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AN ECONOMIC APPRAISAL OF MINING OFFSHORE SAND AND GRAVEL DEPOSITS

by

Massoud Mokhtari-Saghafi[1]

Robert H. Osborne[2]

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[1]Doctoral candidate in economics at the University of Southern California and principal author of this paper.

[2]Associate Professor of Geological Sciences at the University of Southern California and Principal Investigator.

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ABSTRACT

Sand and gravel are primary resources used in many phases of construction and to maintain southern California's invaluable beaches and harbors. Although California has led the nation in the production of sand and gravel since 1942, the four major production districts that supply the greater Los Angeles area are expected to exhaust their supply of saleable-grade material within 25 to 30 years. Since many potentially mineable, land-based sand and gravel deposits are lost to competing land users and mining of these deposits is generally opposed by proximal urban communities, the sand and gravel needs can be met by (1) changing zoning regulations to permit known deposits to be exploited, (2) exploring for new sand and gravel deposits, taking commensurate care to evaluate the geological, economic, social, environmental and legal aspects of exploitation, or some combination of (1) and (2).

Marine sedimentological studies along the inner Santa Monica shelf demonstrate the presence of five major bodies of sand and gravel. Collectively, sites B-I, B-II and B-III contain a minimum of 99×10^6 yd^3 to a maximum of 214×10^6 yd^3 of dominantly sand, of which 55% is suitable and 80% suitable or marginally suitable for beach restoration and nourishment. Site B-IV contains approximately 325×10^6 yd^3 of mostly silt and very fine- to fine-sand, which are of marginal quality for beach nourishment. Site B-V contains from 18×10^6 yd^3 to 66×10^6 yd^3 of sand and gravel, of

which approximately 72% is suitable for construction aggregate.

Under current market conditions and in the framework of a conventional land-based mining operation, the internal rate of return on capital for an onshore economic model is from 8.7% to 11.5% for a new producer, depending on the level of sales and different market assumptions. For the offshore alternative, this rate ranges from 2.5% to 7.5%, depending on the level of sales and different market assumptions. Offshore mining of sand and gravel for construction aggregate is profitable but below the average expected future market rate of interest (10%). The cost of replacing 1 yd^3 of suitable material on a damaged beach is estimated to cost approximately $1.52, therefore a commercial enterprise should be offered at least $1.87 per yd^3 to undertake such a project.

Available sedimentologic information and current market conditions suggest that beach restoration and nourishment are the best uses for the offshore sand deposits along the inner Santa Monica shelf. Future market conditions as well as changing social and environmental attitudes may raise the profitability of offshore mining for concrete aggregate above the prevailing market rate of interest.

INTRODUCTION

On the basis of tonnage, the sand and gravel industry is the largest non-metallic industry in the United States. There are about 7,600 sand and gravel deposits and 6,000 processing plants inthe nation (6). U.S. production of sand and gravel in 1978 was nearly 940 million tons valued at about $2.1 billion. Of the total sold or used, construction sand and gravel accounted for approximately 97% and industrial sand and gravel approximately 3%. California has been leading the nation in the production of sand and gravel for the past several decades.

At the present time, sand and gravel in southern California is primarily obtained from land-based Holocene alluvial deposits. Due to several economic and social factors, possible alternative sources of this commodity are of interest to commercial enterprises. One alternative currently under consideration for local markets in southern California is to dredge sand and gravel from offshore marine deposits. Offshore sand and gravel deposits are also of considerable interest to certain local, state and federal agencies because of their potential importance for beach restoration and nourishment.

Purpose

The purpose of this study is: (1) to evaluate the profitability of offshore mining of sand and gravel in southern California and to compare onshore and offshore alternatives in terms of their profitabilities; and (2) to evaluate the cost of beach replenishment activities in southern California.

The following topics will be discussed to achieve these objectives.

(1) a brief description of markets for sand and gravel in southern California, and especially Los Angeles County.

(2) construction of an offshore economic model including estimates of the costs, benefits and the "rate of return" based on the model as well as an evaluation of the proposed project.

(3) construction of a simple onshore model including estimates of the costs, benefits and the "rate of return" based on this model as well as an evaluation of the project.

(4) a brief discussion of the possibility of offshore dredging of sand and gravel for beach restoration and nourishment; an estimate of the associated costs and benefits and an evaluation of such a project.

Characteristics of Sand and Gravel Markets

Under free economic conditions, demand and supply for each commodity determine the price at which both the buyer and the seller are willing to trade. Sand and gravel, like any other commodity, is traded in the market, and its price depends on supply and demand interactions.

Demand for sand and gravel depends essentially on the level of construction activity. Approximately 98% of all sand and gravel consumed in southern California in 1976 was used for construction purposes. In 1973, when construction activity was high in the United States, sand and gravel consumption reached its peak level of 983 million tons; in 1975, when the construction level dropped, sand and gravel demand also dropped sharply to a low level of 787 million tons.

Nearly 33% of construction sand and gravel goes into the production of concrete aggregate for use in residential and non-residential buildings and engineered construction, such as highways, dams, bridges, waterworks and airports. A conventional six-lane freeway requires nearly 200,000 tons of aggregate per mile, and a large bridge may require more than 500,000 tons of aggregate (19). The average usage of sand and gravel in the construction of commercial and industrial structures is about 55 tons. About 25% of sand and gravel produced is used for road base and coverings for construction and repair of highways and roads; nearly 15% is used for fills, and 15% for asphaltic concrete aggregates. About 10% goes into concrete products and the rest into unspecified uses (6).

Demand for sand and gravel is seasonal, and varies with fluctuations in construction industries. Demand peaks occur during the summer and diminish during the winter months. Table 1 shows the total consumption of sand and gravel in the United States and in Los Angeles County.

Table 1. Sales of sand and gravel (in millions of tons).

YEAR	UNITED STATES*	LOS ANGELES**
1965	907	25.3
1966	933	26.2
1967	904	22.2
1968	916	23.7
1969	936	22.9
1970	944	26.2
1971	918	21.7
1972	913	21.3
1973	983	22.2
1974	904	21.6
1975	787	19.1
1976	883	21.1
1977	895	21.4
1978	937	21.6

*Source: U.S. Bureau of Mines

**Source: 1965-73, California Divison of Mines

1974-78 estimates based on U.S. Bureau of Mines Publications and on industry survey.

Supply and Marketing

Sand and gravel often occur in the same deposit, but the relative proportions of each may vary greatly. There are two basic sand and gravel mining methods: open pit excavation and dredging. The former, dominant in southern California, entails four major steps: site clearing, mining, processing, and reclamation of the excavated area.

Several different types of equipment generally are used for mining and removal of sand and gravel. They normally include draglines, shovels, loaders and bulldozers. The areal extent of the pits range from 2 to 225 acres. Excavation depths range from a few to more than 250 feet and production ranges from a few thousand to over 2 million tons per year (7).

Materials are transported from pits to the processing plant primarily by trucks and conveyor belts. Processing includes washing, screening, crushing and stockpiling. Processing time is short and factories usually produce at a rate lower than their full capacity; thus output can easily be adjusted to match demand in unpredicted situations. Due to these factors and also because of the large tonnage that makes storing costly, actual sand and gravel supply is highly dependent on and nearly equal to the demand.

The price of material at the plant site is lower than the delivered price to the consumer mainly because of the transportation cost. Low value per unit weight and its sluggish real increase, in addition to the cost of transportation, forces the industry to keep its mining and processing costs down. Inasmuch as the transportation cost is critical and the competition in the industry is intense, deposits being considered for possible exploitation should be located near metropolitan areas which are the main markets for the processed materials.

Transportation is normally by trucks and trailers with an averate capacity of 25 tons. Minimum transportation costs are set by the Public Utilities Commission on a zone to zone basis (Tariff 17A). For a distance of 25 miles, the minimum rate is $2.03; for a 40 mile haul, the rate rises to $3.08.

Aggregate supply for Los Angeles County is mainly derived from four production districts (7).

(1) San Gabriel Fan Production District

The San Gabriel Fan Production District is the largest in southern California. This district is located approximately 18 miles northeast of the Los Angeles Civic Center. Of 18.2 million tons of aggregate sold in all of the four districts in 1975, 12.4 million tons were produced in this area. Eastern Los Angeles County including the Civic Center, Orange and Santa Barbara Counties are markets for its products.

(2) Tujunga Fan Production District

This district is located in San Fernando Valley, 15 miles northwest of the Los Angeles Civic Center.

Total production of this district was about 4.3 million tons in 1975. Its output is trucked to the Sun Valley-Van Nuys area, downtown Los Angeles, and the area centered about the Santa Monica-San Diego Freeways interchange.

(3) Upper Santa Clara River Production District. This area is located approximately 30 miles northwest of the Los Angeles Civic Center. Its 1975 production of aggregate was over 0.848 million tons, and was mostly marketed in the Newhall-Saugus-Valencia area.

(4) Little Rock Creek Fan Production District. This district is located approximately 40 miles north of the Los Angeles Civic Center. Its 1975 production of aggregate was over 0.688 million tons, which were marketed in the Palmdale-Lancaster-Pear Blossom region, and also in the Victorville, Tehachapi, and China Lake areas.

Prices

Despite the rising costs of labor, land fuel, and transportation, the real selling price of sand and gravel has risen rather slowly. In terms of 1976 constant dollars, the average price of sand and gravel in the United States has risen from $2.15 per ton in 1965 to only $2.24 per ton in 1978; namely, a 4.2% real increase in 20 years. In Los Angeles County, the real price has increased only 3.2% during the same period.

Although the price of sand and gravel fluctuates seasonally with demand, the price changes have usually been mild and predictable. From 1978 to 2000, prices can be expected to rise more rapidly because sand and gravel will have to be extracted form less favorable sites, and because of the necessity of compliance with more strict environmental land use regulations.

A historical price list of sand and gravel for the United States and Los Angeles County is given in Table 2A. The 1975 price list of final products in the plant site for the four major producers in Los Angeles County is shown in Table 2B.

Table 2A. Average nominal and constant 1978 F.O.B. price per ton of sand and gravel.

YEAR	UNITED STATES		LOS ANGELES	
	Nominal*	Constant '78†	Nominal§	Constant '78†
1965	1.05	2.15	1.09	2.23
1966	1.05	2.09	1.12	2.23
1967	1.08	2.09	1.12	2.17
1968	1.11	2.06	1.24	2.29
1969	1.14	2.01	1.10	1.96
1970	1.18	1.96	1.25	2.08
1971	1.25	1.99	1.32	2.10
1972	1.31	2.00	1.37	2.08
1973	1.38	1.98	1.49	2.14
1974	1.57	2.06	1.63	2.14
1975	1.70	2.03	1.79	2.14
1976	2.00	2.27	2.09	2.38
1977	2.07	2.23	2.20	2.36
1978	2.24	2.24	2.30	2.30

*Source: U.S. Bureau of Mines

§Source: 1965-1973, California Division of Mines

1974-1978 estimates based on the U.S. Bureau of Mines Publications and on industry survey.

†Computed based on the general price level data from "Statistical Abstract of the U.S.", Department of Commerce, 1962-1979 volumes.

Table 2B. F.O.B. selling price of products in four production areas in Los Angeles County.

PRODUCTION DISTRICT	MATERIAL				
	CONCRETE*	ASPHALT*	BASE*	FILL*	AVERAGE[§]
San Gabriel Fan	2.60-2.70	2.50-2.85	2.10-2.95	1.25-1.70	2.58
Tujunga Fan	2.60-3.25	2.55-3.00	2.55-2.80	2.20-2.45	2.85
Upper Santa Clara River	1.95-2.65	1.80-2.65	1.50-2.55	1.10-1.50	2.16
Little Rock Creek Fan	2.60	2.65-2.70	2.60-2.65	1.05-1.30	2.28

*Source: California State Division of Mines and Geology, Special Report, 1979.

[§]Computed

COMPARISON OF COMMERCIAL PROFITABILITY OF OFFSHORE AND ONSHORE MINING FOR CONSTRUCTION AGGREGATE

The profits of an enterprise equals the difference between its earnings and costs. The main complication in the concept of profitability arises from the necessity to convert the future stream of profits and losses into some simple measure expressed as a number such as the "rate of return" or "present value" of the project. The present value of a net future income stream is simply the discounted sum of this stream, the discounting being done at the market interest rate. "Internal rate of return" is in turn, that rate of interest for which this present value is exactly zero. In choosing projects, we may follow the rule that all projects with an internal rate of return higher than the market rate of interest should be chosen. Alternatively, we may recommend that all projects with a positive net present value should be selected. Following either method, it would lead to the same result (see 12 for a description of cost benefit analysis) (4).

Due to the characteristics of the project and the nature of the data, the "internal rate of return" method will be followed in this paper. First, a representative offshore model will be designed; costs, revenue and net income flows then will be calculated. Finally, the internal rate of return will be computed. Comparing the internal rate of return with the ongoing market interest rate will determine the profitability of the project.

Offshore Models for Santa Monica Bay

General Statement

Recent work by personnel of the Sedimentary Petrology Laboratory at the University of Southern California (14, 15, 16, 18) has demonstrated the presence of five major sand and gravel bodies along the inner Santa Monica Shelf (Figs. 1 and 2). All of these bodies lie within the limits of conventional dredging technology (from 5 to 15 fathoms). Collectively, sites designated as B-I, B-II and B-III (Fig. 2) contain a minimum of 99×10^6 yd^3 to a maximum of $214 \cdot 10^6$ yd^3 of dominantly sand, of which 55% is suitable and 80% suitable or marginally suitable for beach restoration and nourishment (16). Site B-IV contains approximately 325×10^6 yd^3 of mostly silt and very fine to fine sand, which are of marginal quality for beach nourishment (16).

Site B-V contains from 18×10^6 yd^3 to 66×10^6 yd^3 of sand and gravel, of which approximately 72% is suitable for construction aggregate (16).

The economic reasons for the selection of Santa Monica Bay as the representative offshore model are as follows:

(1) The deposits have the advantage of being close to Los Angeles County markets. Demand for aggregate in this area is currently over 20 million tons annually. Closeness to some relatively large markets such as Santa Monica and Marina del Rey would reduce the marketing costs and the possibility of facing a lack of sufficient demand.

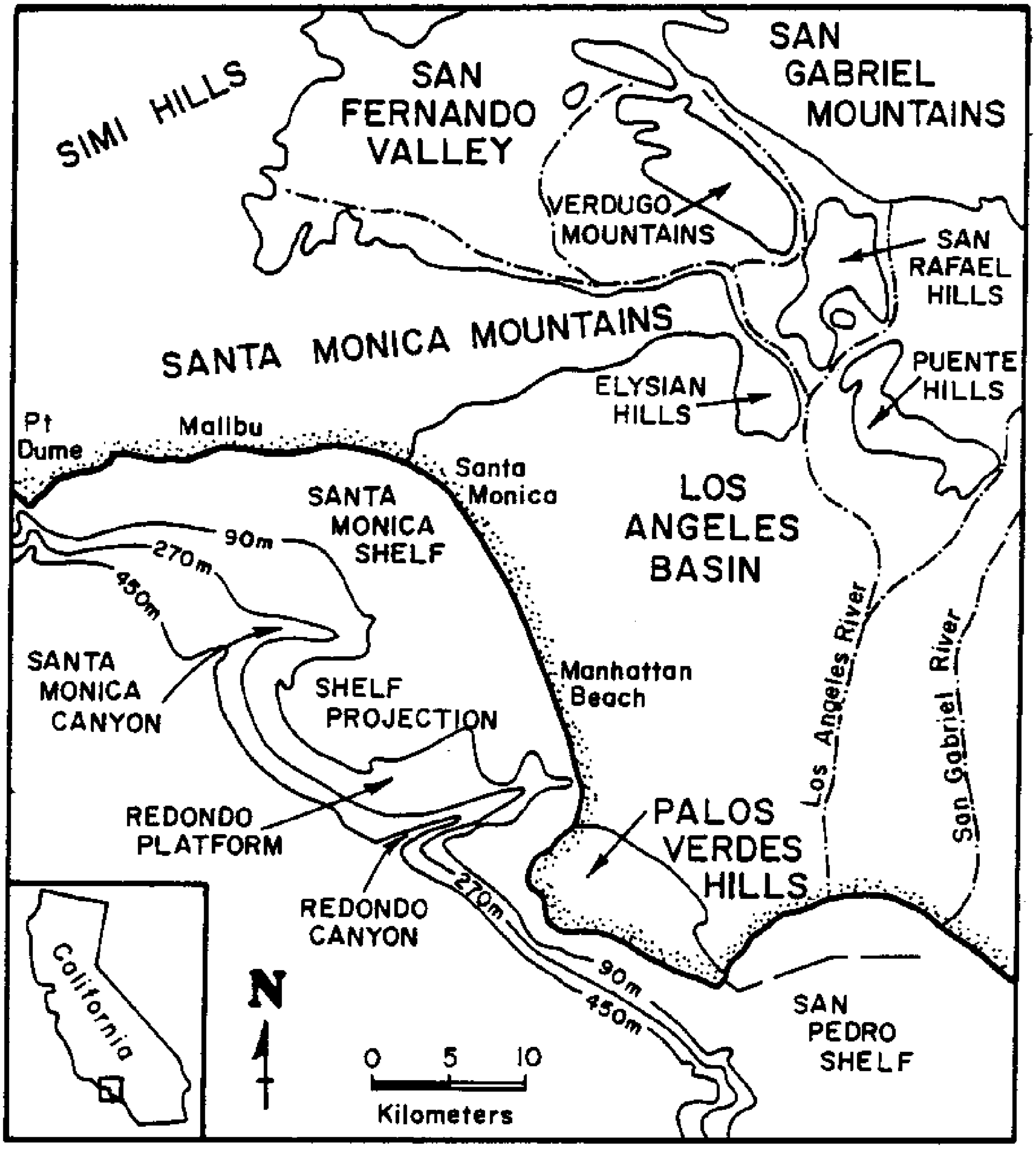

Figure 1. Location map showing bathymetry and physiography of the Santa Monica shelf area. Note position of depth contours.

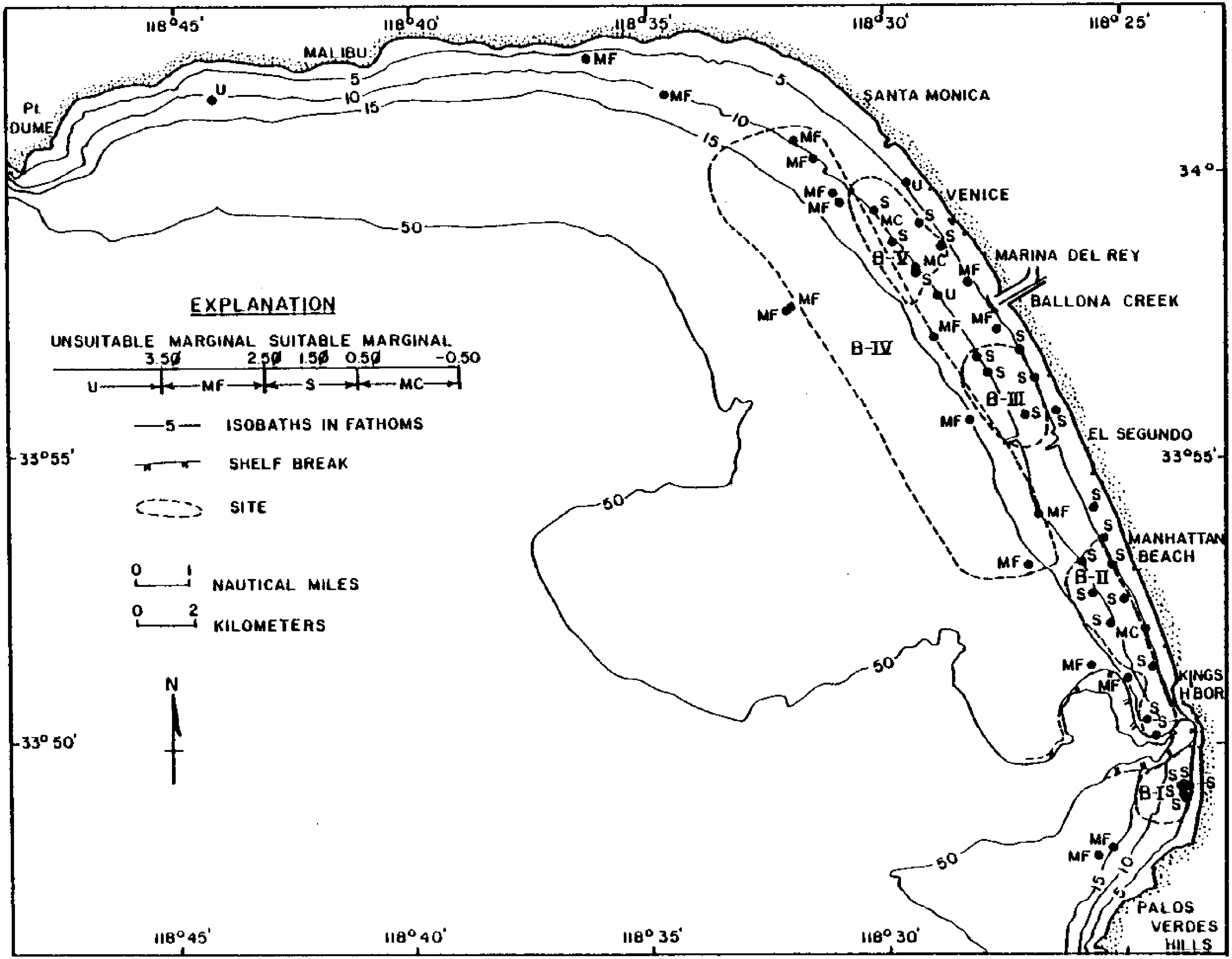

Figure 2. Map showing the location of major sand and gravel bodies (B-I through B-V) along the inner Santa Monica shelf in southern California.

(2) The Santa Monica Bay deposits are closer to local markets than most other production districts. Due to this locational advantage, a higher F.O.B. price may be charged.

(3) The deposits are close to shore, which reduces the capital outlays needed as well as the operational costs.

(4) Water depth in this area is from 5 to 15 fathoms. Dredging from this relatively shallow depth decreases the capital outlay.

(5) The quantity of material is large in three of the four deposits. This quantity is enough for a long-term excavation project.

(6) The quality of material is relatively good, so it would increase the efficiency of processing, reduce the time involved, and, in general, decrease the operational costs.

Approximately 16 acres of land is needed for an onshore processing plant which should be obtained prior to the operations in order to install necessary equipment and provide offices and other requirements. This matter will be discussed at a later point.

Environmental problems associated with offshore mining differ from those of land-based mining. Removal of a large quantity of material form the bottom of the ocean would affect the topography of the sea bottom (9). Such changes could alter the patterns of sediment transport, the local wave and current climate, and the rate of beach erosion. Dredging also generates water turbidity and suspends fine sediment in the water column.

Southern California beaches are important to California residents in particular and to all Americans in general. They are nationally known for the recreation they provide. The economy of the shoreside towns depends on visitors. The existence of sand and gravel processing plants on the beaches could reduce the satisfaction and enjoyment of visitors, lead to declining numbers of visitors, and damage to the local economy.

The Santa Monica Bay area is a residential district with popular beaches. Construction of an industrial plant that may damage the water quality, the environment and the economy in such an area would be strongly opposed by local residents and environmentalists. The fisheries industry might also suffer from dredging unless adequate protective measures were taken.

A marine project permit acquisition in southern California is an exhaustive and time consuming procedure. Such an application must be considered by numerous local and state agencies. A recent count by some companies in the Southern California Rock Products Association has indicated that there are 64 agencies or governmental bodies monitoring the mining industry of southern California (13). The Resource Agency of California, Environmental Protective Agency, and several other organizations have taken strong positions against dredging activities offshore of the southern California beaches unless the effects of dredging on the water quality, on the marine biota and the long term effects on associated natural environment are known (22).

Model Specifications

The model consists of two related parts: an economic part and a technological part. Based on an industry survey, the conclusion was reached that an average producer of sand and gravel in southern California produces about 1.75 million tons of material per year. Here, we allow the production to vary between 1.5 to 2 million tons per annum.

Technological Specifications - Inasmuch as the production is allowed to vary from 1.5 to 2.0 million tons per year, equipment should be obtained to satisfy a 2 million ton production capacity. Assuming the work schedule consists of one shift a day, 8 hours per shift, 5 days a week, 50 weeks a year, the average production rate of the equipment should range from 750 to 1,000 tons per hour.

The market-desired sand and gravel for combination for construction uses is taken to be 45% sand and 55% gravel and the deposit is assumed to carry 65% sand and 35% gravel. Based on these assumptions, some 37% of the materials dredged are not useful for construction aggregate. Thus the actual production rate should be between 1,200 to near 1,600 tons per hour. Maximum dredging depth is 200 feet and dredging is done by a hopper dredge (trailing suction) equipped with a 22 inch diameter pipe. The horsepower requirement is about 2,000 b.h.p. The material is transferred to the shoreside plant for futher processing and distribution. The distance to shore is 4 miles on the average and the one-way trip takes about 30 minutes.

The barges are equipped with self-discharging equipment with a maximum unloading rate of 1,000 tons per hour. To keep dredging and flow of material continuous, a three barge fleet, two 1,000 ton capacity barges and one 500 ton capacity barge are required.

The inland distance to the processing plant is assumed to be 0.20 mile. A belt conveyor transports the dredged material over this distance to the plant. The life of all equipment is assumed to be 20 years and they depreciate at a fixed rate on a straight-line base. The scrap value of all equipment in year 20 is taken to be zero.

It is also assumed that the value of land appreciates at a rate equal to the market rate of interest so that the producer will neither gain nor lose on the capital invested in land. Inasmuch as the offshore operations do not damage the land and the net loss on the capital invested in land is zero, this outlay will not be considered further in this model.

Economic Specifications for Models I and II - Two economic models based on different assumptions will be presented.

The F.O.B. price of material for 1.5 to 2 million tons is assumed to be $2.45 per ton. In Model I, the difference between unit price and unit operating cost of output is taken to remain constant and, as a result, the annual net income of the producer will remain constant throughout the length of the project. The tax rate on net taxable income is assumed to be 55% and the capital is fully invested in the beginning of the project. The average market rate of interest is taken to be 10% (Appendix A).

In Model II, the price of sand and gravel is allowed to increase at a rate of 5% annually. The labor cost at 7%, fuel cost at 10%, onshore processing cost at 5%, and maintenance and miscellaneous costs rise at a 5% rate per year. Insurance and local tax payments per ton of sales are assumed to stay constant over the life span of the project. The result of the assumptions are similar to those of Model I.

It is very ambitious to claim that the cost evaluation of a project such as this is exact. The variety of equipment and its special technical characteristics makes it difficult for an economist to choose which is best, or which does the most exact job. Current literature and concerned industrialists were consulted to obtain a better cost evaluation.

Table 3 summarizes our findings.

Revenue and Rate of Return

Revenue estimation under Economic Model I is listed in Table 4 and for Economic Model II in Table 5.

The internal rate of return under Model I is about 2.5% for the 1.5 million tons assumption and about 4.5% for the 2 million tons assumption. In the framework of Model I, given the constant price of $2.45 a ton, the annual quantity of sales should rise to near 4.5 million tons, or given the constant annual sales of 1.5 million tons, the price should rise to over $4.25 a ton, to bring a rate of return of 10% for this case. If the annual sales is 2 million tons, the price has to rise to about 3.81 per ton to change offshore mining of sand and gravel to an economically feasible project.

In Model II, the rate of return is about 5.5% under the assumption of 1.5 million tons and approximately 7.5% for 2 million tons production assumption. These rates are below the assumed 10% market rate of interest. Assuming everything remains constant, the annual sales should rise to 2.9 million tons to make the project an economically feasible one.

Summary

The internal rate of return obtained in the models presented is below the average market rate of interest (10%). Hence, under the current market conditions assumed in the model, offshore mining of sand and gravel for construction aggregate is profitable but below the current market rate of interest.

Model for Conventional Onshore Mining

General Statement

Land-based mining of sand and gravel is a well established business in the United States and in California. Local producers are familiar with the characteristics of the local market, with the technology available, and with the governmental agencies with which they have to deal.

Table 3. Cost estimation.

CAPITAL COST - Current Value	(million dollars)
Dredging Equipment	2.7
Hauling Equipment	4.3
Processing Equipment	5.4
Subtotal	12.4
Contingency 10%	1.24
Total	13.64
Life of Capital	20 years
Depreciation rate per year	$0.682 million
Value at Year 20	0
OPERATING COST - Dollars Per Ton	
Labor - Offshore	0.40
Fuel	0.08
Insurance	0.36
Landing and Processing	0.70
Maintenance	0.05
Local Taxes	0.20
Miscellaneous	0.05
Total	1.84

Table 4. Revenue estimation of Offshore Economic Model I.

Price Per Ton	$2.45
Operating Cost Per Ton	1.84
Net Operating Income Per Ton	$0.61
Total Net Operating Income	
a. 1.5 million tons production	$ 915,000
b. 2 million tons production	1,220,000
Depreciation $ per year	$682,000
Net Taxable Income	
a. 1.5 million tons production	$233,000
b. 2 million tons production	538,000
Tax Rate - 55% on Taxable Income	
Total Net Income Per Year for 20 Years	
a. 1.5 million tons production	$786,850
b. 2 million tons production	924,100

Table 5. Revenue estimation of Offshore Economic Model II.

YEAR	F.O.B. PRICE Per ton - 5% Increase per year	Operating Cost per ton	Net Income Flow - 1.5 million tons production per year	Net Income Flow - 2 million tons production per year
1	2.45	1.84	786,850	969,100
2	2.59	1.91	820,600	987,100
3	2.70	1.98	861,100	1,023,100
4	2.81	2.06	888,100	1,068,100
5	2.97	2.15	929,612	1,113,100
6	3.11	2.24	968,087	1,158,100
7	3.26	2.33	1,002,850	1,212,100
8	3.42	2.43	1,043,350	1,266,100
9	3.59	2.53	1,091,275	1,329,100
10	3.76	2.63	1,137,850	1,392,100
11	3.95	2.76	1,178,350	1,446,100
12	4.14	2.89	1,218,850	1,500,100
13	4.36	3.02	1,266,100	1,581,100
14	4.57	3.18	1,299,850	1,608,100
15	4.79	3.33	1,352,398	1,671,100
16	5.02	3.48	1,401,100	1,743,100
17	5.26	3.65	1,455,100	1,815,100
18	5.52	3.83	1,502,250	1,878,100
19	5.79	4.02	1,556,350	1,950,100
20	6.07	4.26	1,583,350	1,986,100

Sand and gravel supply for Los Angeles County is obtained from onshore deposits. Total reserves of sand and gravel in the four major production districts discussed previously are currently over 620 million tons. The average annual sale of these districts is near 21 million tons. Under the current social and economic conditions, the available reserves will last for at least 25 more years. If the price of the material increases sufficiently, some known deposits also may become new potential reserves.

Mining in some plants is done by electrical shovels and draglines. Some companies use bulldozers and front end loaders to excavate the material; and in some areas, such as Santa Clara River District, explosives are used (7). Excavated materials are then transported to the plant using a conveyor belt, trucks or both. The sand and gravel is subjected to conventional crushing, sizing, and washing to produce both washed and unwashed products.

Model Specifications

Technical Assumptions - To keep consistency between the offshore and onshore models, we again assume that final product capacity is 2 million tons per year. Production depends on the demand and would vary between 1.5 to 2 million tons annually. The work schedule is also taken to be the same as in the offshore model. It is assumed here that 90% of the excavated material is usable for construction aggregate, so a maximum of 1,100 tons per hour would be mined to produce a maximum of 1,000 tons of marketable material. The equipment used in the mining phase includes a 6 yd^3 bucket-size electrical shovel and a dragline. The haulage is done by trucks and a belt conveyor. The processing plant is taken to be of standard size and shape.

Economic Assumptions - Economic assumptions of this model are taken to be the same as those made in the offshore case, except here we assumed that the difference between the operating cost per ton and the F.O.B. price per ton of sand and gravel is fixed throughout the length of the project. This assumption would keep the net annual income of the producer fixed during the life of the plan.

Cost, Revenue and Net Income

The total capital cost is estimated to be 7.964 million dollars paid at the beginning of the project. The life of the project is 20 years, so the depreciation cost is $398,000 per year. The operating cost is estimated to be near $1.55 per ton, the F.O.B. price is $2.94 per ton, and the tax rate on profit is taken to be 55%.

Table 6 represents the estimated cost, revenue, and net income of this model.

Rate of Return

If the average annual demand of sand and gravel is such that only 1.5 million tons of this commodity can be sold at the price of $2.45 per ton for 20 years, the internal rate of return for such a project will be about 8.7%. If the average sale is 2 million tons per year for 20 years, given the same F.O.B. price of $2.45 per ton, the internal rate of return turns out to be 11.5%.

Project Evaluation

Given the assumptions that the average market interest rate is 10% and that the annual sales is 1.5 million tons, a new producer should not enter the market. Under assumption of 2 million tons of annual sales, a new producer will make a net annual profit of about 1.5% over his capital cost by entering the sand and gravel production market.

If the price and the operating cost both rise with the same rate as the offshore case, even under the assumption of 1.5 million tons annual sales, the producer would gain by investing the initial capital outlay and starting the production.

Although much progress is being made through premining planning, the sand and gravel industry continues to have problems with environmental controls, land-use conflicts, and reclamation practices. Major environmental considerations that must be dealt with in mining and processing sand and gravel are emission of particulate matter into the air, processing water discharges, and noise abatement. Moreover, employee and public health and safety are of a major concern (7).

The transportation of sand and gravel has not, in general, resulted in major environmental problems although the noise and traffic of trucks has been partly responsible for objection to pits and quarries in and near urban communities (13).

Table 6. Cost, revenue, net income stream and the rate of return for onshore economic model.

COST		
Capital Costs: (in million dollars)		
Mining Equipment		1.12
Hauling and Transportation Equipment		0.62
Processing Equipment including Plant Constructions		5.50
Subtotal		7.24
Contingency 10%		0.724
Total		7.964
Equipment Life		20 years
Depreciation rate	10%/year	$398,000
Operating Cost		$1.55/ton
Tax Rate	55% on taxable income	
REVENUE		
F.O.B. Price Per Ton		$2.45
Net Operating Revenue Per Ton		$0.90
NET INCOME		
Income Per Year for 20 Years		
a. 1.5 million tons sale		$ 826,400
b. 2 million tons sale		$1,028,900

The industry should make effective efforts to reduce air and water pollution, reclaim pits after the operation is complete, and to improve the overall appearance of the operating mine, processing plant and transportation facilities.

Measures have been taken to minimize the social cost of the sand and gravel operations in the Los Angeles County production districts. The operations in most areas are sufficiently removed from populated areas that they are not a significant source of irritation to the public. Normal operating procedures are followed, such as controlling dust, enclosing the property with a fence, and confining production to daylight hours. In some areas, most formerly active pits are being used for sanitary landfill or other usages (7).

On the other hand, there are social benefits to the existence of the sand and gravel industry. This industry is essential for construction activities. Any effort by governmental agencies which confines the industry and increases its operating cost will yield an increase in the price of aggregate, because there is no totally suitable substitute for sand and gravel. Most of this increased cost will be transferred to consumers. The industry has created many jobs. It demands a large volume of equipment which, in turn, increases the production of other industries, such as the steel industry, through which even more jobs are created. In general, the aggregate demand of the whole economy is thus increased.

In this study, the environmental and social costs of onshore mining have not been separately computed. However, the operating cost includes the net social cost of these activities.

Comparison of Offshore and Onshore Model

Due to the nature of Santa Monica Bay are, the social cost of offshore mining in this area may turn out to be higher than that of our conventional onshore model. This cost has been partly included in the operating cost of both models. Mainly because of the high cost of equipment to dredge and transport sand and gravel from the mining site to the processing plant, the initial capital outlay required for an offshore operation becomes more than 70% higher than that of an onshore plant. Labor costs, insurance costs, fuel costs, and social costs are more for offshore mining than for onshore. The total average operating cost for offshore mining becomes almost 20% higher than the onshore alternative. Due to these factors, under the same market conditions, the rate of return for offshore ranges from 2.5 to 4.5 percent (Model I) and for onshore from 8.7 to 11.5 percent, depending on the production level.

Offshore mining of sand and gravel is an alternative to the onshore excavation of this commodity. If both activities are operating under the same social conditions and being affected by similar regulations, the question of "at what point offshore mining becomes profitable" is irrelevant. This profitability should be regarded as a relative, not an absolute term. A more advanced and cheaper technology, new governmental regulations, lower interest rates, a higher price of sand and gravel, or a demand increase may cause offshore mining to become a more profitable endeavor. However, these factors also may affect onshore producers and leave the same gap between the rate of returns of these two alternatives.

As this study shows, given the production limits, greater sales yield a higher rate of return. An industry survey confirms this result. The general trend of the industry is towards larger and more advanced plants and larger deposits. In a period form 25 to 30 years, the four major onshore production districts in Los Angeles County all expect to exhaust their supply of saleable material. From a sedimentologic viewpoint, only site B-V contains an appreciable quantity of material suitable for construction aggregate; thus, the vast majority of offshore sand bodies in Santa Monica Bay are best suited for beach nourishment programs. Offshore production should be regarded as a potential alternative source for construction aggregate for the next 25 to 30 years; after that, the selection of mining sites depends on the availability of new onshore reserves and the prevalent economic conditions as well as environmental and social attitudes.

OFFSHORE MINING FOR SUITABLE MATERIAL FOR BEACH RESTORATION AND REPLENISHMENT

General Statement

Beach erosion has been recognized as a serious threat to many coastal communities in southern California. The attention of local, state, and federal agencies has been directed toward understanding this problem and trying to find some reasonable cure for it. Beach restoration and replenishment is considered as a possible way of increasing the life span of the valuable southern California beaches.

Inland sources of sand and gravel can, in some areas, serve as the primary source of developing material for artificial beach nourishment; however, such usage can be quite costly. For some beach erosion control projects in southern California, dry haul of sand has been employed. The cost per cubic yard for this sand has ranged from $0.80 to $2.00 per cubic yard (20). The alternative source for beach replenishment are offshore deposits. In many cases, the latter may be more economical. Santa Monica beach is believed to be one of these cases. Annually, an average of 260,000 cubic yards of sand are lost along the Santa Monica beach coastline (18). The direction of the sand movement is down the coast. Due to the nature of the beach nourishment and because its benefits are received by the entire society, beach replenishment could not be done by a private enterprise whose goal is to earn a profit, unless governmental or local organizations financially support the effort. Here, it is assumed that the government contracts an existing enterprise to accomplish a given project. This way, the problems with environmentalists and the local fishing industry, as well as the problems associated with the acquisition of an offshore dredging permit are minimized.

The environmental and social cost-benefit analysis of the beach replenishment case is highly complicated. The basic social costs are the damage to water quality, changing the environment, and affecting the marine biota due to the dredging activities. The State Water Quality Control Agency, the fisheries industry, and the Environmental Protection Agency are the principal monitoring agencies regarding offshore mining. On the other hand, the benefit of such a project may be high as well. Preventing serious damage to the beaches clearly genefits both the users and the local communities. To estimate the net cost or benefit of this type of project, the possible damage to the fisheries industry, to water quality, and to the environment should be measured; however, the enjoyment of tourists and residents and the improvement in the economy of the local communities as a result of the nourishment also should be considered.

Recently, the Army Corps of Engineers has started a monitoring program in the replenished Surfside-Sunste beach area; considering the long-term effects of the dredging activities in that area. The value of the benefits is still unknown (21).

At the level of our information, these costs and benefits cannot be measured properly; thus we will disregard social costs and benefits in the proposed model and consider only the commercial cost of such a project.

Model for Santa Monica Beach Area

The average offshore sand deposit in Santa Monica Bay (B-I, B-II, and B-III in Fig. 2) contains from 33 x 10^6 yd^3 to 71 x 10^6 yd^3 of sediment. These deposits have an average width of 1.1 miles, an average length of 2.5 miles, and lie approximately 0.8 mile offshore.

We assume that the contract calls for the placement of 1.56 million cubic yards of suitable material along the Santa Monica Beach area. The duration of plan is taken to be one year. This amount would account for a 6 year loss of material in the beach area (1.3 million cubic yards removed during previous 5 years and 0.26 million cubic yards removed during the operation year). If 90% of the dredged material is suitable or marginally suitable for beach nourishment, a total of approximately 1.75 million cubic yards should be dredged. Under the same work schedule as in the offshore mining model, an average dredging rate of 875 cubic yards per hour is required. Due to weather conditions, dredging, transport and deposition is not always possible. Thus we must assume that the dredging rate can be increased to a maximum of 1,500 cubic yards per hour to compensate for the time wasted.

The dredging is done with a hydraulic suction cutter head dredge, equipped with a 26 inch diameter pipe. The average pump speed is 310 r.p.m., the horsepower required is near 3,800 b.h.p., and the maximum length of the discharge pipe is taken to be about 3,000 yards. The average number of employees is estimated to be 40 persons per shift, and their average wage about $8.00 per hour. This would yield a total labor cost of $640,000 annually. The onshore plant is assumed to be provided by the government (contractor) and the company owns the equipment. Hence, only the depreciation rate on equipment (and no rent on land) is considered. However, the company has to move all of the required equipment to the work area and to its headquarters again. Installation and moving costs are technically called the "mobilization and demobilization cost." This cost is estimated to be nearly $700,000.

Table 7 represents a summary of the estimated cost of this operation.

Project Evaluation

We assume that if the producer had employed its equipment on any other project, the maximum rate of profit he would have earned was equal to the conventional 10% interest rate. Thus, he would accept the job if and only if the expected rate of profit is at least 10%.

According to the cost estimation made, an income of about $1.87 per yd^3 is required to satisfy the 10% rate of profit assumption.

Table 7. Cost estimation for Beach Replenishment Model.

Depreciation Per Year (Total)	$350,000	
Depreciation Per Cubic Yard		0.22
Labor Cost (Per Cubic Yard/Year)	$0.41	
Fuel, other Materials and Supplies	0.18	
Maintenance Cost	0.05	
Mobilization and Demobilization Cost (installation, moving and moving insurance)	0.43	
Insurance (equipment)	0.18	
Royalty and Local Taxes[1]	-0-	
Miscellaneous	0.05	
Total	$1.30	
Tax on Net Profit 55%		

[1]Assuming the land is awarded by the government and no royalty paid.

Note: Since the company owns the equipment, there is no capital outlay involved. Hence, only depreciation and insurance paid for the equipment are taken into consideration.

CONCLUSIONS

Sedimentologic studies along the inner Santa Monica shelf have demonstrated the presence of five major bodies of sand and gravel. Sites B-I, B-II, and B-III contain from 99×10^6 yd^3 to 214×10^6 yd^3 of dominantly sand, of which 55% is suitable and 80% suitable or marginally suitable for beach restoration and replenishment. Site B-IV contains about 325×10^6 yd^3 of mostly silt and very fine- to fine-grained sand, which are of marginal quality for beach nourishment. Site B-V contains from 18×10^6 yd^3 to 66×10^6 yd^3 of sand and gravel, of which approximately 72% is suitable for construction aggregate.

Under current market conditions, the internal rate of return for an onshore economic model is from 8.7% to 11.5% for a new producer, depending on the level of sales and different market assumptions. For the offshore model, this rate ranges from 2.5% to 7.5%, again depending on the level of sales and different market assumptions. Offshore mining of sand and gravel is profitable, but below the current market rate of interest (10%). The cost of replacing 1 yd^3 of sand to a damaged beach is approximately $1.52, therefore a commercial enterprise should be offered at least $1.87 per yd^3 to undertake such a project.

Combined sedimentologic data and current economic conditions indicate that beach restoration and nourishment are the best uses for the offshore sand deposits along the inner

Santa Monica shelf at the present time. Future market conditions as well as changing social and environmental attitudes may raise the profitability of offshore mining for construction aggregate above the prevailing market rate of interest. Until that time, offshore mining for beach replenishment might be encouraged to make use of this voluminous marine resource while conserving onshore sand and gravel deposits, which generally are better suited for construction aggregate.

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APPENDIX A. The average expected rate of interest.

Interest rate is one of the most volatile and sensitive economic indicators. It was discussed on page 13 of this paper that a project for which the estimated internal rate of return is higher then the expected market rate of interest is called "economically profitable". The expected market rate of interest is, however, the average rate anticipated to hold in the future. In our study the length of the project was assumed to be 20 years.

The first step was to predict the average interest rate for the purpose of comparing economic models. This was an extremely important step, because the feasibility of the project depends on the accuracy of such projections. The main problem is that there is no unique market rate of interest to use for the purpose of forecasting. Rates paid on saving deposits, on one year treasury bill (T. Bill) accounts, and on five year treasury bill accounts normally differ from one another and do not follow any specific trend. Table A-1 depicts these points.

To overcome this difficulty and to increase the level of accuracy in our predictions, the following steps were taken to obtain an average expected future rate of interest.

1) The rate paid on 3 month treasury bill accounts was assumed as the lower bound proxy to the money market interest rate.
2) The rate paid on 12 month treasury bill accounts was taken as a proxy to the middle range value for the money market interest rate.

Table A-1. Comparison of interest rates paid for various investments from 1965 through 1978.

YEAR	Rate Paid on 3 Month Treasury Bill Accounts	Rate Paid on 9-12 Month Treasury Bill Accounts	Rate Paid on 3-5 Year Treasury Bill Accounts	Maximum Interest Paid on Saving Deposits by Banks
1965	3.95	4.09	4.22	4
1970	6.46	6.90	7.37	4.5
1972	4.07	4.86	5.85	4.5
1975	5.84	6.70	7.55	5.00
1976	4.99	5.84	6.94	5.00
1977	5.27	5.53	6.85	5.00
1978	7.19	7.58	8.83	5.00

Source: "Statistical Abstract of the U.S.", U.S. Department of Commerce, 1970-1979 volumes.

3) The rate paid on 3 year treasury bill accounts was taken as a proxy for the upper bound limit to the money market interest rate.

4) The time series of the conventional lower, middle and upper ranges of the interest rate were collected for the period of 1955-1978 using the collected data. The future values of all three series were econometrically estimated using ordinary least squares method.

5) An average of the lower, middle and upper boundary values of the interest rate were calculated for the next 20 years. These values were calculated to be 8.75%, 9.25% and 10.55% respectively. Given the uncertainty of the future, a 10% average expected future rate of interest was selected. In this process no risk premium was taken into account.