Philippine Engineering Journal (1993) XIV (1): 33-47

PORT OF PULUPANDAN: TIDE MODEL

Enrico G. Gregorio, M. Eng'g
Supervising Research Engineer
National Hydraulic Research Center
University of the Philippines
Diliman, Quezon City

ABSTRACT

This paper describes the physical model study of the Port of Pulupandan siltation problem. A fixed distorted model (1:250 horizontal, 1:50 vertical) reproduces the prototype hydrography. The model uses the Froude criteria but simulation is limited to the tidal variation only. The study is focused on identification and reduction of eddy zones.

Four basic layouts and its modifications are tested. The results of the model investigation lead into the selection of Alternative No. 3 layout that produces promising flow pattern and smaller eddy zones. The selected layout not only exhibits streamlined flow but also entails minimum disturbance to the existing facilities hence less capital investment is involved.

INTRODUCTION

The Port of Pulupandan is a government sub-port. It lies on the western coast of Negros Island (Figure 1), 31 kilometers south west of Bacolod City and immediately south of Pandan Point. Situated at the narrowest point in the Guimaras Strait, the port is located at latitude 10^{o} 31' 8" North, longitude 122^{o} 47' 22" East. The docking facility measuring 21.75 meters wide and 242 meters long, was originally an L-shaped pier with its leg running towards the south. Then, the L-shaped pier was extended by 12 meters wide and 178 meters long, making an angle of roughly 23^{o} with the alignment of the north pier. It is now commonly known as the north pier. Private bulk handling facilities such as the Philippine Bulk Corporation (PBC) and Total Bulk Corporation (TBC) are on the northern side of the harbor. A rock filled jetty 380 meters long is located 550 meters east of the approach pier of the T-shaped pier.

This port serves both domestic as well as foreign vessels. The principal traffic are molasses, sugar, livestock, other agricultural products, fertilizers and machineries.

For the past three decades, the outline of the shoreline has remarkably been altered due to man's activity along the coast. The shoreline has been modified, particularly on the northern side by construction of seawalls. In addition, the reclaimed area where the Philippine National Bank (PNB) warehouse stands is bounded by the rock-filled jetty and the approach pier. This

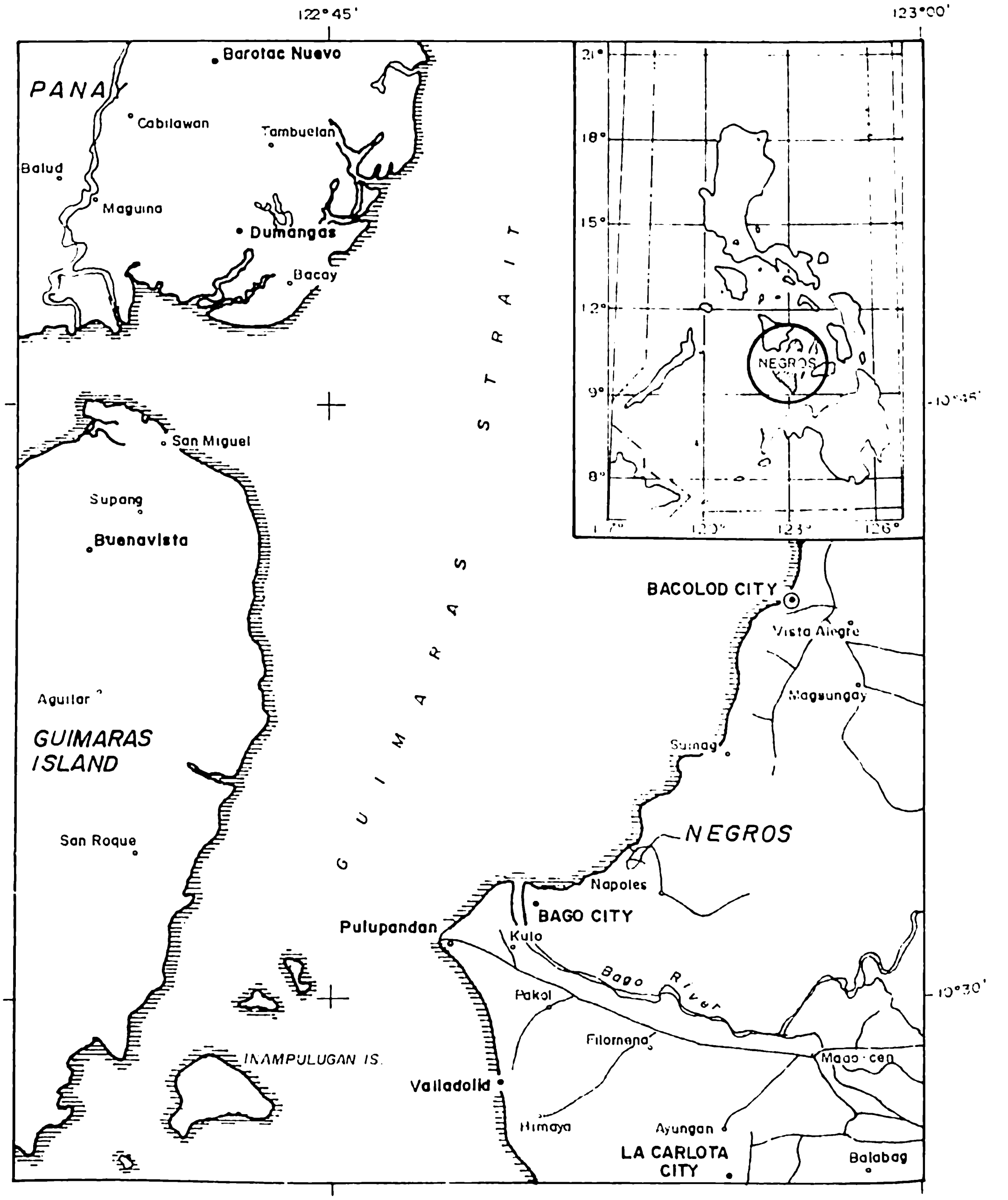

Fig. 1 Location Map

coastline has modified the flow pattern and has introduced large eddy zone which has contributed to the serious siltation problem. Hence continuous dredging along the wharves is necessary to maintain a depth of about 6.0 meters.

Due to the uncertainties in analytical techniques in solution of the siltation problem, a physical model study is undertaken. A simple tide model is employed to identify the eddy current zone for flooding and ebbing conditions and to improve the flow condition near the pier by testing various layouts.

PROTOTYPE CONDITIONS

Origin of siltation for Port of Pulupandan is the sediment load from Bago River. Sediment emanating from the river flows down south by the action of waves and currents and travels from southwest to south at Pandan Point. The effects of the structures near the pier has led the deposition of sediment at the back of pier and in front of the rock jetty. This port suffered serious siltation problem due to topographic and natural conditions. The conceptual siltation mechanism is shown in Figure 2.

Topographic Condition

The Iog-Iog bar extends from north to south about 10 kilometers in open sea and is about 1.5 km from the pier. The sand bar whose origin is not clear stretches from the estuary of Bago River up to Pandan Point. It is parallel to the coastline. The bar was naturally formed through transport of bed load from Bago river by action of waves and tidal currents. The shoreline presents a shoaling beach.

Waves

Direction of transport of littoral drift by wave action is northwards during the south west monsoon and southwards during the north east monsoon. Transport energy of waves from the north east direction is very much stronger than the waves from the south west direction. Thus, transport of littoral drift from the north east is predominant.

Bar at estuary of Bago river and seashore along north side of Pandan Point are eroded by north east waves and transported near the pier but littoral drift is intercepted by artificial structures like the jetty and suspended load is also deposited.

Tidal Current

Tidal current passing through Pandan Strait has rapid velocity of 2-4 knots and gives serious effects on the agitation and transport of sediment. The stagnated currents and eddy currents which are partially produced near the pier seriously influence the deposition of sediment transport.

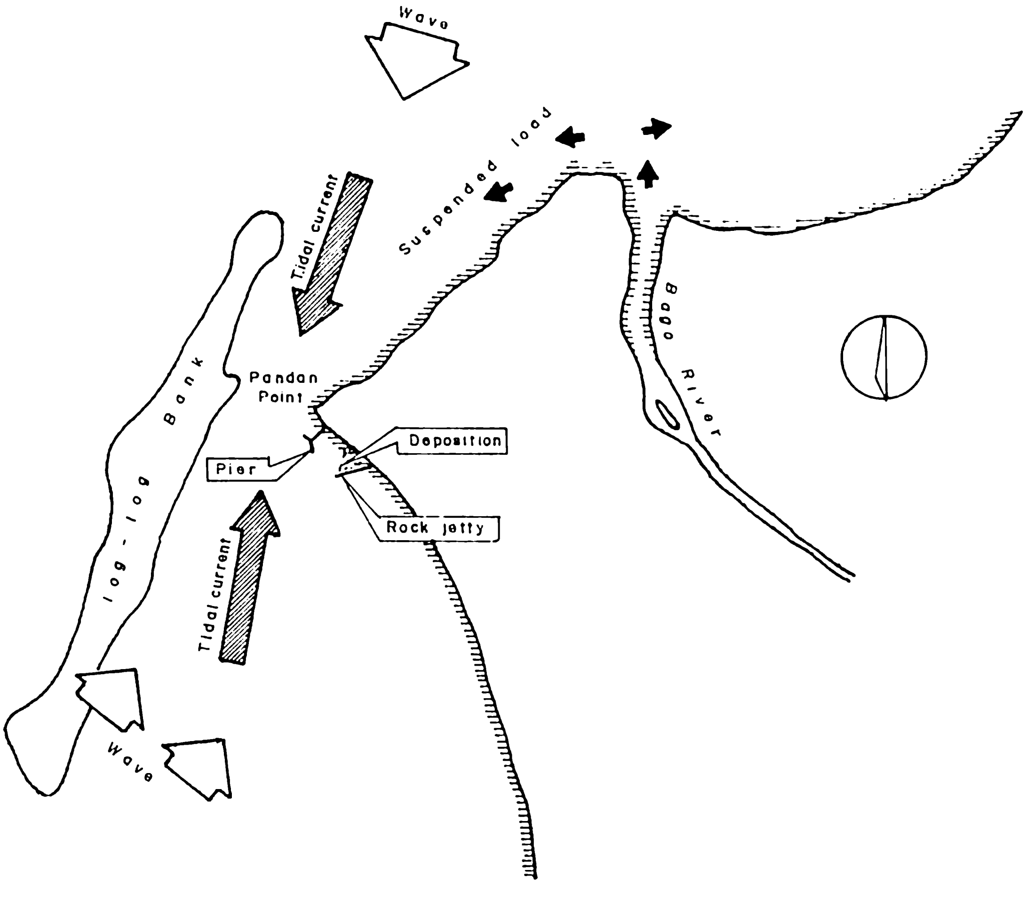

Fig. 2 Conceptual Siltation Mechanism

TIDE MODEL

A distorted model (Figure 3) with a 1:250 horizontal scale and a 1:50 vertical scale was constructed. The model covers approximately 300 square meters. It covers the Iog-Iog Bank, East Channel, Harbor area, North Sea and South Sea of Pulupandan. The Iog-Iog Bank, the East Channel are reproduced with the bathymetric maps from the Siltation Study conducted by Pacific Consultants International and F.F. Cruz in 1983 whereas the Harbor Area, North and South Sea of Pulupandan utilize the bathymetric survey of Basic Technology and Management Corporation (BASIC) in 1985. The bathymetry is molded in cement mortar to the piano wires set at its contour elevation. Acrylic plastic sheet is cut out to reproduce the pier plan. Brass rods with 1.6 mm diameter corresponds to the 0.6 meter by 0.60 meter reinforced concrete piles in the prototype.

The similitude ratios adapted is the Froude criteria. The test program for the fixed bed model is limited in the reproduction of the tidal current mechanism and without wave generation.

Flow parameters are measured through proper instrumentation of the model. A capacitance type wave gauge installed in a stilling well continuously measures the tidal fluctuations. Velocity on selected points near and around the pier is detected by a 5 millimeter diameter current meter. Velocity profiles are also conducted. For ease in the study of flow pattern, 1.0 meter by 1.0 meter model grid system is established. Flow pattern on the surface are traced using different sizes of floating and submerged balls. For flow pattern near the bed potassium permanganate is employed to track the flow direction. Candles on floats photographed for an extended time show the vivid description of the flow behavior.

Water from the recirculating system of the Center is supplied to the two head tanks. Flood condition is simulated by opening the gate valve at the south head tank, while ebb condition is run by opening the gate valve at the north head tank. Flow into the model is controlled by passing portion of the total discharge of the pump through a motorized gate valve.

The tidal variation is simulated by pneumatically actuated flap gates. The raising and falling of the tide levels is done by either elongation or retraction of the pneumatic cylinder at predetermined time interval sent by a timer.

MODEL CALIBRATION

Prior to model calibration, a field survey program was undertaken by BASIC. The more important observations are the float tracking along the East Channel during flooding and ebbing conditions.

The standard test condition for calibration as well as for the study of the various harbor layout is a steady state condition at peak tidal elevation of 1.50 meters above mean lower low water. The same test condition is observed for the flood and the ebb tides.

The model is repeatedly run until the flow pattern in the prototype is closely reproduced in the model. This done by adjusting the location of the water supply line, by installing baffles at the head tanks, by providing guide vanes at approach region and by partial opening of the gate

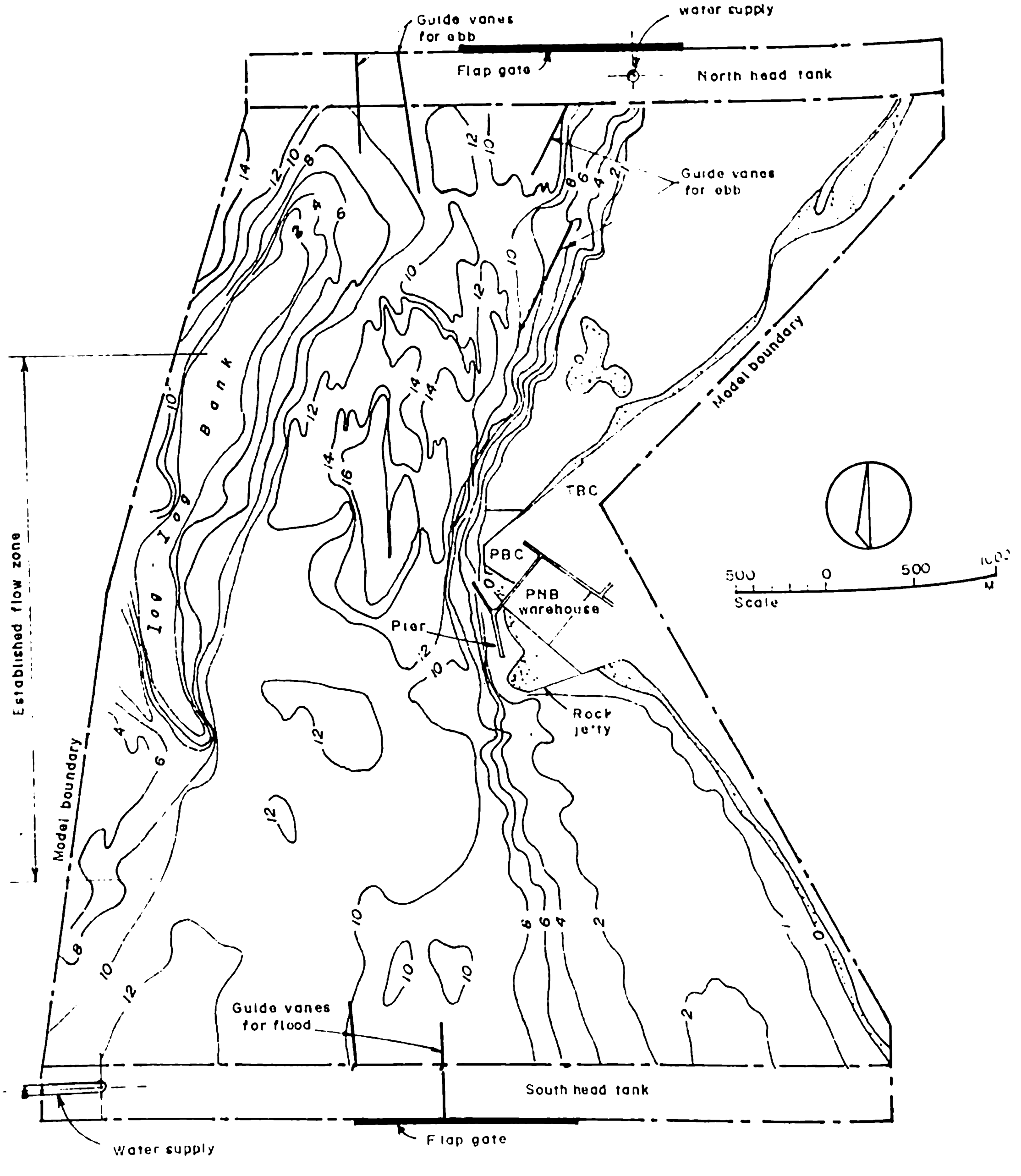

Fig. 3 Model Layout

valve. An established flow zone where there is identical prototype and model flow pattern is identified. This is roughly 1,250 meters to the north and to the south of the pier. Current velocities measures in the model closely approximates the field measurements.

Existing Situation

Having calibrated the model, surface float tracks near the harbor are recorded. The flow patterns help in the identification of eddy zone area. The flow pattern at flood tide is shown in Figure 4. Flows from the south of the rock jetty align with the jetty. Once the flow leaves the end of the jetty, small eddy circulation are formed. Flow further offshore drifts toward the East Channel where the main tidal stream passes. This flow behavior creates some 19.0 hectares of eddy current zone which has almost nil current velocity. This area can be identified as potential area of siltation and extends 100 meters offshore from the pier.

Similarly, the model reveals the flow pattern for ebb tide in Figure 5. The flow relatively follows the shoreline. As the flow traverses southerly, it encounters the protruded PBC seawall which acts as a point of separation. Thus, large eddy circulations with small flow reversals are produced. The flow shifts offshore and follows the East Channel. Some 35.0 hectares is affected by the eddy current zone.

SCENARIOS FOR HYDRAULIC MODEL TESTING

Various options are grouped based on harbor operation and hydraulic criterion. Alternative No. 1 and No. 2 are preferred from harbor operation viewpoint which considered ease of docking and mooring of vessels and availability of additional storage area. Alternative No. 3 and No. 4 seem to eliminate or reduce the extent of eddy current zone and to create stronger and more streamlined tidal currents. The basic alternatives are described below:

Alternative No. 1

This harbor layout (Figure 6) involves the partial removal of the rock jetty and construction of a training dike extending from the PBC seawall to rock jetty. A maximum length of 210 meters can be removed from the rock jetty and some 740 meters of training dike has to be placed without endangering the PNB warehouse.

Alternative No. 2

This case involves also the partial removal of rock jetty but also consist of reclaiming the area from the existing shoreline to the front of the piers which are converted into a solid wharf (Figure 7). Solid dikes are constructed from the rock jetty to the end of the south pier as well as from the PBC sea wall to the end of the north pier.

Both Alternatives No. 1 and No. 2 offer substantial reclaimed area for storage facilities.

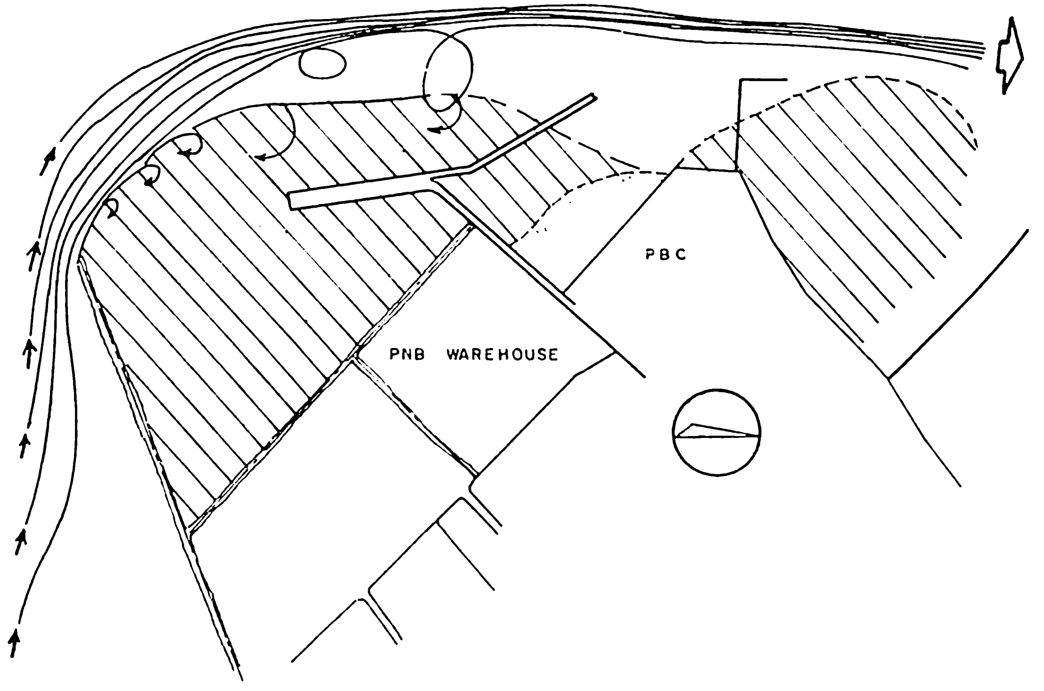

Fig. 4 Floding (Existing Situation)

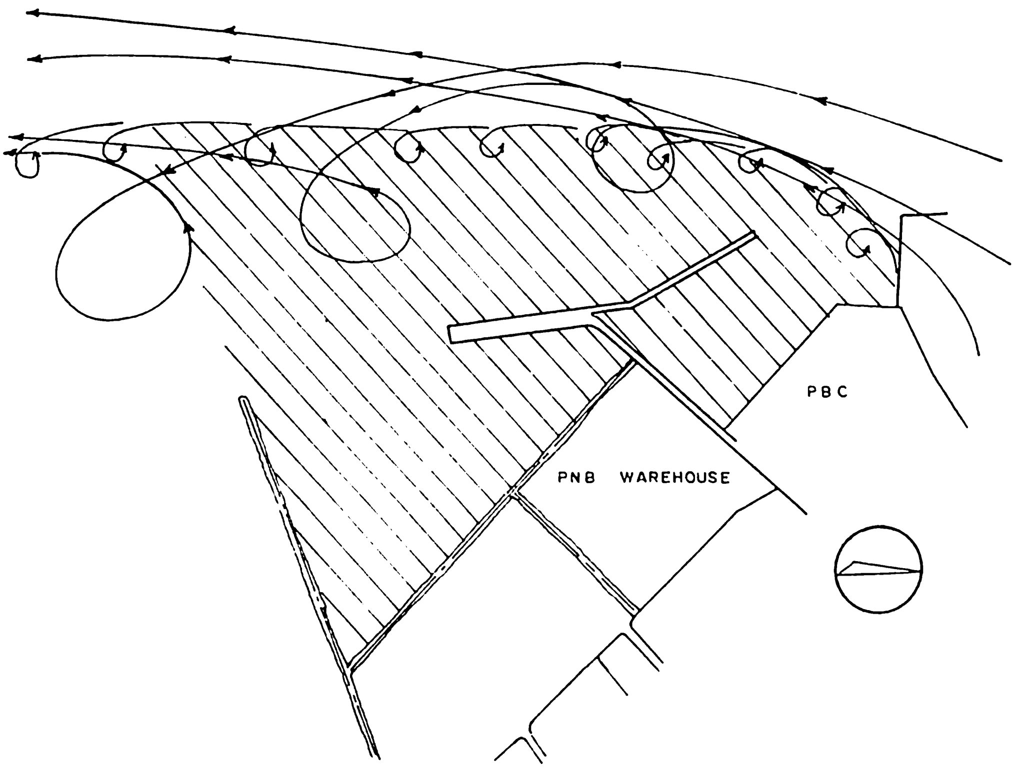

Fig. 5 Ebbing (Existing Situation)

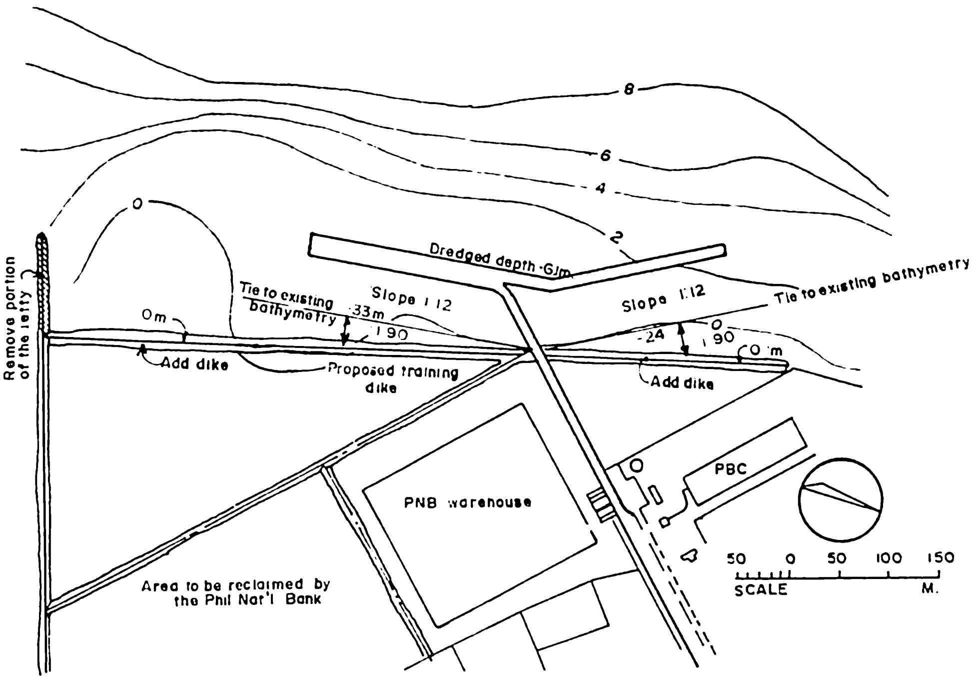

Fig. 6 Alternative No. 1

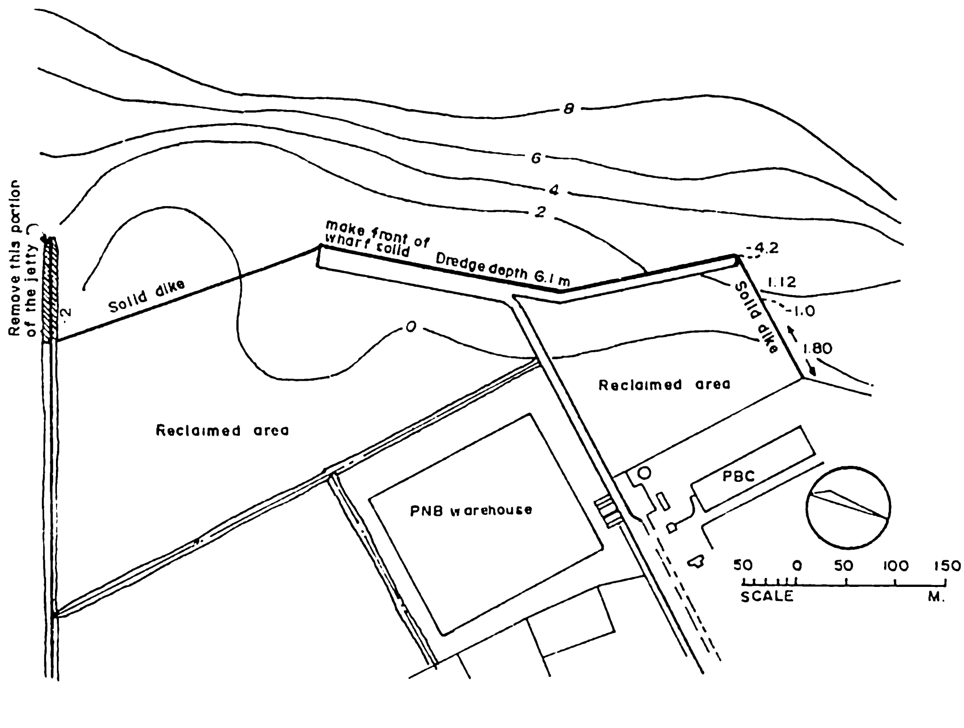

Fig. 7 Alternative No. 2

Alternative No. 3

As represented in Figure 8, this involves the removal of the rock jetty up to the existing shoreline and realignment of a portion of shoreline between the PNB warehouse and the PBC sea wall.

Alternative No. 4

This harbor layout (Figure 9) is similar to Alternative No. 3. The entire rock jetty (up to the original shoreline) is removed and a new shoreline is reestablished south of the PNB warehouse.

In as much as the existing bathymetry does not have the required depth along the pier for the docking sea craft, the bathymetry representing the dredged condition is established. The bottom profile of the dredged bathymetry requires a near shore slope of 1:90 with a width of about 100 meters to accommodate littoral drift alongshore and an offshore slope of varying from 1:12 to 1:14 leading to the design depth of 6.0 meters along the piers.

As the model testing progresses, some of the basic alternatives have to be dropped since it was found in the feasibility study that additional reclamation area would not be needed in the near future. The rehabilitation of the pier has to be confined on the present layout of the pier. Thus, the test was focused on the Alternative No. 3, No. 4 and some modifications

FLOW CONDITIONS AT FLOOD TIDE

The ensuing discussion deals with flood tide (i.e. the tidal current is from south to north) for the design dredged bathymetry. As discussed in an earlier section, the presence of the rock jetty has greatly influenced the flow pattern particularly during flooding as well as the formation eddy current zone. Thus, three basic layouts which have altered the rock jetty are tested.

The flow pattern for Alternative No. 1 shows the main flow near the shoreline is blocked by the rock jetty. As the flow hits the rock jetty, it is deflected and runs parallel to the jetty. Then, the main flow runs parallel to the south pier and drains towards the East Channel. Due to the sharp corner formed by the training dike and the rock jetty, an eddy current zone is induced, covering an area of approximately 10.50 hectares which is smaller than those of the existing situation. In addition, some flow reverses inward at the north pier. The whole of the south pier and portion of the north pier is affected by this eddy current (Figure 10).

With Alternative No. 3, the flow is more streamlined (Figure 11). However, the flow cut through the south pier obliquely. Flow along the north pier is almost parallel to its alignment and meets the main flow of the East Channel at the northern part of the harbor. A small disturbance is produced at the offset shoreline south of the partially removed rock jetty. This has created an eddy circulation area in front of the PNB warehouse with an area of 2.30 hectares.

Test wherein the eddy zone is filled with gravel is investigated. The result reveals that the eddy current zone did not encroach further offshore. Thus maintenance of this scheme is more

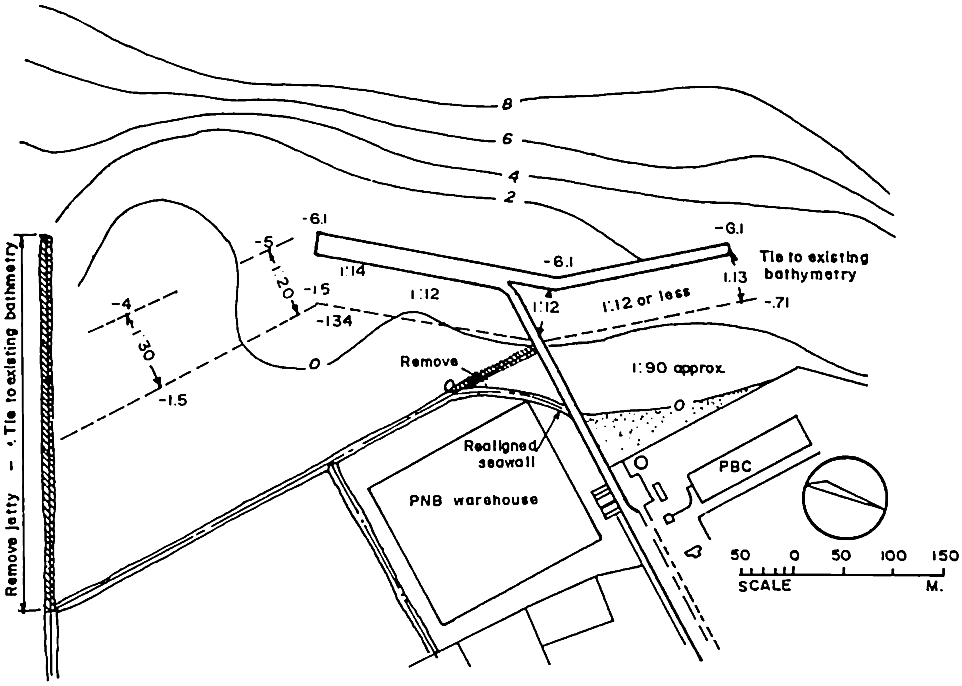

Fig. 8 Alternative No. 3

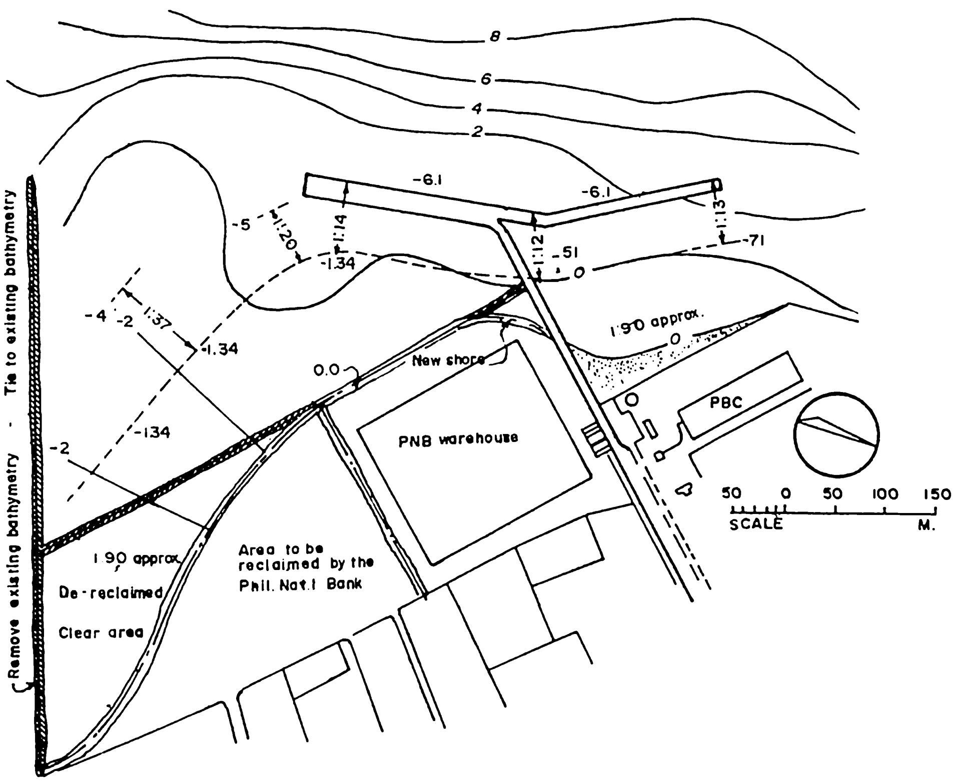

Fig. 9 Alternative No. 4

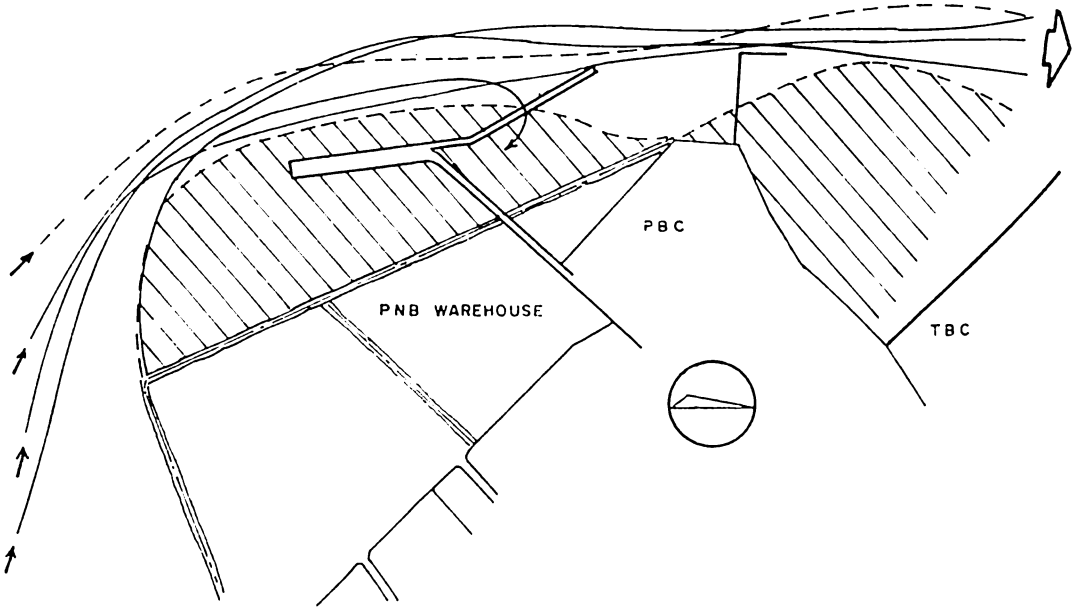

Fig. 10 Flow Pattern and Eddy Current Zone Flooding, Alternative No. 1

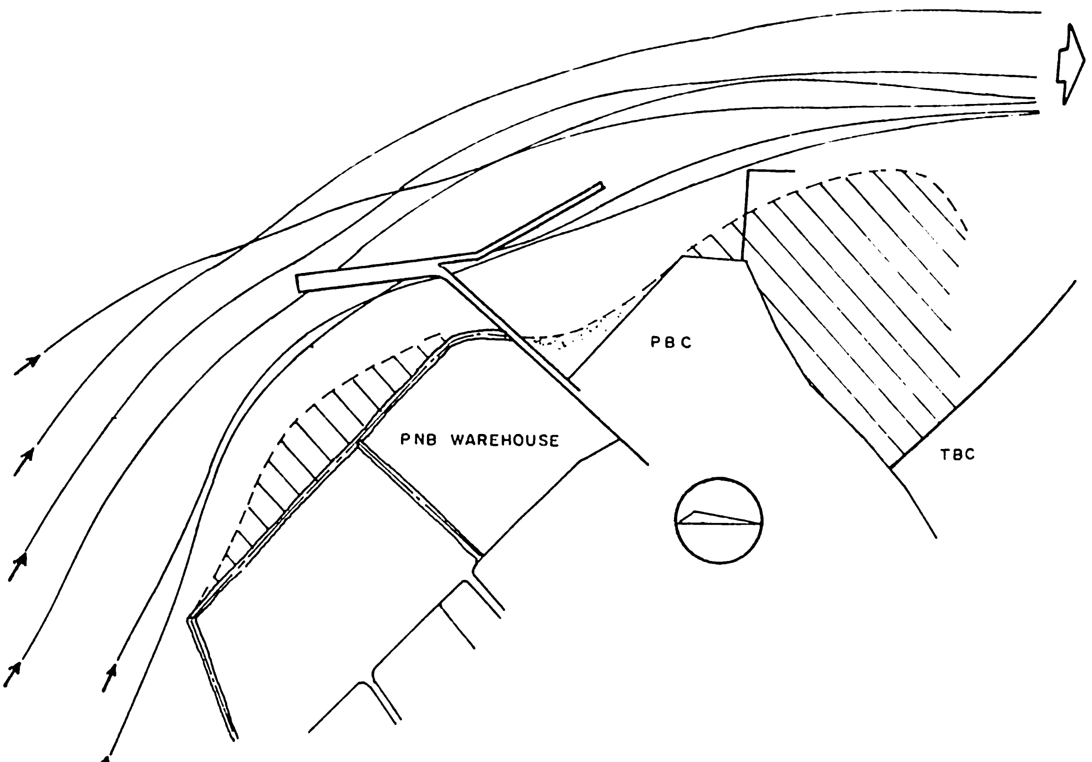

Fig. 11 Flow Pattern and Eddy Current Zone Flooding, Alternative No. 3

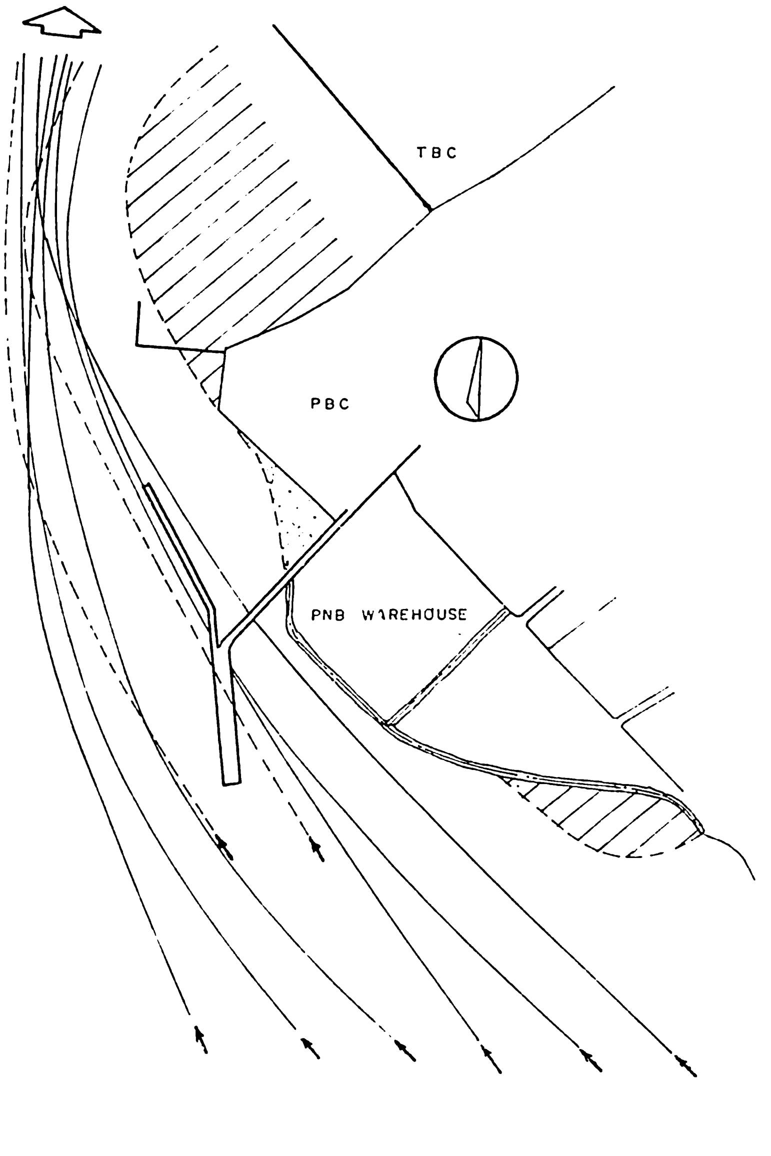

Fig. 12 Flow Pattern and Eddy Current Zone Flooding, Alternative No. 4

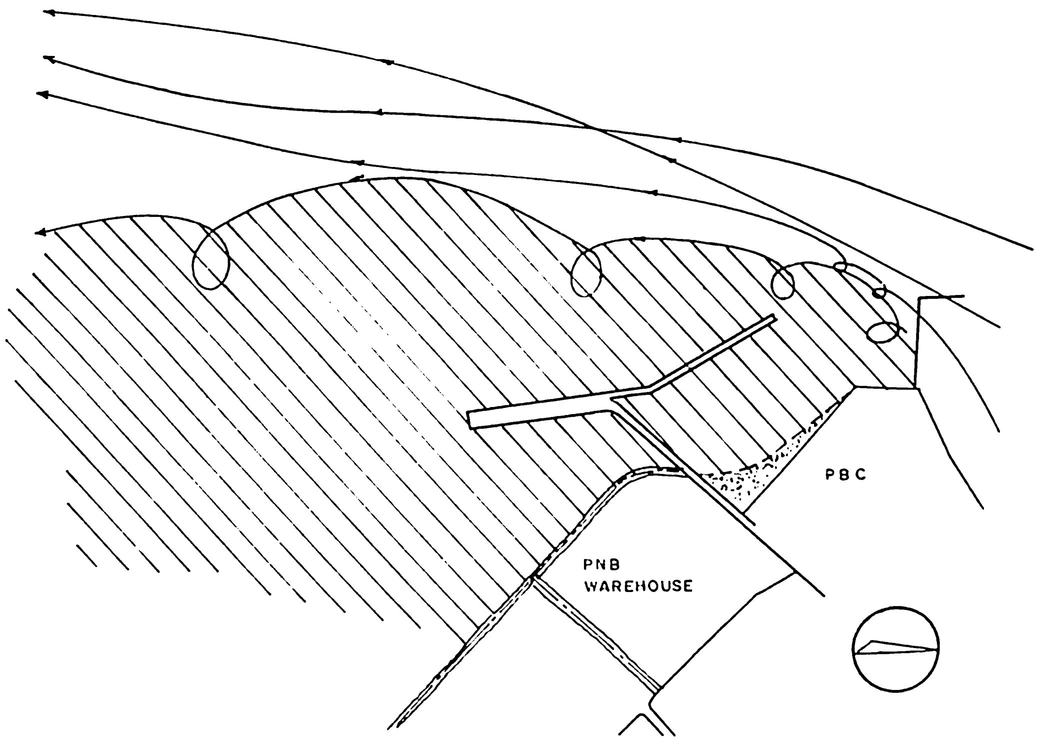

Fig. 13 Flow Pattern and Eddy Current Zone Ebbing, Alternative No. 3

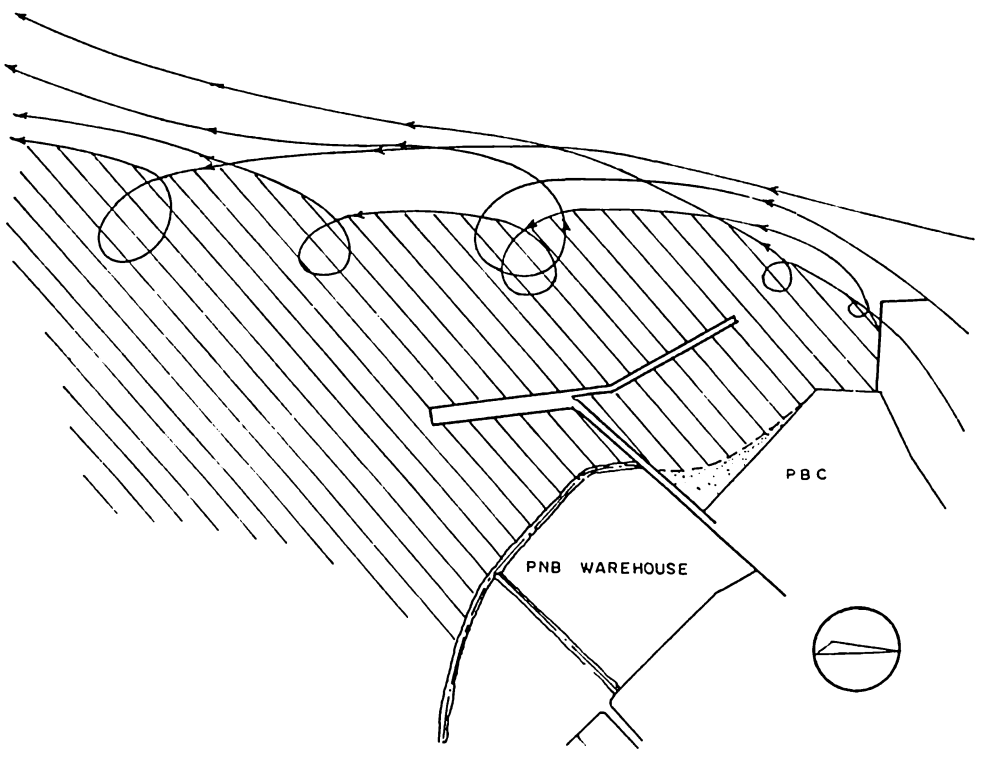

Fig. 14 Flow Pattern and Eddy Current Zone Ebbing, Alternative No. 4

manageable since it does not affect either the north nor the south pier.

Further attempts to improve the flow behavior led to Alternative No. 4. The flow pattern is displayed in Figure 12. The general trend of the flow is very much similar to that of Alternative No. 3. Flow near the shoreline passes through the south pier obliquely while the flow along the north pier is nearly parallel to its alignment. Reverse flow inside the eddy zone does not exist. Sea craft docked along the south pier may experience swaying due to the oblique flow passing through the pier. A small eddy circulation zone, which is about 1.70 hectares, is present along the re-established shoreline. There is also a very small eddy zone north of the approach pier to the pier. The main disadvantage of Alternative No. 4 over Alternative No. 3 is that the eddy current zone is located farther from the pier. However, this is neutralized by the large amount of civil works involved in carrying out Alternative No. 4.

FLOW CONDITIONS AT EBB TIDE

The same steady state flow condition and design dredged bathymetry are imposed during the test at ebb tide (i.e. tidal current is from north to south) for Alternative No. 3 and No. 4. The flow patterns are displayed on Figure 13 and Figure 14 for Alternative No. 3 and No. 4, respectively. The ebb flow has the same characteristics for both layouts. Small swirl motions are formed near the PBC terminal and are carried southward to form larger circulations in front of the pier. Beside this circulation, the main flow passes through East Channel. Comparing the flow with the existing situation, the`flows are found to be similar. Basically, the area affected by the eddy circulation covers roughly 33.00 hectares.

Revision of the boundary conditions at the northern part of the harbor is restricted since causeways and facilities along the shore are owned by private entity. However, model tests are undertaken with a portion of the PBC sea wall chopped off. Model results did not show any promising improvement of the ebb flow pattern. It seems that the eddy zone is largely controlled by the natural topography of the shoaling beach.

REFERENCES

Pacific Consultants International (1984). **The Siltation Study, Harbor Maintenance Dredging Project,** Final Report. Manila, Philippines.

Lavalin International Inc. (1984). **Fourth IBRD Ports Project Phase I, Feasibility Studies Volume 3, Pulupanadan and Tagbilaran,** Final Report. Manila, Philippines.

National Hydraulic Research Center (1986). **Port of Pulupandan Hydraulic Model Investigations,** Final Report. Quezon City, Philippines.