MANDURAH

URBAN GEOLOGY OF THE MANDURAH SHEET

The aim of this Urban Geology survey is to provide information to all those concerned with aspects of raw material and water supply, rural, urban, industrial or transport development. The intention is to point out geological factors which may affect planning on a broad, rather than a specific basis. Detailed site investigations will still be required but it is hoped that this information will provide a useful framework for such further work.

The area covered by the Mandurah Sheet is mainly rural; stock grazing and farming are dominant. Professional fishing is carried out in Peel Inlet and from Mandurah into the Indian Ocean. Two main urban zones, Mandurah (4.0 km^2) and Falcon (Miami 1.5 km^2) occur in the north and northwest respectively; minor suburban areas are developing southeast of Mandurah (near Creery Island) and south of Miami (at Warrungup). Recreation and retirement houses are scattered along the peninsula between the Harvey Estuary and the ocean. The total land surface of the sheet area is 167 km^2 of which about 55 per cent is cleared. Inland waters occupy a further 113 km^2.

The geology of the Mandurah Sheet area was mapped between 1965 and 1967 by G.H. Low, D.C. Lowry and R.W. Lake of the Geological Survey of Western Australia and re-mapped in 1975 and 1976 by E.R. Biggs of the Survey. For the remapping, extensive field traverses were carried out on a base-map scale of 1:25 000, using 1973 aerial photography for minor extrapolation. Additional data were supplied by the relevant sections of the Geological Survey and by G.W. Kendrick of the W.A. Museum.

STRATIGRAPHY

Sediments and sedimentary rocks of Holocene and Pleistocene ages crop out within the area of the Mandurah Sheet, and Lower Cretaceous and Jurassic sediments have been intersected in deep boreholes near Mandurah. Broad physiographic divisions are shown at far right on the inset map.

PLEISTOCENE

The oldest sediments cropping out within the map area are alluvial and marine deposits associated with the Pinjarra Plain. These deposits are assigned to the Guildford Formation which has been dated as probably Early Pleistocene on marine fossil evidence from a shallow borehole near Coolup. Within this area the sediments form a flat, low-lying plain which has been artificially drained and is used intensively for agriculture.

The formation consists mainly of sandy clay within the Mandurah map area, the quartz sand ranging from very fine grained to medium grained with a small percentage of coarse grains. Some zones or lenses of quartz-free clay are present, and in places, especially where surface weathering has occurred, the clay content has been greatly reduced, giving rise to a clayey sand. The sediment is usually mottled in shades of brown, orange, yellow and grey, and is variably laterized and oxidized at the surface. It is probable that Guildford Formation clays floor many swamps beneath a thin cover of peaty sand and silt.

Overlying the irregular erosion surface of the Guildford Formation is the Bassendean Sand, which has an average thickness of 1 to 2 m. This thin stratum is presumed to be the residuum from erosion of a much more extensive and thicker dune cover. Occasional low dunes occur up to 4 m in elevation but the surface generally reflects the subdued Guildford Formation topography. The sand consists of poorly sorted quartz, mainly fine to medium grained, but containing coarse grains in places. Individual grains are angular to subrounded and generally frosted. The sands are off-white to pale grey and rarely brown, indicating increasing humus or clay content (probably as a result of admixture with underlying clays). In several localities a basal layer is present. This consists of a medium to coarse grained, vari-coloured orange, pink and white quartz sand with frosted, subangular to subrounded grains. The colouration is caused by partings and inclusions of iron oxides.

As there is no borehole information, the subsurface extent of, and relationship between, the Guildford Formation and Bassendean Sand are not known west of Lake Mealup. It is probable that some interfingering occurs although this is not shown on the cross-section below.

A major part of the Coastal Belt physiographic division consists of the Spearwood Dune System, an undulose to steeply hilly landform of Tamala Limestone ('Coastal Limestone').

The limestone is mainly an eolian calcarenite (eolianite), partly to wholly lithified and is composed of shell fragments, quartz grains and very minor amounts of feldspar. It is off-white to cream, porous, friable and cavernous in places. The shell fragments and quartz are mainly medium grained but some solution and redeposition has produced structureless travertine and laminated cap rock. Solution-pipe structures and root casts are locally common and cross-bedding is usually present. Weathering of the limestone gives rise to residual red and orange sandy soils.

The limestone occurs in low ridges and platforms, often having a characteristic open heath vegetation; it also forms the many small reefs offshore, between high and low water marks and to a lesser extent between high water mark and the foredunes. At one locality north of Falcon Bay the calcarenite forms sea cliffs, whereas on the western shores of Lake Clifton and Harvey Estuary, it occurs as low cliffs marking former sea levels 1 to 2 m higher than at present.

Included within the Tamala Limestone is the unit mapped as 'predominantly sand'. This sand is a leached weathering product of the limestone and is composed of moderately sorted, fine to coarse quartz grains. Some patches of calcareous sand remain; and boulders, cobbles and pinnacles of limestone, and layers of travertine occur. Sand grains are frosted, subangular to subrounded, rarely rounded, and are varicoloured depending on the degree of leaching or iron-staining and humus content. Typically, the sands are off-white to grey, grading through buff and pale brown to a deep yellow close to limestone and at depth. Some calcareous patches are due to a surface veneer of wind-blown Safety Bay Sand (see below).

The sands associated with the Tamala Limestone form a subdued undulating sand plain supporting a low banksia woodland, as between Mandurah and Miami; or steep dunes supporting a taller open forest, as in the south-west of the area. Inland from Cape Bouvard there are at least 20 fossil strand lines which cut both sand and limestone; these mark successive locations of an embayment in the prograding Pleistocene coast. Although mapped as a separate unit, the sand on these strand lines is identical with that described above.

HOLOCENE

Close to the coast, the youngest dunes, part of the Quindalup Dune System, are composed of Safety Bay Sand. These are steep-sided, rolling dunes extending up to 50 m above sea level and in several localities are actively being built from wind-blown beach sand. The active areas, where vegetation is sparse or absent, are mapped as a separate unit; the stabilised dunes are covered with low shrubs and herbs except for some crests or zones of extensive human use.

The sand is poorly sorted and is composed of medium to coarse, subangular to subrounded grains and a small proportion of fine grains. It is calcareous, frequently consisting of more than 50 per cent of shells and shell fragments. Variable, but small, amounts of heavy minerals occur and are especially noticeable where winnowed by wind. Calcarenite pebbles appear locally where the Safety Bay Sand cover is thin above Tamala Limestone. The sand is usually cream coloured, but may be mottled yellow, fawn and brown, due to iron staining. Charcoal and humus impart local dark colouration where agricultural clearing has occurred.

Lagoonal and estuarine deposits are mapped around the shores of Peel Inlet, Harvey Estuary and Lake Clifton. They form low-lying areas with sedge beds and samphire flats, or sandy beaches and low beach-ridges. Paperbark (Melaleuca spp.) and Acacia woodlands have colonized some of the higher-level deposits. Sedimentation is active, especially along the channel connecting Peel Inlet to the Indian Ocean.

As the lagoonal deposits are distinguished by their mode of deposition within a saline, probably tidal environment, they include several lithologies. Beaches and ridges contain medium to coarse, frosted, white subangular, and grey subrounded to rounded quartz sand. Some spits are composed of fawn, coarse-grained quartz sands. Lower beaches comprise grey, brown and black humic sandy clays, silts and clayey sands, in places with high percentages of decomposing plant material. A saline crust on these sediments is caused by their proximity to a fluctuating salty water-table. Close to the present waterline are black and brown foetid muds and clays which are swampy in part and intercalated with silts and clayey sands. Shells and fragments of shell and limestone are locally common and have undergone solution and redeposition on some low ridges to form a recemented limestone.

Swamp deposits occupy the floors and margins of present or recent shallow depressions, and in many cases are still forming. Where seasonal flooding is regular, the swamp floors are vegetation free, but where natural or artificial drainage has lowered the water table sufficiently, the deposits support open forest. All the sediments contain a moderate to high percentage of peat, imparting a dark-grey to black tone to the matrix which is fine-grained, or rarely, medium-grained sand or silt.

One area of Holocene alluvium has been recognized in a large depression immediately south of Robert Bay. The depression is subject to periodic inundation, although artificial drainage aids rapid surface drying. The sediments comprise interlayered yellow and mid-grey silts and silty clays and brown sands, sandy clays and humic soils. Several patches of grey clayey sand are present and probably represent exposure of the underlying Guildford Formation. Some peaty horizons are also observed. The drainage outlet from the alluvial depression has formed a small delta in Robert Bay.

STRUCTURE

The Pleistocene and Holocene sediments in the Mandurah area are the upper part of over 7 000 m of sedimentary rock filling this section of the Perth Basin. They have been subjected to only slight warping or tilting as a result of sediment compaction and the strata are horizontal or dipping slightly to the west. From seismic and oil-exploration drilling information, faults are known to cut the Precambrian basement and to affect the overlying Palaeozoic and Mesozoic rocks but there is no surface evidence to suggest that Quaternary sediments are affected. One trend line is noted within Tamala Limestone south of Bouvard Trig but that is probably a geomorphological feature such as an abandoned shoreline.

ECONOMIC GEOLOGY

CLAY

No clay is extracted within the sheet area although a deposit revealed in a dam excavation near Heron Point Road appears suitable for brickmaking. Results from brick-making tests on this material are available from the Geological Survey. No other clay deposits are known in the area but it is probable that others occur within the Guildford Formation.

LIMESAND

Good quality limesands are found within the Safety Bay Sand at various localities along the coast. Although no assay information is available, it is likely that limesand suitable for burning or lime-bricks is present within the area.

LIMESTONE

Limestone suitable for cement manufacture, metallurgy, dimension stone and road construction occurs in the Tamala Limestone; the higher-grade (high calcium carbonate content) material generally being in the cap rock. Grade of material varies considerably and proposed quarry sites should be sampled and tested thoroughly to ensure that sufficient limestone of the required quality is present.

The only quarries being operated on the sheet area at present are in shelly limestone of moderately high grade. The product is used mainly for road making. Assay information on some individual limestone pits may be obtained from the Survey.

MINERAL SAND

Minor concentrations of heavy minerals, mainly ilmenite, have been formed by wave and wind action on the beach and foredunes south of Tim's Thicket Road. The fossil shorelines near this locality are considered prospective for heavy mineral sands although high quartz dilution has probably occurred.

PEAT AND DIATOMITE

The various lakes and swamps on the coastal plain are prospective for peat and diatomite but no individual deposit has yet been examined in detail.

SAND

Sand is mined in several places from small excavations in coastal dunes, mainly in conjuction with levelling operations. It has been found suitable for fill and top dressing and is used mainly within the town of Mandurah.

WATER

Between Pinjarra and the coast at Mandurah there are three sets of dunes, the most easterly being the Bassendean Dune System and passing westerly through the Spearwood Dune System to the Quindalup Dune System along the coast. Peel Inlet and Harvey Estuary cut across the Spearwood and Quindalup Dune Systems. The Bassendean Dune System is east of Harvey Estuary.

Some of the lakes and swamps, in the depressions between the dunes, are hydraulically connected to the water table, particularly during winter months when the water table is high. During summer, when the water table is low, some of the swamps and lakes become dry and others retain water perched above the water table by peaty lake deposits.

Groundwater of marginal quality is drawn from bore-holes to supply domestic and pastoral needs. Some is obtained at shallow depths from unconfined aquifers in the superficial deposits and the remainder from deeper confined pressure aquifers of Mesozoic age. The table below is a modified stratigraphic column applicable to the Mandurah-Miami area.

The average annual rainfall is about 850 mm and mostly falls between April and September.

A more detailed survey of the hydrogeology of specific areas will be required as development progresses.

Unconfined (water-table) aquifers

The unconfined aquifers occur in the superficial formations which are mainly littoral, eolian and alluvial in origin. Hard calcarenite (Tamala Limestone) is also widespread and contains water of varying salinities. The superficial formations rest unconformably on the Early Cretaceous Warnbro Group except east of Mandurah where they rest unconformably on ?Late Tertiary Rockingham Sand, which in turn rests unconformably on the Warnbro Group. Depth to the water table varies considerably depending on elevation and location. In some low-lying areas the water table is seasonally exposed at the surface, forming lakes and swamps.

The salinity of the groundwater is highly variable, ranging from less than 500 mg/l T.D.S. (Total Dissolved Solids) to more than 5 000 mg/l. In the elevated areas the salinity of shallow groundwater is often lower than that of the deeper water as a result of localised intake of rainwater. The salinity generally increases with depth and towards the coast. All the lakes and swamps are brackish. On 17 March 1976 Warrungup and Nerigardup Springs were tested for Total Dissolved Solids (Warrungup 2 800 mg/l, Nerigardup 3 000 mg/l). During winter months the salinity of the springs should decrease markedly since these tests were conducted at a minimum flow-period. The salinity of the unconfined groundwater is generally too high for domestic use but is often satisfactory for selected plants and is mostly suitable for stock.

A deep sub-surface channel extends from the north of the map area into the extreme northeast of this area and has been filled with brown and yellow-brown, moderately sorted, coarse-grained, subangular quartz sand (?Rockingham Sand). It extends to a depth of about 65 m below sea level. The unconfined groundwater which occurs within this channel is brackish to saline and is not suitable for domestic or household use.

Confined (pressure-water) aquifers

Five confined aquifers are recognized: the Leederville Formation, the upper, lower and basal (Gage Sandstone Member) parts of the South Perth Shale (all contained in the Warnbro Group), and the Lower Jurassic Cockleshell Gully Formation. The Lower Cretaceous aquifers of the Warnbro Group have a gentle northwesterly dip and a maximum thickness of about 390 m, as at Mandurah No. 1 borehole. These are separated from the underlying Lower Jurassic aquifer by a strong angular unconformity.

The Leederville Formation is a sequence of claystone, siltstone and sandstone of marine or near-shore origin, about 117 m thick (Mandurah Golf Course boreholes). The aquifers are high yielding, but the salinity is variable, generally greater than 1 000 mg/l T.D.S.

e.g. Mandurah Golf Course boreholes: 1 000 – 1 444 mg/l T.D.S.

Mandurah No. 1 borehole: 2 000 mg/l T.D.S.

The potentiometric head near the coast is not known but it declines westward.

Recharge to the aquifers is mostly by downward percolation of rain near the Darling Scarp but may also be from the underlying South Perth Shale, especially in areas where the channel containing ?Rockingham Sand has eroded the green clay barrier separating the Leederville Formation from the South Perth Shale. The green clay has not been recognized in the Miami boreholes.

The South Perth Shale has a gentle northwesterly dip and a maximum thickness of about 170 m (Mandurah No. 1 borehole). It consists of an interbedded sequence of sandstone, siltstone and shale, and is often glauconitic. Pebble beds may occur at its top. It is predominantly marine with some littoral and non-marine intercalations. At its upper surface there is a thin (5 to 6 m) green clay aquiclude below which two aquifers have been recognized.

The upper part consists of thin beds of sand, calcareous sand, and silt, the topmost section of which (about 30 m) contains groundwater of marginal salinity, about 1 000 mg/l but not less than 900 mg/l. The salinity increases with depth, so that the lower part of the South Perth Shale, a sequence of thinly bedded silts and sands, contains groundwater of salinity greater than 2 000 mg/l. The salinity also increases to the west.

The potentiometric head is about 7 m above sea level, and the potentiometric surface has a slight gradient to the west. Recharge areas are to the east and northeast where the green clay aquiclude has been eroded.

The Gage Sandstone Member and Cockleshell Gully Formation aquifers both contain pressure water confined by the overlying South Perth Shale and have potentiometric heads which decline to the west.

The groundwater from these aquifers is brackish to saline, containing more than 2 000 mg/l T.D.S., and the salinity generally increases with depth and towards the west.

Boreholes yielding large quantities of industrial quality water can be obtained from the thick, coarse-grained, sandy beds of these aquifers.

Development

Development of the local shallow groundwater resources to supply major domestic requirements cannot be recommended because of the marginal quality of the groundwater. Only limited amounts of domestic-quality water can be drawn from shallow boreholes in the superficial formation. High pumping rates from these aquifers would certainly induce salt water intrusion from brackish or salty water below.

The most important aquifer is the upper part of the confined South Perth Shale from which yields of between 1 500 m^3/d and 2 000 m^3/d can be expected (Mandurah No. 1 borehole tested at about 1 200 m^3/d and the Golf Course borehole at about 1 600 m^3/d).

Because of salinity, the groundwater is marginal for human consumption, and a careful monitoring system would have to be established to safeguard against saltwater encroachment and subsequent deterioration of the aquifer. In most cases the quality of the groundwater should be suitable for industry and gardens.

ENGINEERING GEOLOGY

It is stressed that this section is a generalized summary, and that specific site investigation is required. Consequently, no attempt is made to quantify such terms as 'moderate' or 'fair'.

GUILDFORD FORMATION

Because of the variable nature of sediments comprising the Guildford Formation a wide variety of engineering properties can be expected. Particular care should be taken over the clayey sections as these could be expansive or sensitive. In general, porosity and void ratio are low; water content, penetration resistance and strength are variable; shear strength is related to water content; and permeability decreases with increasing clay content.

Alternate wetting and drying will cause the clay to swell and shrink, adversely affecting brick-built structures. Pier and deep-beam foundations or concrete rafts on sand pads should be considered, and the use of steel support plates for window and door lintels avoided.

Drainage disposal is difficult, and leach drains constructed of permeable aggregate would be needed. Low, steep cuts are generally stable although slides may result in shallow cuts where seepage occurs. Bitumen roads can be constructed successfully over this formation, but minimum disturbance and side drains to control the moisture content are advisable.

BASSENDEAN SAND

Generally moderately to well graded and cohesionless, except where it contains minor clay, the Bassendean Sand has fairly high porosity, permeability and void ratio, moderate to high natural density, and is not subject to shrinkage. It may well be consolidated beneath a loose surface cover which can be remobilized when dry and cleared of vegetation. It is a reasonable foundation material, but its thickness, degree of consolidation, and depth to water table need to be established during site investigation.

Drainage disposal is only a problem where the sand is thin and mixed with underlying clays, or in areas of shallow water table. As a foundation beneath roads, the sand is fair to good. Where thin, the foundation characteristics are those of the underlying formation.

TAMALA LIMESTONE

Where predominantly composed of calcarenite, the Tamala Limestone includes material ranging from soft to very hard, emphasising the need for individual site examination. The harder material is slightly porous and permeable, of medium natural density, and high to medium compressive strength. Solution cavities occur irregularly and some are filled with unconsolidated sand. Some zones of root casts are observed and these have very high porosity and void ratio, possibly leading to very severe settlement under load. The majority of the limestone has moderate density, moderate permeability, and very low shrinkage. Compressive strength increases with drying after excavation. Steep cuts are commonly stable.

The units composed predominantly of sand are partly consolidated, have a high natural density, high permeability, and no cohesion or shrinkage. Some settlement can be expected beneath foundations. Subsurface pinnacles and thin sheets of dense hard limestone are common and would increase excavation costs. Drainage disposal characteristics are good.

SAFETY BAY SAND

The Safety Bay Sand is a cohesionless or poorly lime-cemented sand of variable thickness, moderate density, high porosity and void ratio, and very high permeability. Settlement under load is common and can be uneven but can be prevented by compaction and stabilization. Cuts steeper than 35° would be unstable except where localized cementation has taken place. Remobilization is common where vegetation is removed.

LAGOONAL AND ESTUARINE DEPOSITS

The lagoonal and estuarine deposits are highly variable and poorly sorted soils (in the engineering sense), low-lying and generally saturated. They are expected to have poor engineering qualities, and, because of rapid lateral lithologic changes, will require very detailed individual site investigation.

SWAMP DEPOSITS

The swamp deposits have moderate natural density, void ratio and consolidation, and moderate to low permeability and shrinkage. They may include irregular, impermeable clay lenses of moderate natural density and void ratio, some of which could be sensitive. These deposits would form very poor foundations and cause irregular settlement. The near-surface water table would impede excavation and drainage, and lessen building stability.

ALLUVIUM

Although more silty than the swamp deposits, the alluvium is expected to have similar engineering properties and therefore to provide poor foundation. The sediments could settle under load and the near-surface water table would adversely affect excavation, drainage and building stability.

EARTHQUAKE HAZARDS

The mapped area is in the 'C' earthquake risk zone. This is a weak seismic zone.

ENVIRONMENTAL GEOLOGY

Some aspects usually considered under Environmental Geology have been discussed in various sections above. The following additional points may be made.

WASTE DISPOSAL

Dry wastes. Provided sites are distant from areas of groundwater extraction, disposal is probably safe in most of the north and west of the sheet area. Caution is required with sites close to Peel Inlet or other inland waters. Few suitable sites for large-scale disposal may be found in the southeast except where the Tamala Limestone sands are relatively thick.

Non-toxic liquid or soluble wastes. Similar comments to those on dry waste disposal apply to soluble waste disposal. Sites in the Guildford Formation would be unsuitable as it is subject to seasonal inundation. Problems are already encountered where agricultural run-off, especially fertilizer, contributes to excessive algal growth in Peel Inlet.

Toxic liquids. A few suitable sites may exist in the southwest where Safety Bay Sand or the sands associated with Tamala Limestone are thick. The risk of polluting exploited groundwater or lakes is too great elsewhere in the mapped area.

SOIL EROSION

Low and sparse vegetation provides a fragile bond to many areas of Safety Bay Sand and is sensitive to physical disturbance, for example by wheeled or foot traffic. Increasing numbers of visitors to the Yalgorup National Park could increase the risks of wind erosion and degradation of the dunes unless path and track protection is provided. Some steep slopes in the residual sand over Tamala Limestone might be subjected to rainwater scour if left without vegetation for long periods.

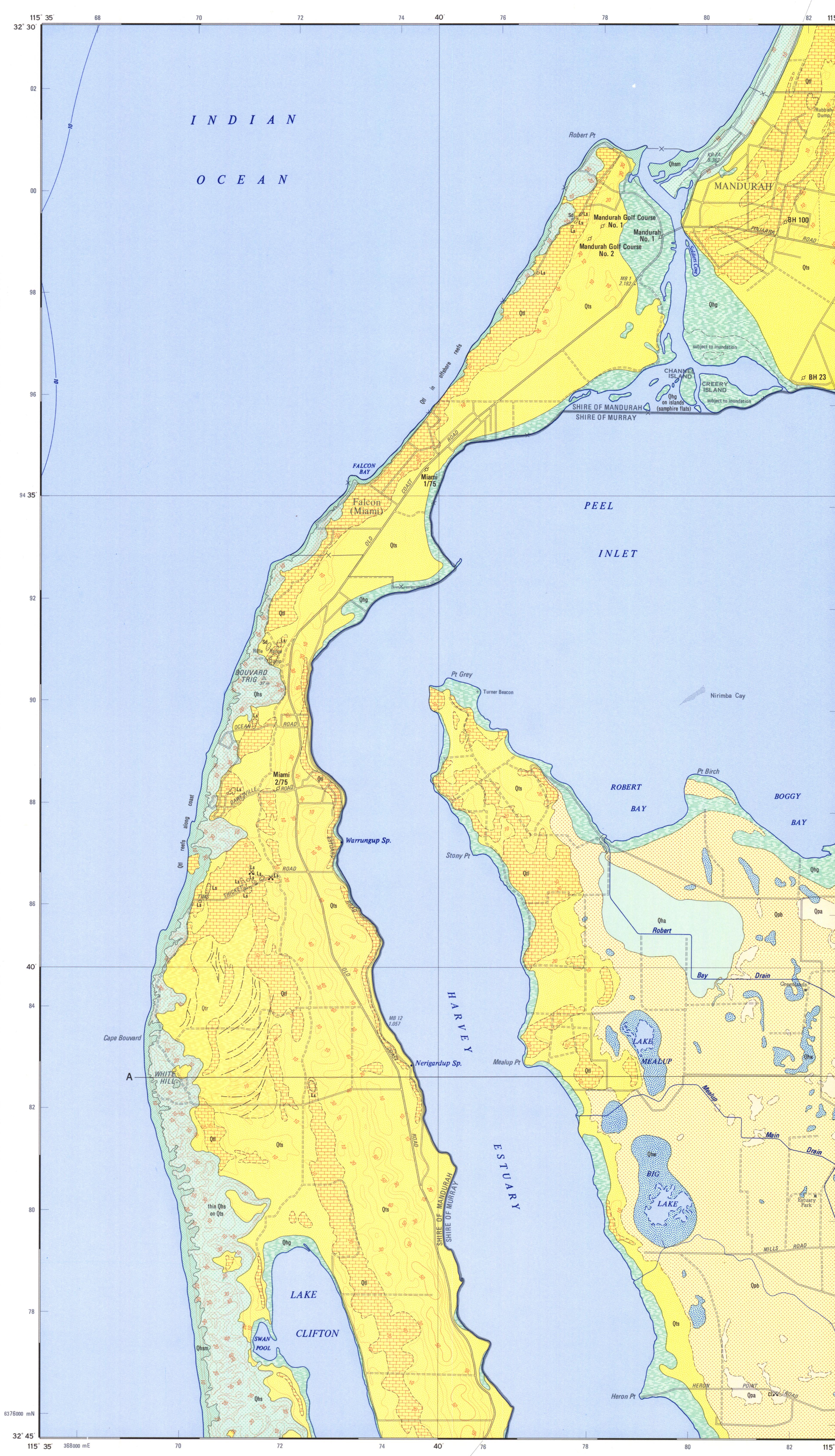
COASTAL EROSION

Most of the southern coastline in the map area is slowly accreting (building up) with sand carried by long-shore drift from the south. North of Miami the rates of accretion and erosion appear to be balanced while north of Mandurah, particularly in the lee of Robert Point, accretion dominates. All parts of the coast are subject to temporary storm damage. Localized erosion has been caused in Mandurah as a result of harbour-works, suggesting that the balance between erosion and accretion is very delicate, perhaps because the natural sand supply is small.

MINING

A few sand pits and limestone quarries have been exploited for road and building materials, some sited conspicuously near Mandurah, others better concealed. Further concealed or camouflaged sites should not prove difficult to establish in the future. Some sites may usefully provide a second land-use as rubbish dumps (as near Bouvard Trig Hill) provided no groundwater extraction areas occur within dispersion range.

Further information may be obtained from the Geological Survey of Western Australia, Mineral House, Perth.



Geology: E. R. Biggs 1975/76

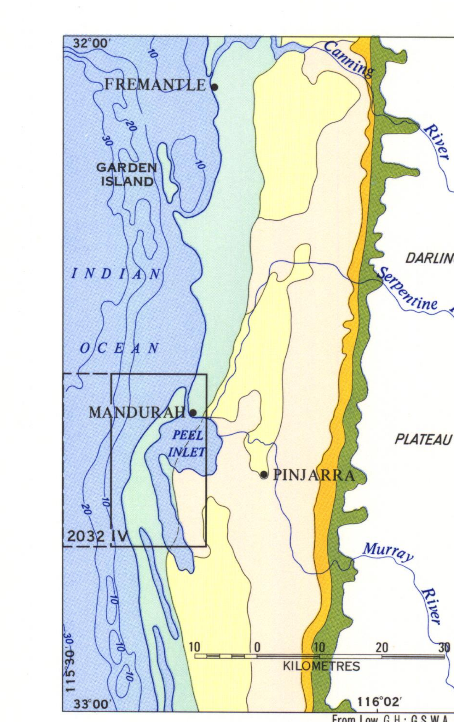
REFERENCE

			Maximum thickness (m)	
CAINOZOIC – QUATERNARY – HOLOCENE	Qhw		5	Swamp deposits
	Qha		15	Alluvium
	Qhg		10	Lagoonal deposits
	Qhsm			mobile dunes
	Qhs		40	SAFETY BAY SAND
PLEISTOCENE TO ?HOLOCENE	Qt		90	TAMALA LIMESTONE
		Qtr		reworked sand
		Qts		predominantly sand
		Qtl		predominantly limestone
PLEISTOCENE	Qpb		15	BASSENDEAN SAND
	Qpa		20	GUILDFORD FORMATION

SYMBOLS

Geological boundary; Accurate; Transitional; Dune crest (December 1972); Fossil strand line; Deep borehole (water); Quarry or pit; Mineral occurrence: Clay, Limestone, Sand; Contour in metres; Watercourse; Drain; Spring; Major road; Minor road; Track; Local Authority boundary; Townsite boundary; Powerline; Homestead; Horizontal control; major; Benchmark, height accurate; Bathymetric contour line, depth in metres

The representation on this map of a track does not necessarily imply right of way.



From Low, G.H., G.S.W.A. Record

PHYSIOGRAPHIC DIAGRAM

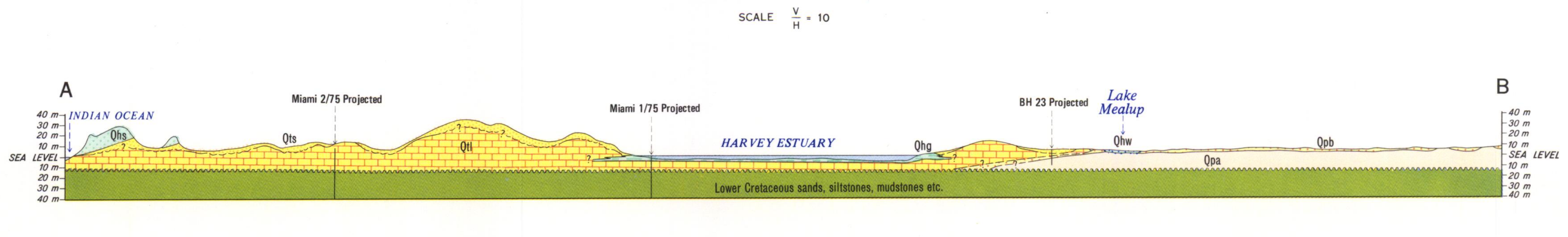
Coastal belt; Bassendean Dunes; Pinjarra Plain; Piedmont Zone; Darling Scarp

AGE		FORMATION	METRES THICK	LITHOLOGY	SALINITY mg/l T.D.S.
QUATERNARY		SAFETY BAY SAND	Up to 40	Calcareous sand	Variable
		UNCONFORMITY			
		TAMALA LIMESTONE	90	Limestone and sand	Brackish to saline
		UNCONFORMITY			
? LATE TERTIARY		? ROCKINGHAM SAND	60	Sand	Saline
		UNCONFORMITY			
EARLY CRETACEOUS	WARNBRO GROUP	LEEDERVILLE FORMATION	120 +	Thick-bedded sand and shale	~1 000 or saline
		SOUTH PERTH SHALE – UPPER PART	100	Thin-bedded sand, silt and calcareous sand	~1 000
		SOUTH PERTH SHALE – LOWER PART	70	Thick-bedded silt and sand	> 2 000
		SOUTH PERTH SHALE – GAGE SANDSTONE MEMBER	110	Thick-bedded sand and shale	> 2 000
		UNCONFORMITY			
EARLY JURASSIC		COCKLESHELL GULLY FORMATION	> 1 000	Thick-bedded sand and shale	> 2000

Compiled and published by Geological Survey of Western Australia. Cartography by Geological Mapping Section, Department of Mines. Topographic base from compilations by Lands and Surveys Department. Printed by Government Printing Office, Perth, 1977.

Copies of this map may be obtained from the Geological Survey of Western Australia, Perth.

DIAGRAMMATIC SECTION A - B



HON. A. MENSAROS, M.L.A.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1:50 000

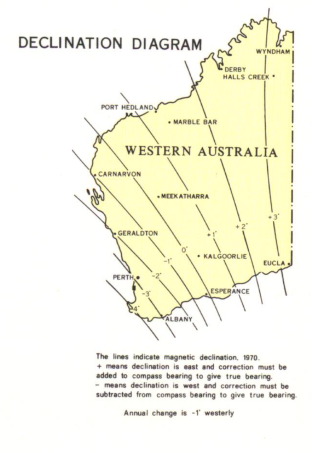
KILOMETRES

CONTOUR INTERVAL 10 m

INDEX TO ADJOINING SHEETS

ROCKINGHAM 2033 III	WELLARD 2033 II
MANDURAH 2032 IV	PINJARRA 2032 I
LAKE CLIFTON 2032 III	HAMEL 2032 II

DECLINATION DIAGRAM



MANDURAH URBAN GEOLOGY

2032 IV

FIRST EDITION 1977