7.3 Structural Measure

7.3.1 Environmental Considerations

The closure of Tortola channel directly influences on the social environment and the ecosystem as a result of stagnation of water body and sediment deposition in both upstream and downstream of the dike as discussed in section 7.6. In order to reduce the adverse effects of alternative B2 scheme, several modifications to this scheme are considered as countermeasures. Such countermeasures are:

- Instead of complete closing dike, submerged closing dike or dike with culvert/slit openings that allows the certain water flow over/through the dike is considered.
- A bypass channel with navigation lock to allow for the passage of boats is considered to mitigate the adverse effects on the waterway transportation of local people.
- The protection measures such as revetment along the bank, are essentially needed to prevent the bank erosion in the Barancas reach due to the significant increase of discharge in the Rio Grande channel.

The modifications for B2 scheme are selected considering the above mentioned requirements.

7.3.2 Alternatives for B2 Scheme

(1) Determination of Alternatives

Taking into the consideration the environmental issues and economic factors, eight modified alternatives for B2 scheme, referred to as [B2-1] to [B2-8] as shown in Table 7.3.1, were studied.

The alternatives [B2-1] and [B2-2] are considered to analyze hydraulically appropriate location for the closing dike along the Tortola channel. For simplification, among the alternatives allowing water flow over/through the dike, submerged dike case is selected only for hydraulic analysis, since the dike with culvert/slit openings would also have similar hydraulic analysis results to that of submerged dike, once it is designed for same flow discharge. The alternatives [B2-3], [B2-4] and [B2-5] will be utilized to determine the suitable height and allowable discharge for the submerged dike, which is as shown in Fig. 7-3-1.

Table 7.3.1 Alternatives for B2 Scheme

Type	Alternative	Main Facilities	Remarks
Closing Dike	B2-1	Closing dike at Tortola upstream	To determine the appropriate location
	B2-2	Closing dike at Tortola downstream	
Submerged Dike	B2-3	Submerged dike at Tortola upstream; H = MSL+6m	To select the suitable dike height
	B2-4	Submerged dike at Tortola upstream; H = MSL+3m	
	B2-5	Submerged dike at Tortola upstream; H = MSL+0m	
Referential Dike	B2-6	Groins at Tortola entrance	To check the applicability of Groins
	B2-7	Groins at Tortola entrance and midstream	
	B2-8	Closing dike at Tortola and Piacoa entrance	To evaluate the substantial increase of discharge

The structural measures such as Groin type or huge scale closing dikes are not suitable measures according to the previous studies. However, the alternatives [B2-6], [B2-7] and [B2-8] are selected as referential alternatives to study and confirm the inapplicability of them as appropriate measures. In the alternatives [B2-6] and [B2-7], effect of Groins to increase the discharge in the Rio Grande channel are examined as they cause least disturbances to the aquatic and social environment by allowing the water flow in the Tortola channel, while alternative [B2-8] was studied to analyze the substantial increase of discharge in the Rio Grande channel.

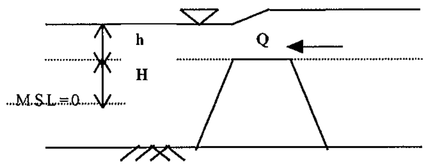


Fig. 7-3-1 System of Submerged Dike

(2) Hydraulic Analysis Using Mathematical Models

In the master plan study by utilizing 1-dimensional hydraulic numerical analysis, the alternative B-2 scheme was hydraulically evaluated and identified as effective, in macro-view point, to reduce the maintenance dredging and provide the required navigation depth for Panamax type vessel at the reach of Guarguapo - Barrancas - Ya-Ya in the Rio Grande channel.

In this feasibility study, 2-dimensional numerical analysis was applied to analyze the hydraulic effects in detail and evaluate the appropriate dyke system for implementation with due consideration to the effects due to the increase of discharge, especially the extent and intensity of the bank erosion, sediment deposition, etc.

The applied 2-dimensional numerical model is composed of 3 modules; hydrodynamic module, sediment transport module and bed change module. At a certain time step, flow is calculated in hydrodynamic module based on the current channel bed elevations. Using the calculated flow condition, sediment transport and the bed change are calculated in sediment transport module and bed change module, respectively. At the next time step, flow is calculated based on the updated bed elevation as shown in the schematic diagram below. (Fig. 7-3-2)

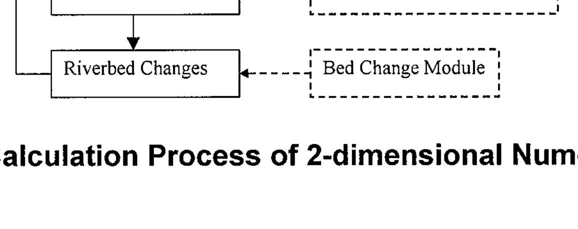


Fig. 7-3-2 Calculation Process of 2-dimensional Numerical Model

The Continuity Equation and Momentum Equation for an Incompressible Fluid under the assumption of shallow water depth were solved for flow calculation applying Alternating Direction Implicit (A.D.I.) solution method. As for sediment transport analysis, "Total Transport Mode (equilibrium) " was selected with an explicit scheme. The Engelund-Hansen formulation, also used in the 1 dimensional numerical simulation in previous study, was applied in the calculation of total bed load transport.

The orthogonal curvilinear co-ordinate system was used to generate the grid mesh in the calculation domain as shown in Fig. 7-3-3. The bed elevations were specified using the results of bathymetric survey carried out for this feasibility study. Boundary conditions (water level, discharge and roughness, etc.) were set up as shown in Fig. 7-3-4. In order to validate the model, calibrations of flow and riverbed changes were carried out.

If flooding on the riverine floodplain and sandbars is considered in 2-D mathematical simulation, in the process of the numerical calculation, the time step must be decreased to avoid the instability due to coexistence of large depth in channel and shallow depth on floodplain. Hence, it would require long computation time and huge computational capacity. One of the most important objects for this analysis is to confirm the characteristics of sediment transport in channel for which effect of riverine flooding is minor. In this sense the riverine flooding is not expressed in the mathematical model.

Taking into the consideration of the vast extent of objective area and the complicated river networks, the river improvement study is conducted through two steps applying one dimensional and two dimensional hydraulic simulation analyses.

In first step analysis described in the previous chapters, one-dimensional hydraulic analysis is applied to reproduce the channel bed profile in the whole objective area, placing attention to the prevailing relationship between the discharge, bed height, channel width, etc. In addition, according to the analysis of the characteristics of changes in channel course, it was identified the "longitudinal variation of channel bed elevation due to bed shear force as a consequent of channel width and/or discharge variation" as a key point aiming at river improvement. Accordingly, practical alternatives of channel improvement were discussed in macro viewpoint. As for analyzing characteristics of changes in river course for the vast and complicated river areas, at least, it is required a period of several decade or more for the long term analysis. This long term analysis was conducted and obtained satisfactory results, by using one-dimensional analysis, because of the present specific channel conditions, uniform medium fine sand of riverbed material through the whole stretches, and the prevailing simple and regular discharge pattern with seasonal changes.

For the second step, two-dimensional analysis that considers secondary flow phenomena, is conducted to evaluate the hydraulic effects such as eroding the side banks and the changes in deepest channel bed at complicated meandering sections as well as the effects of lowering the navigation channel bed, by the structural measures in the selected river sections. The time scale for this analysis should be carefully selected taking into the consideration the requirement of reproduction of the effects of sediment load discharge in the downstream section in the objective areas and the heavy computational burden of 2 dimensional calculations.

The details of the 1 dimensional and 2 dimensional model applications are described in the Supporting Report to Chapter 7.

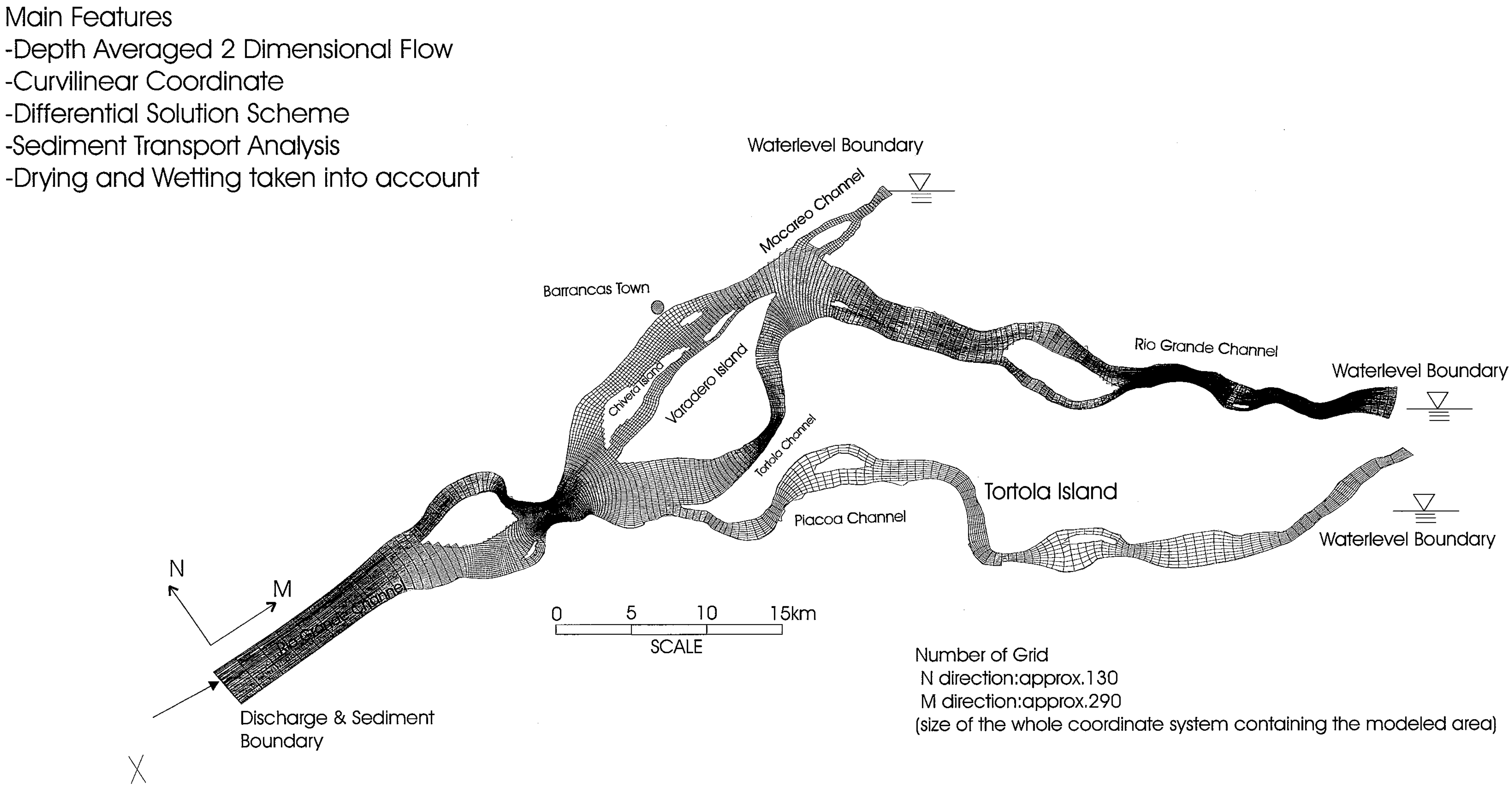
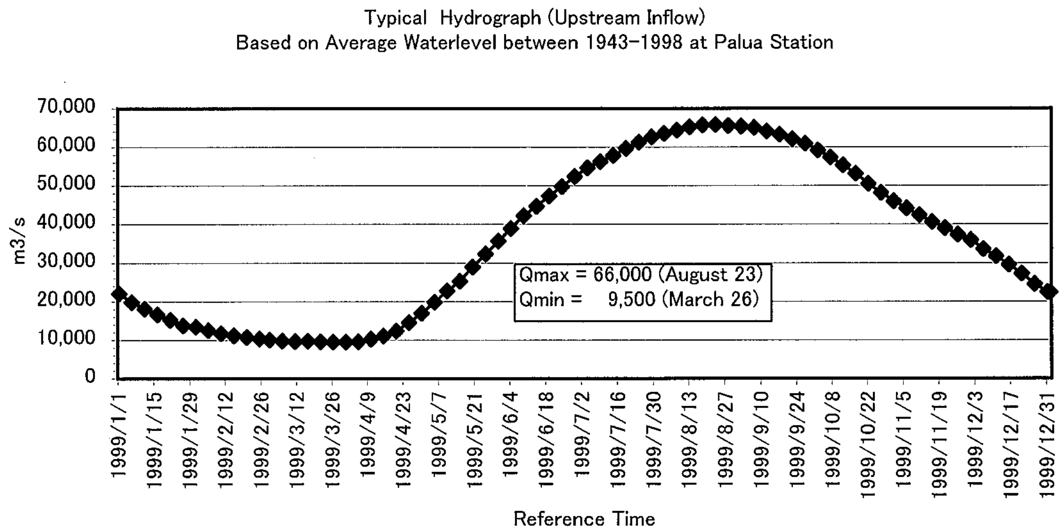
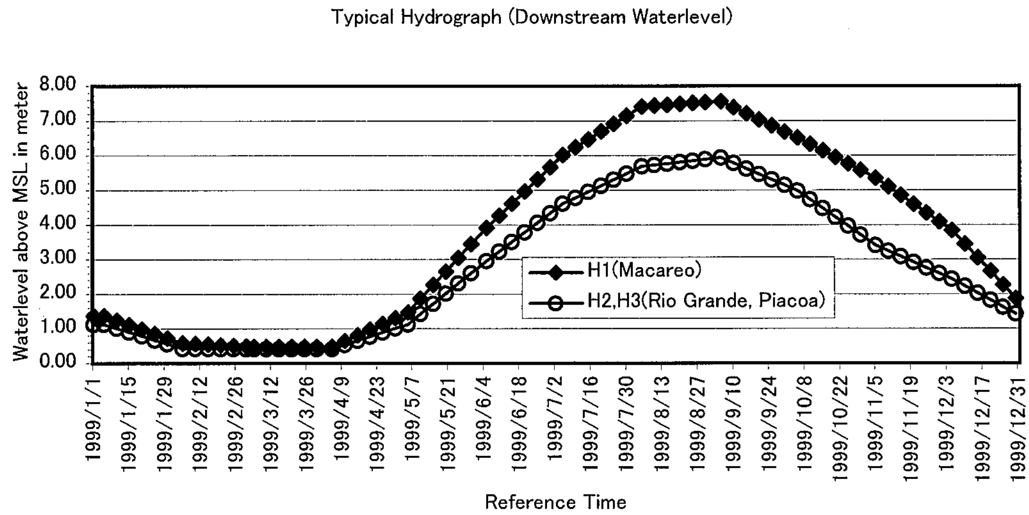


Fig.7-3-3 COMPUTATIONAL GRID FOR 2-DIMENSIONAL SIMULATION





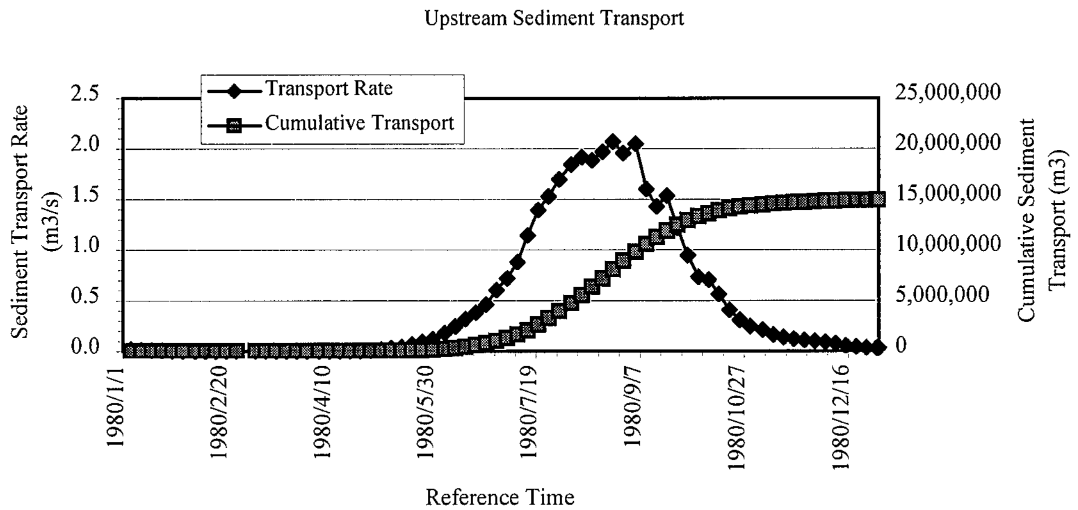


Fig.7-3-4 Boundary Hydrographs for 2-Dimensional Simulation