CHAPTER 78

DESIGN OF A SMALL TIDAL INLET

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ABSTRACT

Estero Punta Banda on the Pacific Coast of Baja California was to be improved and stabilized as a small boat harbor by the construction of twin jetties. The throat area-tidal prism relationship at this entrance agreed with that of other inlets on sandy coasts in equilibrium. This throat area was retained in the jetty spacing. The major question to be resolved was whether to retain the entrance in its present position at the north end of the lagoon or to cut a new entrance at the south end. The former position was chosen.

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Estero Punta Banda is a small tidal lagoon located along the shore of the Bay of Todos Santos on the west Coast of Baja California, about sixty miles south of the Mexico-United States border and seven miles south of the Port of Ensenada. This lagoon is formed by a sand spit (Punta Estero) which extends northward from the headland (Punta Banda) which forms the south boundary of Bahia Todos Santos. Fig. 1 is taken from the survey of the U. S. Ranger, made in 1886. Fig. 2 is an aerial photograph of the lagoon and adjacent beaches. Fig. 3 shows the existing entrance channel and the sand spit to the south.

The generally good weather and warm waters of Southern California are favorable to all-year boating, and the boat population has grown rapidly in recent years. The number of small boats based south of Santa Barbara is estimated to be more than a quarter of a million. Berths for small boats are scarce; most of the land adjacent to the small boat harbors has been subdivided and developed as building lots. Attractive overnight, cruising opportunities are limited, by weather and sea conditions and by the availability of harbors, to the shore and offshore islands between San Diego and Point Conception. Extension of the convenient and safe boating area southward along the coast of Baja California, ultimately as far as La Paz, is a development which would benefit both Mexico and the United States. Estero Punta Banda is within small boat day-cruising range of Southern California.

The Port of Ensenada has been developed primarily for fishing and general cargo. A breakwater gives full protection of the anchorage area and wharves against waves from north through west. Protection against waves

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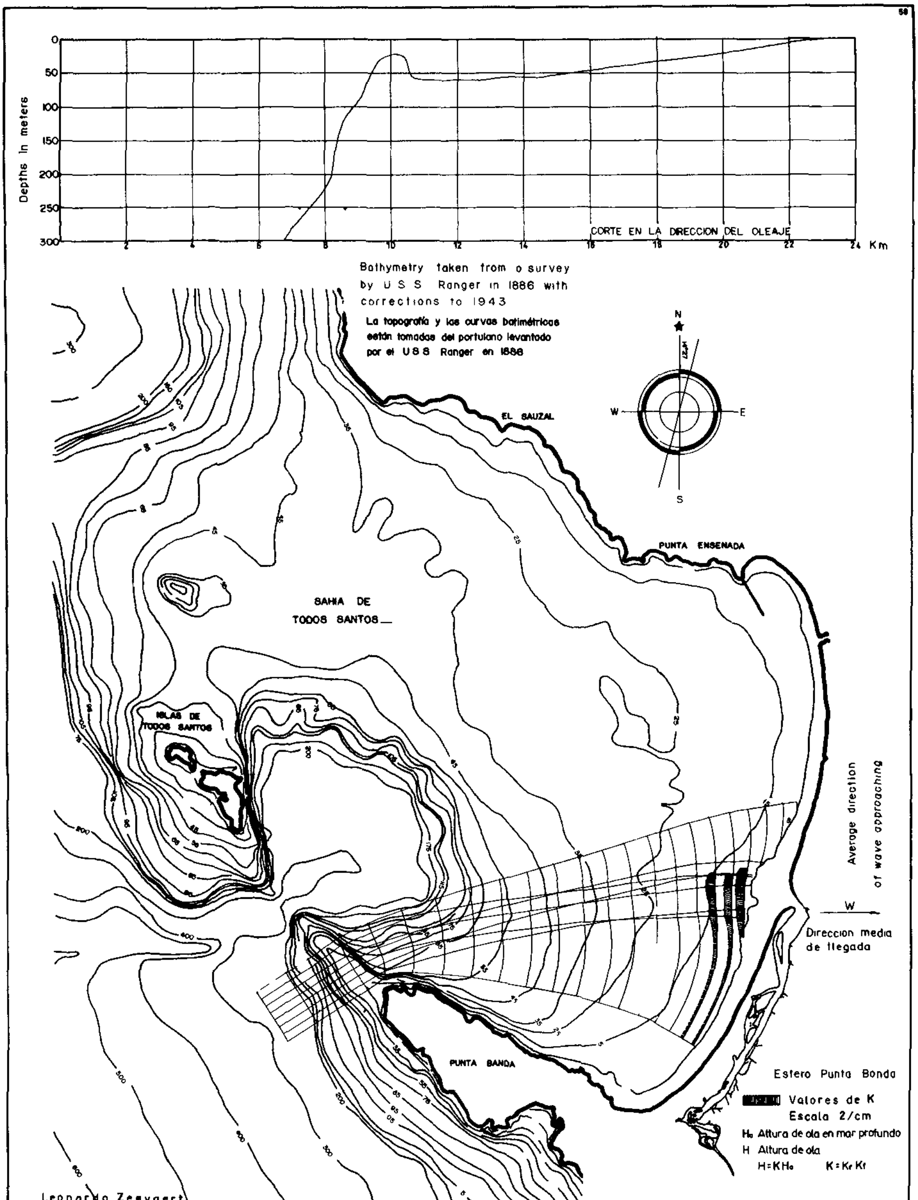

FIG No 1

WAVE REFRACTION DIAGRAM

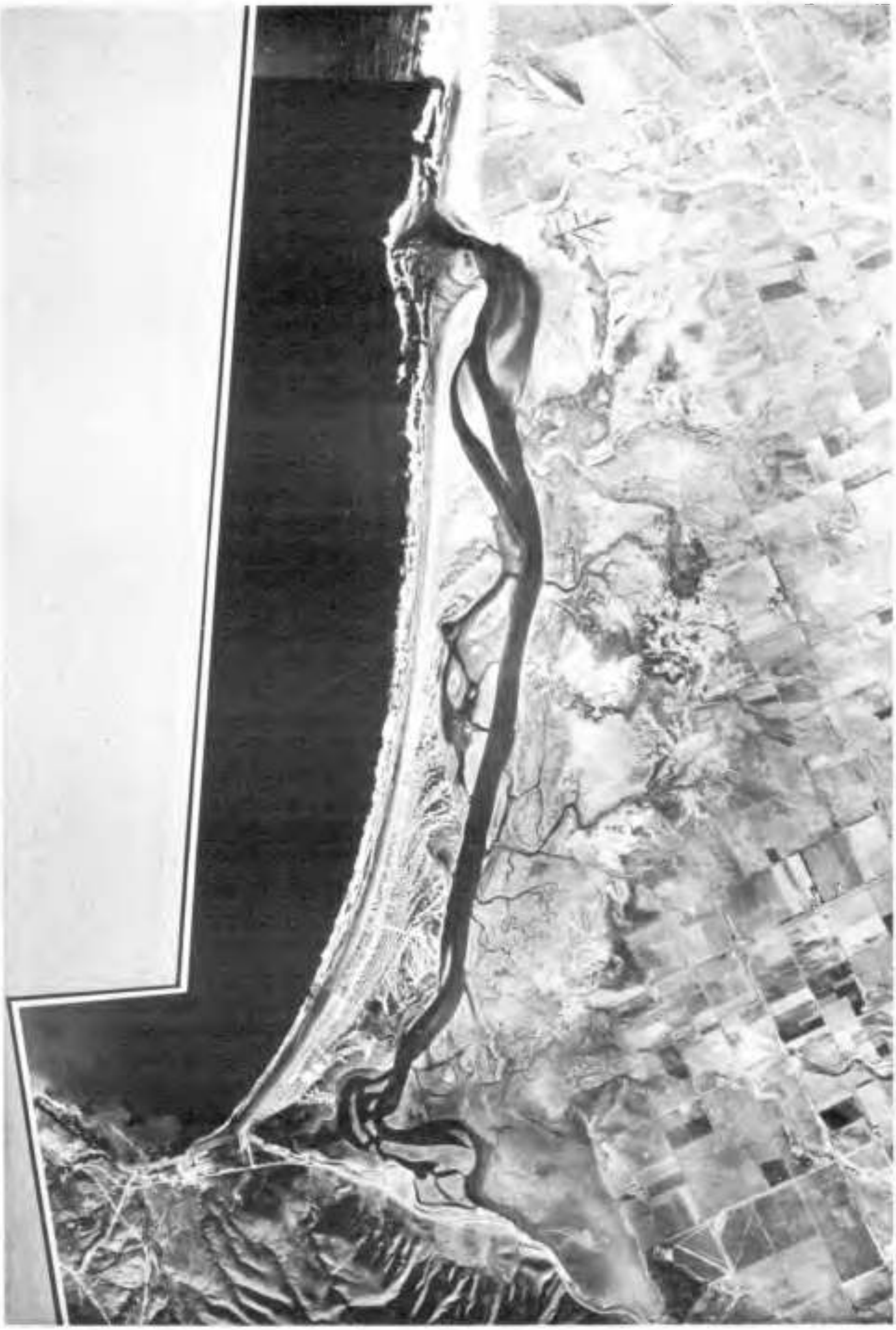

FIG. No. 2

Page 4 - Fig. 3 ENTRANCE CHANNEL

from the south-westerly quarter is adequate for large vessels but not for small pleasure craft. The area available for anchoring or berthing small boats is limited; the commercial harbor may be enlarged in the near future to accommodate the increasing traffic and tonnage of cargo ships and this will further decrease the area available for pleasure craft.

Estero Punta Banda is the first inlet south of the International Border suitable for development as a small boat harbor. The entrance channel, which has not been improved, is used infrequently because the bar channel shifts position and the controlling depth is inadequate. A small resort hotel at the north end, a gun club near the south end, and farms along the mainland side of the bay are the only developments of consequence in the adjacent area. The proposed development, of which the improvement and stabilization of the inlet channel is an essential feature, included a yacht anchorage and marina, a 288 room resort hotel, and a subdivision of waterside building lots. Fig. 4 is the immediate plan for the development of the bay.

The objective of this study was to develop a design which would improve and stabilize the entrance channel into Estero Punta Banda, preserve the existing interior channels which are in good condition, and avoid both erosion of the shoreface of the sand spit, Punta Estero, and wave damage to the developed property at the north end of the lagoon. The shores of the lagoon are almost completely undeveloped and a coordinated plan of development could both increase the low water area and the tidal prism and could also increase the usable upland; the proportions of the entrance channel should be such as to provide a navigable depth of 4 m below MLLW with the present tidal prism and later to accommodate an increased tidal prism. Circumstances of financing and jurisdiction make it desirable to design the channels and structures so as to require a minimum of maintenance.

Estero Punta Banda lies at the seaward edge of the Maneadero Valley which was formed by submergence of a block lying between the rocky peninsula of Punta Banda and the upland north of the inlet. Scarps still mark the location of the two fault lines. The valley was once a deep embayment which has been filled in an earlier geological era by sediments from the San Carlos and San Miguelito water-sheds. These streams rise in forested, mountainous areas, where the run-off is substantial, but their flows are almost completely absorbed by strata of fissured and permeable extrusive igneous rocks in their lower reaches. There is no evidence of substantial flow into the bay in recent years and consequently, no provision has been made in the plan to divert flood flows and sediment, as has been found necessary in similar inlet developments in Southern California.

Punta Estero, the sand spit enclosing the bay, has grown northward from Punta Banda during recent geological times. Evidence of this growth is discernible in Fig. 2 which shows dune lines and vegetation marking earlier positions of the inlet. The north end of the sand spit is pressing the inlet channel against the consolidated upland on its north side, which is formed by the cliff of the northern fault line of the Valley of Maneadero. The shoreface of the spit, Punta Estero, appears to have reached an equilibrium position, but historical surveys are not available to substantiate this conclusion.

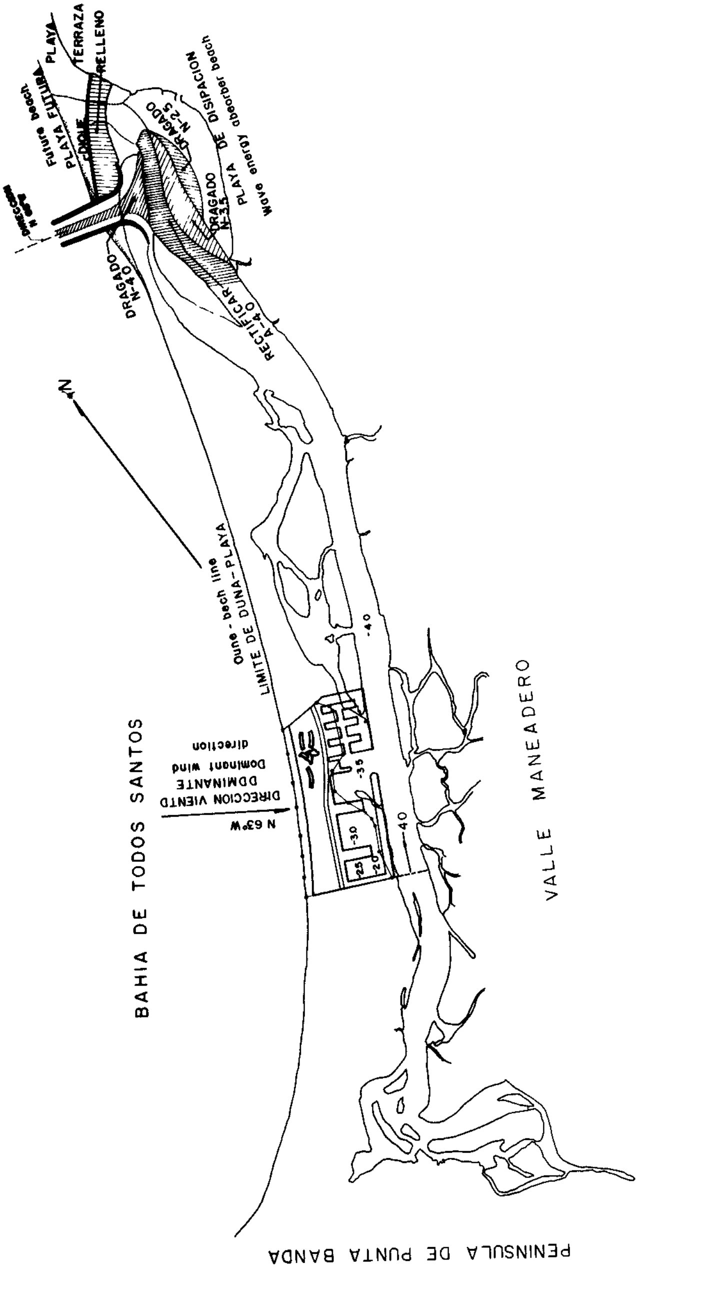

Fig. 4 - PROPOSED ENTRANCE AND IMMEDIATE DEVELOPMENT

The north face of the headland Punta Banda, extending seaward perpendicular to the base of the sand spit Punta Estero, is being eroded and is supplying boulders, coarse gravel, and fine sand to the base of the spit. Fig. 5 shows the shoreface of the spit at its junction with the headline. Fig. 6 shows the size of the beach surface material as a function of position along the beach. A study of the most frequent diameter with very little variations on either side of the entrance channel. However, a slight reduction in diameter of the surface material occurs at the sharp bend of the sand spit beach close to Punta Banda Peninsula at points 3, 4 and 5, Fig. 6. At these locations gravel and boulders are evident on the beach surface, Fig. 5. The wave refraction diagrams show that wave acti' is considerably less active in this area (see Fig. 1).

The configuration of Todos Santos Bay is such that the Punta Banda inlet is exposed to waves between N 55° W and S 57° W. Refraction diagrams were drawn for waves approaching in this sector for wave periods of 15, 10, 8 and 5 seconds. From these diagrams the directions of the waves at the inlet were determined for each assumed sea and swell wave direction. It was found that the bottom contours around Todos Santos Island would cause some focusing and intensification of waves. In order to select the direction of the jetties to stabilize and protect the entrance to the lagoon, the available data[1] were reviewed. Wave directions considered in this study were:

a).	Extraordinary strong wave action	N 73° W
b).	Medium and strong seas	N 61° W
c).	Medium and strong swells	N 65° W
d).	All wave action	N 62° W

This study yielded N 68 ± 5° W as the best alignment for small-boat operation of the jetties at the entrance channel to the lagoon. This direction coincided with the direction of the dominant wind and it is very nearly perpendicular to the general alignment of the sand spit.

There is no natural trap or other means of measuring the annual volume of littoral material reaching the base of the sand spit, Punta Estero. The headland is eroding slowly and must be contributing some material to the beach, but the rate of loss has not been established quantitatively. In addition to the wave data on the Sea and Swell Charts there were available wave hindcasts for an ocean station NW of Point Conception (Lat 35° 30' N, Long 122° W), about 400 miles distant from Estero Punta Banda. Using these data and the refraction diagrams, the northward and southward components of littoral transport were computed for points on the shore at the inlet and at the base of the sand spit[2]. The results were as follows:

[1] Atlas of Sea and Swell Charts Northeastern Pacific Ocean. Published by the U.S. Navy Hydrographic Office under the Authority of the Navy. H. O. Publ. No. 799-D.

"Wave Statistics for Seven Deep Water Stations Along the California Coast." Scripps Institute of Oceanography, La Jolla, California.

[2] Caldwell, Joseph M. "Wave Action and Sand Movement near Anaheim Bay, California." U.S. Army, Corps of Engineers, Beach Erosion Board, Tec. Memo. No. 68, February 1956.

Page 8 - Fig. 5 BEACH MATERIAL AT SOUTH END OF SAND SPIT

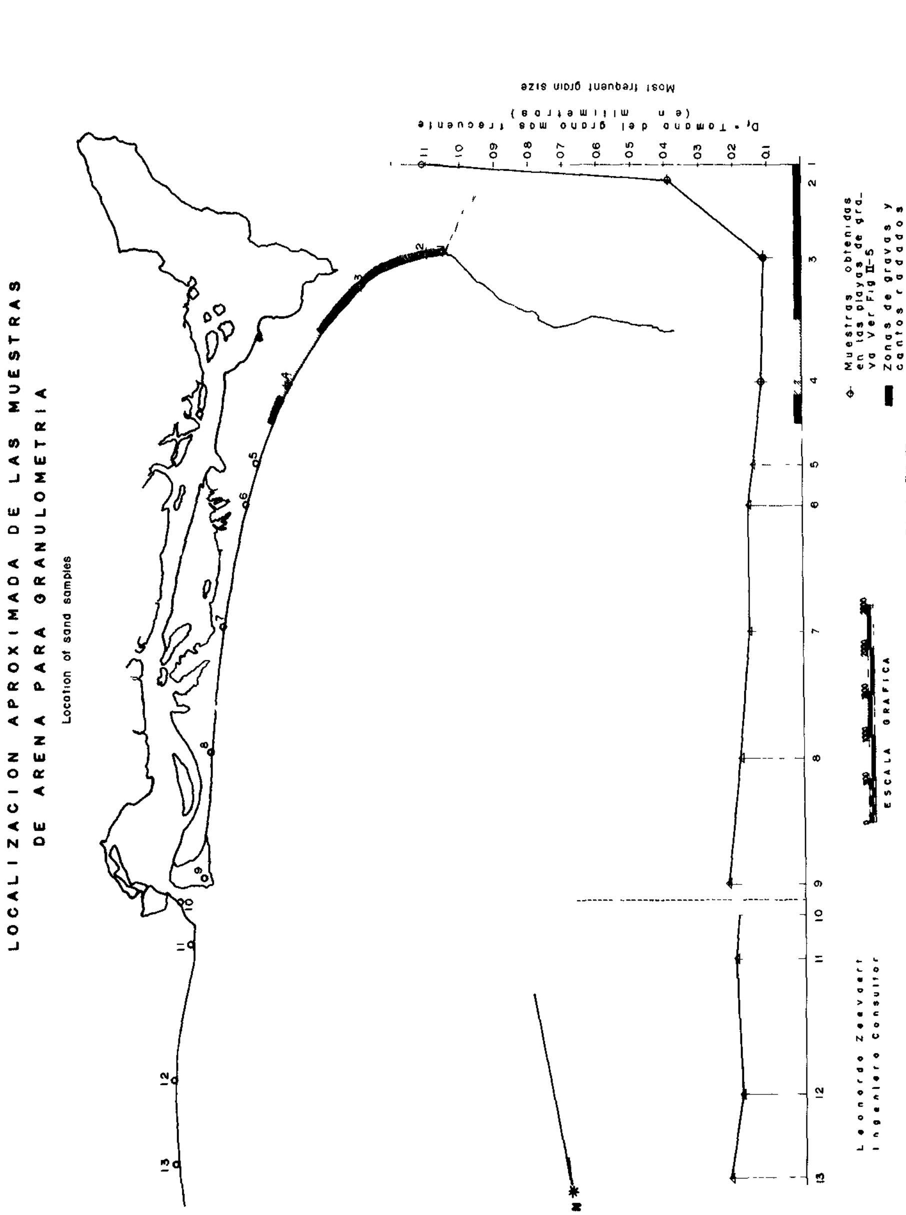

FIG No 6

Fig. 6 MOST FREQUENT GRAIN SIZE OF SAND ALONG SAND SPIT

Computed Littoral Transport (m^3/ year)

Location	Northward	Southward	Net Annual
South end of sand spit	273,000	40,000	233,000 North
Estuary entrance	273,000	247,000	26,000 North

These results are approximations because the relationship between wave energy and littoral transport is not known precisely and the probable error is large, the wave data available pertained to a distant station, and the refraction effect of Todos Santos Islands is considerable. However, two conclusions do seem to be justified, namely:

1) Sand movement northward along the sand spit at its junction with Punta Banda is not negligible, and this conclusion agrees with the evidence from materials on the beach and from the erosion of the headland.

2) Net annual northward movement at the location of the existing entrance is small.

Local wind data were not sufficiently detailed to permit calculation of the movement of sand from the beach into the lagoon. Winds are generally light, but even a light wind moves sand wherever vegetation has been removed. As an indication of the magnitude of wind drift, a wind of 16 mph at 5 m above the beach blowing 1 hour per day would transport 14,000 cu mts per year across the length of the sand spit. The actual net drift into the lagoon may be several times this figure.

The area of the lagoon is 2.6 Km^2 at mean lower low water; 10.7Km^2 at mean higher high water. The maximum dimension of the lagoon is 11.5 kilometers. The average diurnal range of tide in the ocean is 1.6 m; the minimum range, 0.7 m; the maximum range 2.6 m. Tide staffs along the channel in the lagoon, reading maximum and minimum levels on each tide, showed the ratio of the tide range in the lagoon to that in the ocean to be 1.03. The computed lag in tide between the mouth and the upper end of the lagoon, using $C = \sqrt{g \times d_{av}}$ is 46 minutes at MLLW. The observed lag of low water, between gages near the mouth and near the upper end was 43 minutes. These facts about the ratio of ranges and the velocity of advance show that the tide proceeds through the lagoon as a solitary wave with little reflection from the upper end and little effect of either friction or storage.

Surging or seiche action is a problem at many small-boat marinas. At Estero Punta Banda, there are no continuous tide gage records which would show the existence of absence of surging. The survey party which made the hydrographic surveys and observed the tide staffs in the months of June and July 1964, saw no indications of surging. The basic period of oscillation along the long axis of the lagoon is approximately 103 minutes at MSL. Transverse periods of oscillation range from 19 seconds near the entrance to 281 seconds at the pond at the upper end. Thus, some part of the lagoon might be in resonance with a wide range of exciting frequencies.

The tidal prism of the lagoon, the volume between MHHW and MLLW is 8.45×10^6 m^3. At the gorge, the area of the existing minimum flow cross-section below MSL is 520 m^2; the width at this section is 95 m at MLLW and 370 m at MHHW; the maximum depth at the gorge is 7.5 m below MLLW.

An important feature of the configuration of the estuary is that a preponderance of the surface area is located at the south end, especially at low stages. The tidal prism of this area must traverse most of the length of the channel during each tide, and this fact accounts for this very good natural channel and its maintenance.

Current velocities were measured at the gorge section by means of floats to determine the maximum surface velocity and to compare this velocity with the mean velocity across this section at the tide range and flow areas existing at the time of measurement. On a diurnal range of tide, the maximum surface velocity at the gorge is on the order of 1.14 m/sec and the mean velocity, 0.70 m/sec.

Hydraulic Design. Experience in similar situations in Southern California indicated that twin jetties would be required to stabilize the entrance channel to Estero Punta Banda.

There are two feasible locations for the entrance, one at the north end of the lagoon near the existing inlet channel and another, at the south end, adjacent to the headland Punta Banda. A choice between these two locations depends primarily on the magnitude and direction of the littoral transport of sand and the consequent condition of the shoreline after the jetties were in place, but other factors were considered. The advantages and disadvantages of the two locations were:

South End: Closing the entrance at the north end would permit access to the sand spit, Punta Estero, by road directly south from Ensenada without circling the bay. The refraction diagrams showed wave action to be lighter at the south end than at the existing entrance. Dredging the inlet channel would be more costly here because it would be longer and be dug in gravel and cobbles; more dredging would be required to create an adequate anchorage near the entrance. Although the rate of littoral transport from Punta Banda is probably small, the storage area south of the south jetty would also be small and would soon be filled, permitting whatever sand movement there is to enter the entrance. Furthermore interruption of sand movement by jetties at the south end would disturb in some degree the equilibrium of the sand spit. The tidal regimen of the interior channels would be altered drastically.

North End: Locating the improved channel at the north end, in substantially the natural location, would bring the least disturbances of the regimen lagoon and inlet. The improved channel must be moved a short distance south from the present location to protect the developed shore on the north side. Erosion either of the spit south or of the upland north is not likely, but if there is a greater littoral transport than expected, the adverse effect on the shoreline would be least with the entrance located here. This location is closer to the quarry for jetty stone if a trestle is built across the inlet. Somewhat greater intensity of wave action will occur here. Access to the spit by road around the lagoon is a disadvantage.

The choice was made to locate the entrance channel at the north end of the lagoon on the basis that this location involved a lesser change in the existing regimen of shore and lagoon.

The specifications underlying the hydraulic design were:

1) A stable, safe entrance channel with a controlling depth of 4 mts of MLLW.

2) Tidal currents should preserve the outlet channel between the jetties and the bar with little maintenance dredging; the interior channels already in satisfactory condition should require only minor maintenance.

3) The stabilized inlet should permit an increase of depth at a later date, if the tidal prism is increased as recommended.

4) Waves entering between the jetties should be dissipated by an absorbing beach to minimize local wave action inside the jetties and to limit surging in the bay. Adequate space must be provided for a wave-absorbing beach.

5) The sharp turn in the navigation channel near the gorge should be increased in curvature.

6) The developed water front north of the entrance should not be exposed to waves entering the inlet.

At a location approximately 650 mts south of the present channel (see Fig. 7) the inlet channel could be connected to the estuary bay channels by a gradual transition. This location has the disadvantage that the existing channel must be closed after the jetties are built and the channel between them dredged, but this choice of location best meets the design specifications enumerated and justified the added cost as compared to improving the channel in its present location.

The flow area of the gorge of the existing inlet fits almost exactly on the curve of tidal prism versus flow area which has been found to be generally applicable to tidal inlets on sandy coasts[3]. The tidal prism of 8.45×10^6 m^3 could be expected to maintain a channel flow area of 575 m^2 below MSL at the minimum point. The desired depth of the navigable channel below MLLW is 4 mts; the centerlines of the jetties were made almost parallel and 160 mts apart. Fig. 7 shows a cross-section of the jetties at their outer ends and the entrance channel between. The actual channel will probably have a somewhat greater maximum depth and the best channel will probably lie north of the centerline.

[3] O'Brien, M. P., "Equilibrium Flow Areas of Tidal Inlets on Sandy Coasts." Proceedings of Xth Conference on Coastal Engineering, Tokyo, Japan, Sept. 1966. Vol. 1, p. 676.

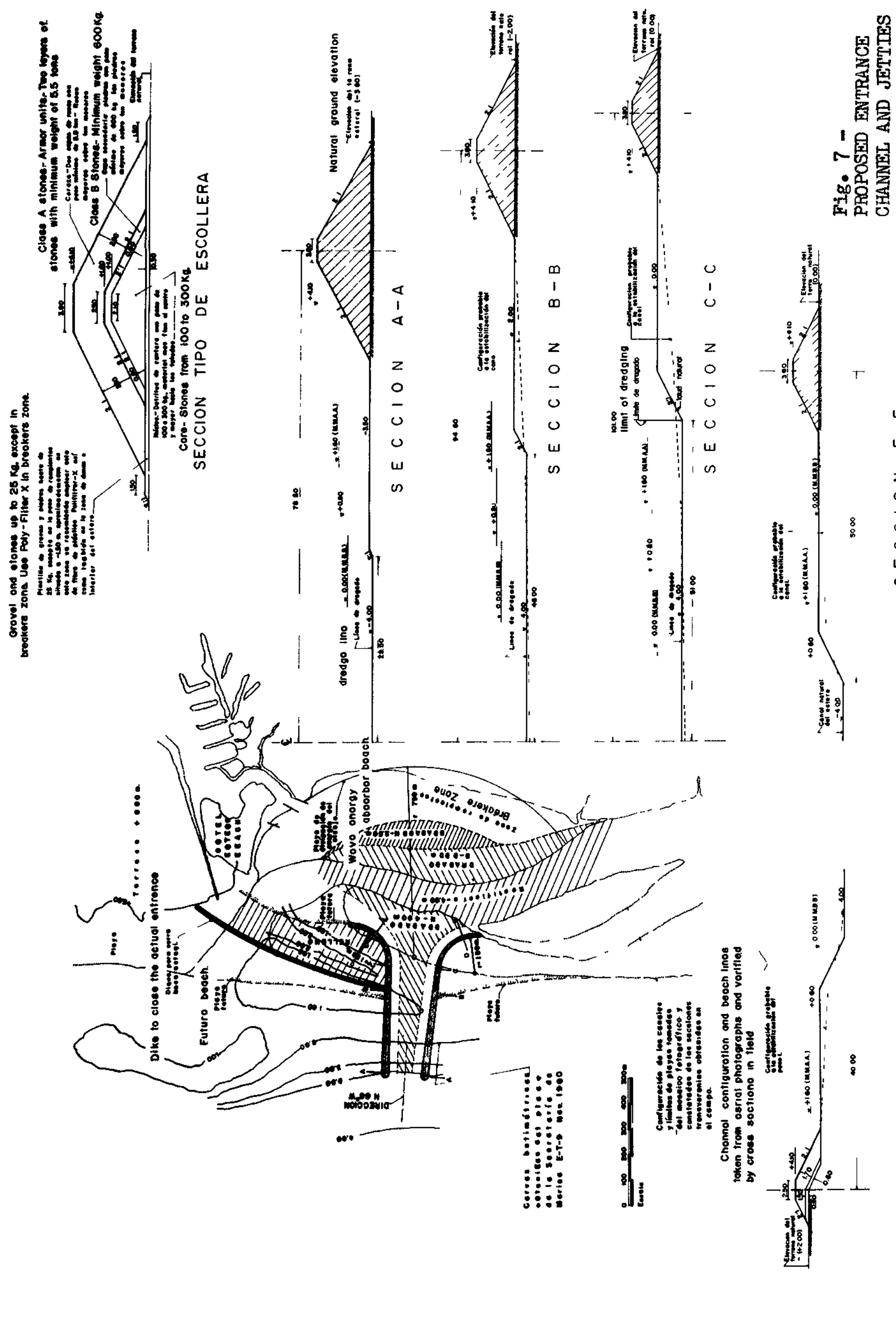

Fig. 7 - PROPOSED ENTRANCE CHANNEL AND JETTIES

The interior shores of the lagoon are almost devoid of improvements which would interfere with a coordinated plan of improvement which could both increase the tidal prism and also the usable upland area. It was recommended that a bulkhead line be established approximately along the position of the HW line and that dredging in the inter-tidal zone be used to fill landward of the bulkhead line. If this plan were followed, the tidal prism could be increased to 12 x 10^6 m^3 and the minimum flow area at the entrance channel would be increased to 780 m^2. To match this increase in cross-section area, the channel would deepen to about 6 m; the jetties should be extended about 500 mts to stabilize this greater depth. Dredging of the interior channels to 5.5 m near the entrance and 4.5 m at the southern end would be desirable to make these depths consistent with the deeper entrance channel; once deepened by dredging these deepened channels should require little maintenance.

Storm waves will enter the channel; bottom friction, diffraction and refraction against the jetties will reduce their heights but the largest wave will retain appreciable amplitude at the inner end of the jetties. Nevertheless, the high spreading of the waves crests after passing the jetties will permit interior navigation even in medium large swells, Fig. 7. A wave absorbing beach, Fig. 7, will be located on an arc centered on the entrance and will be graded to a flat slope to cause breaking and full dissipation.

Structural Design: Exposure to wave action at Estero Punta Banda is similar to that of the coast of Southern California, where many tidal inlets have been improved and stabilized by means of twin jetties. The design of the jetties at Estero Punta Banda follows the same practices as have proved to be adequate in California.

Studies were made from the economical point of view, of various types of armor for the jetties. The elements studied were concrete cubes, tetrapods, tribars, quadripods, akmon and some other armor units. The most economical solution was found to be the use of igneous rocks found in the area. The criteria used to determine the weight of the stones for the armor units of the jetties was Hudson's investigations[4], using a wave height corresponding to the highest possible breaking wave in front of the jetties. The seaward ends of the jetties were designed for 0% damage and the adjacent section along the sides of the jetties for 10% damage. The weight of the stones was reduced gradually to one half of this weight at the beach. The inside slopes of the jetties were protected with lighter stones, as shown in the design drawing, Fig. 7.

The choice among possible construction methods and sequences will be made by the owners and the contractor and will be determined by costs. Under any construction plan adopted, it is important that the inlet be kept under control during the construction and that the old channel be closed as soon as the new one is opened. Fig. 8 shows the ultimate configuration of the jetties and channels. One feasible sequence of operations is to build a trestle across the existing channel to transport stone from the quarry,

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4 Hudson, Robert Y., "Laboratory Investigation of Rubble-Mound Breakwaters." U. S. Army Engineer. Waterways Experiment Station, Vicksburg, Mississippi.

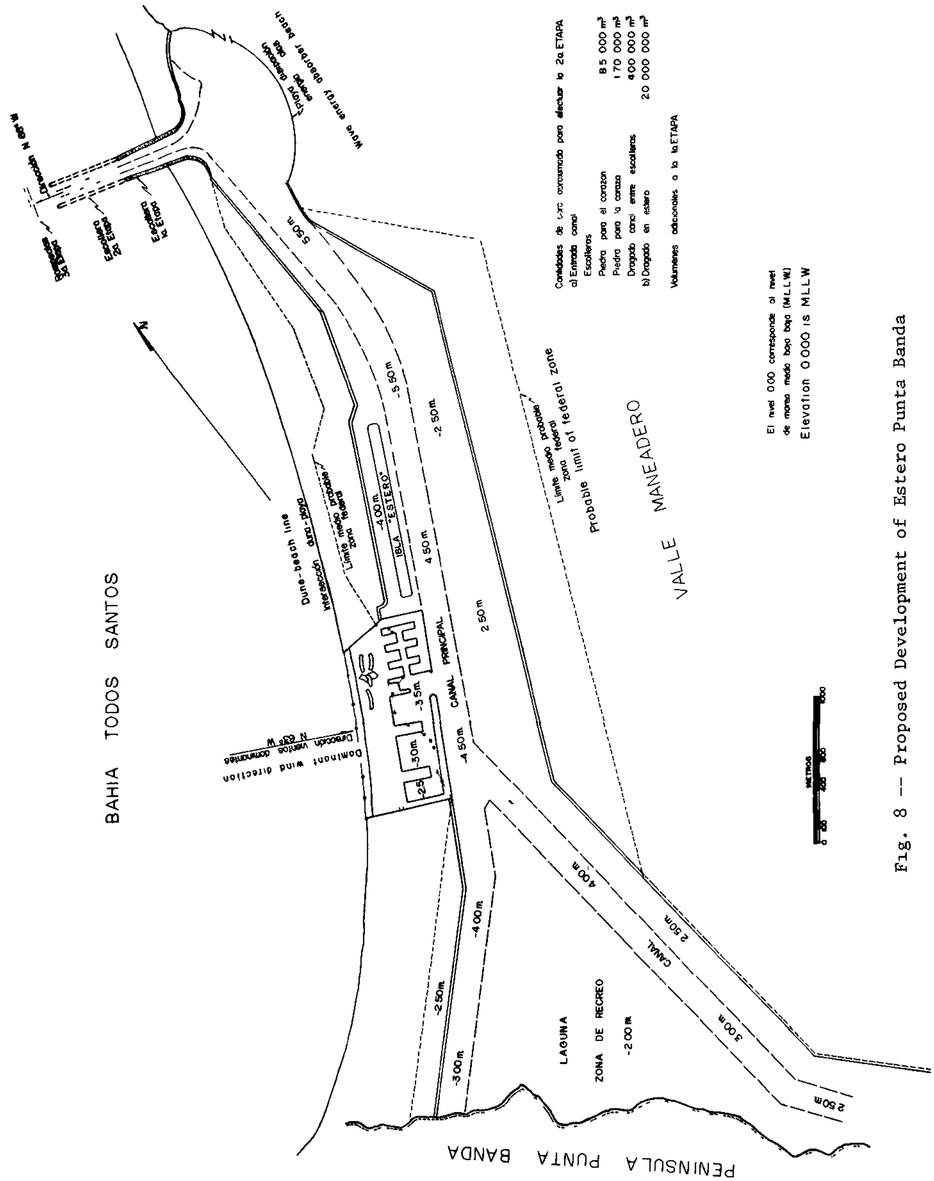

Fig. 8 -- Proposed Development of Estero Punta Banda

build the two jetties to full ultimate sections across the beach, dredge between the jetties and, as this cut nears completion, begin closure of the old channel by dumping stone from the trestle and by depositing dredged material on the north side of the north jetty. In this matter, the flow would be diverted to the new channel. Most of the dredging in the lagoon and the construction of the wave absorbing beach would be deferred until the new flow regime had been established.

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