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A Reconnaissance of the Construction Material Resources & Natural Physical Constraints of the Newcastle & Cessnock 1:100,000 sheet areas.

by

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Accompanying plans

Plan 7617 - Location plan of Study Area.
Plan 8123 - Newcastle 1:100,000 sheet:Construction material resources.
Plan 8124 - Newcastle 1:100,000 sheet:Natural physical constraints.
Plan 8125 - Cessnock 1:100,000 sheet:Construction material resources.
Plan 8126 - Cessnock 1:100,000 sheet:Natural physical constraints.

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Map reference

Newcastle 1:250,000, SI/56-2
Newcastle 1:100,000,9232,I,II,III,IV

Singleton 1:250,000,SI/56-1
Cessnock 1:100,000, 9132,I,II,III,IV

ABSTRACT

The geological setting of the Newcastle-Cessnock region indicates that a number of engineering geological considerations are potential constraints to the large scale urbanization of certain areas.

The factors include land stability, flooding, particular soil and rock conditions resulting from the natural geological and topographical setting, coastal erosion, mining subsidence and waste disposal.

Mineral resources (heavy mineral beach sands and coal) and potential construction material resources (suitable for use in the building of the urban centres) are present in the region and provision must be made in town planning for their long term extraction.

The environmental setting of the region has suffered considerable degradation as a result of development in the past. Some rehabilitation is possible especially of the water-ways. Care will have to be exercised however, during future development to preserve areas of estuarine habitat.

Conjunctive use of the plans and text will enable considerable pre-assessment of the hazards or assets which potentially apply to lands in the region.

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INTRODUCTION

In mid 1975, the New South Wales Planning and Environment Commission requested the assistance of the Geological Survey in providing information at a broadscale on those geological aspects which potentially could influence the future urban expansion of the Newcastle-Cessnock region.

Potential constraints arising from natural physical processes such as land slip, flooding and coastal erosion, together with the problems associated with extractive resources and surface land subsidence due to underground coal extraction, are foreseen as imposing restrictions to uncontrolled urban growth.

This report formalizes the preliminary data, with the exception of the detailed information on coal resources, supplied in August 1975 to the Newcastle regional office of the N.S.W. Planning and Environment Commission. Some changes in the geological base map and additions and refinement of constraint and resource areas have been made since the original information was supplied. However, it should be clearly appreciated by all users that the compilation has been prepared at 1:100,000 map scale because that is the scale at which regional planning is being undertaken. Hence the various areas defined as being either potentially subject to geological hazard or containing potential resources, should be taken as indicative only.

The manuscript data on coal resources (not herewith) was compiled on 1:50,000 scale enlargements of the old 1:63,360 scale military maps. The main feature of the coal resource maps is that the 150 m (500ft) depth (to the top of the topmost coal seam) contour has been shown as an indication both of the presence of potentially open "cutable" coal and also of the limit of major land surface subsidence manifestations.

The areas delineated on the maps as a result of this study, should not be taken as a final zoning or land use classification, but rather should be used as a guide in assessing the relative cost/benefit of undertaking particular developments in alternative locations. It should be borne in mind always, that any given site or area can be used for any purpose regardless of the site hazards: it just costs a lot more to utilize the high risk or hazardous areas.

For the purposes of this report, the study area comprises most of the Newcastle 1:100,000 map sheet and the eastern half of the Cessnock 1:100,000 map sheet. Plan 7617 shows the study area in relation to the other sub-areas which together make up what has been termed by the Geological Survey as "the Central Coast Region" for the assessment of low cost extractive resources.

CONCLUSIONS

Appraisal of the environmental geological setting of the Newcastle-Cessnock region has shown that a number of engineering geological factors should be taken into consideration when contemplating the large scale urbanization of the region.

Many of these individual engineering geological factors introduce what effectively is a major constraint to urban development, unless very expensive procedures are used to overcome the hazard. In some cases however, the natural geological factors are a potential hazard for one type of land use but may be advantageous for another form of use. Hence although the engineering geological considerations are summarized below, it is preferable that the maps accompanying the report, which depict the various land surface classifications, should be used in conjunction with the text discussion, to evaluate the potential hazards which could be associated with use of a particular region for a given purpose.

The major geological considerations listed below are discussed in more detail in succeeding chapters of the report.

1. The proneness of certain soil/rock sequences to develop land slippage if poor engineering or construction (subdivision layout) practices are followed. Areas of steep slope shown on plans 8124 and 8126 when underlain by thick soils, will inevitably suffer land movement, unless considerable attention is given to long term improvement of slope stability during subdivision earthworks and drainage.

Areas in these same zones, on plans 8124 and 8126, where massive cliff forming sandstones form the land surface, will suffer from the natural phenomena of rock falls from the cliff lines. The unpredictability of these falls and their inevitability on a long term basis, suggests that no urban development should be undertaken in such areas.

2. The proneness of widespread areas of land to repeated inundation. Areas shown as subject to repeated inundation are the most hazardous in this respect. However, care should be exercised in those areas shown separately on plan 8124,because of the foreseen difficulty in providing adequate drainage in most of these flat, low lying areas.

3. The proneness of the coastal strip to suffer periods of rapid (and disastrous) storm wave erosion. Beach and dune areas shown on plan 8124 fall within this category and in these areas no development whatsoever should be contemplated.

4. Much of the region is underlain by potentially economic coal resources. The development of industries or utilities to use this energy source and the location of the actual mining sites will potentially result in considerable conflict in land use, unless pre-planned procedures are developed to allow for the effects associated with coal extraction, particularly for the safeguarding of pit-head sites, areas for the disposal of the inevitable refuse materials and appropriate transport facilities.

In this regard it is pointed out that manuscript data supplied to the Commission indicated those areas in which the thickness of strata overlying the topmost economic coal seam was less than 150m (500ft).

In these areas actual open cut mining or severe surface disruption, as a result of shallow underground mining, will occur. Such areas then, cannot be considered for urban housing development within the foreseeable future.

In addition, it is most important that all areas of back-filled open cut extraction should not be used for housing, because of the long term future settlements which will occur in the back-filled materials where these have not been placed by proper engineering methods involving compaction.

5. A large proportion of the low lying area between Hexham and Port Stephens comprises a valuable ground water storage. Considerable care will be required in any proposal to develop these areas to prevent pollution of the ground water resource.

6. The cost to the community of building the urban centres will be considerably increased if provisions are not made to allow for a vastly increased extractive industry in the region to supply construction materials necessary for the actual building of the houses . Resources of clay, sand, aggregate, building stone and road materials, are present in the region, but pre-planning will be necessary to ensure that the resource materials are not sterilized by urban development.

7. A range of rock and unconsolidated sediment types are present, forming the land surface in the region. Particular properties or conditions in terms of inherent and bulk rock strength or resistance to weathering etc., arise with each of these material types. Consideration of these properties prior to initial site selection, will often enable optimization of construction procedures and minimizing of costs.

8. No positive indications of seismic risk can be given for the region. However, it is apparent that the extensive areas of unconsolidated sediments which are present in the region (all zones shown as flood prone or suitable for sand or gravel extraction on the plans) are at higher risk than the areas of bedrock outcrop - albeit the risk in the general region is considered to be slight.

9. No particular rock suite present in the region gives rise to soil and topographic features which could be considered to provide "ideal" conditions for waste disposal procedures. However, areas shown as being potentially suitable for clay extraction warrant detailed investigation to determine the most suitable location in which to develop large scale waste disposal facilities.

10. The extensive network of waterways in the region has suffered a considerable degree of environmental degradation in the past, both as a result of local industrial and urban development pressures, but also as a result of agricultural practices in the upstream catchment. Since the continued economic development of the region depends on multiple use of these waterways it is important that compatible and conjunctive management procedures be instituted. These must allow for improved flood drainage, maintenance of groundwater storage and large scale port development.

SUGGESTED FUTURE INVESTIGATIONS

As a natural corollary of this reconnaissance study, several obvious shortcomings in the availability of information have become apparent. To enable valid detailed planning at a locality scale in the future, it is recommended that studies be commissioned, to provide geotechnical advice on the following aspects.

1. Areas which have in the past been mined for coal. This would require identification both of old open-cuts which have been infilled, and all underground mined areas. These latter should be further sub-classified on the basis of thickness of cover (say 30m, 30-100m, greater than 100m), extracted thickness and percentage extraction. Such a system of classification (along the lines of that attempted for the Ipswich region, Wood and Renfree, 1975) would provide some indication of the likely degree of risk involved in developing given areas for particular purposes. As a corollary, the areas for potential future coal extraction still remaining should be defined (on an open-cut, shallow and deep underground basis).

2. Those areas which will be required to be set aside to allow for sand extraction to meet the regions future needs should be defined. This study would have to assess the local demand/consumption requirements for special purpose glass, foundry and plaster sands and also general purpose fill and construction sands in relation to supply or demand of sand from, or for, adjacent sources or markets, eg. Gosford-Wyong or Sydney. A minimum period of 25 years is foreseen as being appropriate for such a study with periodic reviews on a 5 yearly basis for the ensuing 25 years.

3. A regional waterways management plan should be developed. It is visualised that such a scheme would have to allow for conjunctive use of the waterways whilst preserving existing or potential recreational facilities and aquatic/estuarine environments. Conjunctive use implies that flood control/drainage works and harbour improvements would still allow for irrigation or domestic use of the surface and groundwater in the upstream valley areas and prevent possible salt water intrusion into the coastal groundwater storage areas. It would also have to allow for maintenance or improvement of wetlands habitats for birds and fisheries breeding and spawning grounds. It would also appear essential that any management plan for the Hunter Estuary should take cognisance of any management plans proposed for the Lake Macquarie catchment and the Port Stephens region.

4. Possible effects of extraction of sand and gravel from the bed of the Hunter River and Wollombi Brook should be assessed. It is visualised that this study would consider possible erosional effects on both the upstream and downstream river bed and banks, together with the possibility that improved channel flood flows could eventuate as a result of channel widening, deepening and/or straightening.

The availability of alternative construction materials would have to be considered if the results of the study indicated that continued extraction was potentially moderately harmful.

5. Some thought will have to be given to the possible need for a central brickworks to serve the West Newcastle-Upper Hunter region. This study would have to assess likely product type demands and potential raw material resources.

6. An investigation will be needed to determine the optimum location for new hard rock aggregate quarries to serve the region. It is visualized that the existing quarry at Raymond Terrace will be worked out, say, within the next 10-15 years. It is also likely that the available supplies from the Kulnura-Peats Ridge area will be increasingly required to meet the demands from the expanding Central Coast region. While increased production of coarse river gravels from the Hunter River could meet some of the future Newcastle Regional demand, material from this source probably would not meet the specifications for high quality aggregate. Whilst plans 8125 and 8123 (especially) indicate that, potentially, there are large reserves of rock suitable for aggregate production, for future planning purposes it would be desirable to specifically define the most promising potential quarry sites so that they may be reserved from development.

7. The areas at risk of natural geological hazards need to be more precisely defined. It is visualized that those areas shown on plans 8124 and 8126 which are potentially subject to risk of flooding, landslip (or rock fall) or coastal erosion should be assessed at a much larger (say precinct planning) map scale, prior to any attempt at sub-division. It is foreseen that no one authority or body could undertake the study of all three hazards and hence it would be necessary to commission three seperate studies, the area of each study to be based largely on that shown on plans 8124 and 8126. Ideally the results of each of these studies would lead to some degree of classification in terms of risk or likelihood of the event occurring-such as that put forward for the Gosford-Wyong area by Chesnut (1976) or the Tamar Valley (Tasmania) by Stevenson (1975).

GENERAL GEOLOGICAL SETTING

Considerable detailed stratigraphic information is available on the region. Most of the pre-1966 data has been summarized by Engel (1966). Subsequent work of relevance to the hard rock geology of the region has been largely concerned with evaluation of the coal resources. Work by Roy (1976) and Nicholson (in prep.) provides recent interpretations of the geology of the unconsolidated sediments in the coastal zone. No attempt has been made to summarize these works and readers with a need for particular stratigraphic information are referred to the original papers.

It should be noted that the base plans used for the map sheets accompanying this report comprise internal compilations (by the Geological Survey) of the Newcastle and Cessnock 1:100,000 map sheets showing updated stratigraphic geology (hence the presence of geologic symbols and boundaries).

To allow a basic understanding of the geology and to provide a basis for appraisal of the extractive resources maps (plans 8123 and 8125) and to comprehend how the geology and geomorphology influence the criteria used for the land use/hazards classification maps (plans 8124 and 8126), a brief outline of the geological setting of the area is given below.

The Newcastle-Cessnock region lies on the northeastern margin of the major tectonic unit known as the Sydney Basin which is the main coal basin of New South Wales. The rocks cropping out in the region are mainly of Permian age. Rocks of Triassic age are exposed in the southern and western part of the area. Rocks of Carboniferous age occur to the north of the Hunter River (mostly) and in two isolated areas in the Mt View-Pokolbin region, west of Cessnock.

Although most of the strata were laid down as sediments or volcanics in a virtually horizontally bedded form, the region suffered a considerable degree of tectonic deformation during the early part of the depositional cycle. The effects of this activity are that the Carboniferous rock succession is extensively folded and faulted, and has been intruded by granites in some places (Mt View and Winders Hill). The result is that individual units have a somewhat discontinuous outcrop pattern. The Permian rocks in general have only undergone minor faulting and broadscale gentle folding and hence the outcrop pattern of individual units is much more regular than that of the Carboniferous succession. The Triassic rocks have undergone only very minor broadscale folding and in essence they comprise a virtually horizontally bedded cap rock to the Permian Rocks.

The Hunter River flows eastward in a valley which follows the trend of a major structural fault-the Hunter Thrust.

TABLE I. GENERALIZED STRATIGRAPHY OF THE NEWCASTLE-CESSNOCK AREA

AGE	UNIT			LITHOLOGY
HOLOCENE	Unconsolidated sediments			Alluvium, marine and aeolean sands and lacustrine muds
TERTIARY-JURASSIC	Volcanic necks and igneous dykes			Basalt, breccia
TRIASSIC	Narrabeen Group	Gosford Sub-Group - Terrigal Formation		Sandstone, siltstone, minor claystone
		Clifton Sub-Group	Patonga Claystone	Red-brown and light coloured claystone and siltstone, some sandstone
			Tuggerah Formation	Light coloured sandstone, red-brown and light coloured claystone and siltstone, minor pebbly sandstone
			Munmorah Conglomerate	Light and dark coloured sandstone, siltstone, pebbly sandstone and conglomerate
UPPER	Newcastle Coal Measures	Singleton Coal Measures		Light and dark coloured shale, sandstone, conglomerate and coal
?— —	Tomago Coal Measures			Sandstone, shale, mudstone, minor conglomerates, splitting coal seams
MIDDLE PERMIAN	Maitland Group	Mulbring Siltstone		Siltstone, minor claystone, thin sandstone, limestone
		Branxton Formation		Sandstone, siltstone, conglomerate; varying amounts of pebbles and erratics. Muree Sandstone member occurs at top of formation
?— — —	Greta Coal Measures			Lenticular conglomerates, sandstone, shale, splitting coal seams
LOWER	Dalwood Group	Farley Formation		Sandstone, siltstone, mudstone; carbonate minerals in matrix of some sediments
		Rutherford Formation		Micaceous siltstone, mudstone, lithic sandstone, with erratics; matrix of sediments often calcareous
		Allandale Formation		Lithic sandstone, tuff, conglomerate
?— ↕ —		Lochinvar Formation		Lithic and felspathic sandstone, siltstone, shale, volcanics, with erratics
CARBONIFEROUS	A suite of rocks including massive volcanics, conglomerates, lithic sandstones, mudstones and varves with erratics; very minor limestone horizons and occasional granite			

This fault separates the Permian rocks of the Sydney Basin from the mainly Carboniferous rocks of the New England block.

The oldest rocks in the region are the lower Carboniferous units exposed on the northern side of the Hunter River between Elderslie and Rosebrook. Northwards from the Hunter River the rocks become progressively younger. South of the Hunter River, the oldest rocks consist of the (?)Upper Carboniferous units in the Mt View-Pokolbin area. These are overlain by Permian rocks which progressively become younger in age to the west, south and east, off the old rock basement. These lower Permian strata (see Table 1) outcrop mainly in the Bellbird-Lochinvar region. Middle Permian units (see Table I) outcrop extensively in the Ellalong-Mulbring-Maitland and Raymond Terrace-Limeburners Creek regions. Upper Permian rocks (see Table 1) almost exclusively comprise the outcropping strata in the East Maitland-Killingworth-Newcastle-Lake Macquarie area. Triassic rocks of the Narrabeen Group (see Table 1) from the caps on the ranges west of Mt View, west of Millfield, and cap the Myall and Sugarloaf Range systems.

Basic Igneous dykes are abundant in the Newcastle area, where they are known from coal workings. It is inferred that whilst dykes may not be as abundant elsewhere as they are in the Newcastle area, they almost certainly are present in reasonable numbers in most other parts of the study region.

Similarly with volcanic necks. Whilst none are actually known from the area considered in this report, they are known to be present to the south and west of the sheet areas. Accordingly it appears reasonable to infer that some, as yet undetected, volcanic necks are present in the study area.

The unconsolidated sediments are associated mainly with the alluvial regime of the Hunter River delta and southern Port Stephens. Upstream from Raymond terrace there is very little detailed information on the nature of these sediments.

In terms of planning proposals, the most important aspect of the regional geology is the variation in dip of the strata, since this factor indicates which areas are underlain by coal measure strata. These generalized dip directions are shown on plans 8124 and 8126.

MINERAL AND CONSTRUCTION MATERIAL RESOURCES

The extractive resources present in this region, many of which will be required for the actual construction of the urban centres, have been reported on previously by Adamson (1968) in his compilation of the information available at that time.

More recently Uren (1973) has reassessed the resources of the eastern part of the region with particular emphasis on the clay-shale industry and the availability of road making materials. The eastern half of the Cessnock 1:100,000 map sheet has been informally assessed for availability of road making materials and clay/shale resources by one of the authors (V.G.). Rogis (in preliminary format only) has assessed the coal resources.

Readers with a requirement for detailed information on mineral and construction material resources are referred to these separate works.

However, to complete the assessment of the geological factors which influence development of the region, a brief summary of the potential sources of the major construction material (or so called low cost extractive) and mineral resources, is given in relation to the various areas shown on plans 8123 and 8125. This data is provided because it is necessary to ensure that at all stages in urban planning, provision is made to allow for extraction of the available resources. It must be understood that in precluding extraction from given areas, a potentially valuable resource commodity is being sterilized and commonly the community is being forced to pay a higher price in that a more distant or lower grade resource has to be utilised. The construction materials to build the new urban areas, it must be remembered, have to come from "somewhere", and this "somewhere" is a function of natural geological controls around which urban planning must be designed. Another factor which must be considered in town planning is the essentially transient nature of the use of land by extractive industry. Once the resource has been extracted, the land is available for a subsequent use.

The extractive resources actually available within the study area comprise:

1. Clay/Shale
2. Hard Rock Aggregates (including steelworks slag)
3. Natural road materials ("ridge gravel").
4. Sand (beach, dune and estuarine swamp).
5. Sand and Gravel (river)
6. Coal (and colliery refuse)
7. Topsoil (garden loam)
8. Groundwater
9. Heavy mineral sands (rutile, zircon etc.)

The most likely areas from which these resources can or will be obtained are shown on the map sheets. In most cases the total area of occurrence of the potential resource has been shown. In some cases existing land use constraints suggest that only in certain areas would it be appropriate to consider continued or future extraction.

Brief notes on the individual resources are given below, while Tables II and III, later, list the current extraction sites shown on the relevant plans and indicate the pit owner and nature of the material being extracted.

Table II

Extraction Sites on the Newcastle 1:100,000 Sheet (plan 8123)

Pit Number Shown on Plan	Owner/ operator	Material Extracted and Use
001	Fieldsend F.J.	White shale, mottled clay-earthenware pipes and fittings.
002	Hughes Potteries	White and grey clay - stoneware pipes.
003	Thornton Fire & Brick Building Co.	Grey and brown shales - face bricks, some fire bricks.
004	" "	" " "
005	" "	" " "
006	" "	Light green clay - red building bricks
007	P.G.H.-Turton P/L	White & red clay - building bricks
008	"	Shale - building bricks.
009	"	White clay, brown shale - cream building bricks
010	"	Mottled clay and grey shale - red roofing tiles
011	"	White & grey/brown shales-structural clay
012	"	Mottled clay - roofing tiles
013	Wallsend Brick Co.	Grey and brown shale-building bricks
014	Williams and Bryan	White shale-cream bricks,sewer and agricultural pipes
015	Wardley,H & Sons P/L	White mottled clay & shale-Fire bricks,acid-proof refractory ware
016	Newbold General Refractories	White mottled clay & shale - ladle bricks
017	Waterloo Fire Brick Co Ltd.	Brown and white shale-fire bricks, drain and perforated channel pipes
018	"	Brown & white shale-building bricks
019	"	" " "
020	?Lake Macquarie Shire	White Clay-structural clay products
021	R. Osbourne	Conglomerate - roadbase
022	?shire council	Sandstone, shale - roadbase
023	" "	Mudstone - roadbase
024	" "	Mudstone - roadbase
025	? "	Conglomerate - roadbase
026	? "	Conglomerate - roadbase
027	? "	Conglomerate - roadbase
028	Lake Macquarie Shire	Pebbly sandstone - roadbase, fill
029	Cessnock City Council	Conglomerate - roadbase
030	Lake Macquarie Shire Council	Conglomerate - roadbase
031	Hunter District Water Board	Conglomerate - roadbase
032	R. A. Guildford Pty Ltd	Conglomerate - roadbase
033	Lake Mac. Shire Coun.	Conglomerate - roadbase
034	" " "	Conglomerate - roadbase
035	G.Hawkins & Sons P/L.	Conglomerate - roadbase
036	?	Conglomerate
037	Premier Metal & Gravel P/L.	Conglomerate - road material,concrete aggregate, fill
038	?	Conglomerate - roadbase
039	?	Conglomerate - roadbase
040	Lake Macquarie Shire Council	Conglomerate - roadbase
042	Lake Macquarie Shire Council	Conglomerate - roadbase
043	H. Halpin/Jacob.	Conglomerate - roadbase
088	D.M.R.	Sand - construction and fill sand
089	Hunter District Water Board	Buff sand - construction and fill sand
090	" " "	" " "
091	?	Sand - construction and fill sand

Table II (Ctd)

Extraction Sites on the Newcastle 1:100,000 Sheet (plan 8123)

Pit Number Shown on Plan	Owner/ operator	Material Extracted and Use
092	Hardboards Aust.Ltd	Sand - construction sand.
102	W.J. Meredith	Sand - construction, concrete sand
103	J. Johnson	Sand - concrete sand
104	Cox	Grey sand - concrete and fill sand
105	J. Shoemaker	Yellow sand - concrete sand
106	B.M.I.	Yellow sand - concrete sand
203	Public Transport Commission	Andesite - railway ballast
204	Dungog Shire Council	Rhyolite - roadbase
205	" " "	Conglomerate - roadbase
206	?	Conglomerate - roadbase
207	Dungog Shire Council	Mudstone - roadbase
208	" " "	Sandstone conglomerate - roadbase
209	" " "	Sandstone, conglomerate - roadbase
210	?	Conglomerate - roadbase
211	Dungog & Port Stephens Shire Councils	Mudstone, sandstone - fill, indoor paving
212	Forestry/Commission	Sandstone, conglomerate - roadbase.
214	B.M.G. Pty Ltd.	River gravel - concrete aggregate, filler, decorative purposes
215	B.M.G. Pty Ltd.	Conglomerate - " " " "
216	?	Sandstone, conglomerate
217	Port Stephens Shire Council	Conglomerate,sandstone - roadbase
218	J. Johnson	Conglomerate - roadbase
219	?	Basalt
220	?	Conglomerate
221	C. Adam	Mudstone, sandstone - roadbase
222	?	Conglomerate, sandstone - roadbase
223	B.M.G. Pty Ltd.	Dacite, conglomerate - road surfacing and concrete aggregate .
224	Local landowners	Sandstone - roadbase
225	Stroud Shire Council	Porphyry - roadbase
226	J. Sepos.	Shale, sandstone - fill, roadbase
227	Dungog Shire Council	Conglomerate, sandstone - roadbase

Note: Pit numbering system follows Uren (1973).

Clay/Shale

At present clay/shale materials for the manufacture of ceramic ware and structural clay products are obtained from shale units in the coal measure strata. Any increased rate of population growth in the region will require a considerably greater output and range of clay products than is presently produced. Hence, a number of new sources of plastic clay and raw shale will be required in the future to meet the local demand. Because of the high cost of transport and the major role that structural clay products play in the urban housing industry it is imperative that both clay sources and manufacturing plants be located in close proximity to the urban growth areas.

Clays and shales suitable for a wide range of structural and refractory purposes are to be found in association with coal seams of the Newcastle, Tomago, Greta and Singleton Coal Measures. The areas of outcrop of all coal measure strata are shown on plans 8123 and 8125.

Although certain specific horizons within the coal measures have been more extensively worked than others, material suitable for the manufacture of structural clay products can be found almost anywhere in coal measure shales and siltstones.

Large amounts of structural clay-shale and some refractory clay-shale are being quarried in the East-Maitland-Thornton area. Operating companies in this area are P.G.H. Industries Ltd., Thornton Fire and Building Brick Co. Pty Ltd, Waterloo Brick and Pipe Co. - Waterloo Fire Brick Co. Ltd, and Fieldsends Potteries Pty Ltd. During the 1975/76 financial year, these companies extracted 140,000 tonnes of structural clay-shale and 5000 tonnes of refractory clay-shale from this district. These raw materials were valued at $300,000. Products made from the clay-shale supply the Hunter Valley-Newcastle region. Important future reserves of clay-shale for this purpose can be found in the immediate vicinity of the operating pits, and in the Medowie-Swan Bay area.

Some low grade refractory clay and shale is won from brown and grey shales and an overlying weathered zone of white mottled clay, in the Hillsborough area. Important future reserves of this material can be found in the immediate area.

On the accompanying map , a light blue colour hatching has been used to denote areas within the coal measures where clay has been extracted and utilised for the manufacture of bricks, pipes and tiles, and in some cases for the manufacture of refractory bricks. The colour hatched zone also includes potential areas for future clay extraction.

The areas shown on plans 8123 and 8125 as being suitable for clay/shale extraction are by no means exhaustive. Material suitable for the manufacture of bricks, pipes and tiles has been obtained from a large number of pits, not all of which are located within coal measure strata.

Table III

Extraction Sites on the Cessnock 1:100,000 Sheet (Plan 8125)

Pit Number Shown on Plan	Owner/ operator	Material Extracted and Use
1	? Shire council	conglomerate - roadbase
2	-	conglomerate - potential extraction site.
3	? Shire council	old river gravel - roadbase (abandoned)
4	? Shire council	conglomerate - roadbase
5	? Shire council	conglomerate - roadbase
6	? Shire council	conglomerate - roadbase
7	? Shire council	conglomerate - roadbase (abandoned)
8	? Shire council	conglomerate - roadbase (abandoned)
9	? Moores Earthmoving	conglomerate - roadbase
10	"	" "
11	"	" "
12	"	" " (abandoned)
13	? L. Russell & Son	conglomerate - roadbase
14	"	" "
15	?	conglomerate - roadbase (abandoned)
16	B.P. Kauter & Sons P/L	river gravel and sand - concrete aggregate
17	J.H. Lloyd	conglomerate, rhyolite - bitumen paving, roadbase
18	"	" " " "
19	?	conglomerate - roadbase (abandoned)
20	?	" " "
21	?	conglomerare - roadbase
22	?Shire Council	sandstone - roadbase
23	?Shire Council	conglomerate - roadbase
24	?Shire Council	conglomerate, sandstone - roadbase (abandoned)
25	?Shire Council	conglomerate, sandstone - roadbase (abandoned)
26	?Shire Council	sandstone, shale, coal - ?roadbase (abandoned)
27	Cessnock Shire Council	conglomerate, sandstone, shale - roadbase
28	?Shire Council	conglomerate - roadbase (abandoned)
29	Cessnock Shire Council	conglomerate, sandstone - roadbase (abandoned)
30	?	conglomerate - roadbase (abandoned)
31	Ravensfield Stone Quarry, T.Broime P/L	sandstone - dimension stone
32	?	sandstone - roadbase (abandoned)
33	?Shire Council	sandstone - roadbase (abandoned)
34	?Shire Council	siltstone - roadbase
35	?Shire Council	siltstone - roadbase (abandoned)

These include clay/shale horizons within other Permian units, as well as in units of Carboniferous and Tertiary age.

However, only those areas in which pits are concentrated or in which the outcropping units are known to have a high potential for use in the manufacture of ceramic products, have been shown on the plans.

Hence it is suggested that, wherever possible, the areas shown on the plans should not have incorporated in their use planning, overriding restrictions precluding clay/shale extraction. No doubt any new brickworks required to serve the region can be sited to comply with the overall town planning scheme.

Clay extraction pits located in these areas would eventually, probably be ideal locations for waste disposal sites. Finally of course such sites then become available for a subsequent land use, other than urban housing.

Hard Rock Aggregate (encompassing Crushed and Broken Rock, Steelworks Slag and Dimension Stone).

At present a number of hard rock quarries are operating in the region. These supply the local market and also to some extent special use materials for the Central Coast and Sydney markets.

Products include rough hewn dimension stone, rip rap and crushed aggregate, including railway ballast and prepared road base materials. The major quarries are at Raymond Terrace, Gosforth and Martin's Creek.

These producers extract massive rock from a number of stratigraphic horizons in the Carboniferous succession, where strongly bonded volcanic units are present.

To some extent, an increase in output of these materials will become necessary as an adjunct to the increasing urbanization of the region. The only sources of massive rock which are capable of meeting the needs of the region are those lying within the areas shown on plans 8123 and 8125. Deposits of basalt and less strongly bonded volcanic rocks are also present throughout the region. Whilst these have not been shown on the plans they are also capable of meeting certain types of crushed rock products, as are also the coal measure conglomerates. In addition, increasing use of crushed steelworks slag for concrete aggregate, road surfacing, and prepared road base, is foreseen.

On the accompanying map sheets all the Carboniferous massive volcanic units have been shown hatched. These volcanic units are, in general, well suited for the production of crushed aggregate and have been extensively worked for this purpose. Quarries working such volcanic units are the B.M.I. quarry at Raymond Terrace and the Department of Railways ballast quarries at Martin's Creek.

Roadbase produced from crushing the volcanics tends to be harshly graded and of low plasticity. Although these properties can be improved by the addition of soil or weathered volcanic rock zones, the material still often (in roads) suffers from an excess of moisture. (Water readily penetrates the road-base but is difficult to remove).

Due to the shortage of crushed volcanic rocks and stream gravels in some areas it will be necessary in the future to supplement these materials with aggregate produced from Permian and Triassic conglomerates e.g. Awaba-Morisset area. These conglomerates are presently used extensively as natural roadbase.

Hence it is suggested then, that in environmentally sheltered (that is low visual impact) areas within the hatched zones on plans 8123 and 8125, planning controls should not preclude the development of new hard rock quarries. In addition, provision should be retained for existing quarrying to continue and for some new quarries to be opened in the presently used deposits and also in areas of outcrop of the coal measure conglomerates (plans 8123 and 8125).

Natural Road Material ("ridge gravel")

Base course, sub-base and to come extent re-sheeting and shoulder repair materials for road construction are currently being won from a wide range of locations and from almost all the rock sequences which occur in the region (Randle, 1974). There is little doubt that this situation will continue as increasing urbanization takes place - since this will keep the cost of minor road construction and repair to a minimum.

However, there is almost certainly going to be an increasing requirement for better quality roads traversing the region e.g. National Route I. For these roads, only high quality materials will be acceptable in order to ensure a reasonable life for the structure. In this region, the only naturally occurring materials which are capable of meeting the D.M.R. specifications for A1 road gravel, are the deposits of moderately weathered coal measure conglomerates. Clayey material from the coal measures is likely to be totally unacceptable. Thin bedded sandstones of the Narrabeen Group may be acceptable to a limited extent, particularly for sub-base, as also might some of the more massive sandstones of the Narrabeen Group or the coal measures, when these are partly weathered. In addition, use may be made of some of the colliery refuse which is generated in the area.

At present a high proportion of the materials used in the construction of main roads in the region is "prepared road base" from the aggregate quarry at Raymond Terrace and the river gravel extraction sites at Branxton. This in fact is a misuse of the high quality materials occurring at these sites, and it is foreseen that in the future, as aggregate demand increases in the region, the need to conserve these valuable resources will result in the widespread use of other potentially lower grade materials for road construction, e.g. steelworks slag and colliery chitter.

In the Newcastle region the coal measure conglomerates have a relatively high plastic index and have been used successfully without a bitumen surface, both for road shoulders and for pavement on lightly trafficked roads. Important roadbase quarries in coal measure conglomerates are located at Black Hill, north of Minmi, and near Teralba.

Conglomerate units are also often found interbedded with the Carboniferous volcanics. In these situations, it is common for both to be extracted for use as crushed aggregate and/or road base e.g. Raymond Terrace.

On plans 8123 and 8125 a hatching has been used to denote areas within the coal measures where conglomerate units are being utilised, or have the potential for use, as high-grade natural roadbase (and/or crushed aggregate).

Notwithstanding the possible range of natural and "artificial" road construction material resources available in the region, it is suggested that every endeavour should be made to ensure that urban development does not sterilize all the areas of outcrop of coal measure conglomerates shown on plans 8123 and 8125, and that provision should be retained for suitably sited road gravel pits to be operated as necessary in these units. The proposed Newcastle-Sydney expressway will require large quantities of roadbase in close proximity to the proposed route. It is likely that one or more sites in the Morisset-Awaba area will be required for quarry development to meet this demand.

Sand

Sand of varying quality and suitable for a range of uses is currently being extracted in the region. Most sand grades produced are used locally in the construction and heavy industries. However, some specialized sands are transported to the Sydney and Central Coast industrial markets.

With increased urbanization, an increased demand for construction grade sands (ready-mixed concrete, mortar, plaster) will arise. It will, however, be important to ensure that high quality industrial sands are not used for these "low value" purposes. High quality sands must be preserved for their own most important use. This means that new sources of sand will be required to service the construction needs of the region.

On the accompanying Newcastle map sheet (plan 8123) the potential sources of sand are the older beach and stable sand dunes that occur north of Newcastle, between Raymond Terrace and the coast.

This sand is fine to medium grained and coloured buff, cream, yellow, orange and brown tones. It is currently extracted from pits situated at Raymond Terrace, Tomago, Lemon Tree Passage and Stockton. The sand is used for concrete, construction, moulding and refractory purposes. Some is suitable for the manufacture of colourless and coloured glass.

High quality sand is also present (and extracted) in the Redhead-Dudley Region.

Sand is also present in the actual stream bed and banks of Wollombi Brook (in the plateau lands to the west of Cessnock). However, little is known of the physical sizings or chemical quality of these deposits.

In the vicinity of Anna Bay, sand is extracted from stable dunes and utilised for foundry purposes. The sand in this locality possesses particular characteristics that render it highly suitable for this purpose.

In the Salt Ash - Lemon Tree Passage and Dudley areas sand suitable for coloured and colourless glass making purposes has been extracted from stable dunes. Newcastle Glass Works Pty Ltd and P.B. White Minerals Pty Ltd currently extract sand from these areas for this purpose.

The Lemon Tree Passage, Anna Bay and Dudley areas are the only localities near Newcastle from which sand suitable for foundry and glass sand purposes can be obtained to supply the Newcastle industries.

Sand is present in the study region in a clean virtually ready to use form, primarily in those areas shown on plans 8123 and 8125, and also in parts of the infilled estuary of the Hunter River. "Sand" is also no doubt present in most of those areas comprising the flood prone zones shown on plans 8124 and 8126. However, in these latter areas the sand will almost certainly be present in a generally "dirty" (silty or clayey) form and would need some (perhaps a lot) form of processing, such as wet screening, to make it suitable for use.

The deposits of sand which are potentially the most valuable as a construction material are shown hatched (Redhead and Stockton high dune). The deposits in the zone hatched between Hexham and Port Stephens are hosts to groundwater supplies and heavy minerals and only very restricted development/extraction is likely in these areas.

It is suggested then, that wherever possible, those areas shown on plan 8123 and the area of the entire Hunter River estuary, should not have incorporated in their use planning, overriding restrictions precluding sand extraction. Most of these areas are potential sources of underground water supplies and many are also flood prone or simply low lying areas which may be difficult to drain. In addition, this zone is the host zone for valuable deposits of the heavy mineral suite (zircon, rutile, etc).

<u>Sand and Gravel</u> (river)

Sand and gravel deposits are found along the course of the Hunter River from above Muswellbrook to the coast.

The extent of these deposits within the study area is shown by hatching on the accompanying plans (8123 and 8125).

The sand is coarse and contains a large proportion of rock fragments. It has been extracted from a number of localities along the river and utilised without processing for construction purposes and as a filter medium.

Washed river gravel is produced from the Hunter River at various locations above Maitland. Below Maitland, the gravel content diminishes, the clast size decreases, and larger proportions of silt are present. On the map an inferred "cut-off" line is shown near Raymond Terrace. Although gravel and sand exist downstream from this line, the material is considered to be at too great a depth for economic extraction.

Between Maitland and Greta the gravel is small, generally less than 3 cm, in size. In this region the proportion of sand is high. Upstream, the size of the gravel increases and at Singleton pebbles average 7-8cm in size, while the proportion of sand present, decreases.

Because of the clast size, only a small percentage of the gravel below Singleton requires crushing. Most is well rounded and smooth. The highly polished surfaces of the gravel pebbles makes them unsuitable for road material and, in this use, they have been mostly replaced by crushed aggregate. River gravel is a preferred concrete aggregate because the smooth well rounded pebbles generally require no crushing and provide better workability and ease of compaction than crushed aggregate.

The gravels above Singleton are coarser in clast size and a considerable amount of stone requires crushing. This gravel is more suitable for road wearing surfaces.

In the Hunter River and in the Williams and Paterson Rivers, large and important reserves of sand and gravel are present. Most are suitable for construction purposes. However, as discussed in a later section, the possible erosion effects resulting from extraction from within the stream channels must be assessed to determine which areas can be safely utilized.

Coal and Colliery Refuse (Chitter and washery tailings)

As indicated earlier in this report, a considerable proportion of the study region is underlain by coal measure strata. To date it is very approximately estimated that less than one tenth of the total available coal reserves have been extracted. Hence it can be expected that coal mining activities will continue to have major impacts on the urban development of the region. These impacts will take the form of colliery pit tops, coal (surface) transport routes, colliery refuse disposal areas and areas subjected to varying degrees of land disturbance effects (ranging from actual open-cutting to surface lowering by subsidence).

The preliminary manuscript data compiled by Rogis (1975) and held by P.E.C.'s Newcastle Office is intended to provide basic coal resource information for use in future planning. The problems associated with extraction of this mineral are extremely complicated and it is not proposed to discuss the ramifications here (it in fact is the subject of deliberations by a joint technical / planning committee).

However, mention is made of one aspect. This is, that continued large scale coal extraction in the region will result in a considerable volume of colliery and coal washery refuse being generated in the future in this region. In the past very little use of such material has been attempted in New South Wales, partly because of economic factors, but very often because the refuse was generated distant from places of possible consumption.

However, in this region in the future, the problems of transport distance are minimal. Hence it will be largely on the basis of environmental planning considerations versus user acceptibility, that the refuse, disposal: use, ratio, will be determined.

It is suggested that the successful results of the C.S.I.R.O. fluidized bed combustion tests indicate that colliery and washery refuse processing for a range of secondary uses is practicable. Such uses could be engendered on a widespread basis by appropriate environmental controls on refuse dumping procedures or restrictions on the opening of new extractive industry pits for road construction and general purpose fill materials. In addition, bearing in mind that probably not all the refuse generated in the area will be usable (insufficient market or uses for total volume available) properly designed land reclamation schemes can be developed to use the unmarketable volumes of refuse. This matter is mentioned in a subsequent section of this report, where it is pointed out that raising flood prone areas above flood level by fill reclamation,often tends to cause increased flooding somewhere else.

<u>Topsoil</u> (Garden loam)

With urban development there always arises a requirement for topdressing soil for urban beautification, parklands and household gardens. In the Newcastle-Cessnock region a number of the outcropping rock sequences generate relatively poor quality (agricultural) soils, while in a number of environments, potentially more productive soils are present.

It will be important to relate park management practices and urban/rural zoning to these differing soil types. In this connection the work of the Soil Conservation Service of N.S.W. (Emery, pers comm.) will provide ideal base data for such considerations.

However, it will also be necessary to make provision for the extraction of top-dressing soil.

It is likely that the rich alluvial soils associated with the Hunter River, in particular, will be the most suitable. Consideration of how extraction might best be undertaken, with minimal impact on the river banks or flood plain, will be necessary. Here again the Soil Conservation Service of N.S.W., together with the Water Resources Commission and Public Works Department may be able to provide advice.

Underground Water

The region has a reasonably reliable and relatively high rainfall and relatively low density of population in the hill lands, which comprise the stream catchment areas. Thus no real problem in terms of water availability presently arises.

However, it is foreseen that as increased urban and industrial development takes place, in conjunction with increased high intensity farming, e.g. market gardens, the increased demand for water could necessitate serious consideration being given to the possibility of utilising all available underground water to supplement surface water supplies in at least some parts of the region.

While it is inferred that groundwater could be obtained from bores sunk in almost any of the rock formations of the area, the yield would probably be, in most cases, too small to be of any real value. However, it is visualized that bores sunk in areas of unconsolidated sediments would be capable, in general, of sustained production of appreciable volumes of water, although elucidation would be required of the quality of the water so produced and of the long term safe yield of the bore (to prevent undue draw down or incursions of brackish or salt water).

At present, extensive use is being made of water pumped from the alluvial deposits of the Hunter River flood plain upstream of Raymond Terrace for use in dairy farms, in market gardens and probably also for domestic supplies. In general, water from this area would be expected to be of reasonably good quality except near Raymond Terrace, where minor salt contents could be present as a result of the nearby presence of the tidal zone of the river.

A consideration which may affect the usefulness of water produced from the river alluvial flats, both now and in the future, and for which no information is apparently available, is that of the effect on water quality of heavy applications of fertilizer over a long period, e.g. for clover growing. It is quite possible that some deterioration in quality in terms of dissolved solids may have occurred already (and been recognised) in intensively farmed areas where groundwater has been extracted over a long period, say, the last 20 to 30 years.

In addition to the stream alluvial deposits, there are extensive areas of estuarine, marine and aeolian deposits present in the region between Raymond Terrace and Port Stephens.

This area currently yields almost one third of the supplies distributed by the Hunter District Water Board. Hence the continued viability of this resource is most important. It is not known whether a significantly increased rate of production could be achieved from these (Tomago) sand bed areas, although it is known that there is a considerable fresh water outflow from them directly into Tilligery Creek.

It is apparent then that no development should be contemplated which might appreciably reduce the potential yield from the sand beds - both from the point of view of alienating a valuable resource, but also because of the huge capital cost involved in providing a replacement surface water storage scheme.

Continued large scale use of the stream alluvial deposits and sand bed areas for water supply requires the imposition of controls on land use over the entire catchment of a groundwater storage area, so as to prevent undesirable effects on water quality. The extent to which such land use controls would affect future urban development and high intensity farm holdings can be gauged from the relative distribution of areas of rock outcrop and sediment infilled areas shown on plans 8124 and 8126.

<u>Heavy Mineral Sands</u>

Processing of limited areas of coastal sand deposits in the region bounded by Raymond Terrace-Newcastle-Port Stephens, for the extraction of the heavy mineral fraction is likely to continue for some considerable period (?20 years).

The areas likely to be subject to mining (because they contain heavy mineral concentrations) are now reasonably well known. In essence, these areas comprise a series of generally narrow, east-west trending zones in the region between Hexham and Port Stephens, and in narrow northeast-southwest trending zones along the beach and high frontal dune complex between Stockton and Morna Point. Roy (1976, in prep.) has found that generally uneconomic concentrations of heavy mineral are present under Fullerton Cove. It would thus be expected that similar uneconomic concentrations would occur in the areas covered by the Kooragang Island complex and the Tilligerry Creek lowlands.

In planning land use for the large flat areas between the Hunter River and Port Stephens it will be necessary to ensure that continued heavy mineral mining is not excluded, specifically in the Tomago Sand Beds and the Stockton Bight frontal high dune zone.

ENGINEERING GEOLOGICAL CONSIDERATIONS

Before large scale urban development takes place on those lands in the northern or western part of the region which are presently used for farming or grazing, it will be necessary to assess the impact of a number of naturally occurring physical factors which could impose constraints on the planning options. These constraints include (apart from the lands containing the low cost construction materials which will be required for the actual building of the new houses and which have been discussed in the previous chapter):

(a) lands prone to repeated inundation or with low slope gradients which may be difficult to drain.

(b) lands prone to rock fall or surface soil movement.

(c) lands prone to coastal erosion.

(d) filled lands resulting from open-cut coal mining or construction material extraction.

(e) lands deeply underlain by coal bearing strata and hence in which surface subsidence effects could arise during future mining.

(f) lands in which particular surface soil or outcropping rock conditions could effect the nature of foundations required for structures.

(g) areas which currently, are being used or potentially are capable of being utilized, for groundwater storage.

(h) some areas being more suitable for waste disposal.

(i) certain areas having potentially a higher Seismic Risk.

(j) lands underlain by rocks with particular properites which could introduce problems in sub-surface excavations.

Each of these factors is discussed broadly below. However, specific investigation of many of the above factors will be required prior to final land use definition. This is especially the case with the factors of flooding, landslip, and any proposal for the use of backfilled extraction areas or colliery refuse dumps for urban housing.

<u>Flooding (Ease of Drainage)</u>:

The Newcastle - Cessnock region lies in a moderately high rainfall region in which exceptionally heavy rainfalls can occur. The region includes some elevated hilly areas, but has a high proportion of topographically low, undulating to flat areas. A river which drains a large catchment flows through virtually the middle of the region. A number of major tributary streams join the main river almost in the centre of the study area. All these streams have periodic major floods.

In addition, there is a common local association of relatively steep hillslopes and flat valley floors. Hence, it becomes apparent that there is considerable potential for actual flooding or sheet wash inundation to occur in a number of areas as a result of rapid runoff.

Thus under this aspect of land classification an attempt has been made to differentiate on a broad scale, the essentially flat low lying lands of the region into categories of risk in terms of their proneness to inundation during periods of rainfall. This factor can be considered as reflecting the ease (or difficulty) of providing adequate drainage to given areas.

Since the object of this investigation is to attempt to predict future hazard potential,it becomes important to realize that a change in land use, from rural to urban, is likely to cause considerable changes in the stream regime of the area. Thus minor creeks and gullies, which under rural land use do not flood may, under the vastly increased runoff effects resulting from complete urbanisation, change their flow pattern to the extent that they pose a serious,albeit short term,flood hazard.

Hence in compiling the flood hazard zones shown on plans 8124 and 8126, subjective consideration has been given to both the topographic setting and the creek/valley shape, relationship. While some areas may appear to have been classified at a higher risk than their past history would indicate was appropriate, the higher risk loading is given as an attempt to predict flood patterns resulting from urbanisation of the valleys.

On plans 8124 and 8126, those areas which are subject to repeated long term inundation and in some places short term sheet wash flooding (flash flooding) are shown hatched. Such areas should not be considered for any use which is not compatible with this phenomenon. Similarly such areas should, in general, not be reclaimed, as such works could affect upstream flood levels. In certain parts of these areas consideration could be given to the possibility of development of canal estates (see later discussion).

The areas defined as prone to repeated flooding essentially comprise large areas of swamplands together with the low and intermediate level flood terraces of streams and some areas of estuarine/alluvial sediment accumulation. Because of this proneness to flooding, several possible uses for these areas other than for urban development suggest themselves, since the cost of effective flood prevention or drainage, could vastly outweigh the advantages to be gained from such works. These other uses include:

(1) Storm water retention runoff basins (that is, artificial lakes).

(2) With the construction of limited improved "pseudo natural" drainage channels, use as parklands (passive) would be practicable (occasional flooding would not be a major disadvantage).

(3) Farming, especially for intense use such as market gardens. (Flooding, to some extent, is an acceptable risk in this activity).

It is pointed out that large scale fill reclamation of these areas will only divert flood/storm flows elsewhere, and this factor would have to be thoroughly assessed (see also later) before major flood mitigation or drainage works were attempted.

The areas shown on plan 8124 as being flat and low lying are rather more likely to suffer periodic sheet wash (flash) or temporary back-up type flooding of short duration rather than the long term inundation effects associated with the main flood prone areas.
Thus the hazards associated with this zone simply reflects the flat nature and low topographic position relative to sea level of these areas, which makes them difficult to drain. With large scale preplanned drainage/sewerage most of these problems can probably be eliminated, especially in the sandy soil regions.

Areas of both these zones would often appear to have potential for urban use in the form of canal estates where these zones occur in the vicinity of the large water bodies in the region.

However, one of the prime requirements for the continued existence of the environmental "charms" of such estates is that the water-ways should be regularly flushed to prevent water stagnation and channel siltation. Only two means of natural flushing are possible - tides and actual stream thru-flow. With the exception of parts of the regional water-ways down-stream of Hexham there is insufficient tidal change in the water bodies to achieve such effects. Similarly, with the exception of the main rivers, only minor stream flows are present in the creeks of the area, except after heavy rain. Hence the desirability of using canal estate type development of these low lying areas, to raise land above flood level, is open to serious doubt in terms of the probable poor quality of the water which will be present in the canalways. The possibility of a huge scale development of canal estates in the Tilligery Lowlands, designed to utilize tidal delay flow between Fullerton Cove and Port Stephens would have to be considered in relation to the waterways management plan discussed earlier.

Obviously, all the other areas of the region outside these zones are at minimal risk in terms of potential for inundation - because they have sufficient land slope to allow downslope drainage.

Land Stability

Many workers have discussed the physical, mineralogical and engineering soil mechanics basis of land stability. Essentially it has been concluded that a combination of land slope angle (angle of repose) and moisture content of the soil are the primary controls with modifications (for better or worse) on these controls by such other factors as clay mineralogy of the soil, proportion of clay/silt sized particles in the soil mixture, thickness and permeability of the soil profile and nature of the soil/rock interface.

Obviously on a large scale investigation, such as this study, it is not possible to accurately assess in detail those modifying factors outlined above. However, they have been borne in mind during this study and have been used on a subjective/interpretive basis in the classification system adopted.

In general terms, land stability can be taken as an expression of the long term ability of sloping land surfaces to retain their present spatial relationship. The present (undisturbed) setting of the land surface is considered to be the natural land slope and hence the aspect of "stability" is normally applied to "natural slopes".

In considering a format for a land stability classification for use by planners it is obvious that some form of generalization of the zoning must be used.

This arises from the fact that there is no clearcut line/figure/criterion which can be applied, on which an area can be classed as either stable or unstable - there is a complete transition between the two.

This can be appreciated, if it is realised that every slope is continually subjected to degradation. This degradation may be imperceptible - slow viscous downslope movement: creep; or relatively sudden: falls, slides and flows. In general terms, the definitions used by other workers and here followed are:

Falls = rock falls; mass in motion travels mostly through air; mainly of massive sandstone units where these are undercut by erosion of softer underlying units (shales) until failure takes place, often along a vertical joint plane in the sandstone.

Slides = mass slides; movement caused by finite shear failure along one or several surfaces. There are several sub-types including rock debris slides and slumps.

Flows = movement within a displaced mass; sufficient shear stress to cause shear failure at head of slide; material behaves in a viscous manner; earth flows and talus flows are typical.

Creep = very slow downslope movement; material behaves in a viscous/plastic manner; movement is imperceptible on short term basis. Essentially gravitational movement occurring at or near the soil surface.

In addition to these processes, there is also the aspect of proneness to soil erosion of certain soils - their erodability. This is often related to an actual soil property - dispersiveness, etc. - when there is a poor vegetation covering. However, the effects of major land surface movements, such as described above, vastly increase the potential for certain soils or areas to suffer soil erosion. Separate studies by the Soil Conservation Service of N.S.W. (Emery, pers. comm.) considers this aspect (of soil erosion) in detail.

In the Newcastle - Cessnock Region it was apparent early in the process of defining zones with specific degrees of stability (or instability potential) that a fairly "broad brush" and quite a deal of intuitive inference would have to be used.

Firstly, it should be clear that primarily the concern is with catastrophic land movement - not creep. Hence while rock falls from the cliff lines are spectacular, the most common type of movement, and that which is potentially the most damaging in this region, is a combined slump-flow type.

Secondly, the use of a natural slope stability classification does not necessarily provide an assessment of the potential for induced instability which could arise during urbanization. These induced changes can arise as a result of clearing of the natural vegetation (deep rooted trees help to bind the soil profile), extensive cutting and filling type earthworks for roadworks, or in extreme cases, for reshaping of the topography, or by poorly conceived changes in the drainage of the area especially in areas of thick or potentially unstable soil accumulation. Hence, bearing in mind that this aspect of land classification is aimed at defining the hazardous areas, that is, the areas which have a potential for landslip once their present natural state is disturbed, it was considered necessary only to consider the two main factors of land slope and surficial soil nature (see later for further information on this criterion), since without adverse conditions in both these aspects, slippage is most unlikely.

On plans 8124 and 8126, those broad areas which are considered likely to suffer from surface soil (land) slippage or rock falls from inland cliff lines, have been incorporated within the zones shown hatched. In most cases these areas should not be cleared of their timber cover (where this is still present) or developed. In those instances when use must be made of these areas (for transport or service routes) particular care must be taken with all cut and fill procedures and the foundations for structures.

It will be noted that some of the areas shown as potentially subject to landslip on plan 8124, in fact encompass parts of the present urban areas of Newcastle. This is intended to show that: landslip should not be unexpected in these areas (should it occur); not that, it will occur. This fine distinction arises here because during urban subdivision improvements to the drainage regime and stabilization of cuts and fills (by retaining walls) can appreciably improve the long term stability of marginally stable areas, and in parts of the area zoned as unstable, this has in fact occurred.

By the same token there is no doubt that a considerable proportion of those areas shown on plans 8124 and 8126 as potentially subject to landslip or rock fall, are quite suitable for urban development, provided that good engineering practice is followed. However, the object in delineating these areas at this broad scale is to highlight the fact that if development is proposed in these areas, then considerable detailed geotechnical investigation would have to be undertaken to more specifically define the constraints and indicate the types of desirable engineering techniques that should be used to improve any marginally stable areas.

Coastal Erosion

In considering the management of the coastal zone it is important to realize that the coastline is in effect the mechanical interface between the land and the sea. As with all interfaces, considerable wear and tear occurs. To minimise wear, engineers use a lubricant. In the case of a coastline, composed of rocky cliffs there is no lubricant present and the sea progressively (albeit, generally slowly) abrades the coast. However, those coastlines consisting of beaches and dunes composed of sand, have a natural lubricant present in the form of the loose sand. This sand is moved back and forth by the waves and along a beach by the longshore currents.

In a beach in which the only sand movement is simply backwards and forwards from the beach to the surf zone and vice versa, the beach is stable. When, coupled, with this backwards and forwards movement, there is longshore drift of sand into the beach, together with an exactly balancing longshore drift of sand out of the beach, and sand is not lost from the beach to the back dunes, the beach is said to be in dynamic equilibrium. If however, one of the directions of sand movement is more pronounced, the beach is either accreting or as in New South Wales, more commonly, eroding.

This process has particular relevance for a large part of the coastline of the study area. Roy (1976) comes to the conclusion that the beach backing onto Newcastle Bight is subject to erosion as a consequence of loss of sand from the beach/surf zone onto the back dunes. The sand lost is reflected by the recession of the beachline at the southern end (Stockton) and the accumulation of mobile landwards migrating sand sheets in the region east of Williamtown and at Anna Bay.

It is likely that erosion of the beaches south of the Hunter River is also occurring, though perhaps with not such obvious effects. Hence on the Newcastle sheet (plan 8124), that zone along the coast which is subject to periodic sand movement during severe storms has been broadly defined by a hatch. This zone is in what is termed a "state of dynamic equilibrium". Any interference with the natural form of this zone particularly its front face is certain to cause major ramifications of erosion (advance of the sea/retreat of the coastline).

Removal of sand from the back of this zone, where it is wide and well developed, is generally acceptable, since this sand is effectively lost from the circulating system. The proviso that must always be applied however, is that a sufficient width of dune is left between the beachfront and the extraction area to allow for the major erosion effects caused by severe storms.

In terms of the major sand blowouts along the Stockton Bight dune line, it is apparent the stabilization by re-vegetation of the dune front, is necessary to prevent further loss of sand from the system, and also to prevent continued encroachment of the mobile sand front onto arable or urban lands.

Filled Land

As a result of continued coal mining in the region, all the considerable areas of (presently) shallowly buried coal will have been extracted within the near future (10 years) by open-cut methods and the excavated area will have been only loosely back filled with various materials, most likely, the overburn stone and soil. There will also be a number of much more localized and smaller areas in which a "hole" will have been left over from open-cut coal mining or have been excavated in the process of clay/shale (for brickmaking) or gravel (for road construction) extraction.

If such "holes" are subsequently loosely backfilled, they will have similar characteristics to filled open-cut coal mining areas. So also will all areas used for disposal of colliery chitter or coal washery wastes, if such wastes are just loosely dumped. All these areas are likely to have unpredictable characteristics arising from the fact that the fill material will not have been compacted during emplacement, and hence will be subject to irregular settlement.

Such land is quite unsuitable for low cost housing during the full period over which settlement of the fill is taking place, estimated at about 100 years. The use of such areas within this time period could only be considered safe if piles were sunk to genuine bedrock or if the foundations for all structures were elaborate, e.g. adjustable rafts.

Such areas of filled land can only be considered for open space recreation purposes or, after re-vegetation, for say grazing or forestry. The possibility of re-developing such areas into high grade crop lands in the short term would appear to be uneconomic because of the large additions of fertilizers which would be required and because of both the complete lack of any true soil structure in the fill material and its extremely high permeability.

Mining Subsidence

It must be remembered that in excess of half of the study area is underlain by coal measure strata. In most of these areas there are a number of coal seams, many of which are economically exploitable at present. In the future some of the seams not now considered for exploitation, will almost certainly be worked. This means that all the lands underlain by coal measure strata could be subject to some degree of land surface lowering by subsidence.

Since a degree of subsidence is a virtual certainty in many areas, it is appropriate that considerable provision should be made for these effects. This provision in fact can be made during planning (design), especially of major engineering structures.

In any attempts to assess the amount and surface effects of subsidence which could occur, it is necessary to consider a number of factors.

Firstly, the thickness of coal which could be extracted is dependent on both the actual thickness of good quality coal present and also on the actual method of extraction. Extraction of thicknesses of 5 m (18 ft.) by underground methods is readily practicable. In near surface totally extracted areas (say 30 m of cover) the maximum amount of surface subsidence could be of the same order as the thickness of coal extracted.

With increasing cover thickness, the percentage of the extracted height which was transmitted to the surface as lowering, would progressively decrease to the normally accepted ratio of half the extracted thickness. It is likely that a cover thickness of 400 m would result in a surface lowering of about 1.5 m after large scale extraction of a 2.5 m thickness of coal.

Secondly, the nature and thickness of the overlying strata may influence the type of visible subsidence effects at the surface and, perhaps to some extent, the amount of actual surface lowering. It is apparent that in those areas where only shallow cover, consisting of massive thickly bedded conglomerate or sandstone, overlies the coal seams, subsidence effects would generally be uniform with virtually no massive cracking or block lowering (after total extraction) since these units contain very few vertical joints. Some surface cracking or breaking and block subsidence above the goaf edges is possible at the margins of the area of the lens of massive rock.

Where the overlying rock sequence consists mainly of thinly interbedded sandstones, shales and claystones, the more normal subsidence process of uniform surface lowering by strain bending will occur, and it is unlikely that any visible surface effects would be generated.

The nature and extent of visible subsidence effects in the areas in which moderately thick talus/soil profiles are developed (eastern and northern sides of the Sugarloaf Range) could be variable. However, it would seem reasonable to assume that because of the thickness of cover and general non-rigid nature of the soil and immediately underlying rocks, that the visible surface effects of subsidence would be minimal.

In those areas (or more correctly zones) in which cliffs are developed in the massive sandstones of the upper Narrabeen Group (Sugarloaf and Myall Ranges), even small amounts of surface movement could result in the development of open cracks and rock falls from the cliffs. Pre-planning of the location of goaf edges in relation to surface cliff lines could largely overcome these problems.

In the areas of marine, estuarine, and stream deposits of unconsolidated sediments, the surface effects of subsidence are likely to be unnoticed on the whole.

When considering possible constraints on surface subsidence effects it is apparent that flood prone areas would not be subsided unless they are to be made deliberately into water-ways. Similarly, low lying areas adjacent to existing water-ways would not be subsided if they would become flood liable or actually submerged as a result. In all other regions e.g. under existing water bodies and undulating lands (provided that systematic extraction to acheive a nominated end product (uniform surface lowering) was followed), no unduly disruptive changes to the land form or drainage of the region, would occur.

The Department of Mines has defined a number of Mine Subsidence Areas in the region for the purpose of ensuring that structures are built utilizing appropriate strain criteria in the design, so as to minimise eventual subsidence results on buildings.

While it is not possible to specify within what time scale the region will have had most of its coal resources extracted, it is apparent that present demands for coal will ensure that probably in excess of 75% of coal reserves in the areas with cover of less than 500 m, will be extracted within the next 20 - 50 years.

Regions likely to be subject to surface subsidence effects as a result of underground coal mining are widespread on the two sheet areas (plans 8124 and 8126). The directions of dip of the coal measure strata are shown by arrows. In these directions the depth below the surface, of the topmost coal seam, increases. The areas in which coal measure strata actually outcrop are shown hatched. In these areas open-cut coal mining could take place. Reference should be made to the separate manuscript plans on coal resources held by P.E.C. (Newcastle) for more detailed data, particularly for definition of the zones in which subsidence effects could be major because of the thinness of the overlying strata cover.

Surface Rock/Soil Conditions

In an earlier section of this report, a brief outline was presented of the general geology of the region in terms of hard rock stratigraphy. However, stratigraphic geology is an unsatisfactory basis, when used alone, on which to make an assessment of the suitability of an area for urban development, since no indication is available of the potential hazards associated with particular rock or soil lithologies. Hence while all the plans show stratigraphic geological boundaries on the base, a number of interpretive additions and modifications have been made so as to define zones in which an assessment can be given of the surface rock/soil conditions in particular areas. In a later section of this report, an appraisal is given of the nature of hazards which could arise in major excavations in the underlying hard rock sequences.

Since the aim of this study is to allow identification of high risk as against low risk areas, in terms of cost of servicing or utilization for a particular purpose, it was considered desirable to keep the number of zonations to a minimum. However, the variety of rock and soil materials present in the area made this difficult. As a consequence broadscale classification only has been made, with the object of simplifying the interpretation into groups which each have important implications for potential uses.

In order of general decreasing risk, and to some extent in this context, decreasing costs of utilization, the zones defined on the plans are briefly described below.

The highest risk areas are inferred as being those underlain by thick (20 to 40 m) sequences of generally poorly consolidated alluvial and estuarine sediments comprising gravels, sands, silts, clays and peat. These areas, in general, correspond to the extensive regions shown on plan 8124 as being prone to repeated flooding. The more limited areas on the western margin of plan 8124 (associated with Wallis and Fishery Creeks and the Hunter River) and the areas on plan 8126 which are also zoned as flood prone, suffer to a lesser extent from this hazard of poor foundations. This is because, in general, the thickness of poorly consolidated material in these areas is considerably less (inferred as being commonly less than 15 m) than in the more extensive areas near the coast.

The areas shown as "groundwater storage" on plan 8124, and "sand suitable for construction and industrial purposes" on plan 8123, suffer a slight degree of hazard in terms of foundation conditions, arising from the large thickness (greater than 20 m) of virtually loose sand present.

Areas of outcrop of coal measure strata shown on plans 8123 and 8125, potentially are at risk from a number of hazardous foundation conditions. These include:

(a) the presence of coal seams

(b) the alternating sequence of thin beds of hard and soft rocks

(c) the presence of massive, hard conglomerate lenses.

Coal seams, when weathered in the near surface zone, are compressible and would provide very poor foundations. The alternating sequence of hard and soft strata means that differential weathering occurs - the softer units commonly being much more highly weathered than the hard units. This can result in thick accumulatings of talus type soils, which on moderately steep slopes would be at risk of landslip.

The presence of massive hard unjointed conglomerate lenses means that virtually no soil is present. Hence any intended excavation (e.g. for services trenching) encounters hard rock within 1 metre of the land surface. Blasting or jackhammering would be the only means of excavation in such areas. Those areas on plan 8123 which are shown as optimum future sources of A1 road construction materials would be subject to this "hazard". In addition to this factor, a further "hazard" is introudced by the presence of such units (conglomerates). This is the effects on the amenity of the environment (by quarries) which could arise because of the near ideal nature of this rock for the production of A1 road construction material.

Although not differentiated by hatching, areas shown on plans 8123 and 8125 with "Rn" symbols, are underlain by the generally massive sandstones of the Narrabeen Group.

In general these units tend to give rise to low cliffs of hard rock outcrop. On less steep slopes, thin soil profiles may be developed or thin accumulations of talus may be present. The only problems introduced by this zone are those relating to servicing - the massive boldly outcropping sandstones require expensive excavation techniques. To some extent the association with the high risk cliff lines of the potentially unstable zones shown on plans 8124 and 8126, together with the scenic value of much of the area of these zones, suggests a non-development role for them - when the likely high servicing expenditure is taken into account.

Those areas on the western side of the Newcastle sheet, and in the central eastern part of the Cessnock sheet, which are shown unhatched on plans 8123 and 8125 respectively, and with symbols prefixed Pm or Pd, potentially are at risk if used for purposes which are incompatible with the presence of saline groundwater. The rocks underlying these areas were deposited under marine conditions and the soils generated on them are as a consequence high in sodium chloride. This mineral content becomes manifest during dry periods when the groundwater rises under capillary action.

Groundwater Storage Areas

In an earlier chapter of this report it was pointed out that there were extensive groundwater resources in the region, many of which are being extensively utilized. On plan 8124 the hatched zone extending from near Hexham to Port Stephens encompasses the groundwater storage area of the Tomago Sand Beds. Obviously any development in this zone must not generate water pollution effects. However, there are other areas throughout the region from which local supplies of groundwater for household and irrigation uses is possible. These locations are broadly defined by the areas shown hatched on plans 8124 and 8126 as prone to repeated flooding. Similar protective measures, in terms of land use, need to be instituted in these areas also. The protective measures must relate to such aspects of groundwater hydrology as infiltration/recharge areas and the direction of groundwater movement. In the context of continued utilization, the effects of over-withdrawal by users or arising from drainage, flood mitigation or port works, on the salt water/freshwater interface must be considered.

It is unlikely, in view of the relatively thin and near surface nature of the water bearing horizons, that extraction of ground-water would result in any significant surface lowering (subsidence).

Waste Disposal

The prime aim of all waste disposal is the seeking of a safe and permanent procedure which minimises the risk of pollution of the regional water regime. The water regime, it must be remembered, comprises both surface waterways and underground slowly migrating storages. Hence it is pertinent to consider the effects of poorly conceived or poorly controlled disposal procedures,and also to define the optimum criteria for the selection of sites which are less prone to causing pollution.

As development of the region continues, a growing volume of solid and liquid wastes, mainly household garbage and waste water and urban run-off water, with a major contribution of industrial waste,probably including some noxious liquids, will require correct disposal, if the full amenity of the region is to be preserved. All disposal procedures must be aimed at ensuring that polluting liquids, or leachates from solid wastes, are not discharged to the natural environment. That is, they should be collected and/or effectively processed.

Firstly, it must be borne in mind that discharge of polluting liquids into a flowing surface stream causes a resultant "tail" which extends downstream. This tail can extend for a considerable distance downstream but the distance over which effects extend is dependent on the dilution ratio and the amount of turbulent aeration of the water body. If the dilution ratio is low or if no flow takes place e.g. a pond, lake,or tidal balanced stretch of estuary, the effects on water quality can be cumulative. Discharge or leakage of effluent liquids into the groundwater regime can have equally disastrous effects, although these may be manifested somewhat more insidiously.

Secondly, while a flood is capable of quickly flushing a surface water channel clean and thus allowing regeneration, no technique other than the passage of time is readily applicable to cleanse sub-surface water storages once they are polluted (excluding artificial flushing where this is in fact possible).

It is essential then, that if the amenity of the water ways and groundwater resources of the region are to be preserved, all domestic waste water should be subjected to tertiary treatment and appropriate reuse e.g. for garden watering, or, after nutrient removal, for makeup/ reuse,or disposal to an ocean outfall. Assuming that this in fact occurs, then it is foreseen that the main problems of waste disposal in the region will arise in respect of urban run-off water, household garbage, industrial wastes (including boiler clinkers and fly ash and noxious liquids) and coal mine and washery residues. Each of these materials has distinctive properties and almost certainly, because they are generated at different locations, will be disposed of separately. However, in all cases the following basic criteria in terms of selection of suitable disposal sites should be followed.

Obviously all non-burnable wastes will be disposed of using land reclamation (filling) techniques,perhaps after recovery of recyclable materials. Hence the control of seepage effluents (leachate) will be the major problem, while control of any air pollution problems and incorporation of visually aesthetic protection or screening procedures will also be important.

To ensure the control of seepage effluents, the ground materials underlying the site should consist of near impervious soils, while the general site topography should be such as to minimise surface catchment water-flow introduction.

These optimum conditions are present in the region in a number of locations as a result of the presence of old extraction sites, and also, because of the occurrence of areas underlain by coal measure strata composed largely of clayshale type lithologies that weather to produce a gently undulating topography with a thick clay soil profile. Thus it is foreseen that sites for household garbage and industrial wastes disposal could be readily selected from within the zones on plan 8123 shown as "areas of outcrop of coal measure strata", particularly in the regions south from East Maitland and north of the Hexham - Kurri Kurri road.

Although possibly somewhat less than optimum conditions for waste disposal sites exist in the Cessnock region, as compared with the Newcastle region, areas underlain by rocks of the Dalwood and Maitland Group offer some potential. Thus areas which are not screened on either of plans 8125 and 8126 and which have a rock unit symbol prefixed by Pd (Pdl, Pda, Pdr, Pdf, Pd) or Pm (Pmb, Pmm, Pml, Pm) can be considered as being generally suitable for the location of land-fill type waste disposal sites, especially where these units are deeply weathered and have given rise to a clayey soil. Old brick clay pits located in such units or in coal measure strata, are obvious sites worth careful appraisal in terms of suitability for the disposal of noxious liquid wastes on a short term basis.

At present there is no requirement for fly ash disposal in the region. However, there is a continually growing demand in adjacent regions for fly ash disposal sites. Hence it is considered appropriate that brief mention be made of the factors associated with such disposal. The problem of large scale disposal of power station fly ash is somewhat different to "normal" industrial waste disposal in that the actual leachates are relatively inoccuous. However, the disposal/storage procedure used may involve collection and settling using salt water. In such situations every endeavour should be made to select a pondage basin from which salt water leakage to the fresh groundwater regime does not occur. Alternatively, the pondage should be sited in an area with an existing salt groundwater regime. It is mentioned that while fly ash can be used for a number of industrial/commercial applications when it is collected via a fresh water medium, its potential for use after collection in salt water is at present very low.

The type and nature of the coals of this region, as presently known, indicates that there is a potential for problems to occur arising from the generation of highly acid leachates from land surface disposal sites of colliery or washery refuse.

However, provided care was taken, it would seem that the need to dispose of potentially large amounts (in the long term) of dry colliery refuse, wet coal washery tailings (and perhaps power station clinker of inert waste slags), provides a golden opportunity to improve the amenity of a large proportion of the swamp and flood prone zones in the region by means of land fill reclamation. (With the proviso, that changes in the flood regime introduced by such reclamation are carefully considered). In addition, there is the very real possibility that a perhaps considerable proportion of the production of these materials could be utilized, e.g. for roadworks, brick manufacture and prepared aggregate (light-weight after suitable processing). It is likely that transport costs and environmental controls potentially could have a large influence on the choice of disposal means. For example, areas formed-up by the disposal of wet, fine sized coal washery refuse, if such materials are disposed of separately to pondages, are likely to be almost as difficult to re-use in terms of subsequent land use as areas used for disposal of fly ash. However, if such material is blended with coarse, or dry, refuse, it is generally much easier to dispose of satisfactorily (in terms of suitability on a long term basis for a subsequent land use) or to utilize as a construction material (see later section).

Sites for the disposal of these types of wastes must be located reasonably close to the originating source (because of the volume generated). Kooragang Island will obviously be a potentially suitable disposal area for inert industrial solid refuse for many years. A number of other areas - Wallsend, Shortland, Killingworth - are potentially suitable for carefully planned swamp reclamation using colliery refuse.

This then leaves only the problem of disposal or suitable processing of the urban storm water run-off. If this waste is allowed to flow into the waterways of the region, large scale degradation of water quality and the aquatic environment is likely to occur, particularly to Lake Macquarie. Considerable thought will have to be given to the relative merits of direct discharge to the Hunter River or to an ocean outfall, storage in a retention basin (artificial lake) or discharge to the existing estuarine lakes coupled with constructed and much improved tidal flushing of these water bodies.

The potential suitability of the incipient swamps along the lower parts of Wallis and Fishery Creeks and in the region south of Hexham, for large flood or run-off water retention basins, and then using natural filtration and purification by seepage from the swamplands to the existing drainage regime, suggests that such a scheme is worthy of investigation.

<u>Seismicity</u>

With the increased capital cost and size of all present day civil engineering construction projects, it is important that adequate consideration should be given to the extent that seismic (earthquake) criteria could influence location and design of a structure.

The main criterion which can be utilized in designing a structure to safely withstand a seismic event is the ground acceleration resulting from an event of nominated location and magnitude. However, the paucity of recorded seismic data for this region makes the use of such design procedures at present largely empirical.

The nearest recording centres are Sydney (Riverview Observatory) and Armidale. On the basis of the most intense event recorded in the central coast region of New South Wales, it is interpreted that an event of Richter intensity 5-6 occurring within a radius of 150 km from Newcastle is likely on a 40 year recurrence basis. Whether derived design criteria on this basis genuinely provides a long term safety factor is completely unknown.

One other aspect of seismicity which should be taken into account in the siting of major structures is that of the influence that substrata conditions have on surface intensity effects. It is well recorded from overseas experience that hard rock (bedrock) provides a much more stable and secure foundation during seismic phenomena than do areas of unconsolidated alluvial sediments. It is theorized that thick unconsolidated sediment sequences show intensified surface damage to structures, relative to adjacent hard rock areas, under the influence of the same seismic event, as a result of dilatency effects induced in the unconsolidated materials, especially if these are at a high level of saturation. From this consideration then, it is possible to infer that, in all those low lying or flat areas of alluvial or estuarine deposits, areas of man made fill or with near surface water tables (swamps), any seismic event affecting the region will cause enhanced vibration phenomona. Similarly because of the risk of rock falls induced as a result of seismic events, areas below cliff lines within the regions shown on plans 8124 and 8126 as being at risk in terms of landslip, are at higher risk than are other areas of bedrock outcrop. Specifically, the cliff lines on the Sugarloaf and Myall Ranges are at high risk in terms of this hazard.

Foundation Conditions

In this section an attempt is made, from geological inferences, to predict the type of rock conditions likely to be encountered during major construction projects in the Cessnock - Newcastle region. That is, these notes provide geological guidance for engineering purposes as to the way the rocks of the region will have to be treated or supported and the way the rocks are likely to behave, in large openings such as deep road cuttings and tunnels.

It is pointed out that many of the governmental and semi-governmental constructing authorities (DMR, PWD, CWD, Railways, Shire, City and Municipal Engineers, Electricity Commission, etc.) will have detailed records of site investigations carried out in parts of the region. The following notes attempt to provide only a brief synthesis, which can be used as a basis for determining the nature and scope of site investigations that should be undertaken, prior to major construction projects.

Two major considerations control all excavation work - inherent rock strength and mass (bulk) strength or stability.

The former factor is related to the specific lithology or rock type (basalt is stronger than sandstone) and is modified by secondary processes, such as physical weathering or chemical alteration, which usually cause a reduction in inherent rock strength. Mass rock strength or bulk stability considers the overall effect of natural or induced weaknesses, such as bedding, jointing or shearing, on the ability of the whole rock mass to free stand.

Naturally there is a close interaction between these two considerations, and it is this interaction which controls the ability of a particular excavation technique to operate satisfactorily e.g. whether the rock can be ripped or needs blasting, whether it can be machine tunnelled, what batter angles are stable in cuttings, or the extent that physical roof or wall support mechanisms (rock bolts, etc) are required. Each of the main lithotypes present in the region are considered separately below on the basis of ease of excavation, bearing capacity and any foreseen problems in terms of engineering construction.

The massive pebble sandstones and conglomerates in the coal measures (areas underlain by these units are shown hatched on plans 8123 and 8125 as potential sources of A1 road materials) are almost certainly the strongest rocks in the region, in terms of mass strength. However, in terms of inherent strength on a small scale, the nature of the rock: hard pebbles of cherts and quartzites set in a coarse grained poorly cemented sandstone, is variable and essentially it is only of moderate strength.

The high mass strength of the rock is a result of the lack of bedding and jointing within the unit. This means that in large excavations, steep batter angles can be used (near vertical) and that probably only minor physical support would be required in tunnels. The generally only moderate inherent strength character of this rock would suggest that machine tunnelling could be practicable, although the economic feasibility of this technique is as yet untested.

The lack of jointing and bedding, together with the high quartz/quartzite/chert content of the rock, means that weathering effects are minimal, giving rise to only a thin surface completely weathered rock/soil covering, and probably only appreciably reducing rock strength in the uppermost 1 - 2 m of the bedrock mass. This rock then is likely to be unrippable when fresh or only slightly weathered.

Despite the sandstone type matrix, the rock is only slightly permeable.

However, if major joints are present these could allow some degree of water-make in underground openings.

These individual conglomeratic lenses are believed to be of channel infill form and to have a relatively long (several kms) and narrow (½ to 1 km) extent of development, with thicknessess of up to 30 m.

The massive sandstones of the upper Narrabeen Group (shown unscreened with the symbol Rn on plans 8123 and 8125) and the Waratah Sandstone (which comprises the unit shown hatched on plans 8123 and 8125 as a potential source of dimension stone) are almost as strong in terms of mass strength as the conglomerates, but in terms of inherent rock strength, the sandstones are in general, stronger than the conglomerate. This difference in mass strength properties is due to the presence of bedding (admittedly often quite thick, ranging up to 10 m, especially in the Waratah Sandstone), and the common development of a pronounced joint pattern in the sandstones. On a small scale, the sandstones are inherently stronger than the conglomerates because of their finer grain size and the more extensive cementation of the grains with siderite and silica (and in places, with lime carbonates).

In large open excavations the massive sandstones can be cut to steep batter angles (near vertical). However, it is essential that consideration should be given to the jointing pattern and the interaction of the joints with the bedding planes, to assess the likelihood of wedge type "drop-outs" of large joint-bounded blocks from the walls. Similar comments apply to the matter of assessment of the need for roof support in tunnelling - quite often no problems arise, while at other times a few key placed rock bolts might suffice. In the case of natural cliff lines, the presence of bedding and the joint pattern, together, often control the actual cliff morphology and influence the extent that rock-fall effects are generated (in conjunction with the undercutting of softer units).

When assessing the inherent rock strength of the massive sandstones, in terms of machine tunnelling capability, it will always be necessary to bear in mind that no two sandstone "beds" are identical. Depending on the particular sedimentary structure reflecting the environment of deposition, and such textural features as grain size, matrix nature and degree and nature of cementation, individual sandstone "beds" can range in strength from being friable in hand specimens to extremely tough. That is, with unconfined compressive strengths ranging from less than 6890 kPa (1000 psi) to greater than 62,000 kPa (9000 psi), commonly averaging about 34,000 kPa (5000 psi).

Although these units are often strongly jointed and frequently have clearly defined bedding planes, the fact that they are essentially quartzose means that the rock is only moderately weakened by weathering processes. In fact weathering virtually only leaches the rock of much of the matrix and oxidizes and leaches in part any carbonate cement. Thus, if the rock has a siliceous cement it is only affected to a minor degree by weathering and quite often, even after an extensive period of weathering, is still very robust. That such rock types are present is shown by the fact that the massive sandstone units form abundant bold outcrops with minor inter-outcrop areas carrying only a thin sandy soil cover. While weathering effects within the rock mass probably do not normally extend to depths of more than a few metres, where close spaced jointing is present, weathering of the rock immediately adjacent to the joints can extend to quite considerable depths (30 m).

Massive sandstones are often rippable even when fresh. However, this is only because there are sufficient jointing or bedding weaknesses present to allow ready rupturing. Thick bedded units would be virtually unrippable even in outcrop, this is especially the case with the Waratah Sandstone.

The rock is for all intents impermeable (because of the high matrix and cement contents). However, where major joint sets are present, some degree of water-make would arise in underground openings.

The interbedded sandstone, siltstone, shale sequence of the middle and lower Narrabeen Group and the Newcastle Coal Measures in particular (prefixed respectively with the symbols Rn and Pnl, Pna, Pnb, Pnm on plan 8124) will provide the most varied and generally most unpredictable rock conditions in the region. The Tomago Coal Measures (prefixed Pt on plan 8124) are also included in this grouping.

The general unpredictability of the rock conditions underlying these areas is a result of the presence of strong sandstone units, often quite thickly bedded, randomly interbedded with thinly bedded weaker siltstone and in some cases shale/claystone and coaly sequences. The Tomago Coal Measures have a somewhat lower proportion of massive sandstone interbeds and as a consequence can be considered to be an essentially shaley and coaly sequence. The inherent strength, mass strength, and weathering characteristics of each of these distinct rock types are widely divergent. This means that it is not possible to quote typical or average criteria.

The problem which arises as a result of the interbedded nature of this rock unit is that associated with the effects of differential weathering.

The coal seams and thin bedded siltstones and shales are more vulnerable to weathering than the sandstones. Thus on steep hillslopes, undercutting of the sandstones usually occurs, leading to the formation of low cliffs and resulting in the collapse of sandstone blocks and the formation of a scree or talus type soil. Away from the actual hillslope, e.g. under ridge crests or in floors of valleys, it is quite normal to encounter moderately to highly weathered siltstones and shales underlying considerable thicknesses of only slightly weathered or even fresh sandstone.

As a consequence of this interbedding and the variability of rates of weathering, it is most important to take considerable care in the choice of batter angles in cuttings and excavations and also to provide adequate physical support in large diameter tunnels. What might be termed a "trap" when excavating in this rock unit is the fact that when fresh the siltstones and shales appear only slightly weaker than the sandstones and hence there is a tendency to treat the siltstones and shales in a similar manner to the sandstones; that is, to expect them to be reasonably robust. However, even after a short period of exposure (say several months) sufficient weathering effects could have been generated to cause problems of fretting or minor rock falls etc, of the siltstones and shales. Eventually this process leads to undercutting of the sandstone beds with resulting block collapse. Numerous minor road cuttings in the Newcastle region and also the deep cutting at The Gap, on the road between Brunkerville and Freeman's Waterholes, show these effects quite clearly.

Abundant jointing is present in the sandstones and to a less marked degree in the shales and siltstones of this unit, and this factor, combined with their generally thin bedded nature, means that as a rule, rocks of this unit are rippable even when fresh (unweathered).

In any proposal to machine bore tunnels in rocks of this unit it would be necessary to avoid any massive sandstone beds which were present and also, so as to minimise shock loading effects (with a tunnel located half in sandstone and half in shale), to select tunnel levels so as to take advantage of uniform lithological sequences e.g. all siltstone or all shale.

Individually the rock types of this group are impermeable. Hence only where pronounced or extensive close spaced jointing was present would water-make in underground openings be noticeable.

In those areas underlain by the essentially shale/claystone and coaly shale sequence of the Tomago Coal Measures, general "soft rock" conditions are likely to be reasonably uniform except where sandstone interbeds are present.

An important characteristic of the shale and clayshale rocks of these sequences is their proneness to very rapid weathering once they have been exposed. The product of weathering is a yellowish to greenish-grey, gritty, mixed-mineral clay. When wetted this clay commonly swells and becomes plastic and tends to flow downslope until a residual repose angle of about $6^{o} - 8^{o}$ is reached. Fortunately, clayshale units rarely exceed a few metres in thickness and hence stabilization or support measures are readily practicable. However, where such units occur in outcrop, forming gently sloping lands, considerable care must be exercised during engineering works. Any proposal to undertake excavation on a large scale in such units, whilst not encountering any difficulties because of the soft lithological character (weak inherent strength), will have to take into account the implications of the low residual repose angle, which effectively means that cuttings have to be battered at gentle angles or protective and supporting works provided, if long term stability is required. At angles steeper than $6^{o} - 8^{o}$, plastic flow will occur progressively as the shale/claystone weathers.

The common associate of excavation, fill reclamation, will also encounter some degree of difficulty, especially if the rock is primarily claystone. These problems are related to difficulty of achieving high compaction of the material, since even when virtually fresh the claystones have a relatively high plasticity. It is considered that major reshaping of the topography should only be carried out under engineering supervision, in areas underlain by this rock group.

In tunnelling it is likely that complete support lining would be necessary, since exposure to air and water would cause rapid and continued fretting from the roof and walls. Roof bolting without fine steel mesh would be ineffective. These interbedded units are impermeable and hence little water-make would be expected in underground openings.

In all those areas shown hatched on plans 8124 and 8126 as being prone to flooding, together with those shown on plan 8124 as being either flat, low lying or areas of groundwater storage or prone to coastal erosion, the nature of the bedrock underlying the surficial covering of unconsolidated sediments, can be related to one of the zones discussed previously, simply by reference to the surrounding rock type symbol or hatching shown on the relevant plan. However, one factor, other than the thickness and nature of the overlying sediment present in these areas, will need assessment. This is the degree and extent of weathering of the bedrock. Since this bedrock was an old land surface, it would have been subjected to weathering processes both before the overlying sediment was deposited and also to some degree, as a result of the permeability of the overlying sediment, since the overlying sediment was deposited.

In the areas encompassed by these zones on plan 8124, the depth to bedrock is likely to be so great that no excavation and only foundations for major structures, actually reach rock. This is especially the case with all areas located to the east of Duckenfield, since underlying the landward side of the coastal marine sand mass, a thick sequence of compact fluvial gravels and clays are present (Roy, 1976a).

One problem which will arise in many of these areas will be the differentiation between transported sediment and in-situ completely or highly weathered bedrock, where the bedrock is of a similar lithology to the overlying sediment; e.g. river gravels overlying conglomerate, clay over claystone and lithic river sand overlying sandstone. However, since piled foundations to support major structures will almost certainly be essential in all these areas, this differentiation may not be important for geotechnical appraisal.

All excavations in these areas will encounter major problems of near surface ground water tables and large water inflows arising from the high permeability of the sediments, especially at the contact between the sediments and the underlying bedrock. Generally this water will however, be of "fresh" quality.

Two problems in regard to foundation conditions which have not been discussed above are those of the extent of the possible presence and the nature of dykes and faults in the hard rock succession.

It is known that within the Sydney Basin there is a common development of basaltic dykes intruding all the lithotypes. In general it is known that the principal orientations of these dykes follows that of the regional major jointing/faulting patterns. This pattern in the Newcastle region is reflected by the major orientation of approximately northwest, with a less pronounced joint orientation of approximately northeast.

In general most of the dykes and faults that have been mapped in the past seem to follow the northwest orientation. However, quite significant dykes and faults at other orientations have been noted.

There is no ready method of detecting the presence of either faults or dykes in the bedrock by simple surface inspection. Occasionally lineaments can be recognised on aerial photographs which may indicate the presence of some structural feature. However, generally dykes and faults are only discovered during actual excavation. Occasionally their presence may be indicated during site investigation drilling.

There is no general rule as to the nature of the problems which either dykes or faults could introduce into the design of an excavation or the foundations of a major structure.

However, the following comments indicate the range of conditions which could be associated with these features.

Most dykes are vertical and are renowned for varying rapidly and erratically in thickness, both in the vertical plane and along strike. Similarly, offsets are common, while silling and bifurcation are somewhat less so, also both in the vertical plane and along strike. Thicknesses vary from centimetres to tens of metres (occasionally) with a typical average of about 1 m. Although the dykes are composed of dolerite/basalt, they are frequently completely weathered to a kaolinitic clay to depths greater than 30 m. At times, induration effects are imparted to the wall rocks. Many examples of (weathered) dykes intruding shale and sandstone can be seen in road and railway cuttings in the region and in headlands along the coastline in the Nobby's - Merewether area.

The nature of faulting which could be present in the region is extrapolated from that recorded in the underground colliery workings of the Newcastle and Cessnock areas. Most faults are of "normal" type and exhibit high angle movement surfaces with minimal development of crush zones. However, "reverse", low and high angle faults with crush/pug zones up to 1 m wide have been recorded, especially in the Cessnock region. Throws of most faults are less than 6 m but throws in excess of 30 m have been recorded, again especially in the Cessnock Region. Characteristically the throw varies along strike. A feature which has been noted is that while some faults have considerable vertical extent and strike lengths of several kms, the great majority have only a very limited extent both vertically and along strike. This has led to the postulation that the minor faulting occurred as a result of compaction and lithification processes early in the formation of the rock sequence, while the more extensive or larger throw faults may represent the results of post formational tectonic forces.

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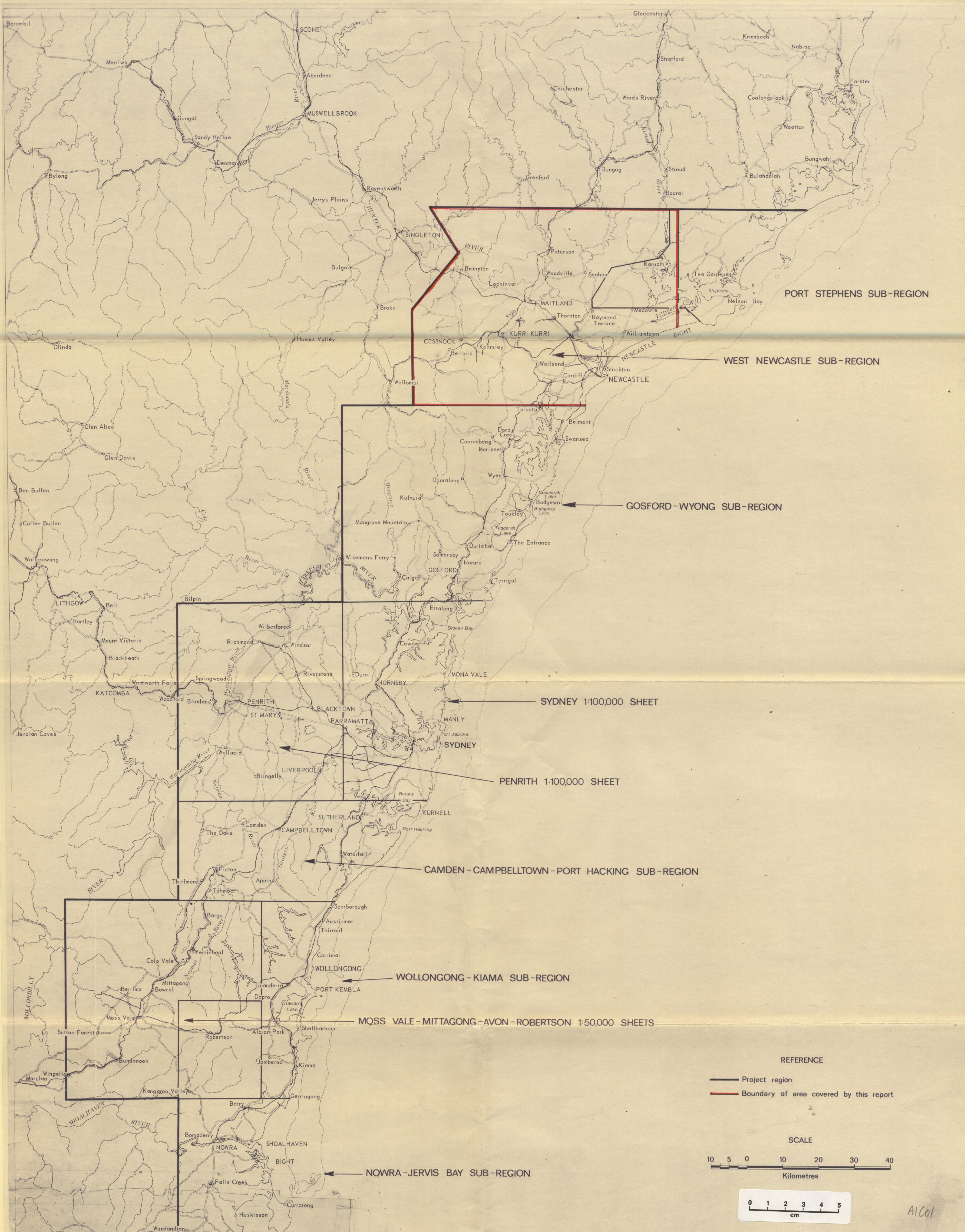


N.S.W. CENTRAL COAST LOW COST RESOURCES PROJECT

LOCALITY PLAN SHOWING SUB-REGIONS

Geological Survey of N.S.W.
Department of Mines
Report by W. Chesnut
Date: 28.11.75
7617

GS1975 159

AUSTRALIA 1:100,000

NEWCASTLE

SHEET 9232

A1 Col

SCALE 1:100,000

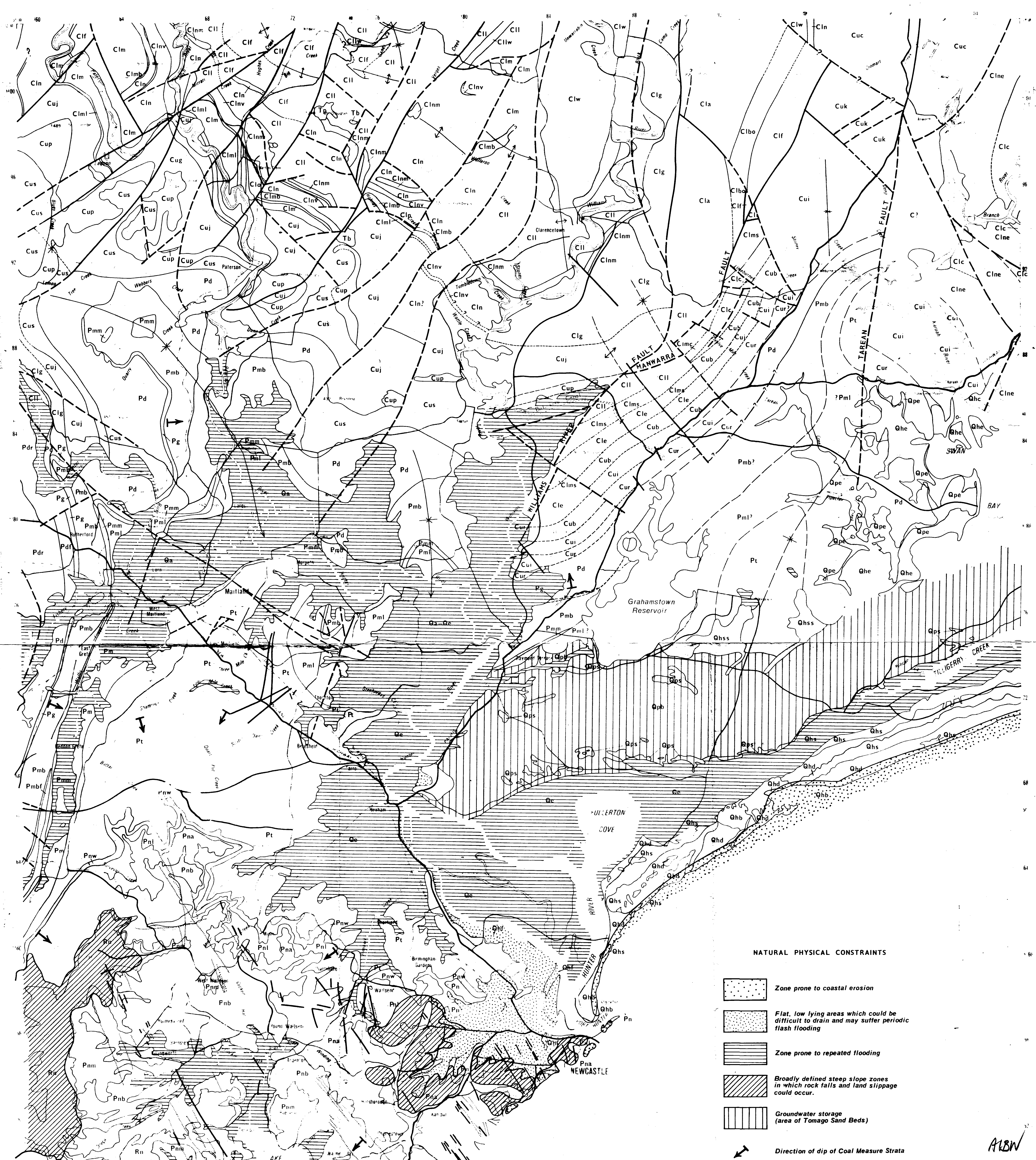
BLACK NUMBERED GRID LINES INDICATE 4 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID ZONE 56
GRID VALUES ARE SHOWN IN FULL ONLY AT THE SOUTH WEST CORNER OF THE MAP

CONTOUR INTERVAL 200 FEET

Geological Survey of N.S.W.
Department of Mines
Report by W. Chesnut & V. Gobert
Date 24.5.77

8123

NEWCASTLE



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CESSNOCK

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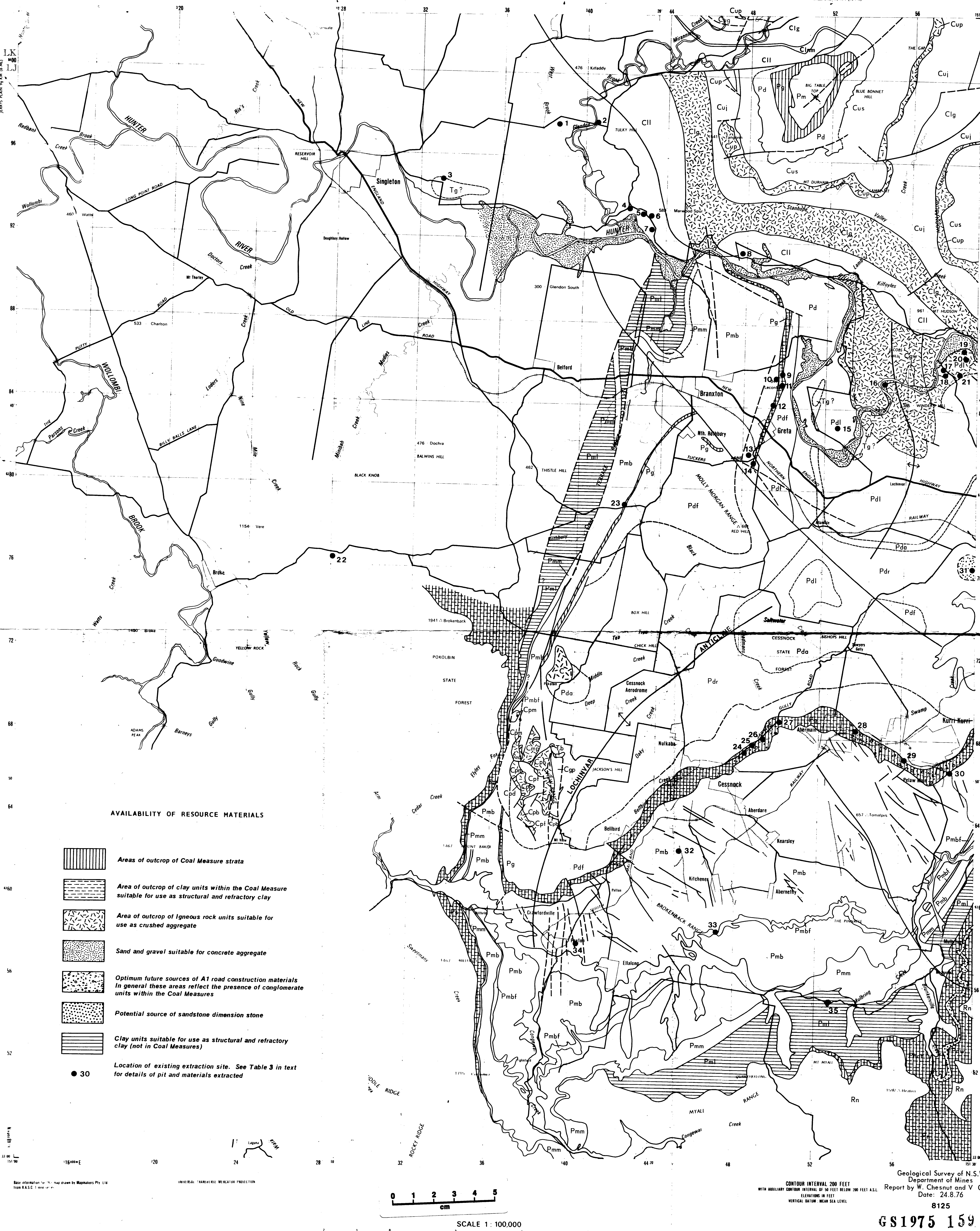

CONTOUR INTERVAL 200 FEET

ELEVATIONS IN FEET

VERTICAL DATUM: MEAN SEA LEVEL

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BLACK NUMBERED GRID LINES INDICATE 4,000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID ZONE 56

GRID VALUES ARE SHOWN IN FULL ONLY AT THE SOUTH WEST CORNER OF THE MAP

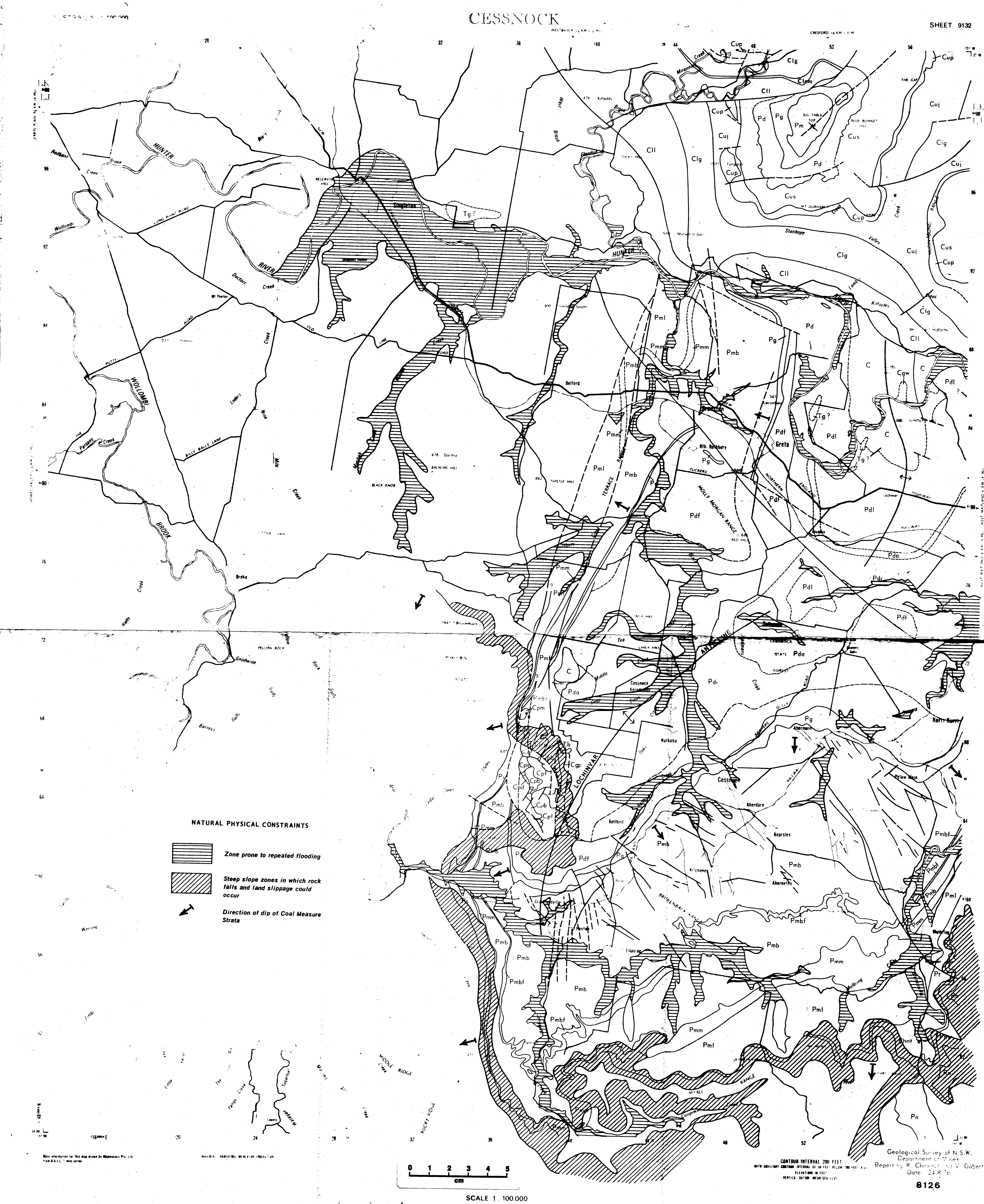
UNIVERSAL TRANSVERSE MERCATOR PROJECTION

Geological Survey of N.S.W.
Department of Mines
Report by W. Chesnut and V. Gobert
Date: 24.8.76

8125

GS1975 159

A1BW



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