CHANGES IN AGGREGATE PRODUCTION AND USE IN VICTORIA, BC

Terence S. Coulter, P.Eng.
Thurber Engineering Ltd.
Victoria, BC

Paper prepared for presentation
at the Recycling Materials for Use in Highway Design Session
of the 2003 Annual Conference of the
Transportation Association of Canada
St. John's, Newfoundland and Labrador

1. INTRODUCTION

Development in the conurbation of Victoria, BC, on the south east corner of Vancouver Island, has benefited from having many good quality sand and gravel pits in the immediate vicinity. Over the years, many of the pits have become depleted and, while undeveloped deposits of sand and gravel near Victoria still remain, these now cannot be accessed because of encroaching development and land-use zoning changes.

The local demand for aggregates continues to increase as the population expands in the overall Capital Regional District[1] (CRD). The aggregate supply and demand in the CRD has been studied over the past 15 years and the changes in the types of materials and the sources of production have been observed. These studies show a major shift to aggregate production from sand and gravel pits to quarry sources, an increase in the use of recycled Portland cement concrete (RPCC) and asphalt concrete pavement (RAP) in aggregates, and importation of increased volumes of aggregates from outside the CRD.

This paper describes the trends in aggregate supply in the CRD and its implications for future aggregate production.

2. AGGREGATE SOURCES

In the immediate vicinity of Victoria, significant quantities of granular material were deposited in post-glacial times in ridges in the Saanich Peninsula and in the deltaic deposits between Finlayson Arm and the Strait of Juan de Fuca as shown in Figure 1. West of the Victoria urban area, granular materials from glaciofluvial outwash and ice contact deposits are present, as shown in Figure 2. For a variety of reasons, including material quality, size of deposits, and transportation costs, these potential sources have not been significant in the overall aggregate supply to Victoria[2].

An inventory of operating aggregate sources was carried out in 1990 and 1998, and updated in 2003. The location of existing and closed pits in those years is shown in Figures 1 and 2. The most important sand and gravel pit in the region is the Construction Aggregates Producers Pit in Colwood which has been in production since 1919. In some past years, it has been the highest producing pit in Canada with an output of 4 million t per year. Over its 80 year life, in excess of 60 million t of sand and gravel has been extracted. In the recent past, the pit has supplied over one-third of the local aggregate demand, and a significant proportion of the output has been exported to the Lower Mainland and to

---

1 The CRD as used herein refers to the mainland area within the Capital Regional District, and excludes the Gulf Islands.

2 "Victoria", as used herein, refers to the Victoria urban area that includes 13 municipalities which form the major urban area within the Capital Regional District.

Washington State. In addition, about 50% of the aggregate production now comes from quarrying bedrock in part of the site. Though still a major producer, the extractable reserves are rapidly diminishing. Plans are being prepared to redevelop the site for a large residential community and aggregate production is scheduled to end in 2006.

The recent trend of developing rock quarries for the manufacture of higher value construction aggregate, particularly for asphalt products, has arisen in response to diminishing supplies of sand and gravel. These quarried rock sources are mostly located west of, and close to, Victoria.

The increasing role of quarry sources in the aggregate supply for the area is shown in Table 1, and the locations of these quarries are shown in Figure 1.

TABLE 1 - NUMBER OF PITS AND QUARRIES

Year	Number of Major:	
	Sand and Gravel Pits	Bedrock Quarries
1990	9	1
1998	5	5
2003	5	6

In addition to the local pits and quarries, a relatively minor but growing amount of aggregate is supplied from outside Victoria by trucking from west (Highway 14) and north (Highway 1).

Facilities for unloading barges in the Victoria area are found on the harbour in the City of Victoria. Material is typically supplied to these facilities from tidewater-based pits on Georgia Strait and, currently, from Producers Pit. Other potential barge unloading sites are north of Victoria off Highway 1 (e.g. Bamberton, Cherry Point, Cowichan Bay) as shown in Figure 1, but these have not been developed for unloading aggregate. The current Producers Pit aggregate loading facilities will be removed when the pit is closed and the zoning is changed to “Residential”.

3. AGGREGATE PRODUCTION

3.1 Annual Quantity

The amount of granular material produced in the CRD has always been greater than the local demand, and the surplus has been exported. The annual production of both processed and unprocessed granular materials and quarried rock are given for 1978-88 in Figure 3, based on unpublished data from the BC Ministry of Energy, Mines and Petroleum Resources [1]. This data shows a wide variation, with annual production ranging from about 2.2 million t to 4.8 million t. This variation is considered to be predominantly due to fluctuating exports from Producers Pit.

Data for aggregate production for 1993 to 1997 and for 2002, as summarized in Figure 4, was obtained from interviews conducted with the major pit and quarry operators. This information indicates that in recent years the annual production of granular material from pits and quarries has varied between about 2.4 million t and 3.0 million t. The total aggregate production (from sand and gravel and from quarried rock) at Producers Pit in 1996 was about 1.6 million t, of which 900,000 t was consumed in the CRD [2].

The amounts shown in Figure 4 include material from non-commercial sources, such as:

- Production from forest company, municipal, Regional District or Ministry of Transportation pits used for construction and maintenance of their roads, which is estimated to be about 150,000 t/year.
- Aggregate produced from bedrock excavations for on-site use, such as at the CRD landfill and during reconstruction of the Trans Canada Highway where an average of about 150,000 t/year were produced in 1995-97.

If material from all sources, including from pits and quarries and from non-commercial sources, is taken into consideration, the estimated peak production was about 3.1 million t as shown in Figure 4.

3.2 Exports

In 2002, about 0.9 million t of aggregate was exported from Producers Pit. The amount exported has varied over the years depending on the demand in the Vancouver area and in Washington State. The amount of exports has to be deducted from produced amounts to determine the local usage.

3.3 Imports

The amount imported into the Victoria area is estimated to be about 250,000 t per year, or roughly 10% of granular material used in the CRD. A variety of materials are imported, including lower grade material like pit-run for fill applications and higher grade material such as that used in manufacturing concrete aggregate.

3.4 Recycled Material

Currently, recycling operations typically combine natural aggregate along with RPCC, RAP, and reclaimed aggregate to meet appropriate specifications. The processing facilities are typically adjuncts of concrete and asphalt operations. The quantity of RPCC and RAP used locally in the manufacture of recycled aggregate amounts to about 150,000 t/year. These materials are typically combined with natural aggregate to give a combined total amount of recycled aggregate of about 300,000 t/year. The recycled products are used primarily in road construction and in site development as graded aggregate and as engineered fill.

RAP is also used in manufacturing hot-mix asphalt concrete and the amount of RAP used in this process is estimated to be about 30,000 t/year locally.

An estimated 6,000 t/year of crushed glass from bottles is produced and is predominantly used for specific applications such as in drainage aggregate. There is little demand for glass in other aggregates, and it is specifically excluded in some specifications such as for the City of Victoria[3] [3] and BC Master Municipal Contract Documents[4] (MMCD) [4].

The proportion of recycled materials currently used in aggregates in the Victoria area is estimated to be about 7% of the total aggregate demand.

4. AGGREGATE DEMAND

4.1 Historical Usage

The amount of granular material used in the Victoria area has been determined by considering:

- Total production from CRD pits and quarries,
- Production from on-site, and non-commercial sources,
- Exports from pits and quarries,
- Imports from outside the region, and
- Recycled production.

The total amount used in recent years in the Victoria region, from all sources, has ranged from 2.3 to 2.7 million t per year, as shown in Figure 5.

---

[3] Standard Specifications Section 2, Base and Sub-base Preparation, Sub-section2.2(a): “All materials shall...be free from lumps of clay, silt, decomposed rock, glass, organic or other deleterious matter.”

[4] Aggregates and Granular Materials, Section 02226 Sub-section 2.11: Recycled Aggregate Material: “Recycled material should consist only of crushed Portland cement concrete; other construction and demolition materials such as asphaltic concrete, bricks, plaster, etc. are not acceptable”.

It is noted that the amount of material supplied from Producers Pit has recently been about one-third of the CRD demand. A considerable increase in imports can be expected when the pit ceases to operate.

4.2 Aggregate Demand Forecasting

Analyses forecasting the requirements for granular materials has been presented in a number of studies. A variety of models, of varying complexity, have been proposed based on determining aggregate demand for specific end uses, such as for an individual residence, and then projecting the total aggregate demand for that use based on forecasts for residential construction. In general the local lack of satisfactory data is a major drawback for such models.

Predicting aggregate demand using regression analysis to correlate demand with factors such as population, GDP, and other commonly generated statistics has been considered to be reasonably satisfactory for the Lower Mainland of BC [5]. In carrying out this type of analysis, it is necessary to have historical data for the aggregate usage and for the appropriate statistics over a reasonable time period.

Statistics provided by CRD Planning indicate that the current (2003) population in the Victoria urban area is approximately 331,000 and the annual growth rate is estimated to be 0.95% [6]. Based on the 1993-97 aggregate usage data and the population statistics for the CRD, the average annual aggregate demand in the Victoria area appears to be reasonably estimated within a range of ±10%, as shown in Figure 6, by:

Average Aggregate Demand = 7.8 t/person/year

This is in the range reported by others of 7 t (US) and 5.2 t (UK) [7], and 8 t (US) and 12 t (Canada) [8].

Over the next 20 years, the average annual aggregate demand in the Victoria area will likely increase by about 25%, from about 2.6 million t in 2002 to about 3.2 million t in 2022.

5. FUTURE SUPPLY OF NATURAL AGGREGATE

5.1 Sand and Gravel

The information provided by pit operators indicate that the current reserves in existing sand and gravel pits in the immediate Victoria area are approximately 4 million t.

The volume of sand and gravel available west of Sooke is estimated to be significant and new sources in this area could be sufficient to meet demands in the CRD for some time provided transportation issues can be overcome.

Despite the increasing proportion of aggregate manufactured from rock sources, aggregate from natural sand and gravel will continue to be required. Sand and gravel is preferred, or essential, for manufacturing products where the workability of rounded particles is advantageous, such as washed aggregate for pea gravel, drain rock and concrete. It is estimated that the requirement for such aggregate manufactured from sand and gravel in the future will be at least 20% to 30% of the total demand, or about 700,000 t per annum.

The current annual rate of sand and gravel production in the CRD is approximately 1.8 million t, but the rate of extraction varies significantly between pits. If the Producers Pit is closed as scheduled, sand and gravel production in the CRD will be restricted to the area from Sooke and the Saanich Peninsula, north of the city. In about 10 years, it is considered that sand and gravel production in the CRD will essentially be in the extreme western part of the Regional District west of Sooke.

Sources outside the CRD will undoubtedly supply a large volume of sand and gravel to the local market. It is anticipated that a significant amount of sand and gravel for concrete manufacture is likely to be imported by barge. In the absence of new importing facilities, these materials will enter the region near the heart of Victoria city.

5.2 Bedrock Quarries

The reserves in the present quarry sources in the vicinity of Victoria, estimated to be about 20 million t, are likely to be sufficient to meet the demand for aggregate for the next 10 to 15 years. In contrast to sand and gravel sources, aggregate production from rock sources in the Victoria area could be increased by expanding the existing facilities or starting new quarries, provided mining permits can be obtained. At present, one quarry application is being considered west of the city.

There is no doubt that the proportion of aggregate manufactured from locally quarried rock will increase as the supplies of sand and gravel become depleted, and will approach 50% of total aggregate demand within a few years. This shift in production is occurring as the costs for importation of sand and gravel material from more distant locations is becoming more costly due to transportation charges, thus offsetting the costs for drilling and blasting quarry rock. For instance, in the Lower Mainland quarrying is considered to become viable when the haul distance for sand and gravel is greater than about 45 min by road. [9]

6. USE OF RECYCLED MATERIALS IN AGGREGATE

6.1 Background

Manufacturing aggregates by combining crushed recycled materials with natural aggregates began, in a significant way, in the Victoria area in the late 1980's. Unfortunately the operation lacked a consistent input stream of specific types of material, with the result that the output stream was very variable. Accordingly there was a lack of enthusiasm for using these products. As the industry developed and matured, quality control and product consistency was improved and this has resulted, in the past several years, in greater product acceptance.

RAP and RPCC are the most important recycled materials used locally, and therefore only these materials are considered herein.

Since the volume of the output depends on the quantity of available asphalt concrete and Portland cement concrete, recycled aggregates will likely remain below about 10% of the total aggregate requirements in the Victoria area.

6.2 Acceptance

Although RPCC and RAP has been used in aggregate for many years, the trend was reinforced by the adoption of policies designed to prolong the life of landfills. Restricting certain recyclable materials including concrete and asphalt has resulted in additional costs for disposing of these materials, and consequently resulted in the systematic use of these materials in aggregate. As a result, a number of aggregate producers now routinely provide materials that incorporate RPCC and RAP.

Acceptance of aggregate materials containing RPCC and RAP has been gained by testing and evaluation of the materials, by assessing the products against conventional aggregate specifications and by experience with their use. However, specific policies, protocols and specifications are not in place locally that govern the use of aggregates containing recycled products.

The discussions following pertain to the use of aggregates used as construction materials such as road base and trench backfill, and do not address their use in manufacturing structural materials like PCC or asphalt concrete.

6.3 Specifications

Aggregate specifications fall into two main categories: gradation and durability. The former specifications can be met by using appropriate processing methods, regardless of whether the material is a natural or recycled product. Material durability is an inherent property of the particles. Durability specifications are meant to ensure that the aggregate particles can resist breakdown and alteration under long term use caused by loading stresses and by environmental conditions such as freeze-thaw.

Aggregate incorporating recycled materials have to meet the gradation and durability criteria that were developed for natural aggregates to ensure the longevity of the product.

In addition to these specifications, recycled aggregates have to ensure that non-conforming materials such as wood and brick are not present.

6.4 Durability

Studies have been made of aggregate containing various proportions of recycled materials to address durability concerns for these products.

In general, aggregate containing RAP and RPCC, in commonly approved proportions, appear to meet durability specifications. Table 2 summarises test results obtained in studies carried out to determine the properties of local recycled aggregate relative to current BC Ministry of Transportation (MoT) specifications for 25 mm base course aggregate.

TABLE 2 - PROPERTIES OF RECYCLED AGGREGATE

		Sample				Specification
		A	B	C	D	
Material (percent by mass)						
Natural Aggregate		73	56	42	65	
RAP		7	13	16	35	
RPCC		19	30	42	0	
Other		1	1	0	0	
Test Procedure						
$MgSO_4$ Soundness (ASTM C88)	FIne	9	10	13	11	max. 25%
	Coarse	2	2	2	2	max. 20%
Sand Equivalent (ASTM D2419)		55	57	74		min. 40
L.A. Abrasion (ASTM C131, Grading C)		-	-	29		max. 60% (1)
Degradation (BC MoT I-9) [b]		67	76	73	62	min. 35

Note 1: Ministry of Transportation Ontario specification for Granular A (pre-1994)

6.5 Proportion for RAP and RPCC

While there appears to be some agreement regarding the acceptability of using RPCC in aggregates, the same cannot be said for RAP.

Many jurisdictions specifically permit use of RPCC, with no defined maximum percentage, in crushed base course and/or trench aggregates including, for example:

- BC Master Municipal Contract Documents (MMCD)
- Ministry of Transportation Ontario (MTO)
- Ontario Provincial Standard Specifications (OPSS)
- City of Calgary

Other jurisdictions allow the use of RPCC, since it is not specifically excluded by aggregate specifications. Generally, an unwritten allowable maximum proportion of RPCC has been established by these jurisdictions based on local conditions:

- City of Victoria 50%
- Municipality of Saanich 50%
- City of Edmonton 65%

OPSS fully define the acceptability and the criteria for the use of RAP in granular base and subbase [10]. In other jurisdictions, the permissibility of RAP in granular base, subbase or trench aggregate is not well established. Its use appears to depend on local acceptance and discretion. Where RAP is permitted by specifications, the allowable proportion of RAP is typically not defined.

Some observations regarding the use of RAP in granular aggregates are as follows:

- BC MMCD prohibits RAP in general use[4], but permits an undefined amount in base course from cold milling and full depth reclamation operations[5].
- Some municipalitites that have adopted the MMCD have developed local Special Provisions or have tacitly permitted the use of RAP in base and trench aggregates.
- The City of Edmonton produces and uses a crushed base course product (“63 mm Reclaim”) generally consisting of 60% RPCC and 25% RAP.
- OPSS permits up to 30% RAP in base course.
- MTO allows up to 30% RAP generally, and up to 50% in some conditions such as full depth reclamation [11].
- While silent on the acceptability of RAP in aggregates, some Victoria municipalities permit up to 50% RAP in aggregates for base, subbase and trench backfill applications.
- Although not directly permitted by specifications, BC MoT has used RAP in subbase aggregate from material produced by a full-depth reclamation operation.

---

[5] Section 02574 Cold Milling, and Section 02575 Full Depth reclamation

It is difficult to proportion an input stream consisting of recycled and natural materials to assure a consistent output stream. In one study conducted by the author, eleven samples were taken in accordance with ASTM D75 from a 20 mm crushed aggregate stockpile containing RPCC, RAP and natural aggregate. Categorizing the component materials visually in a laboratory yielded a wide range in the proportion of the different materials in the product, as illustrated in Table 3.

TABLE 3 - COMPONENTS OF RECYCLED AGGREGATE

	Percent of component material, by mass, retained on 4.75 mm screen			
	Natural Aggregate	**RAP**	**RPCC**	**Other**
Average	56	13	30	1
Standard Deviation	11	6	9	1
Maximum	73	24	44	3
Minimum	42	6	18	0

While in this instance the wide scatter in the results are partly due to quality control issues in the manufacture, relatively significant variations in the proportion of recycled material can be expected to exist throughout a stockpile. This makes it difficult to conduct meaningful compaction tests for reasons outlined later.

A major consideration in determining the allowable RAP content is the fact that the aggregate strength decreases as the RAP content increases. An MTO study indicated that above 30% RAP content, the strength of aggregate determined in CBR tests was unacceptable [11]. This showed that the CBR at 30% RAP was just over one-half of that for aggregate with no RAP. In a study by the author using a 20 mm base course aggregate, having a gradation shown in Figure 7, the CBR decreased with increasing RAP content as indicated in Table 4.

TABLE 4 - CHANGE IN CBR WITH RAP CONTENT

Product Proportions		% RAP particles >4.75 mm size (by mass)	CBR (%)
RAP	**Natural Aggregate**		
25%	75%	16	30
35%	65%	23	29
45%	55%	30	19

6.6 Permeability of Aggregates containing RAP

The permeability of product containing RAP is one that is of major concern since poor drainage of a road structure is probably the most frequent cause of pavement distress.

Permeability of a well graded aggregate is mainly a function of the fines content (% passing 0.075 mm screen). An MTO study [11] indicated that *"provided the blend of RAP and natural aggregate materials remain within the acceptable limits of a granular A, lack of permeability does not pose a significant problem*". This is in accord with general observations of this material in the Victoria area.

6.7 Field Density

Other investigators have recognised the fact that, for aggregate containing RAP, asphalt cement influences the results of in-situ compaction tests carried out using nuclear densometers [11]. The moisture content displayed on the equipment is greater than the true value, as determined by other test methods. In addition, the density is lower than the actual value.

In a study by the author, a comparison was made using nuclear and sand cone procedures to determine density and moisture content at six locations in a backfill consisting of 20 mm aggregate containing about 6% RAP and 40 % RPCC. The average in-situ density test results are summarized in the Table 5.

TABLE 5 - SAND-CONE & NUCLEAR DENSITY TEST RESULTS

	Nuclear Method		Sand-Cone Method		Nuclear /Sand-Cone
	ASTM D2922	ASTM D3017	ASTM D1556	ASTM D2216	
Wet Density (kg/m^3)	2172		2246		97%
Dry Density (kg/m^3)	1976		2093		94%
Moisture Content (%)		10.0		7.4	135%

This data indicates that even a relatively small amount of asphalt cement can make a significant variation in the measured in-situ density. In this case, the nuclear densometer under-estimated the actual density by 6%. This is important since specifications require that an aggregate attains a density that is not less than, typically, 100% of the value determined in test procedure ASTM D698. In this example, using a nuclear densometer as a basis for acceptance of density would penalize the contractor.

A possible solution, and one that is sometimes adopted, is to conduct initial correlation tests using both sand-cone and nuclear densometer test methods. From this data, a method-based approach can be developed for acceptance, e.g. determining the minimum number of passes of a particular compactor. For some applications, for instance in trench backfilling, this requires constant vigilance of an inspector in order that the compaction can be "signed off".

It is evident that use of RAP in construction aggregates requires a greater degree of inspection and testing than where natural aggregates alone are used, in order to provide the assurance that the aggregate placement meets specifications for compaction.

6.8 Construction

There is general agreement from a variety of jurisdictions that recycled aggregates for road, municipal and land development applications are easy to work with, even in moderately wet conditions.

In some instances, it has been commented that support is better than for natural aggregate and this may reflect the fact that the material has a higher proportion of crushed and angular particles.

7. SUMMARY

Studies of the aggregate industry in the Victoria area indicate that the annual amount aggregate demand is approximately 8 tonnes per person, for a total of about 2.5 million tonnes per year for the region. The amount required over the next 20 years will be about 60 million tonnes.

The local source material is changing from sand and gravel to bedrock quarries. An increasing amount of recycled material including Portland cement concrete, asphalt concrete and natural aggregate is being produced in response to environmental policies and economic considerations. The amount of recycled material will be governed by the annual amount of demolition products from roads and structures. The amount of recycled material as a proportion of the total aggregate demand is about 7% and it is unlikely to exceed 10%.

Current local specifications are vague on the acceptability of recycled material and do not address the criteria for their use, such as allowable recycled proportions in the products. This situation is not unique to the Victoria area and it appears to be present in many jurisdictions. The standards in use in Ontario provide a comprehensive basis for jurisdictions that are considering adoption of specifications for the use of recycled concrete, asphalt and other materials.

REFERENCES

1. Thurber Engineering Ltd. *Capital Regional District Sand and Gravel Study*, Report to Capital Regional District. Vancouver, BC. August 1990.

2. *Aggregates and Roadbuilding Contractor*, Volume 11, Number 5. Edmonton AB, September 1997. p.17

3. City of Victoria. *Standard Specifications*, Engineering Services, City of Victoria. Victoria, BC. 1996.

4. *Master Municipal Construction Document - Specifications*, Volume 2, Master Municipal Construction Document Association. Vancouver, BC. 2000.

5. Coriolis Consulting Corp. *Development of a Model for Forecasting the Consumption of Aggregates in the Lower Mainland*. Unpublished draft report to the British Columbia Ministry of Energy, Mines and Petroleum Resources. Vancouver, BC. 1996

6. *Population Estimates*, Capital Regional District, Victoria, BC. August 2002,

7. Smith, M.R. and L. Collis, Editors. *Aggregates: Sand, Gravel and Crushed Rock Aggregates for Construction Purposes*. Geological Society, Engineering Geology Special Publication No. 9. The Geological Society, London. 1993

8. Langer, W. 1995. *Geological Aspects of Natural Aggregate Resources and their Development in Canada and the United States*, Proceedings of Aggregate Forum, March 30-31, 1995, Information Circular 1996-6, Ministry of Energy, Mines and Petroleum Resources, Victoria, BC. 1996

9. Hora, Z.D. 1995 *Aggregate Resources of the Greater Vacouver aned Lower Mainland Market, BC: Problems and Future Outlook*. Proceedings of Aggregate Forum, March 30-31, 1995, Information Circular 1996-6, Ministry of Energy, Mines and Petroleum Resources, Victoria, BC. 1996

10. Ministry of Transportation Ontario. *Special Provision No. 110F133 Aggregates for Granular O, A, B, M and Select Subgrade Materials*. Ontario Provincial Standards Volume 2. Ronen Publishing House, Toronto ON. 2002.

11. Senior, S.A., Szoko, S.I. and Rogers, C.A. *Ontario's Experience with Reclaimed Materials for Use as Aggregates.* Proceedings of the International Road Federation/Transportation Association of Canada Conference, Volume 6, pp A31 - A55, Calgary AB. July 1994

FIGURES

Figure 1	Victoria Area Granular Deposits, and Location of Pit and Quarries.
Figure 2	Western CRD Area Granular Deposits, and Location of Pit and Quarries.
Figure 3	Aggregate Production 1978 - 1988
Figure 4	Aggregate Production 1993 - 2002
Figure 5	Aggregate Usage
Figure 6	Projected Aggregate Demand
Figure 7	Gradation of RAP in Base Course Aggregate

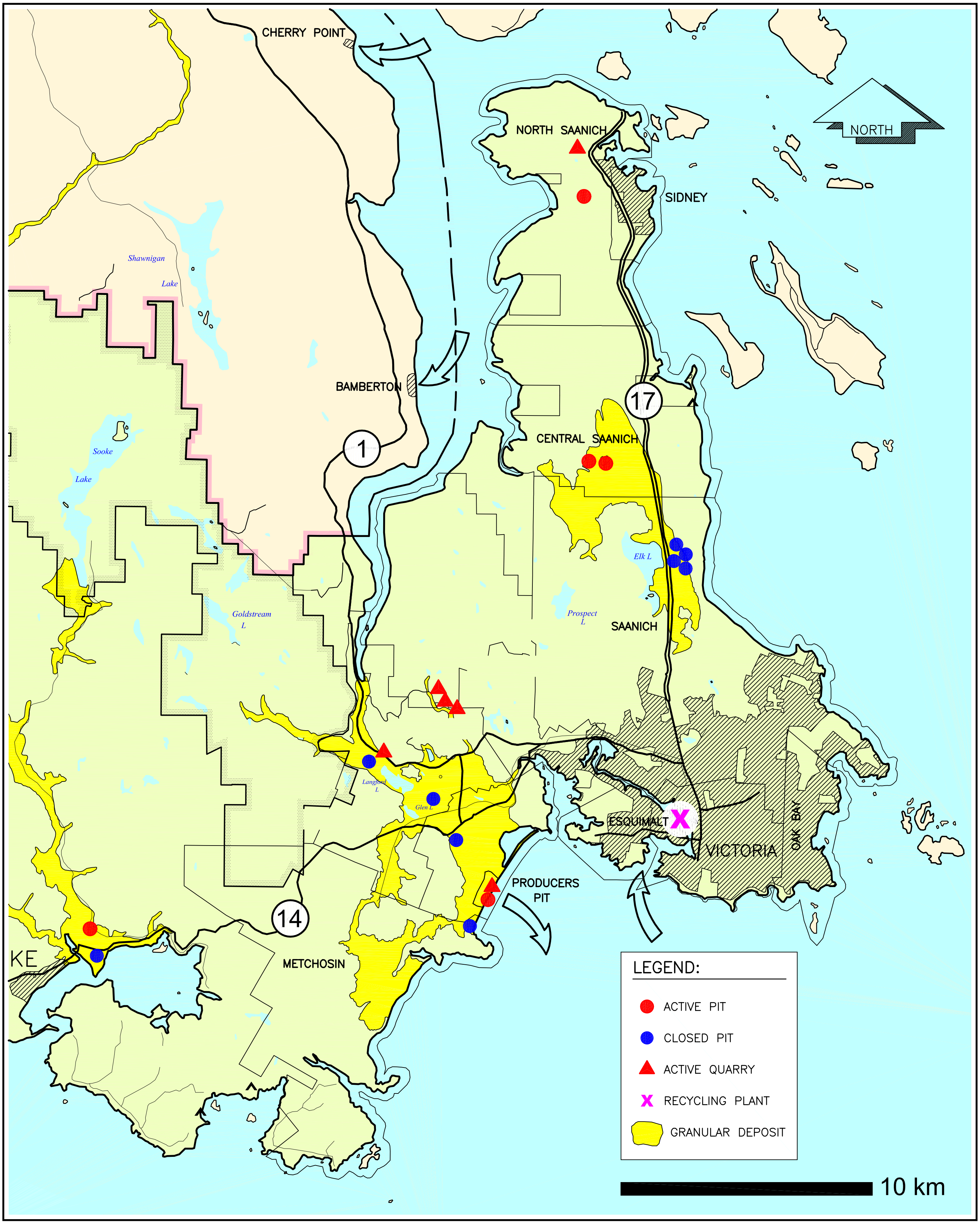

FIGURE 1: VICTORIA AREA GRANULAR DEPOSITS and LOCATION OF PITS AND QUARRIES

THURBER

CAD No.TEF02380.DWG THIS DRAWING IS PART OF A THURBER "REPORT" AND ITS USE IS SUBJECT TO THURBER'S STATEMENT OF GENERAL CONDITIONS FILE No. 1-2-41-4 MAY 1, 2003

FIGURE 2: WESTERN CRD AREA GRANULAR DEPOSITS and LOCATION OF PITS AND QUARRIES

THURBER

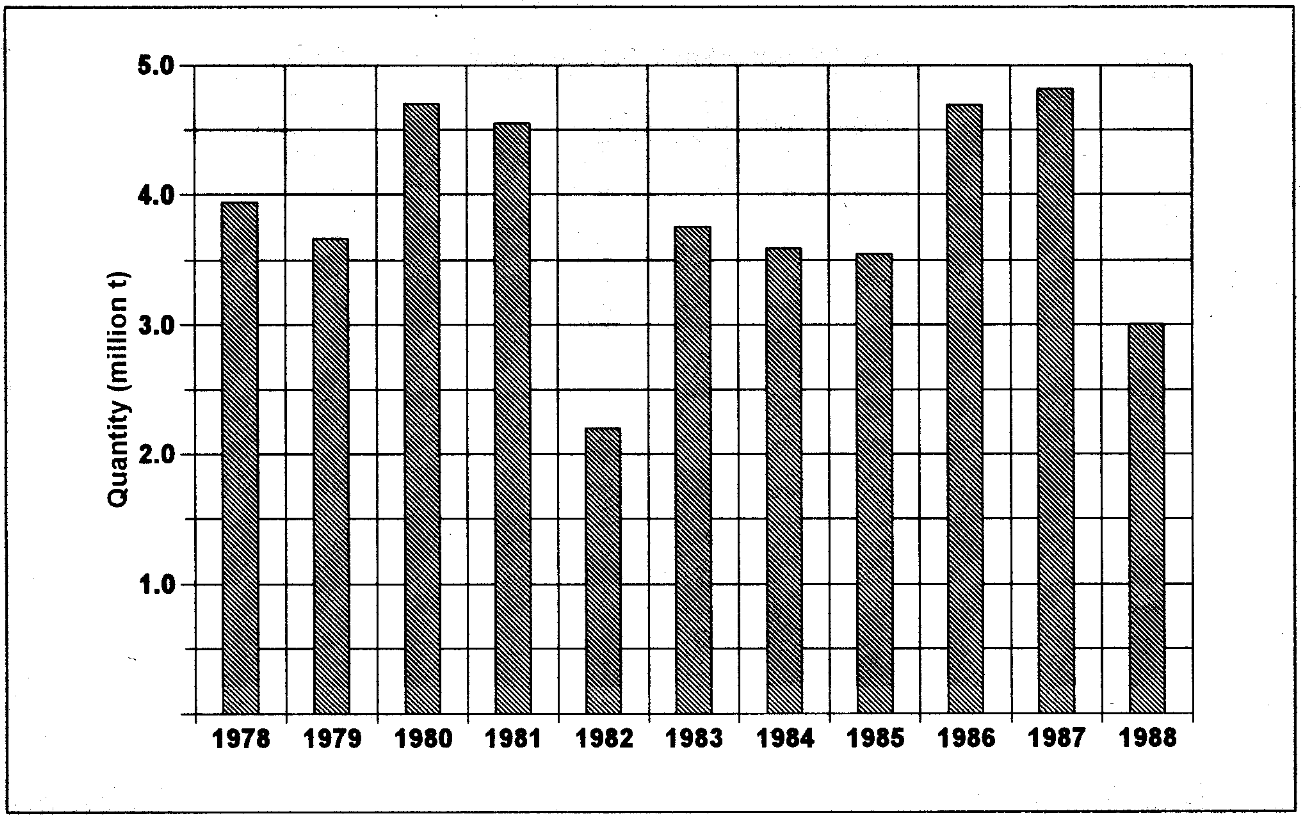

FIGURE 3: AGGREGATE PRODUCTION 1978 - 1988

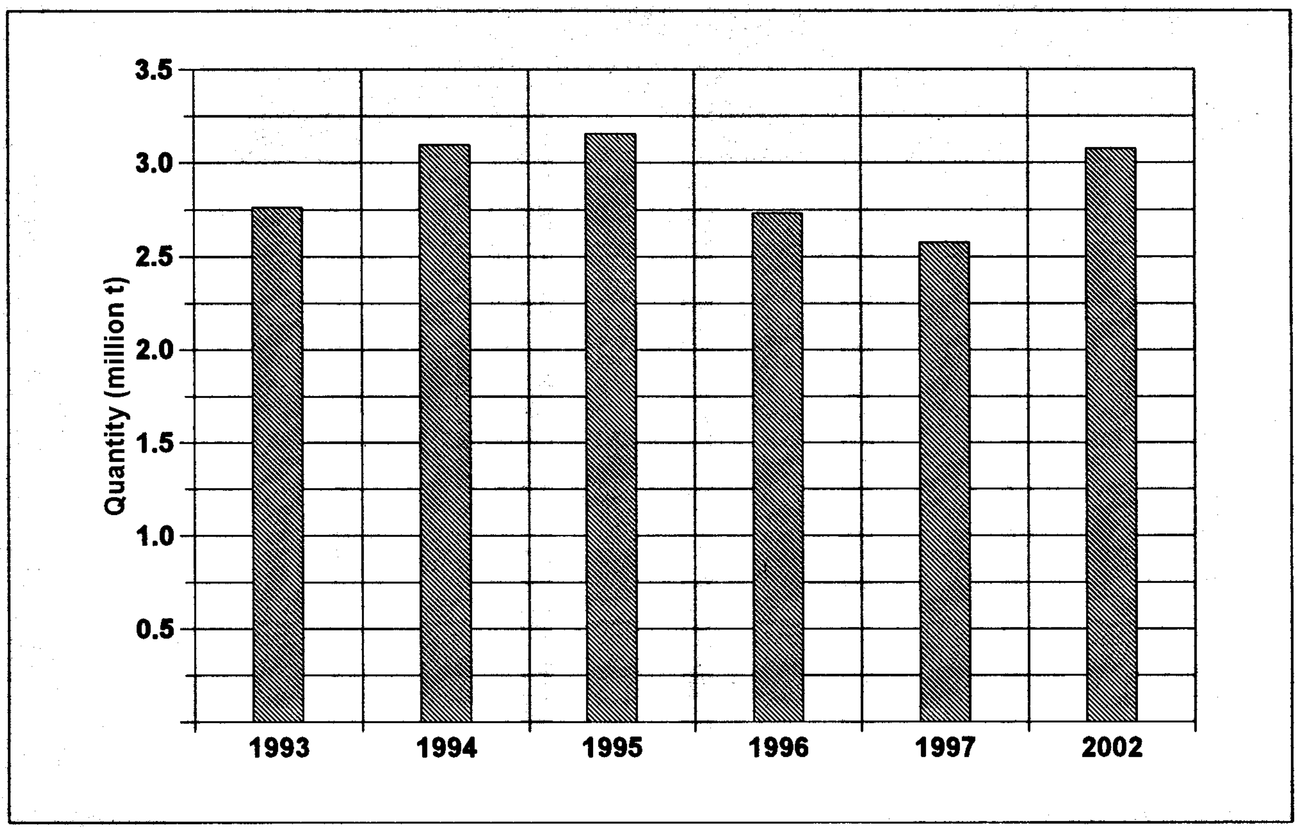

FIGURE 4: AGGREGATE PRODUCTION 1993 - 2002

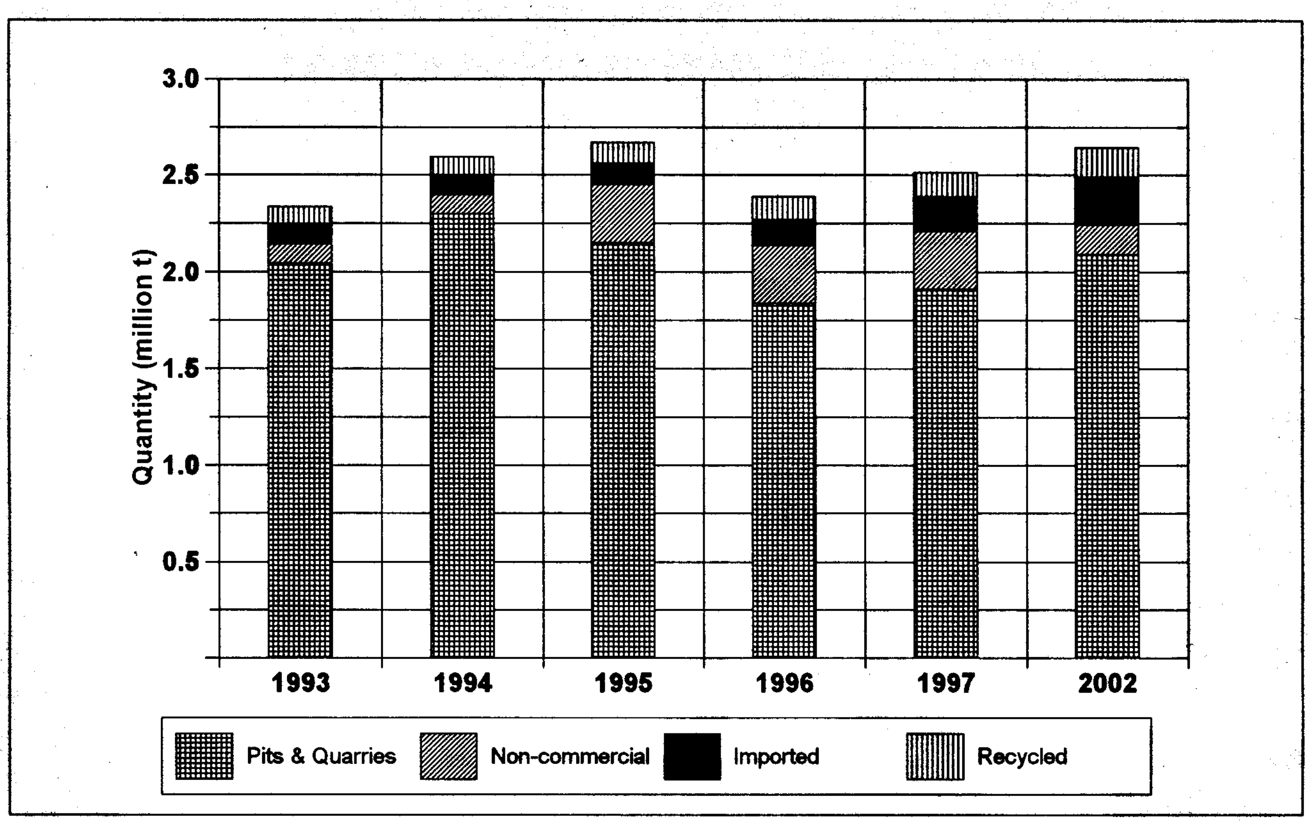

FIGURE 5: AGGREGATE USAGE 1993 - 2002

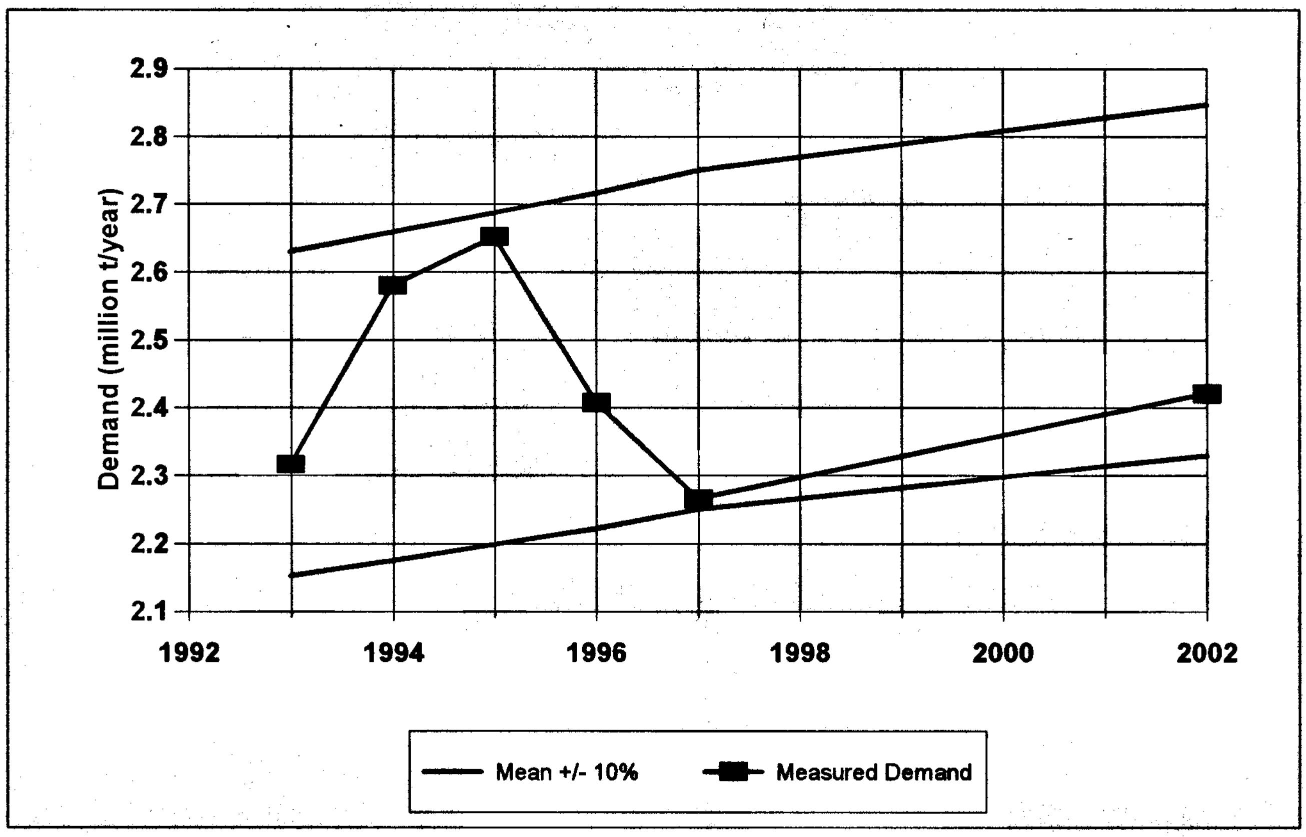

FIGURE 6: AGGREGATE DEMAND

THURBER

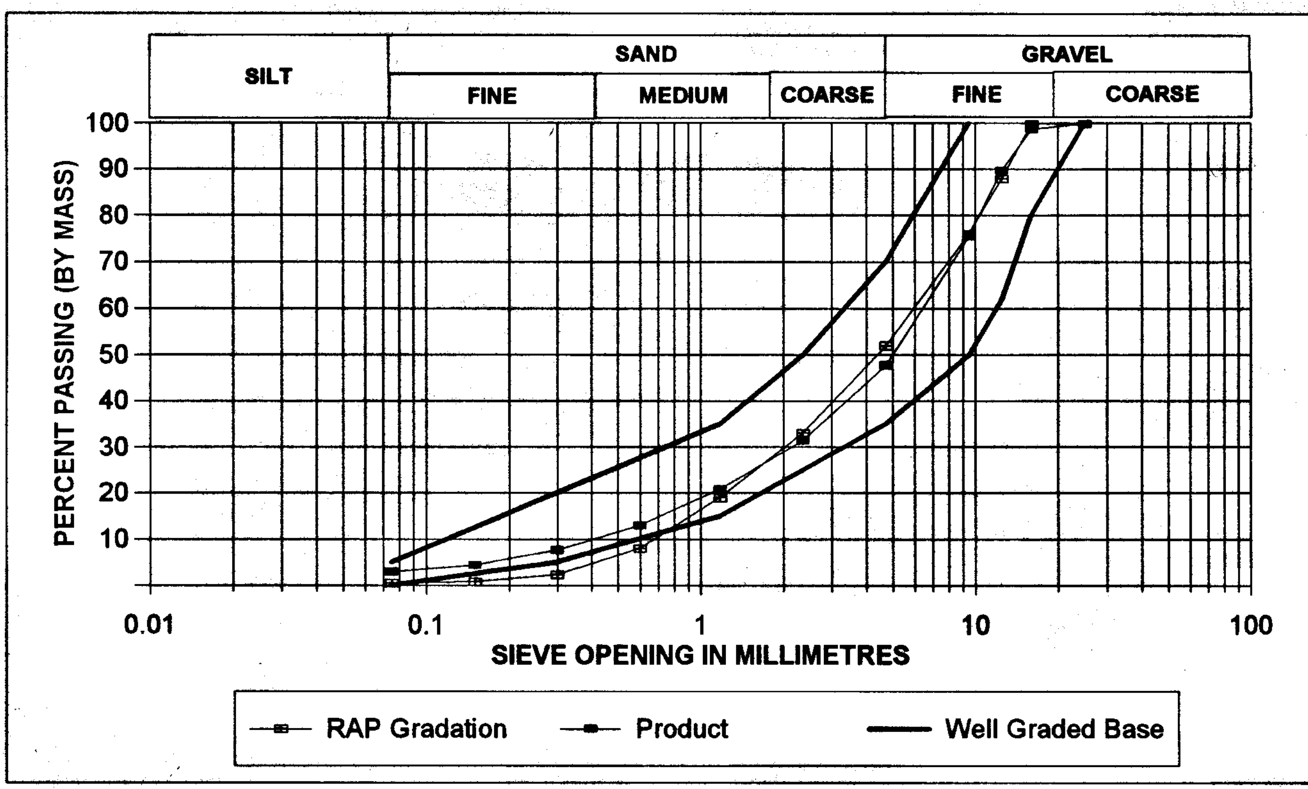

FIGURE 7: GRADATION OF RAP AND CRUSHED PRODUCT

THURBER