WESTERN AUSTRALIA 1: 50 000 URBAN GEOLOGY SERIES

HARVEY - LAKE PRESTON

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

PARTS OF SHEETS 2031 I AND 2031 IV

URBAN GEOLOGY OF HARVEY-LAKE PRESTON SHEET

The aim of this urban geology survey is to provide information for 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 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 Lake Preston sheet and the mapped portion of the Harvey sheet represent just over 581 km² of land surface, including ephemeral swamp lakes. A variety of land uses in the area includes residential and light industrial development; pastoral, dairy and market-garden agriculture, some irrigated; 31 km² of State Forest; and part of the Yalgorup National Park. The main urbanized area is Harvey townsite, covering nearly 7 km²; the smaller towns of Wokalup, Benger, Myalup, Binningup and parts of Cookernup and Brunswick Junction together occupy just over 2 km² of land. Two major roads cross the area from north to south, one near the coast, the other parallel with the Perth to Bunbury railway, which is the third main transport route.

The geology of the Collie sheet, which includes Harvey and Lake Preston, was mapped in 1963 by Lowry and in 1975-6 by Wilde and Walker, all of the Geological Survey. Maps were published as 1: 250 000 preliminary editions in 1973, covering the coastal plain, and in 1979, covering the whole sheet.

The Harvey and Lake Preston area was remapped in 1979 for this urban geology edition, by Biggs of the Survey, using 1: 40 000 aerial photography (dated 1977) and closely-spaced traverses. East of the Darling Fault, the work of Wilde and Walker was used with very minor modification, mainly on the scarp face. Text data were provided by Biggs, Wilde, Commander and Mather of the Geological Survey.

PHYSIOGRAPHY

As can be seen from the inset physiographic diagram, the mapped area extends from the Darling Plateau and Scarp westwards across various coastal plain units to the Indian Ocean. The Darling Scarp is a fault-controlled, fossil marine erosion feature modified by later sub-aerial weathering. The piedmont zone consists of sediments deposited on the early shoreline. The plateau to the east is an eroded surface of the uplifted Yilgarn Block of ancient crystalline rocks.

The coastal plain is characterised by a broad, level-alluvial belt with lines of sand dunes and limestone ridges on its seward side. Former near-shore lagoons are now represented by Lake Preston, Leschenault Inlet and strings of seasonal marshes immediately inland from the active coastal dune system.

STRATIGRAPHY

Rocks of Archaean age crop out along the eastern edge of the mapped area, in places thinly mantled with eluvial soils, in others covered by a thicker laterite profile which is assumed to have been formed mainly in Tertiary times. West of the Darling Scarp, are unconsolidated and semi-consolidated Quaternary sediments ranging in age from Pleistocene to the present.

ARCHAEAN

Distinctive **calc-silicate gneiss** crops out in the extreme southeast of the area. It has a medium-grained diopside-epidote-plagioclase-microline-sphene assemblage, with local garnet, magnetite and quartz. The proportions of microcline and plagioclase vary considerably. Myrmekitic intergrowths are common, and quartz forms rounded inclusions within feldspar. Associated with the gneisses are white quartzites with laminae from 2 to 20 mm thick, and some tightly folded micaceous quartzites.

About 2 km north of Beela, an outcrop of **hornblende gneiss** forms two hills. The layered gneiss consists of quartz and feldspar, minor hornblende and some biotite and occurs with amphibolite bands. Minor rock-types within the mapped unit are white and grey, finely-banded quartzites and quartzose gneisses, and grey and pink coarse-grained foliated granite.

Biotite gneiss is the most common rock east of the Darling Scarp within the mapped area. It consists of various proportions of quartz, microcline, plagioclase, biotite and, locally, garnet. The most obvious banding is due to variations in the amount of biotite present. The rock is mainly a fine-to medium-grained, mesocratic, pink and grey banded gneiss, with local intercalations of pink, coarse-grained, sheared and augen gneisses, and mesocratic white and grey granulite. Pink and white granite, containing crosscutting or concordant white quartz veins, is locally abundant. Occurrences of several minor rock-types include melanocratic migmatite, pale orthoquartzite, black biotite gneiss, blue-grey and grey-green amphibolite, and dark green hornblendite xenoliths.

An area of **augen gneiss** east of Benger, partly concealed by laterite, consists of a coarse-grained, quartz-microcline-oligoclase-biotite (-hornblende) gneiss with microcline augen. The rock ranges in colour from white through pink to dark grey with increasing hornblende content. Other rocks observed within the unit are a melanocratic, feldspathic amphibolite and a leucocratic even-grained granite.

PRECAMBRIAN

Mafic dykes intrude all Archaean rock-types and may therefore be late Archaean or Proterozoic in age. They have a northeasterly trend except southeast of Wokalup where several large dykes trend west-northwest. The melanocratic, blue-grey rocks are tholeiitic quartz dolerite or gabbro, consisting of andesine-labradorite plagioclase, augite, hornblende, minor quartz and accessory apatite, sphene and pyrite. Quartz-feldspar-epidote veining is common. The dolerite is widely jointed and fractured, reflecting the post-tectonic activity close to the Darling Fault. Many dykes show some degree of alteration, with saussuritization of plagioclase and breakdown of pyroxene to fibrous amphibole.

Conspicuous **quartz dykes and veins** crop out at White Rocks and east of Wokalup, trending slightly east of north. They were probably injected along fractures associated with and parallel to the Darling Fault. Barren of minerals other than localized iron oxide staining, the white quartz is crystalline and opaque, the opacity being caused by abundant fracture planes.

? TERTIARY

A lateritic conglomerate occurs immediately southeast of Harvey and extends eastwards outside the mapped area. Within this area it comprises angular pebbles and boulders of laterite, quartz and quartzite in an orange sandy lateritic clay. Elsewhere the pebbles are rounded and the rocks, known as the Harvey Beds, are thought to be of fluvial origin but near Harvey have clearly become mixed with colluvial material which has travelled only short distances. No age has been established for these unfossiliferous beds but, from field relationships, they are thought to be of Tertiary or early Pleistocene age.

Extensive **laterite** caps the metamorphic rocks of the Darling Plateau but has been eroded close to the scarp. It is typically pisolitic or massive, and brown, orange or purple depending on the amount of iron-cementation or manganese staining. The unit may be well lithified to unconsolidated and is usually associated with orange pea-gravel and varied amounts of white sand and fawn clay released by weathering. The most common erosion product is an orange sandy clay supporting pebbles of quartz and laterite up to 100 mm in diameter, the clay : pebble ratio being in the order of 30:70. The laterite is 1 to 6 m thick above pallid zone sandy clays.

QUATERNARY

The oldest Quaternary deposit in the area is the **Yoganup Formation** which, in its type area to the south, is a shoreline sand deposit. North of Harvey some terrestrial modifications must have occurred, because the formation is a moderately-sorted, clayey sand, mainly medium-grained but ranging from fine to coarse. Individual quartz grains are mostly subrounded, some are subangular and only about 2 per cent rounded, in contrast to the type area where rounded grains predominate. Subangular to subrounded pebbles of granite and laterite, and rounded quartzite pebbles have been found in sands. These data suggest major dilution of the shoreline deposit by colluvial and alluvial admixture. Very fine-grained heavy minerals, particularly ilmenite, are locally common as accessory minerals.

The Yoganup Formation sand is usually off-white at surface grading through cream to yellow, orange and brown with increasing depth, reflecting a decrease in leaching with depth. The grains are mainly frosted, some clear translucent and most, below the leached zone, are coated by an iron oxide film. Beneath the Guildford clays is a unit of shelly sand, known as the Jandakot Beds (see section), which is seen to interdigitate with Yoganup Formation from borehole information.

The **Guildford Formation** shapes the physiographic zone known as the Pinjarra Plain. It is variously composed of sandy or silty clays, clayey sand and small areas of semi-lithified laterited clay. All types are generally brown or fawn, mottled orange; less common clay colours are red, green and grey. The included quartz sand grains are fine to medium grained, mainly subangular, both frosted and clear. Pebbles of quartz and laterite are locally abundant, and a basal sand horizon has been recorded from boreholes. Adjacent to sand dunes in the west of its outcrop, the Guildford Formation may be obscured by up to 50 mm of washed or wind-blown sand. In many places the upper stratum of the formation is marked by a spring-line where water percolating through overlying sands encounters the impermeable clayey layers.

Bassendean Sand forms the easternmost and oldest of three dune systems which are roughly parallel to the coast. The sand is fine to medium grained, in places coarse, especially towards the base of the unit. It is grey to off-white at surface, passing through cream and pale buff to yellow at depth. Individual quartz grains are subangular, some subrounded or very rarely rounded; most are frosted but up to 40 per cent may be clear at some locations. The sand now occurs as a series of weathered, irregular, rounded dunes, generally with gentle slopes. Several interdune depressions are characterized by swamps or thickly vegetated fine-grained humic sands. Slicks of very fine-grained heavy minerals, typically ilmenite and limonite, are seen where wind-winnowing has occurred. As the surface sand is physically indistinguishable from that associated with Tamala Limestone (see below), the Bassendean Sand unit is mainly delineated on its physiographic features.

A sub-unit of the sand has been mapped where the sand is thin, rarely over 5 m thick, and reflects the subdued topography of the underlying Guildford Formation. It is considered an erosion remnant of a formerly more-extensive dune cover.

Tamala Limestone and its associated **sand**, form the Spearwood Dunes physiographic unit, immediately west of the Bassendean Sand. In general, these dunes are higher than the Bassendean Dunes, have steeper slopes, especially on their eastern edge, and occur in more continuous ridges.

The limestone is principally a lithified eolian calcarenite, although minor marine, shelly lenses occur locally. It is commonly covered by a thin eluvial layer of orange sand, leached to white at surface, containing boulders of broken limestone. The rock varies in hardness from friable to completely lithified and generally has a low calcium content (from 30 to 65 per cent $CaCO_3$). The main porosity is a medium to coarse quartz sand with rare feldspar and fine ilmenite. Indistinct to definite horizontal bedding and well-defined cross-bedding suggest shallow off-shore to estuarine deposition conditions, probably backed by sand dunes. Fossil traces include root casts and moulds, lithified ?worm burrows and indistinct mollusc and gastropod casts.

Apart from the ridges south and southeast of Mialla Lagoon, the limestone occurs in a subdued topography, on the east of the Preston-Leschenault depression, presumably as a result of marine erosion in later Pleistocene or Holocene times. Limestone probably occurs at no great depth beneath sand ridges east of the Old Coast Road as it has been encountered in shallow drillholes and in four small limestone pits in the pine plantations.

The sand element is mainly derived from the calcarenite by decalcification on weathering but there is also evidence for a separate, eolian origin for some strata, where dune bedding is exhibited and sand grains are pitted and polished. In general, the sand does not show any bedding features, and the fine to medium grains are subangular to subrounded and poorly to moderately sorted. Off-white near surface, the sand becomes yellow with increasing iron-oxide coating at depth, and is characteristically bright orange within a metre or two of limestone. Beneath the iron coating, most grains are colourless, a few are yellow, orange or pink.

Minor **colluvium** is widespread on the Darling Scarp and Plateau but has only been mapped where it forms a thick and continuous layer. It is typically found in shades of brown and orange, and consists of angular to subangular pebbles and cobbles set in a sand, silt and clay matrix. The pebbles reflect the underlying or adjacent bedrock and commonly include quartz and laterite as well as the crystalline rocks. The unit includes minor eluvial soils and some local alluvially-reworked material in narrow watercourses. The quartz and feldspar sand grains are mainly subangular with lesser amounts of subrounded or angular grains. Very fine-grained ilmenite is a common accessory mineral. Field relationships suggest the colluvium began forming in the Pleistocene and is still being deposited.

Lagoonal deposits occur along the shores of Lake Preston and Leschenault Inlet and floor the intervening low-lying land. The sediments are brown and black silts and muds, and lenses of very fine-grained sand on flats fringed with samphire. Several areas of medium-grained sand fringe Lake Preston and contain abundant pink shells of the gastropod *Coxiella*, indicating a Holocene, hyper-saline non-marine environment. Other fossils from a "sand and seagrass fauna" indicate an age of deposition from mid to late Pleistocene in a shallow near-shore environment, suggesting progressive isolation of lagoons from the ocean with water salinities steadily increasing through evaporation and marine fauna being replaced by more recent hypersaline forms. Calcareous peaty sands are locally common and are composed mainly of shell fragments and sand, and partly of lime redeposited from solution.

Holocene alluvium occurs in all the watercourses in the mapped areas, mostly too localized to show at this scale. Thicker, mappable deposits occur only in the Brunswick and Wellesley Rivers and adjacent to Leschenault Inlet. The Leschenault deposits appear to be allovially reworked sand from the Tamala Limestone unit and are almost certainly time-related to adjacent lagoonal deposits.

Alluvium lithologies may vary rapidly within a few metres, and commonly include fine to coarse sands, silt, sandy clay and smooth clay. Other units encountered are partly-consolidated conglomerate, mud and loam. Sand grains are generally subrounded, some subangular or angular, most are clear and polished, some frosted and some pitted, indicating that some of the material has been derived directly from weathering rocks and some from reworking of other deposits. Along the rivers, alluvium forms low levees backed by fertile, flood-prone, level terraces.

Swamp deposits have formed in depressions within the Spearwood and Bassendean Dunes and, at Benger, on the Pinjarra Plain. The deposits are typically dark grey or brown, fine sands or silts with varied but significant amounts of peat. Quartz grains in the deposits are mainly subangular but range from angular to rounded, reflecting the varied parent materials. Most swamps are ephemeral and appear in the dry season as playas or areas of closed hydrophytic vegetation. Benger Swamp has been cleared for market gardening.

Sediments in Benger Swamp appear to be mainly reworked from adjacent units, particularly the Guildford Formation sandy clays. The western portion of the swamp is characterized by three subparallel ridges about 1 m high, formed of sandy silt. These are reworked Bassendean Sand and probably represent former shorelines of a lake in this location.

A grey-brown limestone near Kwaliup Lagoon is included with the swamp deposits. It is a very fine-grained, almost pure, limestone with some small unidentified organic remains and some iron-staining in holes and cracks. It appears to have been formed by surface or shallow water-table deposition in a clear, lime-rich lake or swamp. It is massive and crystalline and is commonly overlain by about 100 mm of dark brown soil.

The youngest geological unit in the area is **Safety Bay Sand**, which is still being formed as hummocky dunes from material washed up from the ocean floor and then blown inland. It is a cream, calcareous quartz sand in which shells and shell fragments make up 10 to 80 per cent of the whole, probably averaging below 30 per cent. The quartz is fine to medium grained, angular to subrounded, mainly clear and colourless, with some iron-staining on the surface of grains. In places, the base of the unit has been partly lithified to form a friable calcarenite. The unit widely displays dune bedding. The dunes are generally fixed by vegetation ranging from low closed woodland to open heath, and a sub-unit of mobile dunes has been mapped where vegetation is mainly or wholly absent.

ECONOMIC GEOLOGY

CLAY

Clay was extracted from a pit south of Harvey for use as a waterproof lining in sewage treatment ponds. Similar clays may be found throughout the Guildford Formation, especially adjacent to major drainage lines where finer material has been deposited. These and white kaolinitic clays on the Darling Plateau have potential as brick-making clays if blended with suitable plastic clays.

GRAVEL

Pisolitic laterite has been widely extracted from sites on the plateau for building or maintaining roads. Four sites southeast of Benger were being operated during the survey (1979) but extraction tends to be piecemeal and pits may be opened or closed at short notice. Generally, a small pit will be opened to service a particular section of road and abandoned temporarily or permanently on completion of the work.

LIMESTONE

Low-quality limestone, averaging below 65 per cent $CaCO_3$, has been quarried at several localities in the west of the mapped area. Only four sites were being exploited in 1979, supplying minor amounts of stone for road foundations and wearing surfaces. As mentioned above, the calcium carbonate content of the stone is low, and it is therefore unsuitable for high-grade applications such as cement or steel manufacture. The limestone near Kooalbup Lagoon has a higher calcium content but is of very limited extent.

ROCK AGGREGATE

The white quartz vein near Wandlina was exploited for crushed rock aggregate but the quarry has been abandoned for many years. Geniuses on the Darling Plateau have the potential for use as road, rail or concrete aggregate but none has been extracted to date. A quarry just to the east of the mapped area supplied crushed and boulder rock for the Harvey Weir and some local building projects.

SAND

Sand for building construction is obtained from pits near Red Lake, west of Harvey. Abandoned sand pits occur in the same area and near Benger Swamp. The sands are fine to medium grained, subangular to subrounded, and although they do not fully conform to the relevant Australian Standard Specification, they have been found suitable for mortar and concrete use.

WATER

The sandy Quaternary sediments in the western part of the area are the major source of fresh groundwater.

North of Harvey small quantities of fresh (less than 1 000 mg/L) water are present in the Yoganup Formation, and seepages occur where the sands have been washed downslope to overlie the Guildford Formation. The Yoganup Formation is in hydraulic continuity with the Jandakot Beds and the basal sands in the Guildford Formation, which are confined by the overlying clay. Moderate to large supplies are available from these sands, but the salinity increases from about 1500 mg/L near Harvey to just over 4000 mg/L in some of the westernmost Harvey bores (Fig. 1). Yields from the clays in the Guildford Formation are low and the groundwater salinity exceeds 10 000 mg/L in places, contributing to soil salinity problems.

The water table in the Bassendean Sand is close to the surface, creating numerous swamps, and large supplies are available from the 20 to 30 metre saturated thickness. The salinity is mostly quite low, less than 500 mg/L, owing to direct recharge from rainfall.

The Tamala Limestone contains a similar thickness of fresh water but the salinity rises westwards and can exceed 2000 mg/L just to the west of the large swamps, such as Myalup Swamp, due to concentration of salts by evapotranspiration. Mostly however the salinity is less than 1000 mg/L and large amounts of water are used for the irrigation of vegetables and lucerne.

Groundwater from the Tamala Limestone discharges along the eastern shores of Lake Preston and Leschenault Inlet, and the swamps between. A well defined salt water interface is present in the aquifer along the eastern shore of Lake Preston. The salinity of both the salt water in the aquifer, and the water in the lake itself, is about 60 000 mg/L.

A diffuse zone of mixing, in which the salinity increases towards the base of the aquifer, occurs along the coast to the south. Overlying the saline and hypersaline groundwater is a relatively thin layer of fresh or brackish water in the Safety Bay Sand, from which small supplies can be obtained.

The Cretaceous Leederville Formation has been intersected below the Quaternary sediments and consists of a maximum of 200 m of interbedded sands and shales. Fresh water has been intersected only in a thin zone in the top 30 m in Binningup bores and Harvey Bore 1, elsewhere the salinity probably exceeds 1000 mg/L. Recharge to the formation comes from the aquifer to the south, where there is an extensive fresh water flow system, from the Tamala Limestone and Bassendean Sand, and locally through coarse sediments at Harvey.

The Late Jurassic Yarragadee Formation, which also forms an extensive fresh water flow system in the Bunbury area possibly underlies the Leederville Formation in the south of the area.

The Early Jurassic Cockleshell Gully Formation underlies the Leederville Formation in the central and northern parts of the area, and contains large supplies of groundwater with a salinity in excess of 2000 mg/L.

East of the Darling Scarp, water supplies are limited, with small supplies of fresh water being yielded by springs and shallow wells in colluvium and clay derived from weathered bedrock. Small supplies of fresh or brackish water are also present in partially weathered or fractured crystalline bedrock.

ENGINEERING GEOLOGY

The engineering properties of rocks, including such features as strength, suitability for foundations, stability on slopes and in excavations, and suitability as construction materials, depend on geological factors such as mode of origin, composition, and susceptibility to metamorphism, weathering and erosion. The generalized engineering properties of the rocks that occur in the area are described with this in mind.

PRECAMBRIAN ROCKS

These rocks are predominantly granitic types, widely intruded by mafic dykes. Conspicuous quartz veins crop out locally. The rocks are hard and dense when fresh or slightly weathered and make good building foundations. When weathered they become softer and less dense, but the granitic rocks are still adequate for foundations of minor buildings if normal preparation procedures for foundation in clay are followed. In the case of the mafic rocks, weathering products are usually more prone to swelling and shrinking with alternate wetting and drying than those of granitic rocks. This makes poor foundation material, unless special precautions are taken to keep the moisture content constant. The rocks are usually intersected by fractures or joints, some of which may be open and stained with iron oxide or other weathering products. These structures, quartz veins and shear zones, particularly on the face of the Darling Scarp, provide channels for percolating water and contribute to the instability of slopes, excavations and the foundations of engineering structures.

The softer and less dense products of weathering, particularly those from mafic rocks, tend to be unstable on steep slopes and in excavations, especially in winter. They may provide suitable material for the construction of impervious embankments, but individual material testing is necessary.

Both granitic and mafic rocks, when hard and dense in their fresh or slightly weathered state, are suitable for road construction, railway ballast, brickmaker construction, and building aggregate. In fresh rocks the widespread foliation is not a geotechnical problem.

CAINOZOIC

Laterite is a rock with varying geotechnical properties depending on its degree of weathering. When it is hard, dense and massive, it requires blasting for excavation. In this condition it is a good building foundation but subsurface drainage disposal is a problem. When it occurs as a gravel, ferruginous pisolitic set in a clay-sand matrix form a material that is firm when dry, but when wet can become soft and unstable. This laterite gravel when compacted makes satisfactory foundations for roads and buildings, but needs protection against both water erosion and fluctuations in moisture content.

Laterite conglomerates occur in pars associated with alluvium and have similar geotechnical properties. The material is stable in road cuttings east of Harvey.

The Yoganup Formation has the geotechnical properties of a loose sand, though a low vertical face may stand unsupported for a short time. The material is permeable, settlement could occur under load and it requires protection against erosion.

The Guildford Formation has a wide variety of geotechnical properties because of the variable clay content. Natural density is moderate to high, and permeability is low except in sand-rich parts of the formation. Alternate wetting and drying will cause the clay to swell and shrink which makes foundation conditions poor unless special precautions are taken to keep the moisture content constant. Low steep cuts are generally stable, although slides may occur in shallow cuts where there is seepage. Drainage disposal is generally difficult.

Bassendean Sand, which is generally moderately to well graded and cohesionless except where it contains minor clay or silt, has a moderately high natural density, is very permeable and well drained, and is not subject to shrinkage. It may be moderately well consolidated beneath a loose surface cover which can be remobilized when dry and cleared of vegetation. Drainage disposal is only a problem where the sand is thin and mixed with underlying clays, or in areas of shallow water table. The thickness and degree of consolidation of the sand, and the depth to water table, need to be established during site investigation.

Areas mapped as Bassendean Sand overlying Guildford Formation will generally have the geotechnical properties of the latter.

Tamala Limestone, where it is predominantly calcarenite, includes material ranging from soft to hard depending on the degree of cementation. 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 with high porosity, are present, and these zones may lead to severe settlement under load.

The softer, less-cemented material has a higher porosity and permeability and a lower density and compressive strength than the harder, well-cemented rock. Both harder and softer types and zones of unconsolidated sand occur together in an irregular way, which makes the detailed determination of geotechnical properties difficult. Steep cuts are commonly stable.

The unit composed predominantly of sand is partly consolidated, has 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 locally common and, where present, will increase excavation costs. Drainage-disposal characteristics are good.

Colluvium, because it is an unconsolidated mixture of different soils and rock fragments, has extremely variable geotechnical properties. Disturbed slopes are likely to be unstable and to require protection against erosion. Seepage and storm-water drainage-disposal characteristics depend on clay content.

The lagoonal deposits are highly variable, low-lying and generally saturated. They are expected to have poor geotechnical properties which because of rapid lateral changes in lithology are difficult to predict.

Alluvium, because of its various lithologies, has a wide range of engineering properties. Foundation conditions are generally poor, irregular settlement under load being typical. A near-surface water table in some cases would adversely affect building stability and is a problem with excavation and drainage.

The swamp deposits are made of variable, poorly-consolidated material with unsatisfactory engineering properties. The deposits will settle irregularly under load and have low bearing capacity. The near-surface water table would impede excavation and drainage and lessen building stability.

Safety Bay Sand is a porous, cohesionless or poorly lime-cemented, permeable material that is unstable in excavations and prone to wind erosion when vegetation is removed. Settlement, sometimes uneven, is common under load but can be controlled by compaction and stabilization.

ENVIRONMENTAL GEOLOGY

The main environmental question in the area, relating to geology, stems from laterite gravel extraction. In the past, when there was little public awareness of environmental matters, abandoned gravel pits were left in the state they had reached at cessation of mining. Consequences of that action were extensive gullying on steep slopes, the deposition of transported sediment downslope on roads or farming land, and areas with little or no vegetation, usually plainly visible from roads. The present attitude is to attempt rehabilitation of exhausted pits to minimize subsequent sediment-clearing and to reduce the visual impact of bare areas. Rehabilitation options are ripping the compacted pit floor along the contour to increase rainwater infiltration, seeding or planting tree seedlings in ripped ground for long-term soil stabilisation, or management of the pit as some form of social amenity area: for example, a domestic rubbish tip where slopes are shallow; or a cycle or motor scramble track. In all cases, careful attention must be paid to drainage provisions to prevent gullying.

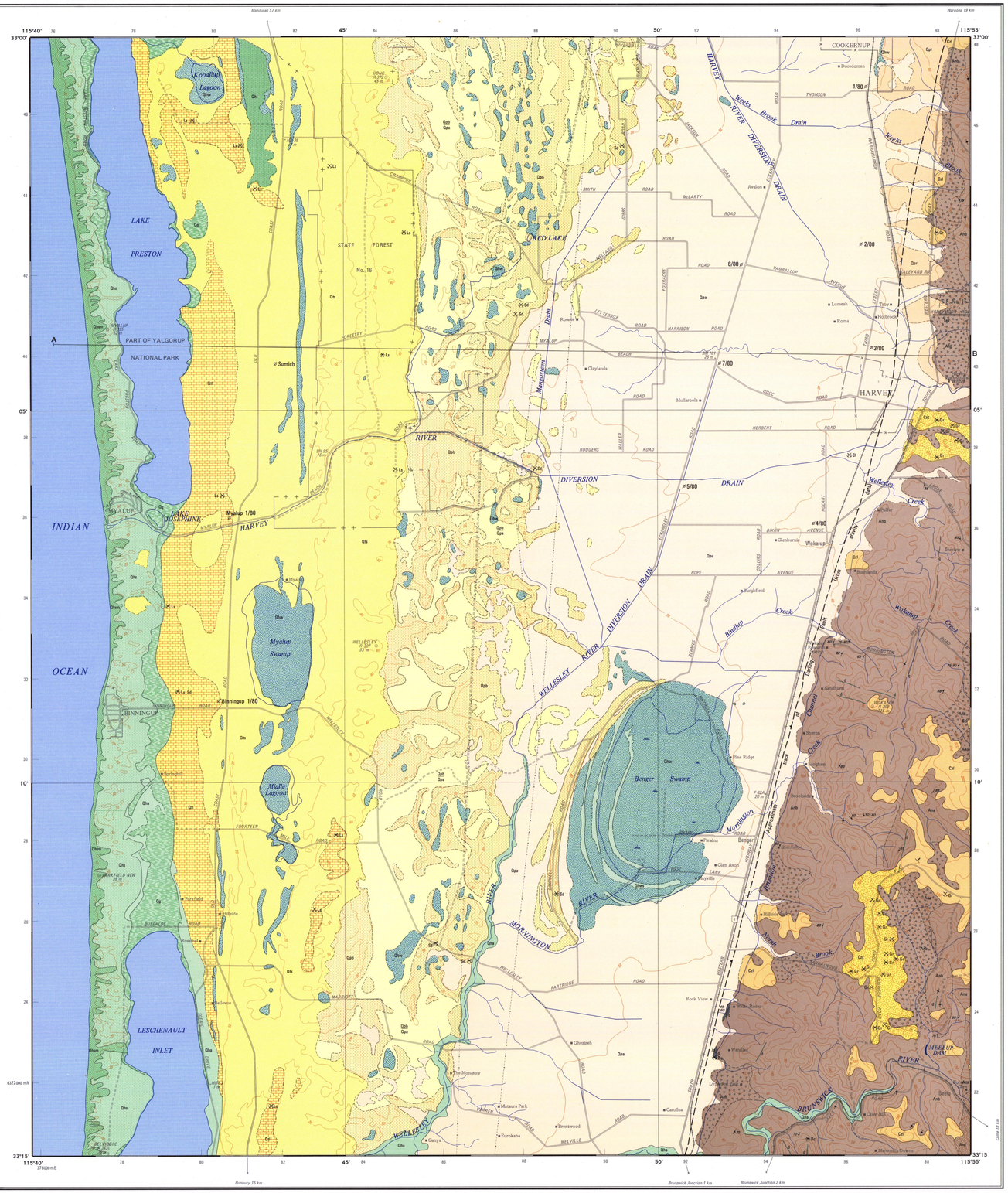
Clearing forest on slopes, for agriculture or other purposes, also exposes soils to the effects of rainwater run-off and increases the chances of erosion. Such effects have not been observed within the mapped area, but they are seen to the south and similar landforms and the erosion potential should therefore be recognized here.

The local authority has identified landscape protection areas where mining activity would be allowed only in exceptional cases or where it could be effectively concealed from regular public viewpoints. The miner would be required to bear the cost of rehabilitation of the land to a subsequent agricultural land-use. Re-seeding of the rehabilitated land is usually carried out in the appropriate season by the farmer with standard farming machinery.

A few gravelled roads on slopes are built with cuttings or embankments which tend to be free of vegetation for one or two growing seasons and are thus prone to erosion. Remedies could include improved drainage, contour bunding, terracing or seeding to produce an initial groundcover among which native plants could re-establish.

Sites for disposal of domestic or industrial waste may be found readily within the thicker sand units throughout the area and, with careful siting, at various localities on the Darling Scarp or Plateau. Sites should be avoided close to groundwater extraction areas, because leachate from the rubbish may reach the extraction boreholes downslope. Mined-out pits may provide convenient sites for disposal, particularly as some residual sand is generally available for covering successive layers of rubbish.

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



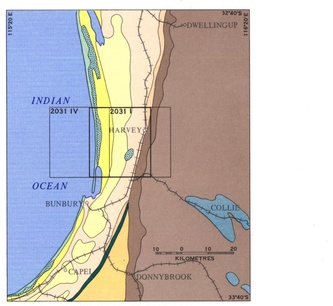
REFERENCE

		PROBABLE MAXIMUM THICKNESS (m)	
PHANEROZOIC / CAINOZOIC / QUATERNARY / HOLOCENE	Qhd	20	Mobile dunes
	Qhs	50	**SAFETY BAY SAND**
	Qhw	2	Limestone associated with swamps
	Qhs	5	Swamp deposits; mainly peaty sands
	Qhd	2	Reworked sand on lake margins
	Qha	7.5	Alluvium; sands and silts
HOLOCENE TO PLEISTOCENE	Qhj	? 3	Lagoonal deposits; muds, silts, shell beds
PLEISTOCENE	Qts	40	Sand associated with Tamala Limestone, high dunes
	Qtl	70	**TAMALA LIMESTONE**; eolian and marine calcarenite, beneath thin sand cover
	Qpb	15	**BASSENDEAN SAND**; low, rounded dunes
	Qpb Qpa	3	Thin Bassendean Sand over Guildford Formation
	Qpw	30	**GUILDFORD FORMATION**; mainly alluvial sandy clays
	Qpr	20	**YOGANUP FORMATION**; sands
? TERTIARY	Crl	7.5	Laterite, massive or pisolitic
	Crc	15	Laterite conglomerate
PRECAMBRIAN	x	120	Quartz dykes and veins
	d	50	Mafic dykes; doleritic or gabbroic
ARCHAEAN	Ans	4000	Augen gneiss, 2 in places beneath eluvial cover
	Anh	6000 2	Quartz-feldspar-biotite (-garnet) gneiss, in places beneath eluvial cover
	Anh	500	Quartz-feldspar-hornblende (-biotite) gneiss
	Anc	1000	Calc-silicate gneiss

SYMBOLS

- Geological boundary
  - Accurate
  - Approximate or transitional
  - Inferred
- Fault
- Strike of foliation
  - Inclined
  - Vertical
- Attitude of laterite slope
  - Steep
  - Gentle
- Deep borehole > 80 m
- Quarry or pit
  - Active
  - Inactive or abandoned
- Mineral Occurrence
  - Clay Cl
  - Gravel Gr
  - Limestone Ls
  - Crushed rock Rc
  - Sand Sd
- Highway
- Major road
- Minor road
- Track
- Railway
- Townsite boundary
- State Forest boundary
- Power line
- Homestead
- Horizontal control, minor
- Benchmark, height accurate
- Watercourse
- Contours, height in metres

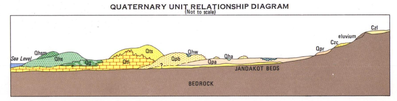
The representation on this map of a track does not necessarily imply right of way



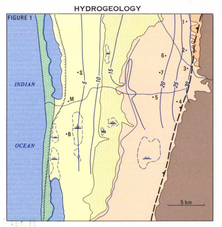
PHYSIOGRAPHIC DIAGRAM

- Quindalup Dunes
- Spearwood Dunes
- Bassendean Dunes and Interdune Swamps
- Major Wetlands
- Pinjarra Plain
- Collie and Wilga Basins
- Darling Scarp
- Whicher Scarp
- Piedmont Zone
- Darling Plateau
- Blackwood Plateau

QUATERNARY UNIT RELATIONSHIP DIAGRAM



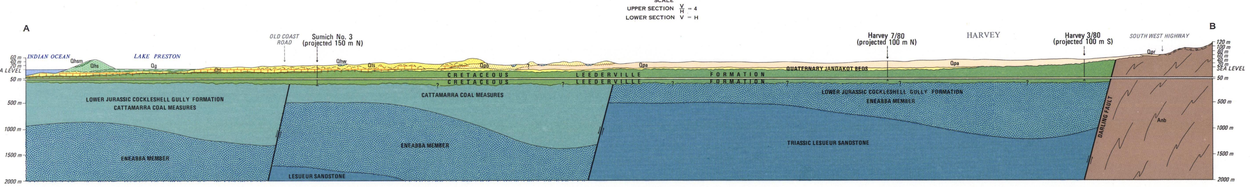
HYDROGEOLOGY



REFERENCE

- Safety Bay Sand
- Tamala Limestone
- Bassendean Sand
- Guildford Formation
- Yoganup Formation
- Archaean Crystalline Rocks
- Darling Fault
- Swamp
- River; drain
- Eastern extent of salt water interface in Tamala Limestone
- Water table elevation (m above AHD)
- Borehole intersecting Leederville Formation
- S Somich exploratory bore
- M Myalup water supply bore
- B Binningup water supply bore
- 1–7 Harvey exploratory bores

DIAGRAMMATIC SECTION A-B



SCALE
UPPER SECTION X – 4
LOWER SECTION Y – H

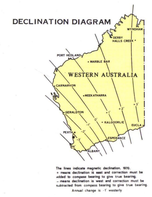
SCALE 1:50 000

1 0 1 2 3 4 5 6
KILOMETRES

CONTOUR INTERVAL 20 m

Ticks inside the sheet edge represent 2 000 metre intervals of the superimposed Australian Map Grid. Zone 50. AUSTRALIAN NATIONAL SPHEROID.

DECLINATION DIAGRAM



The lines indicate magnetic declination. With a mapping declination in east and variation must be subtracted from compass bearing to give true bearing. Annual change is 1' westerly.

INDEX TO ADJOINING SHEETS

LAKE CLIFTON 2032 III	HAMEL 2032 II	NANGA 2132 III
INDIAN OCEAN LAKE PRESTON 2031 IV	HARVEY 2031 I	TALLANALLA 2131 IV
BUNBURY 2031 III	BUREKUP 2031 II	COLLIE 2131 III

HARVEY – LAKE PRESTON

URBAN GEOLOGY

PARTS OF SHEETS 2031 I AND 2031 IV

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FIRST EDITION 1982

Compiled and published by the Geological Survey of Western Australia. Cartography by the Geological Mapping Section, Department of Mines. Topographic base from compilations by the Department of Lands and Surveys.

Copies of this map may be obtained from the Geological Survey of Western Australia, 66 Adelaide Tce., Perth.

Printed by the Government Printing Office, Perth.

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Geology : E.R. Biggs 1979