNEL - WANNANUP DEVELOPMENT

Further to your fax of April 1 1992, our estimates of the groundwater inflow into each canal, the expected quality of groundwater and likely composition of the leachate from the the rubbish tip are outlined below.
A wide range of aquifer parameter values were obtained from limited investigations in the area and the appropriate values for the groundwater inflow analyses have been selected on the basis of the available information. Due to the limited data available, the results should therefore only be used as an indication of the order of magnitude of groundwater inflow into the canals.

1. Groundwater Inflow

Two methods were used to estimate the volume of groundwater flow into the canals. The first (a) is based on rainfall recharge to the shallow aquifer. The second method (b) is based on groundwater throughflow calculations.

(a) Using rainfall recharge

Assumptions used:

- o 55% of residential areas are paved (ie, housing, roads ,driveways, etc);

- o recharge from public open space and lawns is 15%;
- o recharge from paved areas (residences and roads) is 50%; and
- o an annual rainfall of 897mm

Based on the above assumptions, the annual groundwater inflow into each canal is estimated at:

Southern canal: 150 000m^3
North western canal: 190 000m^3
Eastern canal: 44 500m^3

(b) Using groundwater throughflow

Darcy's equation is used to determine the groundwater throughflow into each canal. Aquifer parameters based on earlier work completed by Dames & Moore were used. The following parameters were applied:

- o use of winter water table gradients prior to development;
- o average permeability of 100m/d for limestone strata;
- o average permeability of 40m/d for sand strata; and
- o effective aquifer thickness of 2.5m

The following estimated annual groundwater throughflows were obtained:

Southern canal: 170 000m^3
North-western canal: 175 000m^3
Eastern canal: 40 000m^3

The estimated groundwater inflows into each canal based on the two methods are within 12% of each other.

2. Groundwater Quality

Groundwater quality based on field data indicate that to a depth of up to 5m from the water table, the groundwater is generally fresh to brackish(1000mg/L to 5000mg/L). Below this fresh to brackish groundwater lens, the groundwater is generally saline (5000mg/L up to 36000mg/L). Inflows into the canals will be from the upper fresh groundwater lens.

3. Groundwater Flow from Rubbish Tip to Canal

Darcy's equation was used to determine the groundwater throughflow from the tip to the southern canal. An estimated flowrate of 76 000 m^3/yr is estimated.

4. Leachate Composition

Based on our experience, the typical composition of leachate from landfill sites are summarised in the attached table. However, the actual concentration of each constituent that will ultimately discharge into the canal will be dependent on the following factors:

- composition of the landfill;
- rainfall infiltration rate within and around the landfill;
- permeability of the aquifer; and
- thickness of the unsaturated zone.

We expect that because of the highly permeable nature of the aquifer, any leachate emanating from the tip will be rapidly transported to the southern canal.

Should you have any further queries please do not hesitate to contact me.

Regards,

Alan Deeney

** pH 2.5 – 7.5 *

** BOD5 10,000 mg/L
COD 6,000 mg/L
Total Suspended Solids 500 mg/L
Total Dissolved Salts 15,000 mg/L *

Organochlorine Pesticides. < 0.002 mg/L *
Organophosphate Pesticides < 0.02 mg/L *
Total PAH < 0.02 mg/L *
Total Petroleum Hydrocarbons < 2 mg/L *

** Ammonia Nitrogen 2500 mg/L *
Nitrate 370 mg/L *
Total Phosphorus 30 mg/L
Ortho Phosphate 20 mg/L

Alkalinity 3000 mg/L
Total Hardness 3500 mg/L

** Copper, Lead 15 mg/L
** Zinc 130 mg/L
** Total Iron 400 mg/L
Cadmium < 0.1 mg/L
Total Chromium 3 mg/L
Dissolved Manganese < 14 mg/L *
Arsenic < 0.01 mg/L *
Selenium < 0.01 mg/L *
Mercury < 0.1 mg/L *

Sodium 2200 mg/L *
Potassium 1400 mg/L *
Calcium 1000 mg/L *
Magnesium 250 mg/L *

Chloride 6000 mg/L *
** Sulphate 900 mg/L *
Cyanide-free < 0.1 mg/L *

Note: * Based on available test data.
** Exceeds Primary Sewer target concentrations.