


GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

RECORD 1987/5

**LIMESAND AND LIMESTONE RESOURCES
BETWEEN LANCELIN AND BUNBURY
WESTERN AUSTRALIA**

by

J.R. GOZZARD



**DEPARTMENT OF MINES
WESTERN AUSTRALIA**

Geological Survey of Western Australia

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Perth, 1987

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National Library of Australia Card Number and
ISBN 0 7309 0970 0

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LIMESAND AND LIMESTONE RESOURCES
BETWEEN LANCELIN AND BUNBURY
WESTERN AUSTRALIA

INTRODUCTION

This report details the results of a survey of the limesand and limestone resources of the country between Lancelin and Bunbury. While it draws on earlier work carried out by the Geological Survey of Western Australia, substantial new data have become available in the past five years enabling a refinement to be made of the limesand and limestone resource base of the Perth metropolitan and near-metropolitan region.

This report describes the limesand and limestone geology and resource occurrence. Recent developments in land-use planning policies as they affect extraction are outlined. Limestone has been mined from the Tamala Limestone, Gingin Chalk, Muchea Limestone, and from bog limestones on the coastal plain. Limesand deposits have been mined in the past from dunes at Mullaloo and Woodman Point.

Limeshell deposits have been dredged from the Swan and Canning Rivers, but present workings are confined to the Parmelia and Success Banks in Cockburn Sound.

The importance of Tamala Limestone as a source of lime is evidenced by the fact that most of the material for industrial and constructional use is quarried from this rock unit. This survey concentrates on the assessment of

resources from the Tamala Limestone and Safety Bay Sand. For details of other lime sources the reader is referred to Baxter and Rexilius (1974).

PREVIOUS INVESTIGATIONS

The earliest resource assessment program was undertaken by the Geological Survey of Western Australia in 1950 and 1951 and published as a series of maps (McMath 1952). These maps summarized what was then known about the region to enable planners to steer urban development away from areas of high-grade limestone, plastic clay and other resources. The details of this sampling program, however, did not become readily available until work by de la Hunty (1966). More recently Baxter and Rexilus (1974) carried out supplementary work on the previous survey and summarized all available information on limesand and limestone for the area between Lancelin and Mandurah.

Biggs (1977) conducted a reconnaissance survey of the limestone resources between Mandurah and Bunbury; and was able to delineate five areas worthy of more investigation.

Since 1980, the Geological Survey of Western Australia has been involved in investigations, on behalf of the former Metropolitan Region Planning Authority (MRPA), into the distribution and availability of industrial minerals within the metropolitan region. This study has involved liaison between extractive industry companies, local and State government bodies. Consequently, in 1984, the MRPA was able to formulate and adopt a statement of Planning Policy Basic Raw Materials (MRPA 1984) which aims to protect and conserve industrial minerals and ensure maximum resource availability within the metropolitan region.

Between 1976 and 1982, the Geological Survey of Western Australia published a series of 1:50 000 scale Urban Geology maps of selected areas of the Swan Coastal

Plain north and south of the boundaries of the Perth metropolitan region between Moore River and Bunbury (Fig. 1). The metropolitan region and the Lake Clifton - Hamel area are covered by a series of 1:50 000 scale Environmental Geology maps. Both map series are intended to present relevant geological information for use by urban and regional planning authorities. Appendix I lists those maps which cover the limesand and limestone outcrop within the area under study.

As a result of urban and environmental geology mapping and related work, a wealth of new information has become available with which to update and reappraise the overall resource situation.

These studies have also formed the basis of a proposed Geological Survey of Western Australia bulletin, which brings together all of the applied aspects of geology that have helped to shape the metropolitan region.

USES AND SPECIFICATIONS

In the metropolitan and near-metropolitan region, limesand and limestone are used in a number of industrial and construction applications principally for road building and cement manufacture. Smaller amounts are used for building stone, breakwater construction, lime production, soil amelioration, nickel smelting, glass manufacture, and, until 1982, iron smelting.

ROADBASE

Because of its wide distribution and ease of extraction, limestone is widely used in road pavements either as sub-base or base-course. The Main Roads Department has specified the selection criteria for limestone for use in road construction (Table 1).

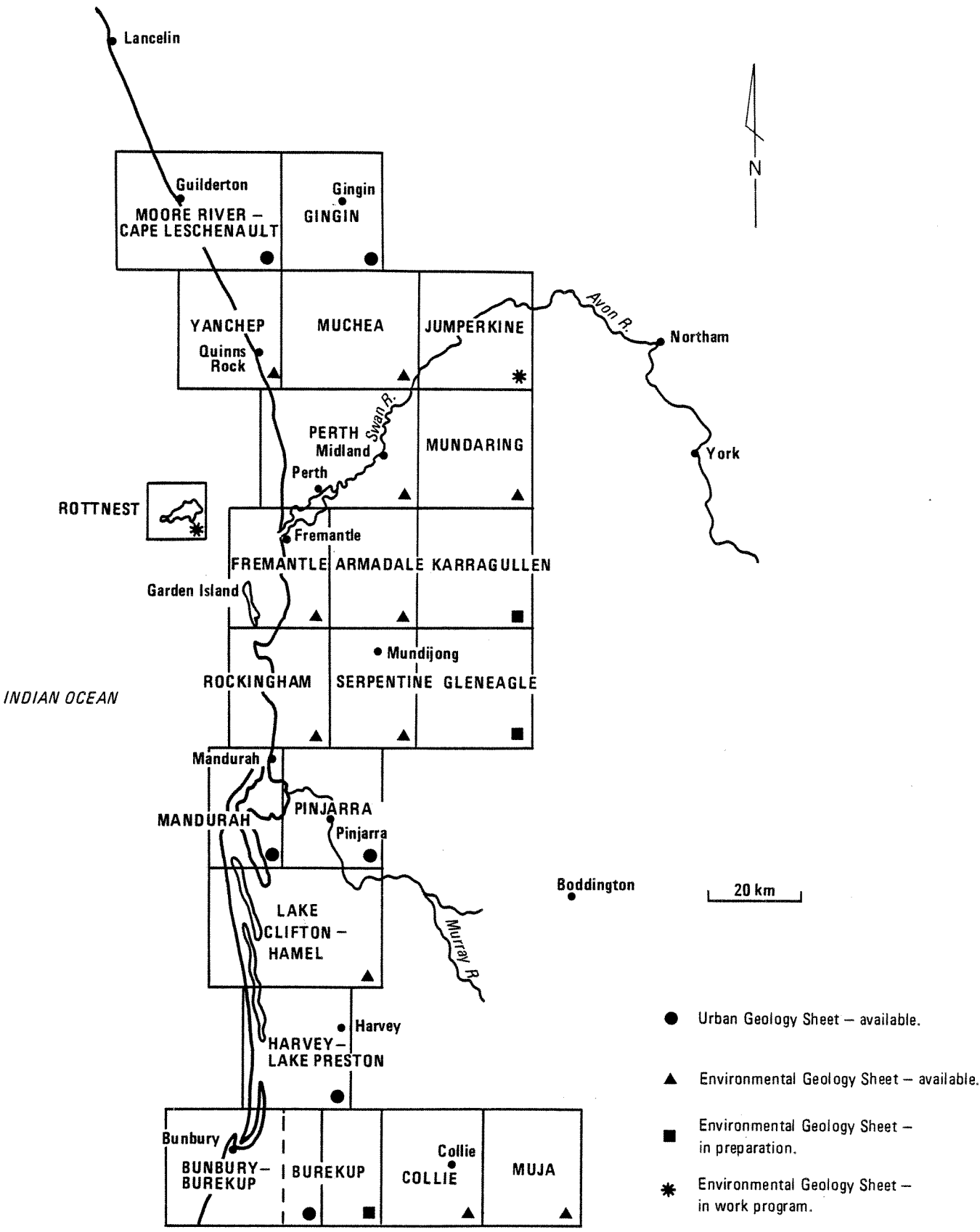


Figure 1. Index to the Urban and Environmental Geology maps.

TABLE 1. SPECIFICATIONS FOR LIMESTONE FOR USE AS
ROAD CONSTRUCTION MATERIAL

	Base course	Sub- base
Los Angeles Abrasion	20 - 60%	20 - 60%
CaCO ₃	> 60%	> 60%
Percentage passing sieve:		
75 mm	100
19 mm	100	60 - 80
4.75 mm	60 - 80
2.36 mm	20 - 40
1.18 mm	20 - 40
Compressive modulus	(a) 28 MPa	(b)
Cohesion	(a) 83 kPa	(b)
Tensile strength	(a) 55 kPa	(b)
Angle of shearing resistance	(a) 45°	(a) 45°
California Bearing Ratio	(a) 80%	(a) 40%
Maximum Dry Compressive strength	(a) 700 kPa	(a) 700 kPa

(a) Minimum (b) Not applicable

CEMENT

Portland cement manufacture requires the calcium carbonate (CaCO₃) content in the raw mix to be about 80%. However, the ratios of the remaining constituents may not be satisfactory so that in practice a limestone containing more than 80% is required. High magnesium (as MgO) levels (>2.7%) are detrimental to cement quality; and silica (SiO₂) + aluminium (as Al₂O₃) + iron (as Fe₂O₃) should be no more than 20% - with silica being equal to each of aluminium and iron oxide.

BUILDING STONE

The properties of limestone relevant to its use as a building stone relate primarily to the stone's texture and hardness. The better quality stone used is fine, even-grained, and of uniform texture and hardness. These properties allow the stone to be readily shaped with an axe. Compressive strengths vary between 4 and 7 MPa.

ROCK ARMOUR

The economic attractiveness of using limestone in breakwater construction arises from its proximity to construction areas. The limiting factor determining a breakwater's ability to resist waves is the specific gravity and the strength of the rock used. Klenowski (1976) and Mather (1985) provide full geotechnical particulars for Tamala Limestone.

LIME PRODUCTION

There is no overall specification of limesand and limestone for lime because of the very wide range of uses. Countless specifications and buyer requirements exist. Available lime (CaO) in the calcined product is important. A few commercial limes contain as much as 98% CaO, the majority about 90%; and, for some uses, lower percentages are acceptable. The chief impurities are silica, aluminium, iron and manganese. The proportion of impurities in the original material is approximately doubled during calcination.

AGRICULTURAL LIME

In the treatment of soil acidity agricultural liming is carried out using limesand or pulverized limestone. The neutralizing value of different liming materials is determined by chemical composition and purity, that is,

the amount of CaO equivalent present. The particle size of the material is also important. The Fertilizer Act (1977) grades agricultural lime as either first or second grade depending on its neutralizing value and degree of fineness. In addition it is desirable for liming material to contain appropriate levels of plant nutrients (e.g. magnesium) in a chemically available form.

FLUX

Limesand and limestone are used as a flux in iron and nickel smelting. Ideally the flux should contain 97% calcium carbonate, with a minimum of 95%. Silica (SiO_2) should be less than 1.5%, phosphorus (as P_2O_5) less than 0.01% and sulphur less than 0.5%. Magnesium (as MgO) should preferably be less than 5%; the nickel smelting process of Western Mining Corporation Limited at Kwinana requires material with less than 2% MgO.

Requirements of material for the glass industry are similar to that for the smelting process but depending on the type of glass being produced the limits for iron, sulphur and phosphorus may not be as stringent.

GEOLOGY OF TAMALA LIMESTONE

Tamala Limestone is of early to late Pleistocene age and consists of both windblown and marine sediments. Ridges of wind-blown sediments have become cemented to form eolianite and are covered with a residual siliceous sand. These ridges make up the Spearwood Dune System. The marine sediments, are also cemented and, with a thin covering of siliceous sand form the Yoongarillup Plain.

It is important to differentiate the limestone of the Spearwood Dune System from that of the Yoongarillup Plain. The generally high water table of the Yoongarillup Plain restricts the depth to which any quarry may be worked dry.

In the case of the Spearwood Dune System, the water table is usually at a considerable depth and consequently will not normally have such a limiting influence.

The limestone outcrop between Lancelin and Singleton falls wholly within the Spearwood Dune System. However, between Singleton and Bunbury, the Yoongarillup Plain is a prominent feature and, in general, occurs between the Old Coast Road and the present day coastal sand dunes (Quindalup Dunes). The limestone of the Spearwood Dune System is usually only found east of the Old Coast Road (Plate 1). Details of specific areas may vary slightly from this general rule and the reader is referred to McArthur and Bartle (1980).

The limestones from the two geomorphic divisions are almost lithologically indistinguishable. They are generally yellow to cream calcarenites, and range from calcareous sandstone to limestone. The colouring is due to the presence of iron oxides. The limestone is composed of fine- to coarse-grained, subangular to well-rounded shell fragments, quartz grains in varying proportions, and small amounts of feldspar. Both small- and large-scale cross-bedding are common, varying from a few to about 50 centimetres. Capping the limestone is a widespread kankar. This is a cryptocrystalline, carbonate-enriched rock formed by precipitation from carbonate-rich waters. The formation of pinnacles and root structures in this kankar is common. The limestone immediately beneath is invariably leached.

Detailed petrographic descriptions of the limestone were given by Baxter and Rexilius (1974).

LIMESTONE QUALITY

Tamala Limestone is typically a heterogeneous rock comprising material grading from sandstone to high-grade limestone. Because of this intrinsic variability in the quality of the limestone, and the extensive formation of kankar, drilling and sampling are the only reliable methods of assessing the resource potential of any area. Assessment is augmented by the collection of samples from both active and inactive quarries and from other man-made or natural sections.

In most cases, a single sample of a quarry face provides little idea of overall quality. Samples collected as part of the current survey generally consisted of either a continuous channel sample cut vertically up a face or as samples of stockpiled material. This sampling method takes into account lateral and vertical variation and probably provides a good indication of overall grade. The survey has also utilized the results of drilling and sampling programs carried out by the Geological Survey of Western Australia and by extractive industry companies.

Tamala Limestone typically grades upward from 50% calcium carbonate and rarely reaches 90% calcium carbonate; magnesium content is usually low, ranging from 0.5% to 1.5% $MgCO_3$ but exceptionally it may be as high as 3% $MgCO_3$. Silica as quartz grains is the only significant contaminant with values upward of 12%. Average concentrations of minor constituents are 0.55% aluminium (as Al_2O_3), 0.20% iron (as Fe_2O_3), 0.3% potassium (as K_2O), 0.1% sodium (as Na_2O_3). Baxter and Rexilius (1974) detail complete chemical analyses of samples from selected areas.

CURRENT AND FUTURE DEMAND

METROPOLITAN REGION

As part of its remit of assessing the availability of industrial minerals in the metropolitan region, the MRPA's Basic Raw Materials Committee addressed the questions of current and future demand of commodities.

From information supplied to the committee by producing companies, the annual production of industrial (i.e. high) grade limestone is approximately 1 Mt and of road building (i.e. medium) grade limestone is approximately 1.25 Mt.

As the building industry is a major consumer of industrial minerals and their products, it can be used as an indicator of future demand. Two scenarios were considered as representing a fully developed metropolitan region at different levels of overall density (MRPA, 1984). Scenario 1 represents housing for 2 million people and Scenario 2 represents housing for 2.9 million people. Using some simplifying assumptions regarding recovery, estimates were made of the proportion of available resources needed in the future. It can be shown that the anticipated demand over the next 50 years for industrial and road-base grade limestone will be approximately 66 and 82 Mt respectively or about 12% of the total available unconstrained resource. Should resources at present identified in State Forest and National Parks. (Plate 1) not be available then the percentage of the remaining resource needed would increase to approximately 18 to 20%.

So, while these estimated proportions indicate that supplies should be adequate to meet future demand, it is more likely that a shortage of material will occur through planning considerations (Sect. Factors affecting long-term resource supply) rather than actual physical scarcity of the resource.

RURAL AREAS

Shire of Gingin

Current production from the six Shire-operated pits is approximately 100 000 t/a. The Shire estimates that it would require 3 Mt of limestone for the construction of roads over the next 30 years. There is little doubt that the resource base of this area is capable of meeting the future demand. However, it would be difficult to say whether the presently available reserves would be adequate to meet the expected demand.

This fact highlights the need for further investigations within this area as outlined below (see Sect. Lancelin to Moore River).

Shires of Mandurah and Murray

There are five working quarries within the Shire of Mandurah: two are operated by the Shire itself, one by the Shire of Murray, and two are privately operated. All quarries produce road-base material.

The Shire of Mandurah pits at Tims Thicket and Thornborough Road produce approximately 20 000 t/a and have limited lifetimes of only 2 and 3 years respectively. As a result of the near exhaustion of present reserves, the Shire is looking to develop further reserves in the Tims Thicket area. It is expected that these reserves will supply the estimated limestone requirements of the Shire of 500 000 t over the next 30 years.

The Shire of Murray extracts 30 000 t/a from its pit on Gordon Road. The pit has an anticipated lifetime of only 1 to 2 years after which the Shire will be looking to develop resources for the future in an area north of Mandurah.

No production information is available from the two privately operated quarries.

Shires of Waroona and Harvey

By far the majority of limestone quarries between Mandurah and Bunbury are to be found in these two Shires. All quarries produce road base with the exception of one near Kooallup Lagoon which produces agricultural lime. No indication of current production rates or estimates of future demand are available for these two Shires.

Main Roads Department

If it is assumed that the Main Roads Department will complete a dual carriageway from Mandurah to Bunbury, maintain and upgrade the existing road, and use limestone to maintain and upgrade section of the Armadale to Bunbury road, then limestone requirements during the next 30 years will be:

- (1) Mandurah to Tims Thicket 300 000 t.
- (2) Tims Thicket to Mandurah Shire Boundary
240 000 t.
- (3) Mandurah Shire Boundary to Lake Preston turn-off 300 000 t.
- (4) Lake Preston turn-off to Forestry Road
300 000 t.
- (5) Forestry Road to Binningup Beach turn-off
180 000 t.
- (6) Binningup Beach turn-off to Bunbury 400 000 t.

Likely sources for items 1 and 2 are the Tims Thicket pits, for items 3 and 4 State Forest 16 (ideally two pits one in the north section and one in the south section)and for items 5 and 6 will be the Binningup Ridge limestone area.

Department of Conservation and Land Management

The Department of Conservation and Land Management (CALM) recognizes the strategic position of State Forests 16 and 65 as sources of limestone for industry. CALM has also provided for its own requirements by securing access to some 0.2 t and 1.6 Mt of limestone in State Forests 16 and 65 respectively. The limestone will be used in the construction and maintenance of roads over the next 30 years.

AREAS OF CURRENT PRODUCTION

At present, major limestone production is concentrated in two main areas which serve the needs of the metropolitan region, north of Wanneroo and south of Spearwood. In both these areas the higher grade limestone supports the cement industry. Production of road-base and other grades of limestone is won from a large number of quarries scattered throughout the study area which serve more local requirements.

MAIN AREAS

Quinns Rock to Wanneroo

Limestone crops out extensively in this area and large quantities are extracted from numerous quarries. Annual production is of the order of 0.5 Mt. This represents about 25% of the total limestone used in the metropolitan region. Production is evenly divided between cement-grade and road-base material, but smaller quantities are used for lime

burning and to a lesser extent building stone and armour stone.

Activity is concentrated west of Lake Pinjar, an area which has been proved to be the only sizable area of high-grade limestone to the north of Perth. There the principal producers are Swan Portland Cement, Cockburn Cement and Readymix.

Spearwood to Tamworth Hill

This is the main area of limestone production in the southwest corridor and is exploited by the two cement companies and a number of other users. Concentration of extractive activity occurs between Thomsons Lake and Kwinana, generally within the rural areas of the City of Cockburn and Town of Kwinana.

Annual production is estimated to be in excess of 0.6 Mt, of which approximately one - to two-thirds is used in the cement industry. The remainder is used as road-base material and, when circumstances demand, armour stone, and to a lesser extent building stone.

Because of its proximity to the Kwinana industrial complex the limestone of this area is considered to be a valuable resource.

OTHER AREAS

Localized exploitation of the limestone resource also takes place at a number of other localities within the near-metropolitan region, albeit on a smaller scale. These operations are described below.

Lancelin to Moore River

The Gingin Shire Council operates 6 limestone pits in this area, three southeast of Lancelin and one each at Ledge Point, Seabird, and Guilderton. Current production is solely for road-base material.

State Forest 65

Currently only CALM extracts limestone from within State Forest 65 for the construction and maintenance of roads. Four areas have been reserved under the Land Act 1933 as quarry reserves for the sole use of CALM and these are worked on an intermittent basis.

Peelhurst to Mandurah

The limestone resources of this area are becoming less important because of the low quality of the resource. Current operations are confined to two areas. East of Singleton, the Main Roads Department and Readymix extract road-base material; and along Gordon Road, Waroona Contracting operate two quarries - also for road-base and fill-grade material.

Tims Thicket

A number of large quarries, both active and disused, are to found along Tims Thicket Road. Both the Shire of Mandurah and the Main Roads Department extract limestone from this locality, which is assuming greater importance, although it does lie within the Yalgorup National Park.

Lake Clifton

Along the Old Coast Road east of Lake Clifton are a number of limestone quarries. Extractive activities are currently confined to two large pits worked by Waroona

Contracting at Tricketts and Tyler and the Shire of Waroona quarry at Lake Clifton townsite.

State Forest 16

Within State Forest 16, there are many small disused pits. Most were opened to service the improving of the Old Coast Road. Current operations are confined to three excavations where CALM extracts limestone for the construction and maintenance of roads within State Forest.

Myalup to Australind

Between Myalup and Burragenup the limestone is exploited at a number of localities, primarily by landowners for local use, although larger contractors do service requirements further afield. The limestone ridge immediately north of Australind is not now exploited because of the inferior quality of the resource.

RESOURCE AREAS

LANCELIN TO MOORE RIVER

This area contains numerous, relatively small, widely scattered limestone outcrops in the centre and east. Near Lancelin and Guilderton, larger outcrops are seen; and it is here that current extraction takes place.

Apart from one quarry at Lancelin and one at Guilderton, extraction is restricted to small pits developed by individual landowners for the construction and maintenance of farm tracks. The quarry on KW Road at Lancelin works the limestone for road-base material on a needs basis. The quarry at Guilderton also works the limestone for road-base material, but a substantial reserve of material suitable for building stones is also being

worked. This quarry holds one of the few substantial reserves of limestone for building stones north of Perth.

Available analyses indicate the general medium grade of the limestone of this area although pockets of high-grade material undoubtedly occur. Further investigation, including drilling and sampling, will be necessary to fully prove the available resources. Such resources should be capable of providing material for industrial activity north of the metropolitan area.

STATE FOREST 65

The limestone resources of State Forest 65 are reasonably well known as the result of assessment surveys by the Geological Survey and the two cement companies. Gozzard (1984a), during a reconnaissance survey, sampled numerous localities between Moore River and Bailey Road and concluded that much of the area contains high-quality limestone. That survey enabled CALM to reserve four quarry areas for their sole use under the Land Act 1933. This reservation and the removal in 1983 of the Temporary Reserve to protect forest areas from the spread of dieback opened up State Forest for exploration.

The reconnaissance nature of the Geological Survey's survey is emphasized. It forms the basis of more detailed drilling and sampling programs aimed at identifying future reserves of high quality limestone.

South of Bailey Road State Forest 65 has been intensively investigated by the two cement companies which have identified large reserves of high quality limestone. These reserves are held under mining tenements and form the basis of the cement industry's future north of Perth. However, part of Swan Portland Cement's reserves lie within the Ridges MPA. Whilst the EPA Red Book System 6 Report recommended that 5 ha of this area be set aside for

limestone extraction there is little probability of this resource being utilized.

The limestone of State Forest 65 is seen to be a valuable resource and is of generally higher grade than other deposits outside the State Forest.

NORTHWEST CORRIDOR

This area lies between Two Rocks in the north and the limit of urban development of Perth's northern suburbs. It includes two major "A" class reserves, the Yanchep and Neerabup National Parks.

The area north of Carabooda has not yet been fully evaluated, and so the area as a whole remains essentially untested. Analyses currently available highlight the variability of the resource, and more detailed drilling and sampling are required to prove the resource.

South of Carabooda the area has been fully explored by the industry and the Geological Survey, and large reserves of both high- and medium-grade limestone have been proved. As mentioned above (Quinns Rock to Wanneroo), current industry activity is concentrated in this area. The area West of Lake Pinjar and east of Wanneroo Road has been proven to be the only sizeable area of high-grade limestone to the north of Perth to be fully evaluated. This area will form the basis of the cement industry in the near future.

South of this area of high-grade limestone, in the Flynn Drive area, large reserves of road-base material have been proven by the extractive industry and by the Geological Survey (Gozzard 1984b). Whilst the industry is centred around Joondalup, the encroachment of urbanization is causing the industry to relocate in the Flynn Drive area where reserves of up to 20 years supply of road-base material are known.

Continuing urban expansion and intensive rural settlement are seen as major threats to the efficient exploitation of the limestone of this area.

SPEARWOOD TO TAMWORTH HILL

In this area, the limestone occurs in two distinct parallel belts. This area has been the traditional source of limestone for the cement industry and is seen as a major future supply area for Cockburn Cement.

In general, the higher quality limestone is found along the eastern belt, and it is here that current production is concentrated. Conversely, the western belt is of generally medium grade and suitable for road-base material only.

The whole area has been one of intensive exploration, and the resources have been fully delineated by extractive industry companies. There is not considered to be the potential to identify further high-grade limestone in this area. Much of the resource is the subject of mining tenements, and appreciable parts are within land owned by quarry operators or the Industrial Lands Development Authority.

The limestone resources of this area are considered to be of prime importance and should be protected from conflicting land uses, primarily urbanization.

TAMWORTH HILL TO MANDURAH

Reconnaissance drilling by the cement companies in the last few years, and other detailed sampling programs, have shown that high-grade limestone is almost non-existent in this area.

Current activity is confined to an area east of Singleton, where Readymix and the Main Roads Department extract road-base material.

The area is one of increasing residential development. This fact together with the general abundance of road-base material elsewhere in the metropolitan area may well preclude the future development of the limestone resource of this area.

BOUVARD TO AUSTRALIND

Essentially, this area includes all the limestone outcrop west of the Old Coast Road together with those outcrops east of the Old Coast Road north of Australind. The area includes the Yalgorup National Park which extends southwards from Tims Thicket to south of Preston Beach Road. There are many active quarries throughout the area, and they principally produce road-base material. The deposit near Kooallup Lagoon, however, is being worked for agricultural lime.

The main areas of production are at Tims Thicket, Tricketts, and Tyler. Road-base quality limestone is extracted by landowners. Whilst the amount excavated is sizable, it is less than that exploited by Waroona Contractors. The best quality stone is to be found near Kooallup Lagoon, and between Tims Thicket and White Hill Road. As stated above, the Kooallup deposit is an important resource and is being worked for agricultural lime, but the Tims Thicket deposits are being worked for road base. The average grade of the Tims Thicket deposit is 74.7% CaCO_3 - ranging from a low of 48% to a high of 90% CaCO_3 . This is the only area between Mandurah and Bunbury known to contain high-grade limestone; and for this reason, it is considered to be of regional strategic importance. It should be a prime planning requirement - to ensure the

future supply to industry - that care should be taken to avoid the use of high-grade limestone for low quality end uses.

Sampling elsewhere throughout the area, except northeast of Australind, confirms the medium-grade nature of the resource and thus its potential for road-base and fill applications. However, an area between Myalup and

Binningup has also been delineated as containing high-quality limestone. This conclusion is based on three analyses only. Notwithstanding, the area can be considered prospective and further investigation is warranted especially as this area is the nearest potential source of high-quality limestone to Bunbury.

The relatively small isolated deposits northeast of Australind have been extensively worked in the past as evidenced by the number of quarries. However calcium carbonate values are generally very low (ranging between 30 and 40%). Thus there appears to be little potential for future exploitation of this resource.

STATE FOREST 16

The limestone resources of State Forest 16 have been assessed by Gozzard (1985), who sampled a total of 21 quarries and other outcrops. Analyses showed the limestone to vary considerably in quality throughout the State Forest, but indicated a small but perceptible rise in quality towards the south from 55.8% CaCO₃ at Lake Clifton townsite to 62.9% CaCO₃ at Bagieau Road. South of Bagieau Road, only isolated outcrops of low-quality (generally about 30% CaCO₃) limestone occur.

Identified resources outside the two MPA's amount to some 300 000 m³. A preliminary assessment of the MPA's identified a further 100 000 m³. However, it is doubtful

if the resource within the MPA's will be utilized (see Forest Protection Policy).

The limestone resources of State Forest 16 are a strategic resource which will become increasingly more important in the future as MRD plans come to fruition. This requirement is over and above the present need to maintain and upgrade the existing road network.

GEOLOGY OF THE SAFETY BAY SAND

The Safety Bay Sand includes the modern dunes occurring along the coastline and the sediments of the Becher - Rockingham relic foredune plain. For the purposes of this report, the Safety Bay Sand also includes the shell sands of the Success and Parmelia Banks in Cockburn Sound.

The onshore units vary from fixed, vegetation covered dunes, some of which are weakly cemented, to drifting sand still in the process of deposition. They comprise fine- to coarse-grained calcareous sand that consists of more than 50 % bioclastic debris (predominantly molluscan) and lesser amounts of quartz. The sequence of parabolic and nested parabolic dunes can be equated with the Quindalup Dune System of McArthur and Bartle (1980). The Becher - Rockingham relic foredune plain is a separate geomorphological unit.

A series of offshore seagrass banks form units of homogeneous carbonate sands. The sands are composed of bioclastic debris with variable amounts of quartz grains. Semeniuk and Searle (1985) have proposed Becher Sand as the name for the offshore Holocene sediments, the Becher Sand.

LIMESAND QUALITY

As a result of the heterogeneous nature of the limesand deposits, the material grades from silica sands containing less than 10% calcium carbonate to carbonate sands with over 90% contained calcium carbonate. The calcium carbonate is in the form of shell fragments and other bioclastic debris; the remainder of the material consists of silica grains, iron oxides, alumina, and some organic material. Generally, the shell fragments also contain up to 5 to 6% of magnesium carbonate.

A study by the Government Chemical Laboratories showed that beneficiation, directed at the removal of the silica grains, was easily effected by electrostatic separation. Calcination of the beneficiated sand, however, can prove difficult owing to its comparative fineness. Nevertheless a product with total calcium oxide in excess of 90%, which is highly reactive, and which has a high degree of plasticity can be produced.

CURRENT AND FUTURE DEMAND

As a pre-requisite to an amendment of the Cement Works (Cockburn Cement Ltd) Agreement Act, 1971 Cockburn Cement produced a Dredging Management Program (DMP) covering the ten year period 1987-1966. It also reviewed past and present production. The quantity of dry sand dredged since 1972, when operations started, is approximately 9 Mt.

The DMP forecasts a requirement of a further 10.8 Mt of dry sand over the next 10 years.

AREAS OF CURRENT PRODUCTION

LANCELIN TO LEDGE POINT

This is the only area of onshore limesand production in the area under survey. Current extraction is limited to

two pits near the Old Ledge Point Road that produce material for agricultural lime and for the glass industry, and one pit adjacent to the Lancelin rubbish tip the sand from which is used as cover material.

COCKBURN SOUND

Cockburn Cement Ltd began dredging limesand from the floor of Cockburn Sound in 1972 within a 5 mile radius of a point located on the eastern shore of Owen Anchorage. Current production is from the Success Bank. It is acknowledged that land-based supplies of limestone and limesand of the required quality - more than 92% calcium carbonate - are not available. This being so, Cockburn Sound is considered to be a strategic source of high grade limesand for the metropolitan area.

RESOURCE AREAS

LANCELIN TO TWO ROCKS

The Lancelin to Two Rocks area contains extensive spreads of vegetated, stabilized dunes. Adjacent to the coast there are also relatively large expanses of unvegetated mobile dunes. These occur principally between Lancelin and Ledge Point. Currently, extraction is limited to three relatively small pits, but plans for future extraction exist for parts of the large area of mobile sand north of Lancelin.

The largest resource of high-quality material is to be found within the area of mobile sand north of Lancelin, where 31 Mt of generally > 75% calcium carbonate material occurs. Apart from the two working quarries on the Old Ledge Point Road, no other deposit of consistently high quality is known in this area. The Lancelin deposit is therefore considered to be of major regional significance.

NORTHWEST CORRIDOR

The Northwest Corridor area lies between Two Rocks in the north and the limit of urban development of Perth's northern suburbs. This area also contains extensive spreads of vegetated and stabilized dunes. Spreads of unvegetated mobile dunes are less common. The area as a whole contains low- to medium-quality limesand; but at Yanchep and north of Quinns Rock, individual analyses of > 75% calcium carbonate indicate the potential for small, high-quality deposits to be located.

FREMANTLE TO MANDURAH

Between Fremantle and Mandurah occurs the expansive tract of the Becher - Rockingham relic foredune plain and the smaller Woodman Point relic foredune plain. Relatively few, small, isolated deposits of unvegetated mobile sand occur between Rockingham and Mandurah.

Whilst occasional individual analyses show calcium carbonate values in excess of 75%, this area, in general, does not contain any significant limesand resource.

MANDURAH TO BUNBURY

South of Mandurah, the Quindalup Dunes form a narrow coastal fringing series of parabolic dunes. Without exception, the available analyses show that these sediments are highly siliceous and, consequently, do not contain any significant limesand resource.

COCKBURN SOUND

Within Cockburn Sound are the sand and shell deposits of the Success and Parmelia Banks. It has been estimated that approximately 55.5 Mt of limesand exist in these two banks. Cockburn Cement, however, after initially dredging

on the Parmelia Bank, moved to the Success Bank in 1977 because low-carbonate sand was encountered.

Cockburn Cement estimates that the area covered by the current Agreement Act is capable of yielding sufficient sand at the current consumption rate for approximately 60 years.

FACTORS AFFECTING LONG-TERM RESOURCE SUPPLY

Until recently, planning authorities have failed to recognize the need to conserve long-term resources of industrial minerals. Whilst it is accepted that the major activities in the rural areas will be agriculture and recreation, these areas also contain resources of industrial minerals whose conservation is of vital importance to the future development of the area.

Whilst urban development, particularly north and south of Perth, is probably the major cause of sterilization of resources, other factors and planning decisions can have the same effect.

As a basic principle, the Department of Mines believes, along with the mining and petroleum industries, that all public land should be available for responsible exploration under conditions approved by the managing agency. It is up to government to decide whether there are over-riding reasons for denying ultimate access to an economic mineral resource once it is located. If mining is permitted the conditions should reflect the sensitivity and environmental value of the area concerned.

FOREST PROTECTION POLICY

When considering the extraction of basic raw materials, CALM policy aims to minimize the effect of extraction on conservation values. The policy allows

government bodies to extract material for use on roads on or within five kilometres of CALM land where economic sources are unavailable outside CALM land. Supplies for other purposes (e.g. commercial use) will be controlled under an approved Mining Act tenement or extractive industry licence under the local Government Act.

The forest is divided into Management Priority Areas (MPAs), which designate primary and secondary uses, usually conservation of flora, fauna, and landscape. Mining is seen to be incompatible with these uses. State Forest 65 north of Perth has four MPA's and State Forest 16 east of Lake Clifton has three.

Within State Forest 65 mining tenements are held by a number of operators but principally Swan Portland Cement and Cockburn Cement. Until recently only CALM was extracting limestone for use in the construction and maintenance of roads within the State Forest but extraction near Smokebush Hill by a private operator is expected to commence in the near future. The limestone of this area is considered to be a valuable resource and of generally higher grade than other deposits outside the State Forest.

Within State Forest 16, as within State Forest 65, only CALM is extracting limestone, again for the construction and maintenance of forest roads; no other operators are present. If it is assumed that the Main Roads Department will complete a dual carriageway from Mandurah to Bunbury and upgrade the existing road network then State Forest 16 will become a strategic source of limestone during the next 30 years.

Acceptance by CALM of extraction within State Forests 65 and 16 in the near future is seen to be a necessary requirement with multiple and/or sequential land use being appropriate.

URBAN CORRIDOR DEVELOPMENT PLANS

The Metropolitan Region Scheme is the statutory basis for land-use planning at the regional level within the Perth metropolitan region. The Corridor Plans provide guidelines for growth within the region. The Corridor Plan features two coastal and two inland corridors within which urban development is scheduled to take place. Strategies for each of the corridors detail the location, scale, and sequence, of actual and proposed development.

Both the Northwest and Southwest Corridors along the coast have large areas of limesand and limestone resources. The corridor strategies recognize the value of the material and suggest that wherever possible the better quality deposits should be quarried well in advance of urban development.

It should be recognized that the limestone resources, in particular, of these two corridors are of sufficient quality and quantity to justify the avoidance of sterilization of the resource by incompatible uses. It is also considered appropriate to ensure that the resource quality is matched to user requirements thus avoiding, for example, the use of high-quality material for road base.

REGIONAL OPEN SPACE

In the metropolitan region, reserves are planned as part of a total metropolitan open-space system. This land can include existing reserves, freehold land, and vacant crown land. The reservation brings the land under the planning control of the State Planning Commission. While quarrying is not an excluded use under the Metropolitan Region Schemes it is prohibited in Regional Open Space unless there are compelling reasons to the contrary even though the two are not necessarily incompatible.

Extraction should be seen as an interim land use. Appropriate rehabilitation programs can be established which restore soil to a condition capable of supporting plant life similar to that which existed previously. After-care then ensures that the vegetation is self-sustaining.

NATIONAL PARKS

The three National Parks within the area of this survey, Yanchep, Neerabup, and Yalgorup, are all "A" class Reserves administered by CALM "for the conservation of the natural environment, the preservation and enhancement of natural beauty and the provision of access and facilities for public recreation".

Until 1981, all National Parks were effectively excluded from exploration. In that year the State Government informed the National Parks Authority to discontinue its policy of no exploration and that should a find of national importance be located, then conditions for mining should be laid down after an Environmental Review and Management Program (ERMP) had been prepared. However, this insistence on the preparation of an ERMP can deter developers. For example, applications for limestone at Yalgorup National Park were withdrawn because the developer foresaw probable refusal by the Environmental Protection Authority to endorse mining operations. Mining in nature reserves and national parks also requires permission from both Houses of Parliament.

It is therefore realistic to suggest that the limesand and limestone contained in the National Parks is a resource that is not likely to be developed.

SYSTEMS 5 AND 6

The System 5 (Northern Sand Plains) study reviewed areas of environmental significance north of Moore River. The System 6 (Darling System) study looked at the area between Moore River in the north and the Blackwood River in the south.

Nine recommendations arising out of the System 6 study affect the potential for limesand and limestone resources within this study area. Five of these are MPA's within State Forest (see sect. Forest protection policy) - Caraban, Clifton, McLarity, Myalup, and Ridges. A further three are National Parks (see National Parks) - Yanchep, Neerabup, and Yalgorup; and one covers "C" Class Reserves 31102 and 33581 at Leda.

Applications for mining tenements exist over the western position of the Leda reserves, because the potential for high-quality limestone has been recognized.

THE ROLE OF PLANNING AUTHORITIES

Planning authorities have the choice of reacting to problems as and when they arise or anticipating those problems in advance and thus responding to them in an orderly manner. In the case of extractive industry, the conflicts have arisen from the need to serve the requirements of a growing population.

The extent to which mineral deposits can be worked depends largely on the present and future implications of planning and environmental concerns. A rational approach to planning is therefore needed if these conflicts are to be avoided. Fundamental to planning should be the recognition that mineral extraction is only a temporary use of land.

Nowhere more than in the Perth metropolitan area has resultant urban expansion posed a threat to the very resources upon which development depends. Concern over the need to protect these vital resources caused the former Metropolitan Region Planning Authority (MRPA) to research the need for, and adopt a regional strategy for, the protection and conservation of industrial minerals. This policy ensures maximum availability of resources within the metropolitan region; and encourages extraction in defined areas, and in a sequence that minimized land-use conflicts.

The vehicles of this policy are Extractive Industry Plans. They are produced by local authorities and identify and protect by zoning areas of high resource potential. Once adopted the extractive industry zonation would be incorporated into the current Town Planning Scheme.

It is not impractical to suggest that this planning policy could be extended to local authorities outside the metropolitan region. To do so would ensure that land is not withheld unnecessarily from either conservation or alternative development. The benefits to both industry and the community are immense. Resources would be protected whilst zoning would encourage local authorities to accommodate industry as part of its overall town planning.

CONCLUSIONS AND RECOMMENDATIONS

In recent years concern for intergrated land-use planning has made it clear that more detailed and comprehensive information on limesand and limestone reserves is required. This information is needed by local and State government to facilitate land-use and mineral planning and to assist in the formation of policies to ensure continuing supplies to all industries for which these materials are required.

This report has reviewed the most significant sources of limesand and limestone for the metropolitan and near metropolitan region. Major areas of limestone working occur north of Wanneroo, near Spearwood, and in an area south of Mandurah. Cockburn Sound is the principal source of limesand while the Lancelin area shows potential as a future large supplier.

While the resource base may seem so large that stocktaking appears unnecessary, this review has highlighted the effects of actual and potential sterilization of the known resource base through accelerating urbanization, declaration of flora and fauna reserves etc. However, the indications are that supplies of limesand and limestone should be adequate to meet anticipated demand, but there is concern that the opportunity for maintaining supplies for future use is becoming more difficult.

The country between Lancelin and Bunbury has been divided into a number of resource areas. It is evident that the largest part of the area's resource base is medium-grade limestone suitable only for constructional uses. Only three areas, State Forest 65 and adjacent country, Spearwood to Tamworth, and Tims Thicket, have proven high quality resources. The limestone near Kooallup Lagoon and between Myalup and Binningup also appears to be of high grade but further work is required to better define its extent. Land-based limesand supplies are restricted to an area between Lancelin and Ledge Point. Accordingly it is essential that the large resources of Cockburn Sound continue to be utilized for many years. If extraction is to efficiently serve the community then it needs to be coordinated and integrated. This approach has been adopted for the metropolitan region by the State Planning Commission's Extractive Industry Committee. Such a policy could be extended to include those areas outside the metropolitan area covered by this report. This would

ensure that supplies of limesand and limestone, particularly the higher grade material, are not prejudiced by incompatible land uses.

ACKNOWLEDGEMENTS

The organizations listed below provided information used in this report and their assistance and cooperation is gratefully acknowledged.

Bell Basic Industries Ltd
Cockburn Cement Ltd
Gingin Shire Council
Harvey Shire Council
Mandurah Shire Council
Main Road Department
Murray Shire Council
State Planning Commission
Swan Portland Cement Ltd
The Readymix Group
Waroona Shire Council

APPENDIX I

MAPS COVERING THE REPORT AREA

Urban Geology Map Series 1:50 000-scale (Fig. 1)

Bunbury-Burekup 2031 III - 2031 II

Harvey-Lake Preston Parts 2031 I and 2031 IV

Mandurah 2032 IV

Moore River - Cape Leschenault 1935 II - 2035 III

Pinjarra 2032 I

Environmental Geology Map Series 1:50 000-scale (Fig. 1)

Fremantle Parts 2033 I and 2033 IV

Lake Clifton-Hamel 2032 II and part 2032 III

Muchea 2034 I and part 2134 IV

Perth 2034 II and parts 2034 III and 2134 III

Rockingham Parts 2033 II and 2033 III

Yanchep 2034 IV

Copies of the above maps are available from the
Geological Survey of Western Australia.

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