4.3 Existing Ferry Operations

4.3.1 Waiting and On-Board Times

During the traffic counts and O-D interview surveys, additional surveys were simultaneously conducted by the Study Team to determine the average vehicle waiting and on-board times at the relevant ferries. The results are summarized in Table 4.15. As shown in the table, the Can Tho Ferry provides the slowest service among the major Hau River ferries in terms of total river crossing time. Interestingly, the Chau Doc Ferry has the fastest service.

Table 4.15 Average Waiting and On-Board Times, September 1997

Ferry	Avg. Waiting Time (minutes)	Avg. Ferry Travel Time (minutes)	Avg. Unloading Time (minutes)	Total Time (minutes)
Can Tho	15.1	12.2	1.5	28.8
Vam Cong	11.7	12.0	1.0	24.7
An Hoa	9.7	11.3	1.0	22.0
Chau Doc	5.1	6.2	0.5	11.8

4.3.2 Ferry Tariffs

Ferry tariffs or fares are provided in Tables 4.16 to 4.19 for the four ferries in local currency. As shown, fares for pedestrians range from 500 dong (US$0.04) at the Chau Doc Ferry to 1,000 dong (US$0.08) at both the Vam Cong and An Hoa ferries. Motorcycle (plus rider) fares vary from 1,000 dong (US$0.08) to 2,500 dong (US$0.21), and those for sedans range from 8,000 dong (US$0.68) to 11,000 dong (US$0.93) during daytime, and even as high as 14,000 (US$1.19) at the An Hoa Ferry during nighttime. Trucks are charged substantially higher fares, e.g., 55,000 dong (US$4.66) for 15-18 ton trucks at the Can Tho Ferry.

Table 4.16 Fares at the Can Tho Ferry, 1997

No.	Category	Fare (Dong)
1	Pedestrian	600
2	Person on Bicycle	1,000
3	Person on Motorcycle	2,000
4	Bicycle-with-Trailer, Motorcycle-with-Trailer, Cyclo	4,000
5	Sedan, Microbus	11,000
6	Bus with <15 seats	15,000
7	Bus with 15-30 seats	21,000
8	Bus with 30-50 seats	26,000
9	Bus with >50 seats	30,000
10	Truck with capacity of <3 tons	18,000
11	Truck with capacity of 3-5 tons	23,000
12	Truck with capacity of 5-10 tons	33,000
13	Truck with capacity of 10-15 tons	40,000
14	Truck with capacity of 15-18 tons	55,000
15	Special Vehicle	80,000
16	Exclusive ferry use/rental	250,000

Source: Can Tho Ferry.

Table 4.17 Fares at the Vam Cong Ferry, 1997

No.	Category	Fare (Dong)
1	Pedestrian	1,000
2	Person on Bicycle	1,500
3	Person on Motorcycle	2,500
4	Vehicle with 4 seats	10,000
5	Vehicle with 5-9 seats	15,000
6	Vehicle with 10-12 seats	18,000
7	Vehicle with 13-15 seats	20,000
8	Bus with <30 seats	25,000
9	Bus with 30-45 seats	30,000
10	Bus with 45-52 seats	35,000
11	Bus with >52 seats	40,000
12	Truck with capacity of <3 tons	15,000
13	Truck with capacity of 3-5 tons	20,000
14	Truck with capacity of 5-7 tons	30,000
15	Truck with capacity of >7 tons	40,000
16	Truck carrying fish/seafood with capacity of <5 tons	40,000
17	Truck carrying fish/seafood with capacity of >5 tons	50,000
18	Trailer, Handcart, Animal Cart	4,000
19	Cost per ton of goods	3,000

Source: Vam Cong Ferry.

Table 4.18 Fares at the An Hoa Ferry, 1997

No.	Category	Fare (Dong)	
		Daytime	Nighttime
1	Pedestrian	1,000	1,000
2	Person on Bicycle	1,500	1,500
3	Person on Motorcycle	2,500	2,500
4	Vehicle with 4 seats	10,000	14,000
5	Vehicle with 5-9 seats	15,000	24,000
6	Vehicle with 10-12 seats	18,000	35,000
7	Vehicle with 13-15 seats	20,000	35,000
8	Bus with <30 seats	25,000	50,000
9	Bus with 30-45 seats	30,000	60,000
10	Bus with 45-52 seats	35,000	70,000
11	Bus with >52 seats	40,000	80,000
12	Truck with capacity of <3 tons	15,000	40,000
13	Truck with capacity of 3-5 tons	20,000	50,000
14	Truck with capacity of 5-7 tons	30,000	60,000
15	Truck with capacity of >7 tons	40,000	70,000
16	Truck carrying fish/seafood with capacity of <5 tons	40,000	70,000
17	Truck carrying fish/seafood with capacity of >5 tons	50,000	80,000
18	Trailer, Handcart, Animal Cart	4,000	4,000
19	Cost per ton of goods	3,000	3,000

Source: An Hoa Ferry.

Table 4.19 Fares at the Chau Doc Ferry, 1997

No.	Category	Fare (Dong)
1	Pedestrian	500
2	Person on Bicycle	700
3	Person on Motorcycle	1,000
4	Bicycle-with-Trailer, Motorcycle-with-Trailer	2,500
5	Vehicle with 4 seats	8,000
6	Vehicle with 12 seats	15,000
7	Truck or Bus	25,000

Source: Chau Doc Ferry.

4.4 Procedures of Traffic Demand Forecast

4.4.1 Types of Traffic

Traffic forecasts are made for normal and development traffic, diverted traffic, and induced traffic. Normal traffic is the traffic that currently uses the existing ferry services to cross the Hau Giang, and development traffic is the traffic that will be generated by the new import-export processing zones in Can Tho. Both of these types of traffic would be expected to grow regardless of whether or not a bridge is constructed. Diverted traffic is traffic that currently travels by other modes or via other routes and would be attracted to use the bridge. It is expected that some freight traffic would be diverted from inland waterways, depending on commodity type, and that some road traffic would be diverted to the bridge from the Vam Cong and An Hoa ferries. Induced traffic is traffic that would arise due to lower costs and greater convenience resulting from the construction of a bridge.

Typically, a bridge project of this nature would be expected to generate local and long-distance passenger and freight traffic.

Both passenger and freight traffic are analyzed. Further, average traffic volumes are individually forecast for different vehicle types. The methods of estimating normal, development, diverted, and induced traffic are described in the subsections that follow.

4.4.2 Vehicle Type

The vehicle types considered are the following:

- motorcycle (MC)
- passenger car (PC)
- light bus (LB)
- heavy bus (HB)
- light truck (LT)
- medium truck (MT)
- heavy truck (HT)

The first four types of vehicles are considered passenger transport vehicles, and the last three types are commodity transport vehicles. Motorcycles-with-trailers, which are commonly seen in the Mekong Delta south of the Hau Giang, are included in the motorcycle category. Passenger cars include only normal sedans or estate cars with typically 4-5 seats, although they may be overloaded with more than 5 occupants. Buses with less than 15 seats are classified into the light bus category, and buses with more than 15 seats belong to the heavy bus category, although further subdivision may seem appropriate. Light trucks have load capacities of 5 tons or less, medium trucks have load capacities of 6-10 tons, and heavy trucks have load capacities of 11-18 tons. Pedestrians and bicycles were not considered in this forecast because the benefits by reduction of time were assumed to be small.

4.4.3 Forecast Year

Traffic demand forecasting was carried out for years 2006, 2010, and 2020 on the horizon of 15 years from the opening year (2006).

4.4.4 Zoning

As presented earlier in subsection 4.1.5, the study area was divided into 57 traffic zones (see Fig. 4.2 and Table 4.8), representing the Mekong Delta and the North-East South Region, which includes Ho Chi Minh City, as well as two external gateways for other parts of Vietnam and Cambodia.

4.4.5 Forecast Procedure

The conceptual forecast procedures are as follows:

- Development scenarios of economic growth in the Mekong Delta and the North-East South Region are prepared for the initial base case;
- Normal and development traffic demand in the form of origin-destination (OD) matrices based on the estimated growth rates by zone and vehicle type are forecast for passenger traffic and freight traffic;
- Diverted traffic from other modes are then forecast for passenger traffic and freight traffic;
- Basic traffic matrices are forecast by summing the normal and development traffic OD matrices and the diverted traffic OD matrices;
- The reduction of travel time between cases with and without a Hau Giang Bridge are estimated, and induced traffic in the future is forecast by applying elasticities with respect to reduction of time to the basic traffic OD matrices;
- Future traffic matrices by vehicle type are constructed by adding the induced traffic OD matrices to the basic future traffic OD matrices; and
- Traffic volumes at bridge and ferry points are then forecast by assigning the traffic OD matrices by vehicle type to the various networks (without bridge, with Alternative A bridge, with Alternative B bridge, and with Alternative C bridge). Route Alternatives (A, B, and C) are described in the next chapter, "Chapter 5 ALTERNATIVE ROUTES".

4.4.6 Normal and Development Traffic

Regional travel demand projections are based on economic growth activity in the Mekong Delta and the North-East South Region (including Ho Chi Minh City). Table 4.20 summarizes forecast gross domestic regional product (GDRP) growth rates by province in the Mekong Delta, and Table 4.21 summarizes these rates by province in the North-East South Region. Although GDRP growth rates were initially provided by the Transport Development Research Center in the South (TDSI South, formerly known as TESI), they were believed to be overly optimistic. For example, the forecast average annual medium economic growth rates for the Mekong Delta and North-East South Region for the period 1995-2010 were 11.1% and 13.2%, respectively. For the high growth case, these figures were 12.3% and 14.1%, respectively. Typically, an average annual economic growth rate higher than 10.0% is not sustainable over such a long period of time, and the application of an 11-14% rate would not conform to standard international practice. Therefore, these growth rates were revised downward to ensure that a conservative approach was followed. More specifically, it was assumed that the average annual economic growth rate in the Mekong Delta from the present to 2010 would be 9.0%, decreasing to 7.0% from 2010 to 2020, and that the average annual economic growth rate in the North-East South Region from the present to 2010 would be 10.0%, decreasing to 8.0% from 2010 to 2020.

Because Chau Thanh district (also known as Cai Rang district, zone 35) in Can Tho Province is expected to receive substantial investment in the form of new import-export processing zones and a new Can Tho port in the near future, the high economic growth rate for Can Tho Province was applied to this zone. Consequently, the development traffic expected to be generated by these improvements was accounted for.

Table 4.20 Forecast Provincial GDRP Growth Rates in the Mekong Delta (Percent per Annum)

Province	1995-2010			2010-2020		
	Low	Medium	High	Low	Medium	High
Long An	8.6	9.2	10.4	7.1	7.5	8.5
Dong Thap	7.3	7.9	8.8	5.3	5.8	6.7
An Giang	7.9	9.2	10.0	5.5	7.0	8.0
Tien Giang	7.0	7.6	8.7	5.2	5.6	6.6
Ben Tre	6.4	7.4	8.6	4.6	5.6	6.6
Vinh Long	9.3	9.9	10.6	8.1	8.5	9.0
Tra Vinh	7.7	8.9	10.1	5.7	6.1	6.9
Can Tho	9.3	10.2	11.2	7.0	8.0	9.5
Soc Trang	10.2	11.5	12.2	6.9	8.5	9.0
Kien Giang	7.6	8.1	9.8	5.2	5.6	7.5
Bac Lieu	6.9	8.9	9.8	4.8	7.5	8.4
Ca Mau	5.3	6.5	7.4	2.3	4.0	4.9
Total	8.0	9.0	10.0	6.0	7.0	8.0

Source: JICA Study Team, based on data provided by the Transport Development Research Center in the South (TDSI South).

Table 4.21 Forecast Provincial GDRP Growth Rates in the North East South Region (Percent per Annum)

Province	1995-2010			2010-2020		
	Low	Medium	High	Low	Medium	High
Ho Chi Minh City	7.1	8.6	8.8	4.1	6.0	6.2
Dong Nai	11.7	11.7	13.2	10.0	9.4	10.5
Ba Ria-Vung Tau	11.6	12.0	14.3	9.0	9.6	11.4
Song Be	11.7	13.3	14.4	9.9	11.8	12.4
Tay Ninh	6.1	7.7	8.3	3.7	5.6	6.2
Total	9.0	10.0	11.0	7.0	8.0	9.0

Source: JICA Study Team, based on data provided by the Transport Development Research Center in the South (TDSI South).

Elasticities of demand for passenger and freight transport with respect to economic growth were applied to the forecast medium economic growth rates for estimating future passenger and freight traffic. These elasticities were used because motorcycle, passenger car, and truck traffic are expected to increase at rates higher than the average economic growth rate, as has been observed for the past several years in the Mekong Delta, while the growth of bus traffic is not expected to keep pace with GDRP growth. The elasticities adopted for use in this study are shown in Table 4.22.

Table 4.22 Elasticities of Demand with Respect to Economic Growth

Vehicle Type	1997-2010	2010-2020
MC	1.00	1.00
PC	1.75	1.50
LB, HB	1.25	1.00
LT, MT, HT	1.75	1.50

Source: JICA Study Team.

Elasticities of 1.00 for motorcycle traffic, 1.75 for passenger car traffic, 1.25 for bus traffic, and 1.75 for truck traffic were chosen for the period 1997-2010, after which the traffic growth rates are expected to decrease, except the rate for motorcycle, which are assumed to remain constant at 1.00. An elasticity of 1.50 for truck traffic was selected for 2010-2020, considering elasticities observed in other Southeast Asian countries, such as Thailand. Taking account of the observed elasticities of passenger and freight traffic demand in the Mekong Delta for the period 1991-95 with value of 1.5 and 2.1, respectively, the elasticities in Table 4.22 for forecasting traffic demand seem reasonable. Further, these elasticities represent lower average annual growth rates for passenger and freight traffic than assumed by the Vietnamese Ministry of Transport and Communications for the country as a whole.

4.4.7 Diverted Traffic

As mentioned earlier, diverted traffic includes traffic that currently travels by other modes or via other routes and would be attracted to the bridge. The latter form of diverted traffic is determined during the network assignment procedure and does not require exogenous analysis. Diversion from other modes to road, as well as diversion due to a change in travel patterns brought about by special developments, however, do require special attention.

Transport systems are rarely independent, and because different modes often compete or complement each other it is desirable to analyze the transport system including all modes. In general, the competing and complementing transport mode with respect to road traffic in the Mekong Delta is inland waterway. No railway is currently operational in the region, and the cargo volume by air transport is negligible at present and in the foreseeable future due to the high cost. While some diversion of international freight traffic is possible from sea and coastal water, the clear advantage of this form of transport for long distances suggests that any such diversion would indeed be marginal. Therefore, only diversion from inland waterways for freight traffic is considered.

The methodology for estimating the volume of diverted traffic from inland waterway to road was based on AASHTO's standard empirical formula tailored to conditions in Vietnam. This revised equation, shown below, assumes that the diversion factor for each origin-destination pair is a function of the travel cost by road, travel cost by inland waterway, freight commodity type, vessel size, and national highway accessibility of both the origin and destination.

$$P_{OD} = \frac{\alpha_O \alpha_D}{1 + \left(\frac{VOC_T}{VOC_{IW}} \right)^6}$$

where P_{OD} = diversion rate from origin O to destination D (%),

VOC_T = operating cost using truck from origin O to destination D (US$),

VOC_{IW} = operating cost using inland waterway from origin O to destination D (US$),

α_O = national highway accessibility at origin O (%), and

α_D = national highway accessibility at destination D (%).

All truck commodity types other than fertilizer and timber were assumed to potentially divert from inland waterway to truck, and only goods hauled by inland waterway vessels with a capacity of 50 tons or less were assumed to potentially divert to truck. Further, it was assumed that the majority of goods diverting from inland waterway to road-based travel would be hauled by heavy truck (about 70%), with about 25% by medium truck and only 5% by light truck.

Another form of diverted traffic will result from the various Can Tho Port improvement projects expected to be complete by 2010. More specifically, goods produced in the Mekong Delta destined for export will travel to the Can Tho Port, not Ho Chi Minh City, as is the current practice. As a result of this change in travel patterns, current export traffic south of the Hau Giang will no longer cross the river by truck, and current export traffic north of the Hau Giang will cross the river by truck. Because the exported volume of agricultural production south of the Hau Giang exceeds that of the north (Table 4.23), this shift in travel pattern will result in a net decrease in export truck traffic across the Hau Giang.

Table 4.23 Agricultural Export Volumes in the Mekong Delta

Area	Food Crop Production (tons in 1995)	Agriculture Export Volume (tons in 1995)	Percent of Agricultural Products Exported (1995)
Southern Mekong Delta	7,266,000	198,000	2.7
Northern Mekong Delta	5,728,000	99,332	1.7

Source: *Master Plan Study on Coastal Shipping Rehabilitation and Development Project in Vietnam, Final Report, Supplementary Reports Vol. 5, Coastal Shipping Traffic Demand,* March 1997.

As indicated in Table 4.23, however, only 2.7% of all agricultural products from the Southern Mekong Delta are exported, and only 1.7% of all agricultural products from the Northern Mekong Delta are exported. Considering that less than 40% of all trucks crossing the Hau Giang (on an average annual basis) carry agricultural products, the factors to be applied to the base river-crossing truck volumes are on the order of 1% and are therefore negligible.

4.4.8 Induced Traffic

Induced traffic arises either because a journey becomes more attractive by virtue of a reduction in cost or time or because of the increased development that is brought about by the road investment. Induced traffic is difficult to forecast accurately and can be easily overestimated. Induced traffic is likely to be significant only in those cases where the road investment brings about a large reduction in transport costs. The Hau Giang Bridge Project can be considered to fall under such an investment.

The common approach to forecasting induced traffic is to make use of information about demand elasticities. Evidence from several countries suggests a price elasticity in the range of -0.6 to -2.0. In general, the elasticity of commodity transport demand with respect to transport cost is much smaller than that of passenger transport demand and depends on the proportion of transport cost reflected in commodity prices.

In this study, the transport cost was substituted by travel time and the following steps adopted for the estimate of induced passenger traffic: (1) first, the reductions in time due to the provision of a new bridge were estimated for each OD pair; (2) the changes in travel time between the "with" and "without bridge" cases were calculated and expressed as percentage changes; and (3) future induced traffic OD matrices by vehicle type were forecast by applying elasticities with respect to travel time to the traffic OD matrices by vehicle type. For passenger traffic a value of -1.0

was adopted as the elasticity (i.e., a 10% decrease in travel time would result in a 10% increase in passenger traffic volume).

Induced freight traffic demand is forecast by a method based on the same principles as for the passenger traffic demand forecast. A value of -0.4 was adopted as the elasticity (i.e., a 10% decrease in travel time would result in a 4% increase in freight traffic volume).

4.5 Results of Traffic Demand Forecast

Forecasts of traffic volumes at bridge and ferry points were determined by assigning the traffic matrices by vehicle type to the networks.

4.5.1 Study Cases

Present river-crossing by ferry capacity is designed to accommodate the present traffic demand; therefore, it is highly likely that future traffic demand at the ferry points will exceed the ferry capacity during peak periods. In such a case, if additional ferry improvement projects are not carried out, traffic diversion from ferry points to other river-crossing ferries or a bridge will be needed. Future traffic volumes using a bridge are assumed to be influenced to some extent by the capacities of ferries at the other ferry sites. For the estimates of ferry waiting times in the "without bridge" case, a simulation program was developed expressly for this study.

Four study cases for the years 2006, 2010, and 2020 were established: (1) "without bridge" case; (2) with Alternative A bridge case; (3) with Alternative B bridge case; and (4) with Alternative C bridge.

(1) "Without Bridge" Case

If no additional ferry investments are made, the present ferry services may not be able to accommodate future river-crossing traffic demand during peak periods. In this case, the passenger waiting times for ferries will grow enormously long and some of the traffic will divert to other river-crossing points. Eventually, the total river-crossing traffic demand within the Mekong Delta will exceed the total capacity of the three main ferry points (i.e., Can Tho, Vam Cong, and An Hoa). To avoid an unrealistic increase in waiting times, ferry improvement projects that can accommodate the latent traffic demand at each ferry point were assumed. Free flow of traffic, which means no ferry capacity constraints, was assumed at the river-crossing ferry sites in the traffic assignment procedure. At Can Tho, Vam Cong, and An Hoa, safe ferry operation levels with 9 ferry boats operating simultaneously and three landing facilities per bank were assumed. The ferry capacities in 2006 at Can Tho, Vam Cong, An Hoa, and Chau Doc were determined including currently planned and/or approved ferry improvement projects.

(2) "With Bridge" Cases

Corresponding to the "without bridge" case, in the "with bridge" cases the capacities of river-crossing ferries were assumed to accommodate the latent transport demand at each ferry point. Therefore, additional investments for ferry capacity improvement are assumed to occur at the same time as for the "without bridge" case. Free flow of traffic, which means no ferry capacity constraints, was assumed at the river-crossing ferry points and at the bridge in the traffic assignment procedure. Also, the bridge toll was assumed to equal the ferry fare for each respective vehicle type.

4.5.2 Traffic Forecast Results for 2006, 2010, and 2020

Traffic volumes at the bridge and ferry points in each case were forecast by assigning the traffic matrices by vehicle type separately to the networks. This method enabled the accurate tracking and reporting of traffic assignments and related statistics (e.g., vehicle-minutes, vehicle-kilometers) by vehicle type.

The MINUTP (see Note in the next page) software was utilized for handling OD matrices and performing Fratar (i.e., growth factor) calculations, and the JICA STRADA software was used for traffic assignments and presentation of graphic displays. MINUTP and JICA STRADA are suites of computer programs that provide the capability to perform the usual functions of traditional transport planning with regard to matrix manipulation, trip generation, trip distribution, and network assignment.

The assignment results for 2006, 2010, and 2020 for the "No Bridge" Alternative and for "With Bridge" Alternative C are summarized in Table 4.24. OD trip desire line displays for aggregated zones and traffic volume bandwidth displays for the 2006 and 2020 Alternative C scenarios are shown in Fig. 4.5 and 4.6, respectively. OD matrices for both motorcycle trips and vehicular trips not including motorcycles are presented in the Annexure for 1997 and Alternative C scenarios for 2006, 2010, and 2020.

All three alternatives attract 29-34% more traffic than the "No Bridge" scenario, and each would require construction of a four-lane bridge to meet traffic demand after 2010.

Regarding the traffic capacity of a four-lane bridge, the hourly traffic capacity of a multi-lane road along a single section is given by the following formula:

$$C_p = C_b \times \gamma_1 \times \gamma_2 \times \gamma_3 \quad \ldots \times \gamma_n$$

where C_p = practical capacity (pcu or vehicles/hour)

C_b = basic capacity (pcu or vehicles/hour)

γ_t = adjustment factor to account for t

Note: MINUTP

MINUTP is a suite of computer programs developed in the United States by COMSIS that provides the capability to perform the usual functions of traditional transport planning with regard to matrix manipulation, trip generation, trip distribution, and network assignment. Similar types of software include TRANPLAN, EMME/2, TRIPS, TRANSCAD, MOTORS, and JICA STRADA.

The basic capacity of a multi-lane road is assumed to be 2,000 pcu/hour per lane. Regarding the adjustment factors, possible factors to be taken into account include lane width factors, side friction factors, and percentage of large vehicle factors. Of these factors, those concerning lane width and side friction can be eliminated (i.e., equal to 1.0) if the lane width is 3.5 m and the side leeway is 0.5 m as currently designed. The large vehicle factor can also be ignored since the traffic volume is expressed in terms of pcu rather than vehicles. Although these assumptions suggest that the capacity of the bridge is equal to 2,000 pcu/hour per lane, the practical capacity will likely be lower due to the capacity constraints of the intersections at both ends of the bridge, particularly that in Can Tho. If this intersection capacity constraint results in a 20% reduction in optimal traffic flow on the bridge (i.e., equivalent adjustment factor of 0.80), then the practical capacity of the bridge can be estimated at 1,600 pcu/hour per lane or 6,400 pcu/hour for four lanes.

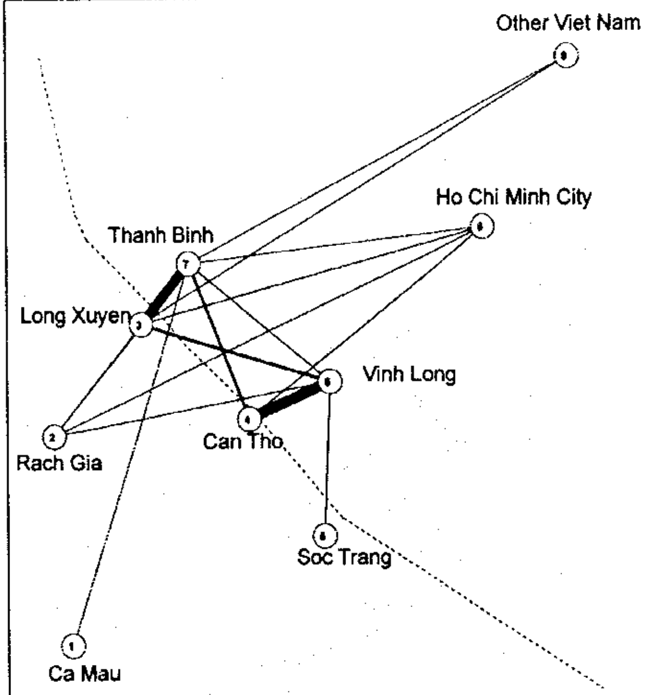
According to the results of the traffic count survey, the existing peak hour rate at the Can Tho ferry crossing was not high at only 7.5% in both directions. If the peak hour rate at the Can Tho crossing is assumed to increase to 8-9% in the future, the practical capacity of the bridge can be estimated at between 71,100 and 80,000 pcu/day.

Those numbers seem rather large, the capacity for a four-lane facility is approximated at 60,000 pcu/day as a general rule.

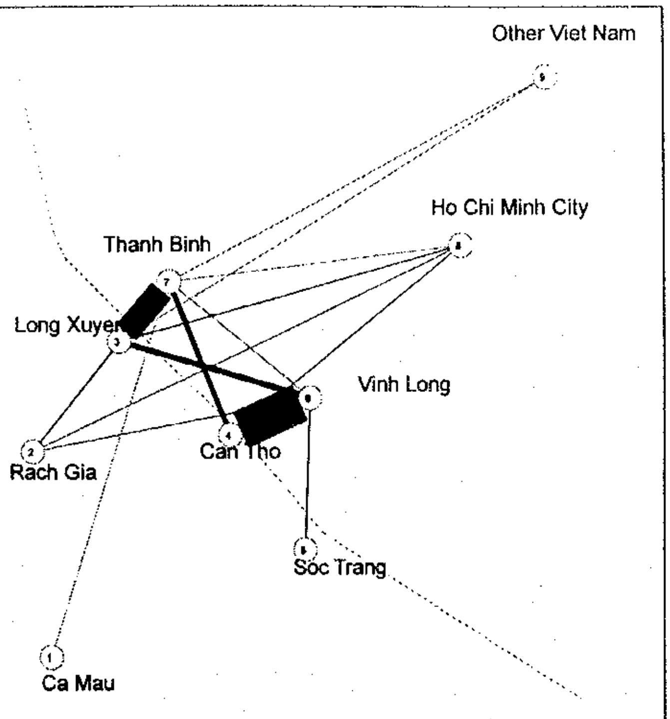
Table 4.24 Traffic Assignment Results at the Hau River Crossing near Can Tho

Description	2006 No Bridge	2006 Alternative C Bridge	2010 No Bridge	2010 Alternative C Bridge	2020 No Bridge	2020 Alternative C Bridge
Normal and Development Traffic in Vehicles/Day						
MC	9,585	10,736	14,125	15,777	31,877	34,972
PC	2,083	2,479	3,846	4,577	10,471	12,387
LB	1,038	1,126	1,676	1,822	3,612	3,922
HB	475	512	750	810	1,532	1,652
LT	738	859	1,332	1,606	3,835	4,614
MT	1,853	2,068	3,484	3,897	10,006	11,180
HT	74	104	138	194	396	542
PCU/Day	13,015	14,688	22,359	25,380	57,213	64,837
Diverted Traffic from Inland Waterway in Vehicles/Day						
LT	0	5	0	14	0	33
MT	0	27	0	70	0	171
HT	0	75	0	191	0	475
PCU/Day	0	287	0	734	0	1,817
Induced Traffic in Vehicles/Day						
MC	0	4,429	0	6,504	0	14,640
PC	0	298	0	562	0	1,578
LB	0	141	0	229	0	498
HB	0	54	0	88	0	182
LT	0	54	0	101	0	311
MT	0	106	0	208	0	627
HT	0	6	0	12	0	36
PCU/Day	0	2,160	0	3,514	0	8,609
Total Traffic in Vehicles/Day						
MC	9,585	15,165	14,125	22,281	31,877	49,612
PC	2,083	2,777	3,846	5,139	10,471	13,965
LB	1,038	1,267	1,676	2,051	3,612	4,420
HB	475	566	750	898	1,532	1,834
LT	738	918	1,332	1,721	3,835	4,958
MT	1,853	2,201	3,484	4,175	10,006	11,978
HT	74	185	138	397	396	1,053
PCU/Day	13,015	17,134	22,359	29,628	57,213	75,262

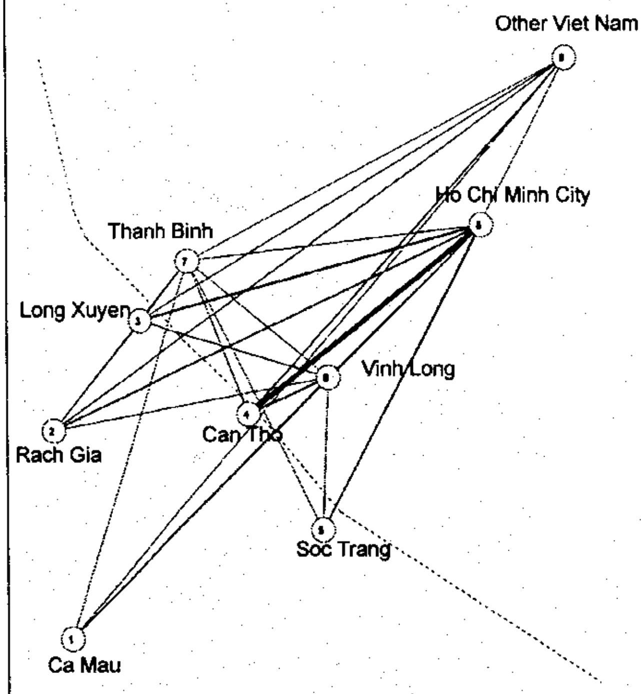
Source: JICA Study Team



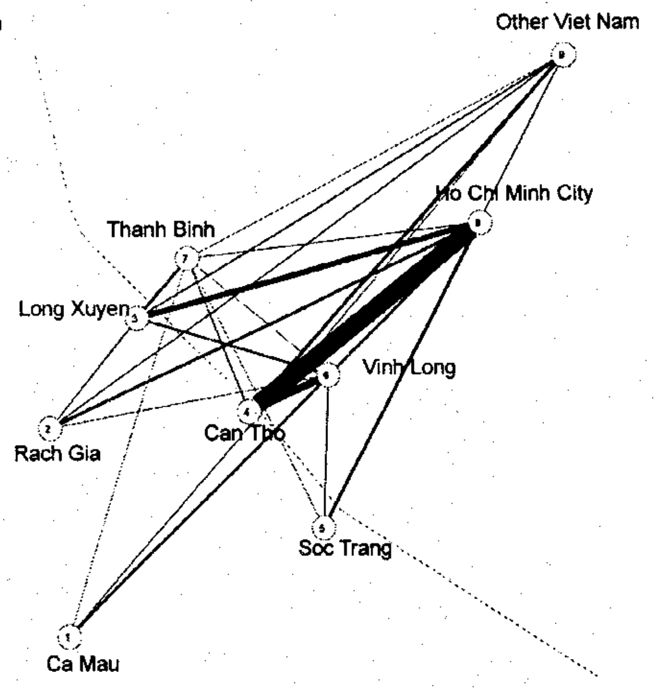
Year 2006 Motorcycle Trips
(with Bridge, ADT)



Year 2020 Motorcycle Trips
(with Bridge, ADT)



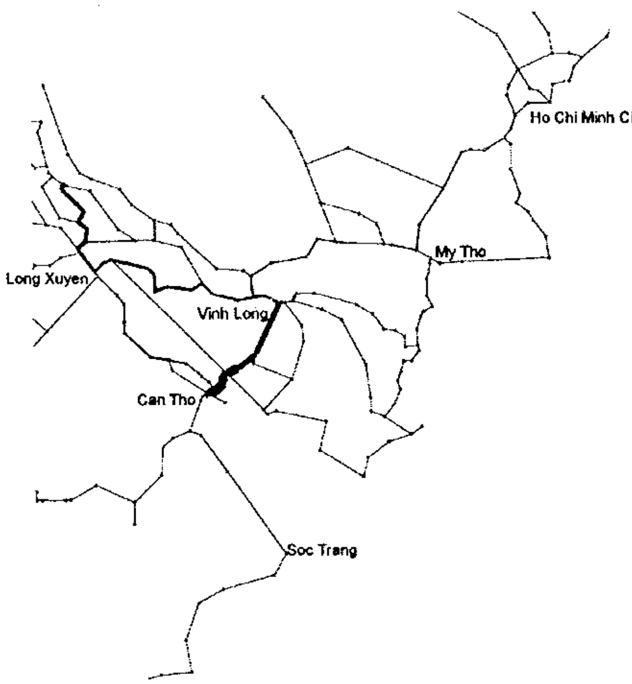
Year 2006 Vehicle Trips
(with Bridge, ADT, Not Including Motorcycles)



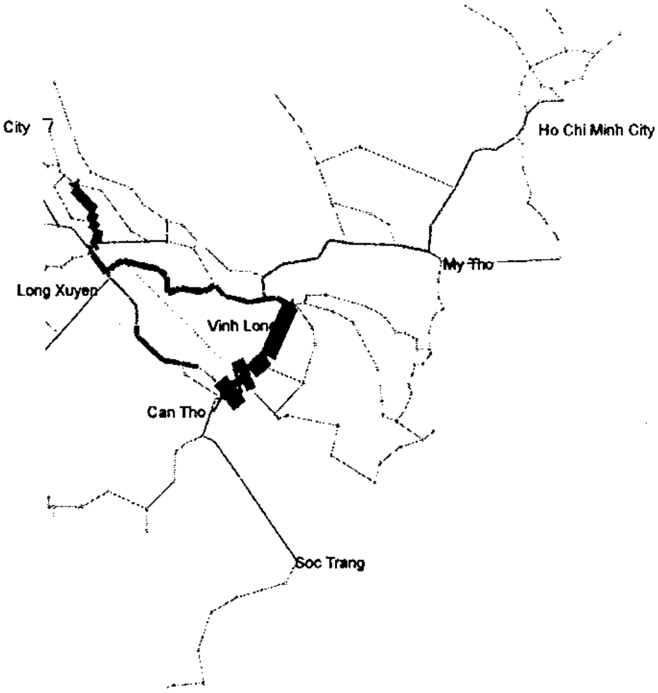
Year 2020 Vehicle Trips
(with Bridge, ADT, Not Including Motorcycles)

The Feasibility Study on the Can Tho Bridge Construction in Socialist Repulic of Viet Nam	Figure 4.5 Desire Lines of Forecast River-Crossing Traffic by Road in 2006 and 2020

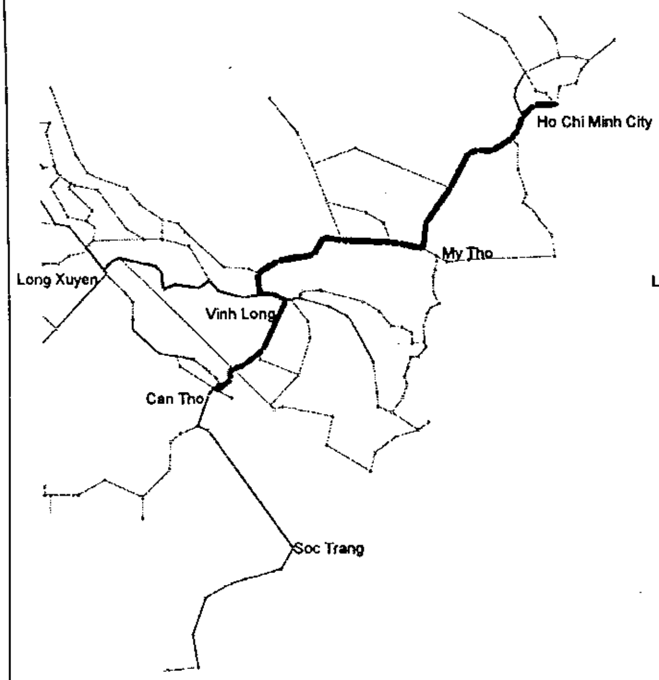
(Developed by the Study Team using JICA STRADA)



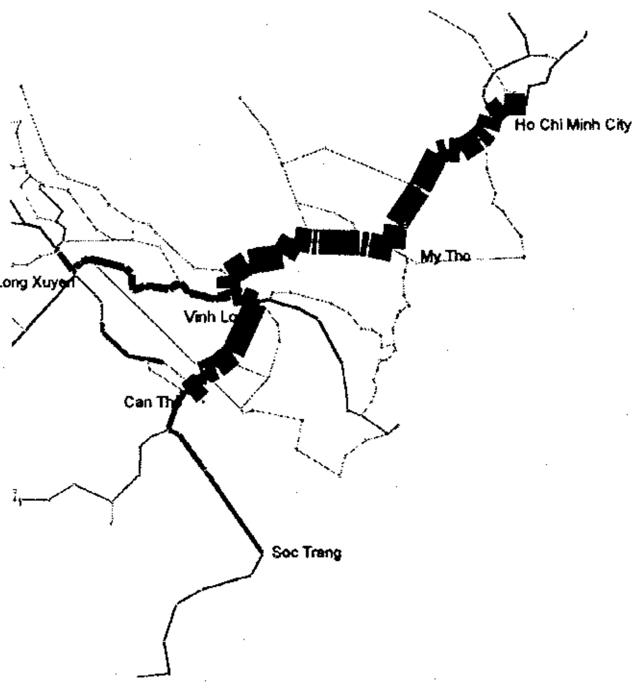
Year 2006 Motorcycle Trips
(with Bridge, ADT)



Year 2020 Motorcycle Trips
(with Bridge, ADT)



Year 2006 Vehicle Trips
(with Bridge, ADT, Not Including Motorcycles)



Year 2020 Vehicle Trips
(with Bridge, ADT, Not Including Motorcycles)

The Feasibility Study on the Can Tho Bridge Construction in Socialist Repulic of Viet Nam	Figure 4.6 Volume Bandwidths of Forecast River-Crossing Traffic by Road in 2006 and 2020

(Developed by the Study Team using JICA STRADA)

The Feasibility Study
on The Can Tho Bridge Construction in
Socialist Republic of Viet Nam

CHAPTER 5

ALTERNATIVE ROUTES

CHAPTER 5 ALTERNATIVE ROUTES

5.1 Setting Up Alternative Routes

5.1.1 Site Features

At present, National Highway (N.H.) No.1, connecting Vinh Long Province on the left bank of the Hau River and Ca Mau in the southern part of Viet Nam, crosses the river by ferry and runs from the north to the south through Can Tho City.

To replace the ferry that is causing a bottleneck to the road traffic with a bridge that crosses the river and allows a continuous road network, the following three alternative routes were studied. (see Fig. 5.1)

- Alternative Route A: Crosses the river about 3.3 km upstream from the existing ferry.
- Alternative Route B: Crosses the river about 750 m downstream from the existing ferry.
- Alternative Route C: Crosses the river via a sandbar about 2.9 km downstream from the existing ferry.

Basically, these routes branch off from N.H. No.1 and then join N.H. No.1 again. The following problems were identified.

- Route A: Crosses the Hau River, and joins N.H. No.91 and then N.H. No.1. Thus, Route A uses part of N.H. No.91 after crossing the river, consequently requiring many cases of resettlement along N.H. No.91 due to maintaining the road width for four lanes toward N.H. No.1.
- Route B: Crosses the Hau River, and goes into the Can Tho City urban area. For about 1.5 km from this point this route joins Nguyen Trai street and proceeds up to N.H. No.1. A new road needs to be constructed through a dense residential area, requiring many cases of resettlement.
- Route C: Requires minimum cases of resettlement and evades the maximum area of the ecosystem, having the functions of a bypass road smoothly branching off and joining N.H. No.1.

Compared with Routes A and B mentioned above, Route C requires fewer cases of resettlement but goes through more soft ground zones, and requires about 1.5 to 2.2 times more road extension. However, this route is far superior to the other two routes in terms of (a) the bypass effect for Can Tho City as seen from the existing traffic network, (b) the approach to the Southern Industrial Zone that has been outlined in the City Master Plan, and (c) the service effect for Can Tho City.

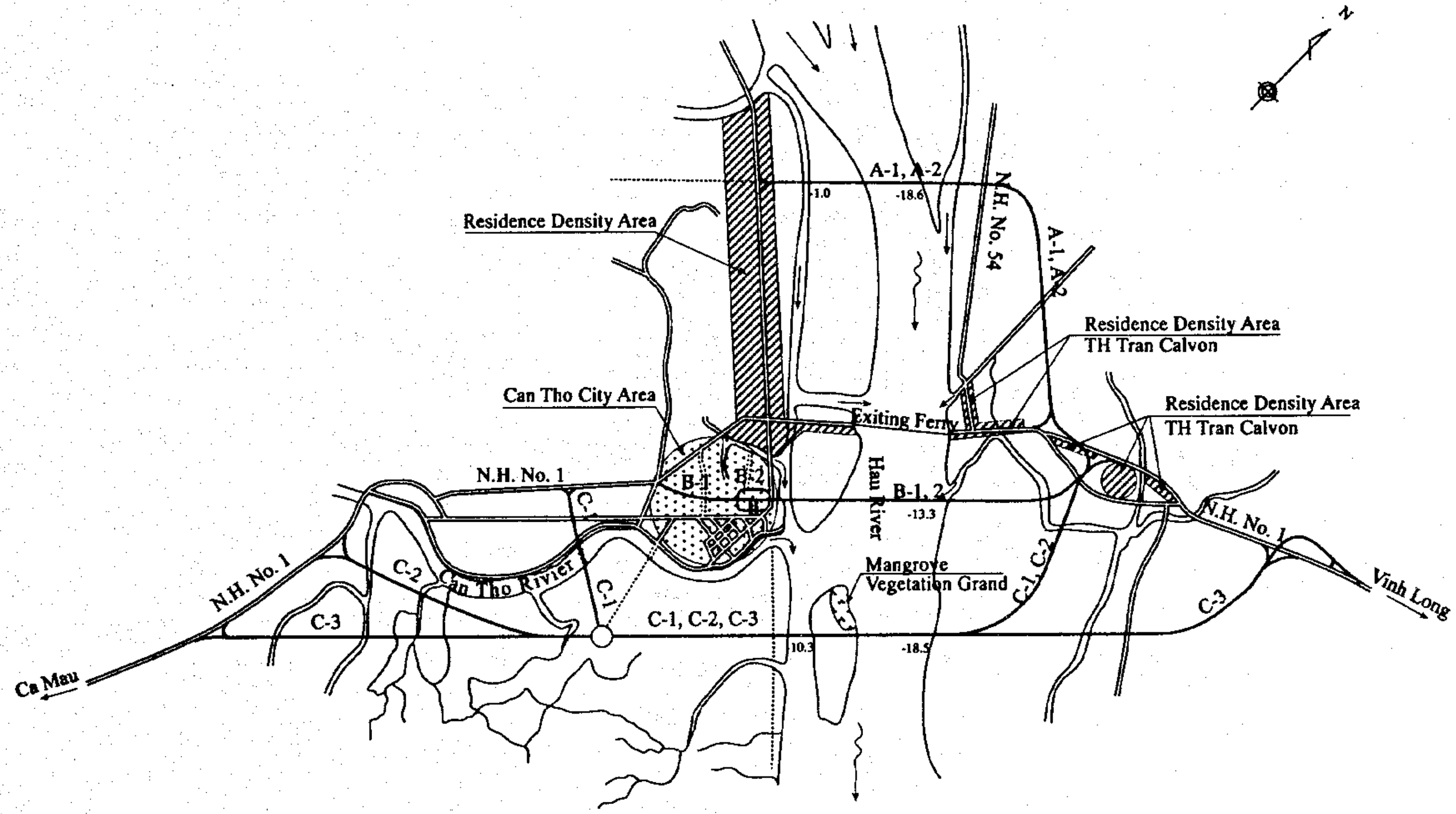
- Depth of the Hau River:

  The maximum depth measurements of the Hau River, taken along the three routes mentioned above, were: -18 m for Route A, -25 m for Route B, and -16 m for Route C.

5.1.2 Future Plan and Current Projects

The future plans and current projects relating to the transport sector are crucial factors which affect the alignment of the alternative routes, especially for determining the connection points to the existing or the planned roads after or before crossing the Hau River. The following current transport plans and projects, which should be considered for the alignment design (connecting points of options), are as follows:

- Improvement of National Highway No. 1A
- Improvement and Widening National Highway No. 91
- Improvement of the existing Can Tho Port
- Tra Noc Industrial Zone (Export Processing Zone)
- Southern Industrial Zone (Export Processing Zone)
- Improvement of National Highway No. 1 (Can Tho - Ca Mau)
- Construction of new road between Quang Trung - Mau Than and Expansion of Tra Noc Airport
- Master Plan of Can Tho City



THE FEASIBILITY STUDY ON THE CAN THO BRIDGE CONSTRUCTION IN SOCIALIST REPUBLIC OF VIET NAM	Fig. 5.1 Site Feature JAPAN INTERNATIONAL COOPERATION AGENCY

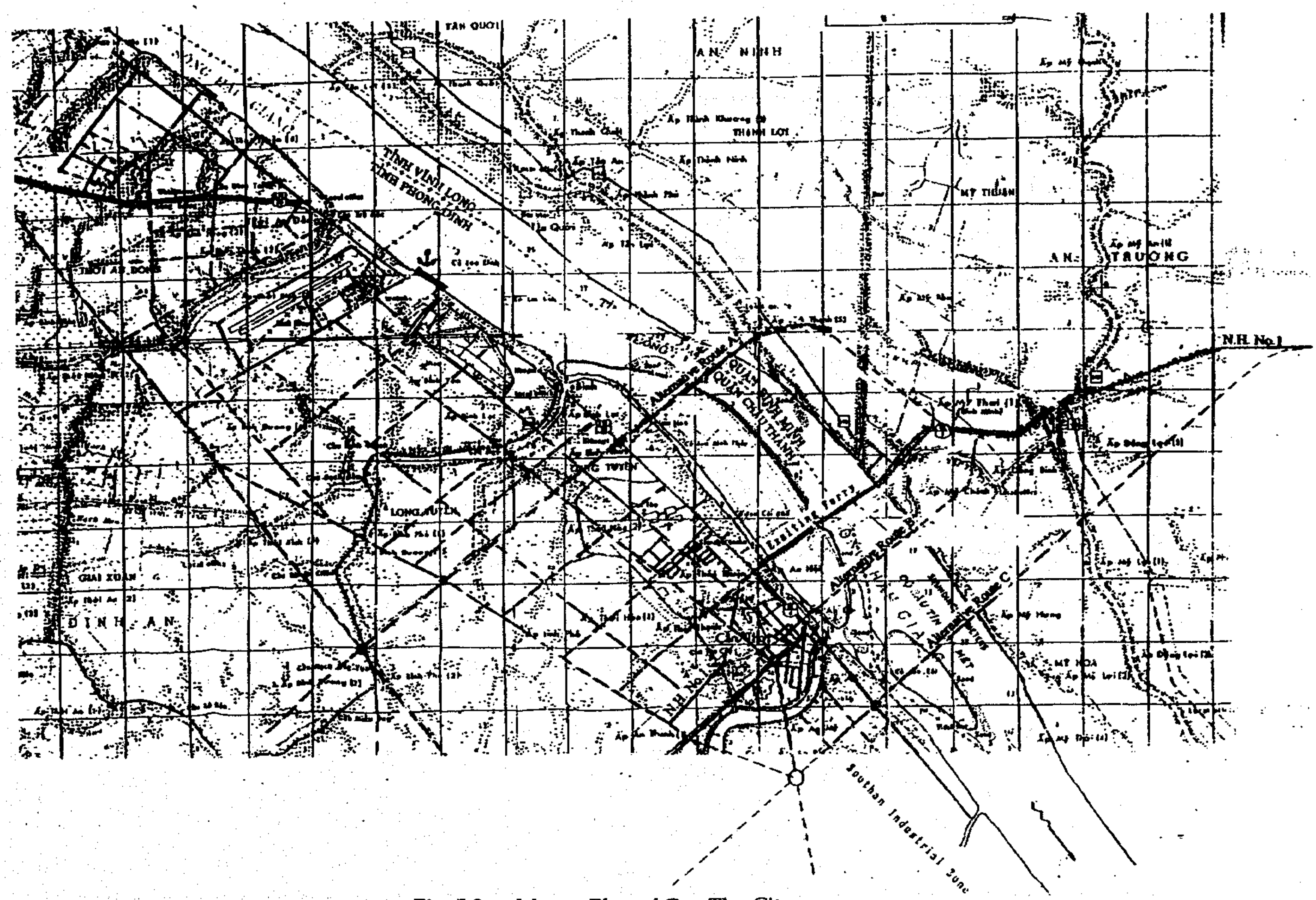


Fig. 5.2 Master Plan of Can Tho City

The current Master Plan, which was issued by the People's Committee Can Tho Province in 1993 and approved by the Vietnamese government in December of the same year, will be crucial for the project implementation. (see Fig. 5.2)

5.2 Options of Each Alternative Route

5.2.1 Alternative Route A

The following two options were examined for the Alternative Route A, which crosses the Hau River 3.3 km upstream from the existing ferry and joins N.H. No.91 and then N.H. No.1.

A-1: Branches off from N.H. No.1 on the left bank of the Hau River then through T.H. Tran Caivon, proceeds through Khom 8 and Thanh Phu, crosses the Hau River, and joins N.H. No.91 and then N.H. No.1. The part of N.H. No.91 used to connect to N.H. No.1 must be widened.

This route meets the prerequisite of branching off from and joining again to N.H. No.1, but has an inferior bypass effect and requires extremely many cases of resettlement.

A-2: This route is the same as Route A-1 up to the point where it joins N.H. No.91, but N.H. No.91 is used to connect to N.H. No.1. However, N.H. No.91 is not wide enough at present (12 m) and will cause a bottleneck for the traffic.

5.2.2 Alternative Route B

This route branches off from N.H. No.1 about 700 m farther away from Vinh Long than Alternative Route A, and crosses the Hau River with a bridge about 750 m downstream from the existing ferry.

The above condition is established because no structure may be built within 500 m upstream or downstream from the existing ferry crossing. This condition also allows the 250-m workspace required for constructing a bridge, and meets the site conditions (that the junction of the Cai Von River and the Hau River must be avoided). Accordingly, two alternative routes were planned: B-1 joining N.H. No.1 at its end and B-2 joining Nguyen Trai street about 1.5 km before N.H. No.1.

B-1: Crosses the Hau River, intersects Nguyen Trai street, goes across the densely populated residential area southward, and joins the irregular cross (4-leg) intersection of N.H. No.1 near Phg An Phu. This route requires many cases of resettlement and joins N.H. No.1 in a very complicated manner (a five-road intersection).

B-2: Is the same as Route B-1 up to the point where it joins Nguyen Trai Street. This route requires less road extension than B-1 and fewer cases of resettlement, but cannot meet the prerequisite of directly joining N.H. No.1.

5.2.3 Alternative Route C

Compared with Alternative Routes A and B mentioned above, Alternative Route C evades the urban area and provides a bypass route for the road traffic in a manner that is consistent with the Can Tho City Master Plan. Accordingly, the following four alternative routes were planned.

C-1: Goes via the same locations as Route C-2 while bearing away from N.H. No.1. This route crosses the Hau River, over the proposed Can Tho Bridge as outlined in the Can Tho City Master Plan, and goes through Can Tho City Phg Hung Lai and joins N.H. No.1.

Compared with C-3, this route requires 5 km less road extension but more cases of resettlement because it goes through the urban area after crossing the proposed Can Tho Bridge as outlined in the Master Plan.

C-2: To decrease the road extension and to avoid bridge construction crossing the Can Tho River, this route branches off from N.H. No.1 at the same location as B-1 and B-2 but links up with C-1 before the bridge over the Hau River and connects to N.H. No. 1 after crossing the existing Can Tho River bridge as outlined in the Master Plan.

Compared with C-3, this route requires 1 km less road extension.

C-3: Branches off from N.H. No.1 before T.H. Tran Cai Von, (a dense residential area on the Vinh Long side of the left bank of the Hau River at Kilometer Post 2061) and arrives at the bridge position (Ap My Hung) about 2.9 km downstream from the existing ferry crossing evading as much residential disruption in the soft ground zone as possible.

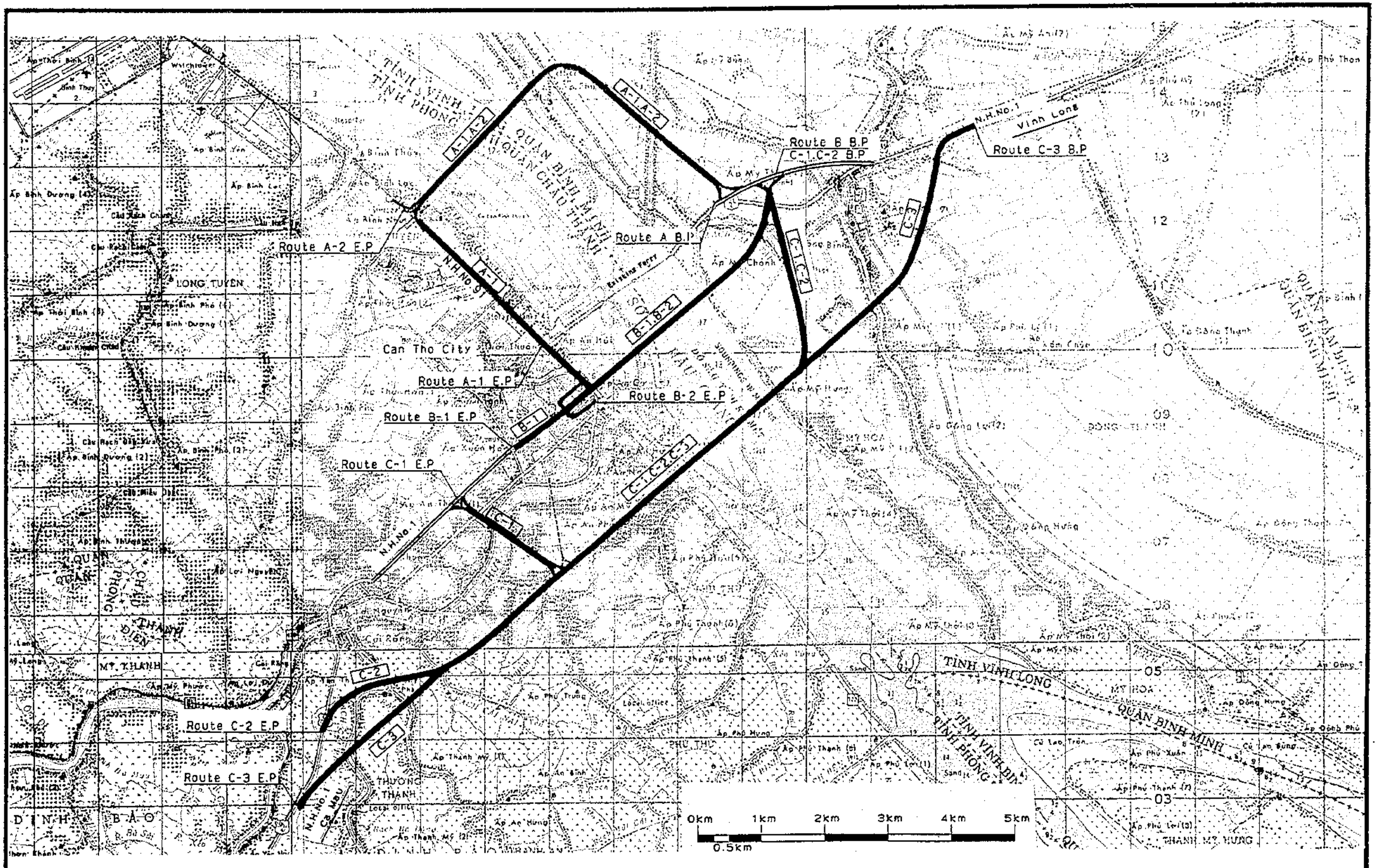
C-2/3: Combined Route of C-3 on the Vinh Long side and C-2 on the Can Tho side. The alignment of this route is superior to C-2, and this route requires 1km less road extension compared with C-3.

Over the entire area of the Hau River right bank, there is the road network and the Southern Industrial Zone planned in the Can Tho City Master Plan. To apply the Master Plan and the park plan for the sandbar where this route goes, this route is therefore constructed farther down to the south. N.H. No.1 goes across the Can Tho City urban area, crosses the Can Tho River and meets this route at Tan Thanh Dong about 3 km toward Ca Mau.

Compared with the other Routes A and B, this route requires more road extension and encounters many soft ground areas. On the other hand, this route requires fewer cases of resettlement, and is superior in (a) the bypass effect in view of the future traffic volume, (b) the approach to the Southern Industrial Zone planned in the Can Tho City Master Plan, and (c) the access to Can Tho City. (see Table 5.1 and Fig. 5.3)

Table 5.1 Options of Alternative Route

Route	Options	Length (m)	Number of Crossings River/Canal		Environmental impact (Resettlement)	
A	A-1	10,500 m	River.......3	Canal.........7	High	- along N.H.No.91
	A-2	7,500 m	River.......3	Canal.........7	Median	
B	B-1	6,380 m	River.......3	Canal.........1	High	- near the connecting point with N.H.No.1 in Can Tho city
	B-2	5,304 m	River.......2	Canal.........1	Low	
C	C-1	10,050 m	River.......1	Canal.........6	Median	
	C-2	12,200 m	River.......5	Canal.......10	Low	
	C-3	15,500 m	River.......7	Canal.........9	Low	
	C-2/3	14,500m	River.......6	Canal.......10	Low	



THE FEASIBILITY STUDY ON THE CAN THO BRIDGE CONSTRUCTION IN SOCIALIST REPUBLIC OF VIET NAM	Fig. 5.3 Alternative Routes and Options
	JAPAN INTERNATIONAL COOPERATION AGENCY

5.3 Approach Road

5.3.1 Control of Approach Road Alignments

To determine the approach road alignments, the following items are considered as control conditions.

(1) Prerequisites

- Branching off from and then joining again N.H. No.1.
- Adhering to the Master Plan of the concerned Province or City.

(2) Natural Conditions

- Ecosystem (mangrove)
- Soft ground zone

(3) Social Conditions

- Prawn Farming
- New Factory
- Cemetery & Crematory
- School & Hospital

5.3.2 Road Structure

(1) Embankment Height

- The Project site is located in the Mekong Delta where flooding is very prone, and therefore, the embankment height of the approach road should be determined based on the flood water levels.
- According to the subsoil exploration conducted by the Study Team, a soft clay layer exists 10 m to 15 m below the ground surface. The height limit of the embankment for the approach roads should be stable from the problems of settlement sliding and/or lateral movement.

- The embankment height limit should be feasible from not only technical but economic viewpoints. Therefore, it should be determined based on the settlement and stability analysis of soils for the approach roads, including cost comparisons.

(2) Soft ground Treatment

For the soft soil condition of the Mekong Delta, the following treatment for improving soft soil for the approach roads is considered.

- To use light weight material for the embankment
- To replace the soils by excavation
- To provide vertical drains for increasing the rate of settlement
- To fill with surcharge as pre-loading, normally 30% of embankment height
- To fill lateral support or counter weight berms on both sides of the embankment
- To reinforce the earth fill embankment using geotextile.
- To provide a sand blanket below the embankment
- To provide piles below the embankment

From the technical and economic viewpoint, the soft ground treatment shown in Fig. 5.4 is recommended.

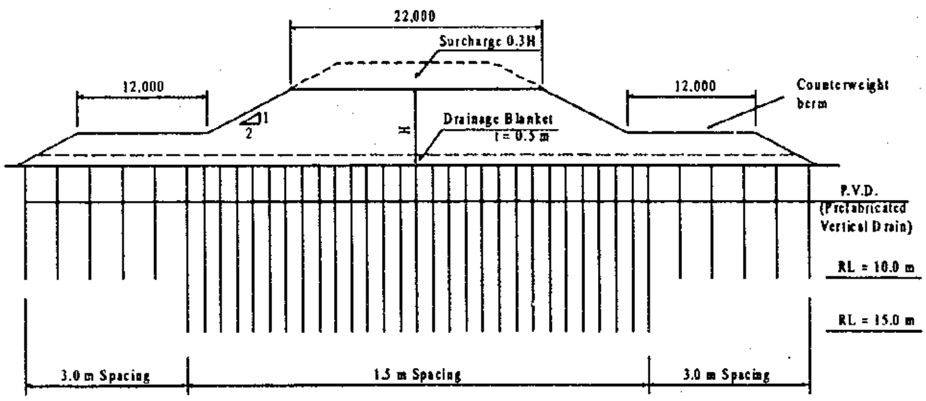


Fig. 5.4 Typical Embankment Section with Soft Ground Treatment

The Feasibility Study on The Can Tho Bridge Construction in Socialist Republic of Viet Nam

CHAPTER 6

NATURAL CONDITION SURVEYS AND ASSESSMENT

CHAPTER 6 NATURAL CONDITION SURVEYS AND ASSESSMENT

6.1 Topographic Survey

The topographic survey was conducted covering the area between the connecting points with N.H. No.1 on both sides of the Hau River (Vinh Long and Can Tho sides) for each Alternative Route. The horizontal coordinates (X and Y) were based on the GPS (Global Positioning System) from a satellite, while the elevations were obtained from the National Bench Mark System in Viet Nam. The survey consists mainly of the topographic survey, river crossing section survey and hydrological/hydraulic surveys.

The following Vietnamese standards were applied to the basic datums needed for the topographic surveys:

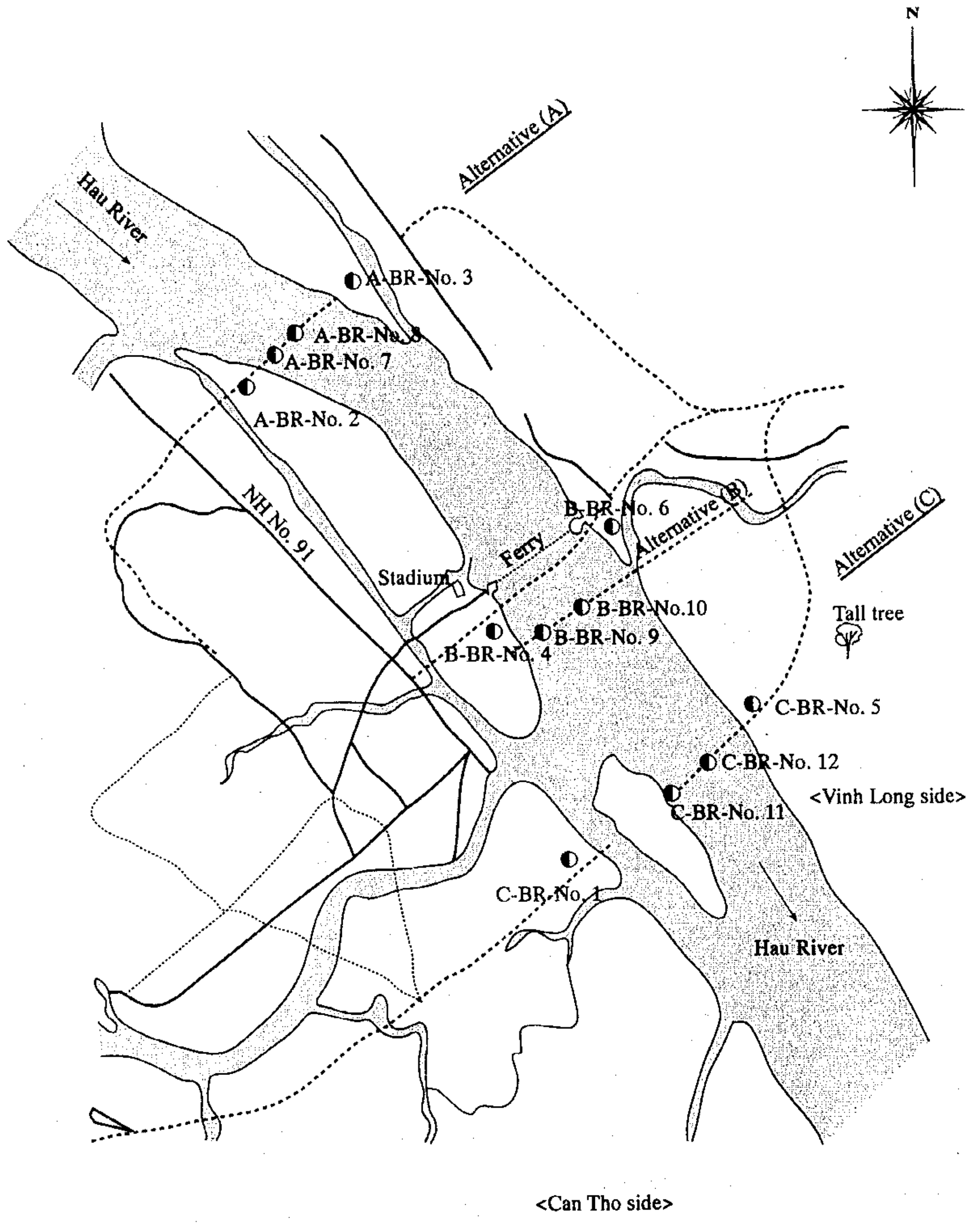
- Projection: Gauss-Kruiger Grid System
- Scale Factor: 1,000 for the central Meridian
- Ellipsoid: Krasopskian
- Vertical datum: Mean sea level at Hon Dau Island (National Bench Mark System)
- Horizontal datum: HN-1972 (National Bench Mark System)
- Central Meridian: The selected Central Meridian 105°00'00" East.

6.2 Geotechnical Survey

6.2.1 Contents of Survey

(1) Mechanical Boring

12 bore holes (1150 meters long in total) have been drilled and taken the Standard Penetration Test (S.P.T). The actual boring locations and results are shown on Fig. 6.1 and Table 6.1.



THE FEASIBILITY STUDY ON THE CAN THO BRIDGE CONSTRUCTION IN SOCIALIST REPUBLIC OF VIET NAM	Fig. 6.1 Borehole Locations
	JAPAN INTERNATIONAL COOPERATION AGENCY

Table 6.1 Boring work

Hole No	Drill length (m)	S.P.T (Nos)
Alternative A		
A-BR-No. 2	100	100
A-BR-No. 3	100	100
A-BR-No. 7	100	100
A-BR-No. 8	100	100
Alternative B		
B-BR-No. 4	85	85
B-BR-No. 6	100	100
B-BR-No. 9	90	90
B-BR-No. 10	90	90
Alternative C		
C-BR-No. 1	90	90
C-BR-No. 5	95	95
C-BR-No. 11	100	100
C-BR-No. 12	100	100
Total 12 Holes	1150 m	1150 (Nos)

(2) Laboratory Test

Undisturbed samples collected by iron pipe in the process of the boring work were examined in the Vietnamese laboratory at Hanoi.

Actual laboratory tests carried out are shown in the following table.

Table 6.2 Items of laboratory Soil Test

Items	Test Specification
- Atterberg Limit	AASHTO T89, T90
- Specific Gravity	AASHTO T100
- Unit Weight	AASHTO T19
- Moisture content	ASTM A 1203
- Grain Size Analysis	AASHTO T 88
- Unconfined Compressive Test	AASHTO T 208
- Triaxial Compressive Test	AASHTO T 234

6.2.2 Regional Geomorphology

The Project site is located in the lower reaches of the Mekong River, approximately 100km from the river mouth (South China Sea). This area is the magnificent water-land, so called Mekong Delta, which occupies 65,170 square kilometers. The geomorphology of this region is a vast alluvial marsh and plain. Around two major rivers i.e. the Tien River and the Hau River (divided from the Mekong), numerous tributaries, lakes and/or marshes join, to form a great water network. On the river sides, low and flat land spread extensively. These lands are the lagoons which were formed as a result of the recent marine recession (Holocene of Geo-age).

The geological base rock layer in this region is Cretaceous Igneous Rock (Granite etc). It is found far from the Project site, near the border with Cambodia.

Generally, the base layer of the Project region is Quaternary sand (Delluvium), and the main geological layer consists of alluvial soils which are summarized in the following table.

Table 6.3 Stratigraphy of Project Area

<table>
<tr><th>MARK</th><th colspan="2">GEO-TIME</th><th>SOIL TYPE</th><th>CHARACTERISTIC</th></tr>
<tr><td>CL</td><td rowspan="5">Quaternary</td><td rowspan="2">Alluvium</td><td>Clay</td><td>Lacustarine and River deposit. High plastic clay. Locally thin sand interbed.</td></tr>
<tr><td>1) ST
CL/ST</td><td>Clay. Silt
Sand mix.</td><td>Mainly clay/silt, very fine sand interlaid
Partially organic carbon silt band interbed.</td></tr>
<tr><td>ST/CL</td><td rowspan="3">Delluvium</td><td>Silt. Clay</td><td>High consolidated hard silt stiffened by a combination of chlorine minerals.</td></tr>
<tr><td>S1</td><td>Sand</td><td>Fine to medium sand Brownish to yellowish in color. Locally contains coarse quartz granules.</td></tr>
<tr><td>S2</td><td>Sand</td><td>Gray color fine sand. Uniform in grain size.</td></tr>
</table>

Note 1) In the Alternative B site, silt with fine sand is predominant, clay is rare.

6.2.3 Geological Condition of the Project Site

Based on the result of boring work and bore samples, the geological condition for each route is described as follows.

(1) Alternative A Route:

a) Clay Layer (CL):

On the ground of the river banks, brown soft and sticky clay is found with a thickness of 30 to 40 m. This is probably lacustarine origin clay which sedimented during the previous marine recession. It consists mainly of high plastic clay but has thin alternate sand layers. The N value of S.P.T (Standard Penetration Test), in this layer is 0 to 5. The river bed material is composed of similar clay and alternating thin sand layers.

b) Clay/Silt Layer (CL/ST):

From E.L. - 40 m to E.L. - 60 m below ground level a brown to dark gray soft clay and silt layer exists. The major portion is a mixture of clay and silt, but in some places it contains organic carbon materials and fine sand in alternating layers. The N value of S.P.T changes from 8 to 30 due to the denser sand layers. On average the N value is estimated at 15.

c) Silt Clay Layer (ST/CL)

From E.L.-60 m to E.L.-70 m below ground level is a brown to gray hard silt layer. The feature of this layer is the high consolidation and stiffness caused by chemical interaction. In grain size distribution silt is more abundant, and the N value ranges from 25 to 35.

d) 1st Sand Layer (S1):

Between E.L.-70 m and E.L.-100 m below ground level is a widely spread, yellowish brown, comparatively high density sand. The sand grains mainly consist of round shaped quartz with a small quantity of mica. In grain size distribution the main composition is of fine to medium sand, but in some places there are coarse granules 2 mm to 4 mm in dia. This layer was reported as gravel in the previous Pre-feasibility Study.

The (SPT) N value lies between 60 to 70.

e) 2nd Sand Layer (S2):

Below the 1st sand layer is a fine sand layer, which can be characterized as the base layer in the Project area. It consists of gray, very well graded high density fine sand and it is assumed to be of marine origin. Almost all the grains consist of round shaped quartz and from the grain size view point the layer is composed of uniform micro fine sand.

The N value is 60 to 80 and exceeds 100 in deeper locations.

(2) Alternative B Route

a) Clay Layer (CL):

Consists of a brown very soft, high plastic clay. This clay widely covers the ground surface and river bed areas but again there are thin alternating 30 to 50 cm thick sand layers.

The N value is less than 5.

b) Silt Layer (ST):

This layer lies below the clay layer (CL) and in stratigraphical order is equivalent to the silt-clay layer (ST/CL) mentioned in the Alternative A Route, but its soil composition is slightly different. The main soil type is silt associated with micro sand, and clay is rare.

The N values are very scattered from 8 to 40 in response to the variable sand mixing ratio. In general the silt layer is soft and loose.

c) Silt Clay Layer (ST/CL)

A brown to gray high plastic silt/clay. Similar to the one in the Alternative A Route, it is well consolidated and hard. The N value is 15 to 30.

d) 1st Sand Layer (S1)

A yellowish brown, comparatively high density sand. The major grain size is fine to medium and contains some coarse granules. The N value is more than 50.

e) 2nd Sand Layer (S2)

A gray marine origin sand. In grain size distribution it consists of a well sorted fine quartz sand. The N value is more than 50.

(3) Alternative C Route

The composition of the soil layer and the associated properties are similar to the Alternative A Route which is mentioned above. A description of the key points of each layer is given below.

a) Clay Layer (CL):

A brown, very soft and highly plastic clay of lacustarine origin. The N value is less than 5 and consolidation settlement should be considered.

b) Clay-Silt Layer (CL/ST):

A brownish soft and highly plastic clay and silt mixture associated with thin sand bands. The N value is 10 to 20.

c) Silt-Clay Layer (ST/C):

A brownish gray, hard and highly plastic silt with clay. It is well consolidated and stiffened by chemical interaction. The N value is 30 to 50.

d) 1st Sand Layer (S1):

A yellowish brown dense sand. The main grain size is fine to medium but in some places contains coarse quartz particles 2 to 4 mm in diameter. The N value is more than 50.

e) 2nd Sand Layer (S2):

A gray well sorted marine sand, which consists of very fine dense quartz grains. The N value is more than 50.

6.2.4 Consideration for Engineering Geology

(1) Soil Properties

Principal soil properties in relation to the engineering works are shown in Table.6.4.

Table 6.4 Soil Properties for Engineering works

Layer Mark	Soil Type	Properties						
		N	C (t/m^2)	ϕ (°)	γd (t/m^3)	qu (t/m^3)	Ip	Cc
CL	Clay	1	1	5	1.2	2	10	0.03
ST	Sandy Silt	10	1	10	1.4	2	20	↑
CL/ST	Clay and Silt	10	1.5	10	1.5	3	20	
ST/C	Silt with clay	30	5	10	1.7	30	20	negligible
S1	Fine Medium Sand	60	0	40	1.7	50	NG	
S2	Fine Sand	70	0	45	1.7	75	NG	↓

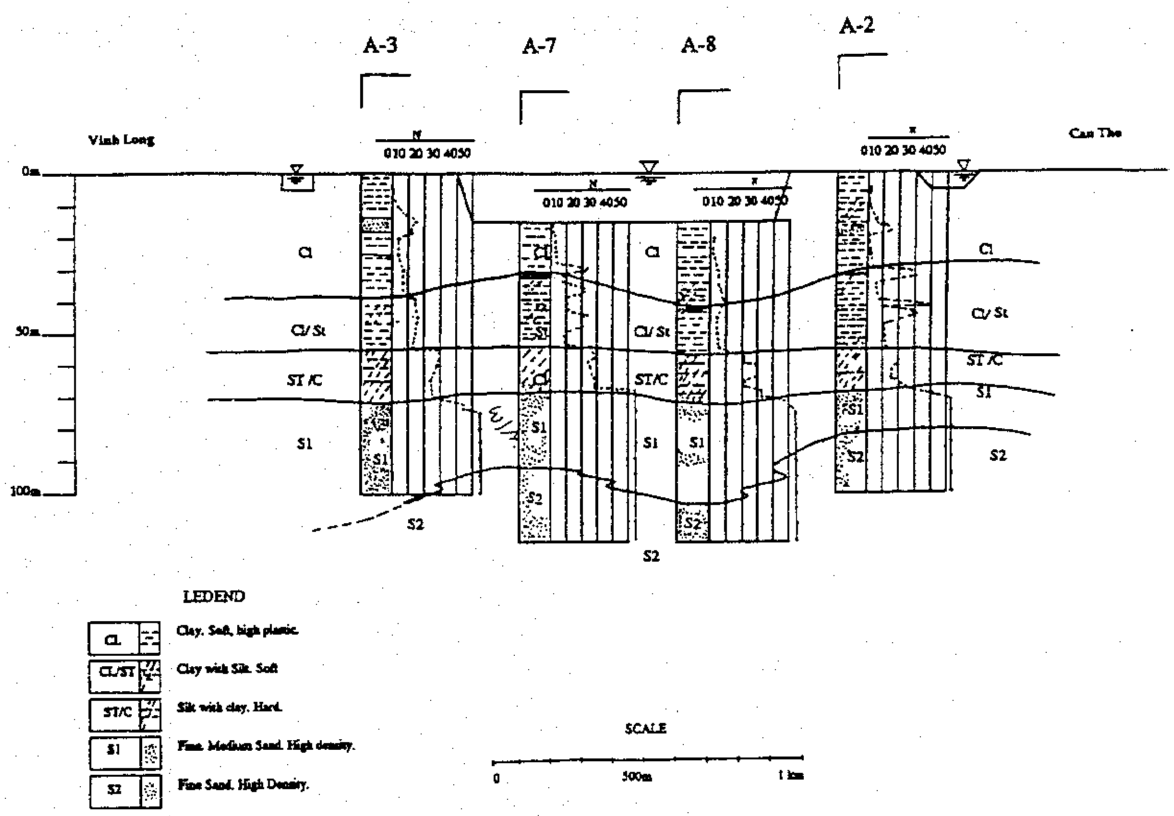
Note: Classification in the first column correspond to those in Fig.6.2

N: N value of S.P.T. C: Cohesion (t/m^2) . ϕ : Inter friction angle (degree).

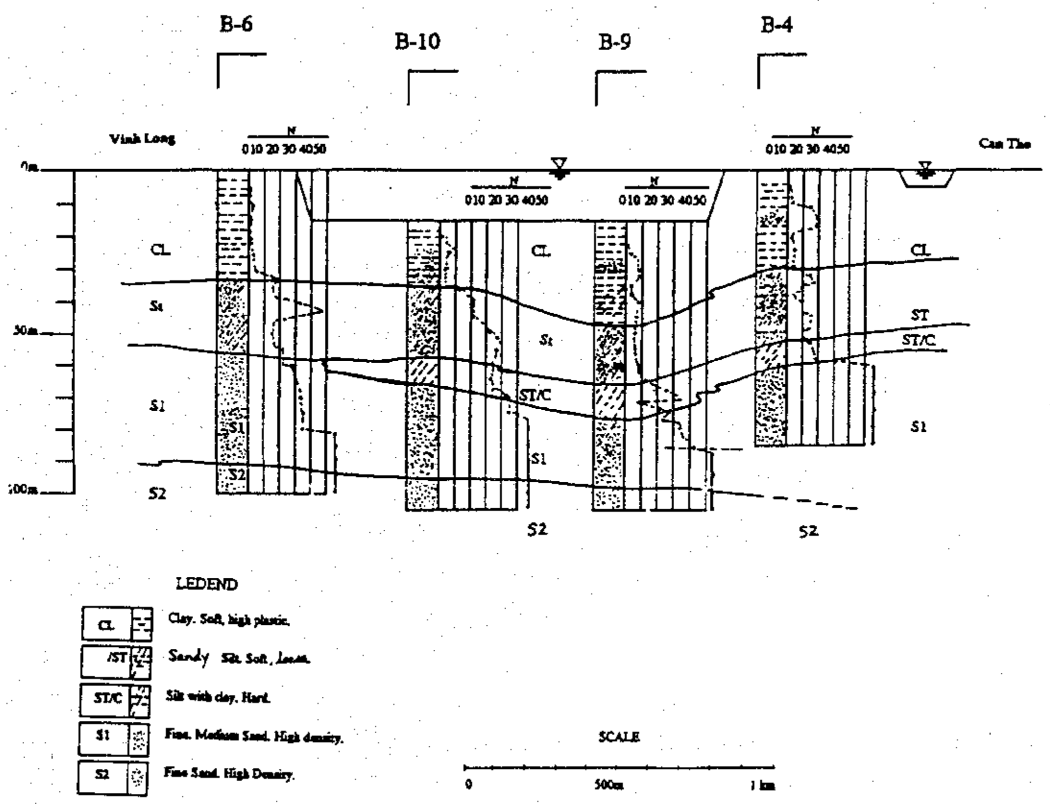
γd: Dry density (t/m^3) qu: Unconfined compressive strength (t/m^2)

Ip: Plasticity index Cc: Coefficient of consolidation.

ALTERNATIVE A



ALTERNATIVE B



ALTERNATIVE C

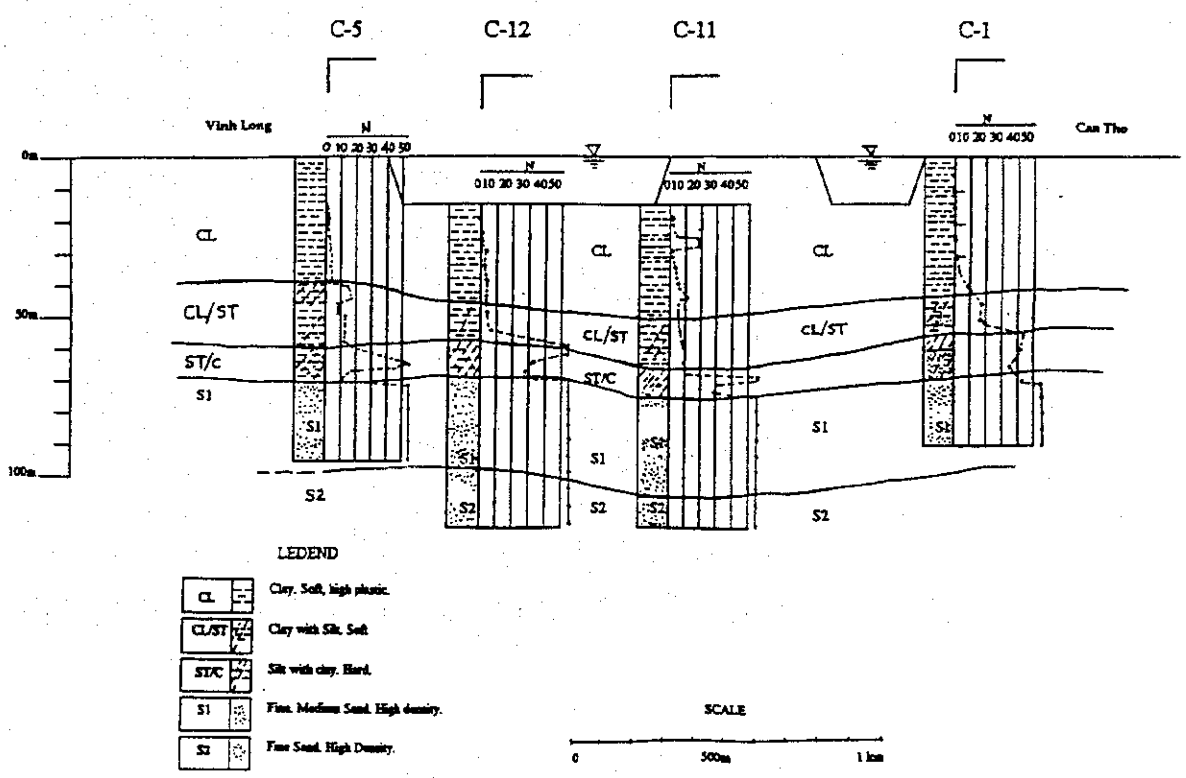


Fig. 6.2 Soil Profiles by Alternatives

THE FEASIBILITY STUDY ON
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(2) Bearing Layer for Pile Foundation.

Substructure piles in the abutments and piers are founded in the "Sand Layer - S1". The foundation depth is estimated at 60 to 95 meters but should be confirmed in the detailed design stage.

The grain size of the sand layer (50% distribution size) with respect to scouring is estimated at 0.5 mm and 0.2 mm, respectively, in layers S1 and S2.

(3) Earth Work Study for the Approach Road

In the whole of the approach road route, a soft and high water content "Clay Layer - CL" extensively overlays the ground and the construction of the road embankment will causes consolidation settlement. A vertical drain of geo-textile material (prefabricated vertical drain, PVD system) is one of the counter measures for increasing the rate of settlement. In the detailed design stage, more laboratory tests (including consolidation tests) are required in order to assess the consolidation settlement of the embankment. In addition, specific clay shear tests are required in order to study the stability of the soft clay layer.

(4) Consolidation Settlement in the Approach Road Embankment

In the soft clay layer (CL), consolidation settlement will inevitably be caused by the construction of the road embankment and, therefore, effective countermeasures should be considered.

The following key soil characteristics regarding settlement are commented on.

a) The values of the Atterberg Limit are empirically estimated as follows. Liquid Limit (LL) = 60, Plastic Limit (PL) = 30, and Plastic Index (PI) = 30. Judging from those values the vertical drain method is appropriate but its effectiveness is difficult to estimate without further tests.

b) The shear strength is small ($C = 1$ ton/m^2, $\phi = 5^0$ assumed), and, therefore, step loading is applicable for the road embankment construction.

c) In the case that a vertical drain system is adopted, the structure piling will become more effective.

d) During the actual construction, measurement of the settlement behavior, strain of the layer, and pore water pressure is required.

(5) Subsoil Survey Program for Detail Design

- Boring and S.P.T. (Standard Penetration Test)

  For the bridge structure, at every pier and abutment position, boring is required to confirm the bearing capacity of the sand layer. In addition, with regard to the approach road, boring is required in the high embankment section to clarify the characteristics of the soil layers.

- Laboratory Test

  In addition to ordinary laboratory testing for the bridge and road projects, consolidation tests and tri-axial tests of undisturbed samples are required in order to carry out a more precise foundation design in the consolidated settlement layer. On the other hand, chemical analysis (measurement of PH and salt content) is required for materials used in the concrete works.

6.2.5 Possible Bearing Stratum of Each Alternative Route

Route A (see Fig. 6.3)
The mechanical boring results show that the soil classification of the upper and middle parts are clay and the lower part is sand. The upper part, from 10 m to 40 m, is a soft layer with an N-value between 1 to 4. The middle part with an N-value of 4 to 25 (40 m to 60 m), can be considered a comparatively good soil layer. The lower part with N-value more than 50 (70 m to 100 m), consists mainly of fine to middle size sand and can be judged to be the soil layer which will be able to support the greater reaction forces from the superstructure.

Route B (see Fig. 6.4)

The soil classification of the upper and middle parts are clay and the lower part is sand (as for route A). The upper part with an N-value of 1 to 5 (10 m to 30 m) is in the soft soil layer. The middle part with an N-value of 5 to 35 (30 m to 60 m), is in a comparatively good soil layer. The lower part with an N-value of more than 50 (60 m to 100 m), consists of fine to middle size sand, and shall be considered as the bearing stratum.

Route C (see Fig. 6.5)

The soil classification of the upper and middle parts are clay. The lower part is sand. The upper part is a very soft clay layer with an N-value of <5 (20 m to 40 m deep).

The middle part with an N-value of 5 to 35 (40 m to 70 m), is clayey soil and a comparatively good soil layer. The lower part with N-value of more than 50 (70 m to 100 m), is considered as the bearing stratum.

Consequently, the bearing stratum required to support the bridge structure adequately is to be the soil layer classified as S1, which exists at a depth of 70 m to 95 m.

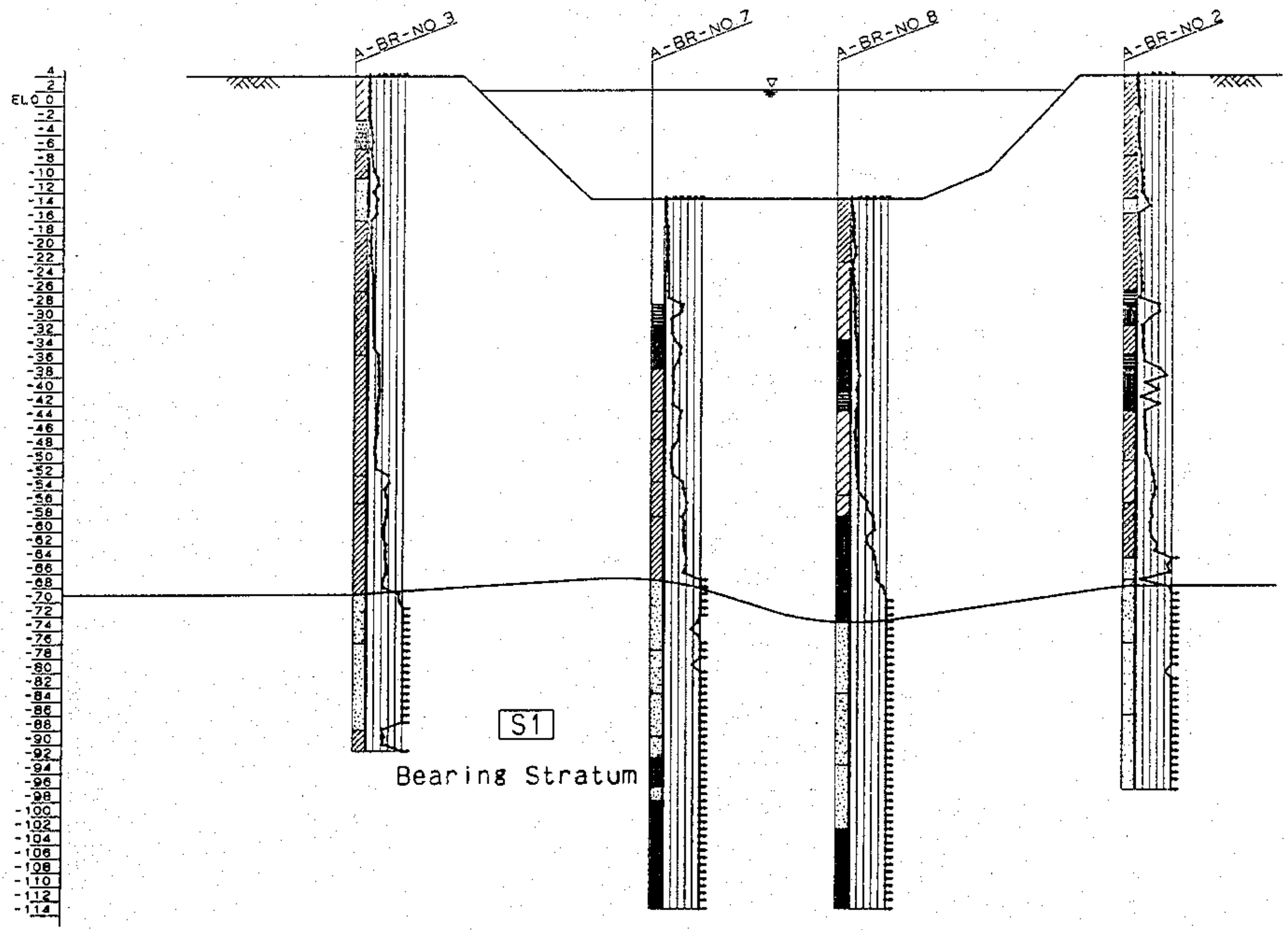

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Fig. 6.3 Bearing Stratum at A-Route

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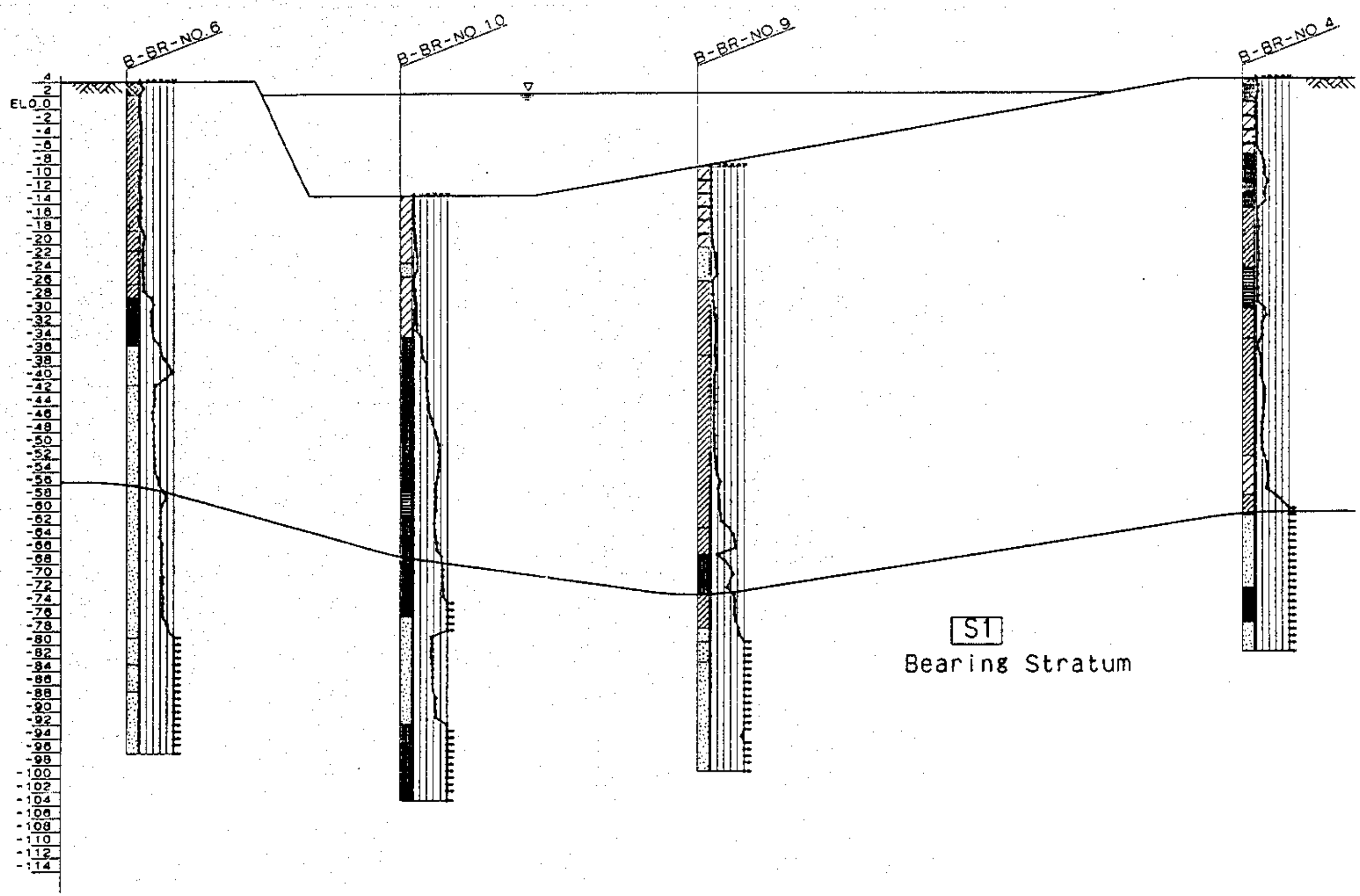

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Fig. 6.4 Bearing Stratum at B-Route

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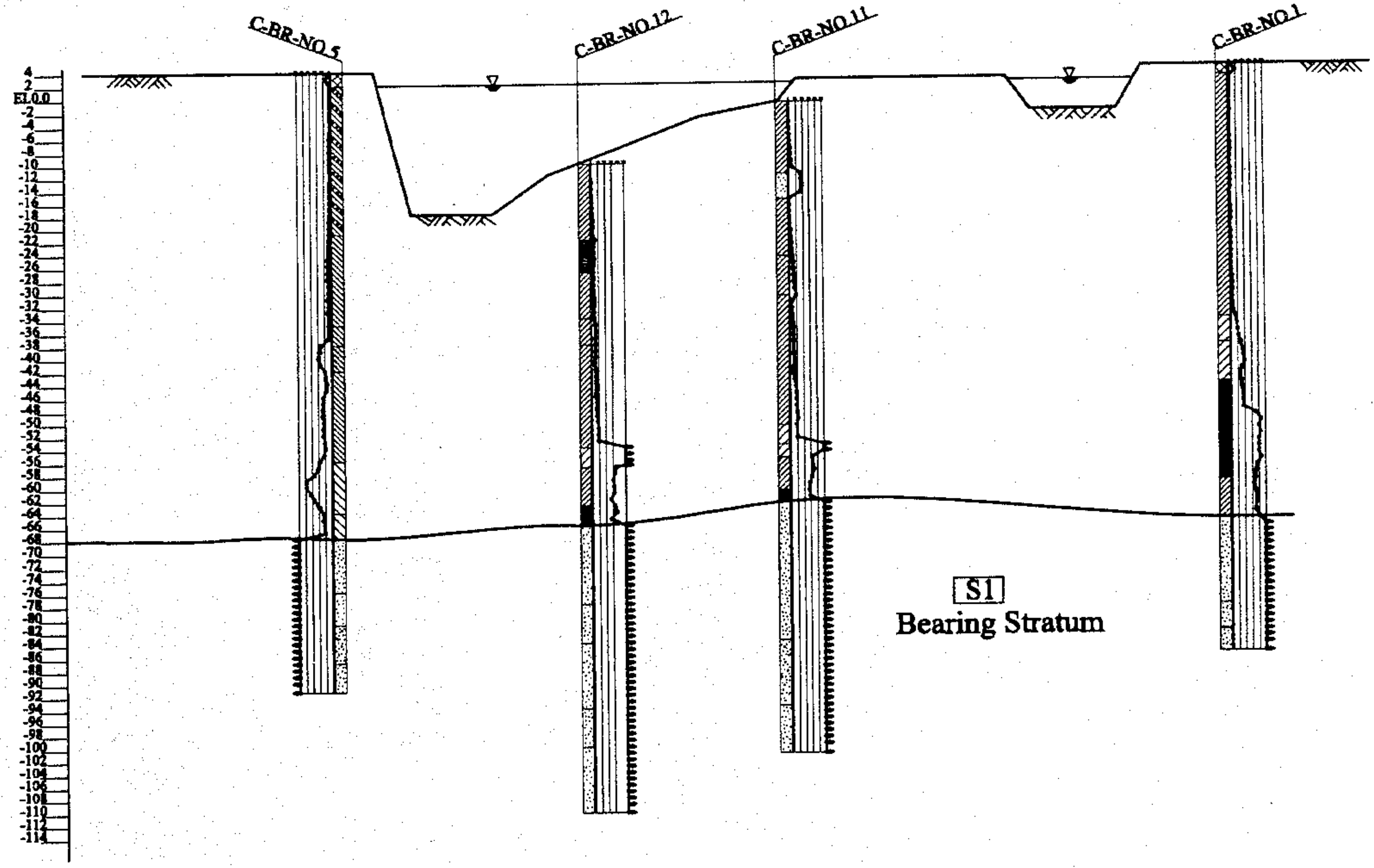

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Fig. 6.5 Bearing Stratum at C-Route

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6.3 Earth and Rock Materials

6.3.1 Materials and Possible Locations

The locations of earth and rock materials are shown in the following table.

Table 6.5 Earth and Rock Materials

Material Kind	Geological Name	Location (distance to site)
I Concrete Aggregate	1) Andesite 2) Granite	Bien Hoa (300 km) Nui Sap (120 km)
II Concrete Sand	River sand	Dong Nai (300 km)
III Asphalt Aggregate & Base/Subbase	1) Andesite 2) Granite	Bien Hoa (300 km) Nui Sap (120 km)
IV Sand Mat and Drain	1) River sand 2) River sand	Long Xuan (50 km) Dredging Soc Trang (60 km) Dredging
V Road Embankment (Subgrade)	1) Clay 2) Clay/Silt	Side Borrow River Dredging, Mixing with Long Xuan, Soc Trang Sand

6.3.2 Material Characteristics and Engineering Considerations

1) Concrete Aggregate

Bien Hoa Andesite and Nui Sap Granite are available for concrete aggregate (both coarse and fine crushed aggregates).

It is assumed that compressive strengths (qu) exceed 500 kgf/cm^2 in both types of rock. Flakiness of the crushed aggregate and the degree of alkaline reaction must be examined.

2) Concrete Sand

The natural river sand of the Dong Nai is available for fine concrete aggregate. The degree of alkaline and salt content should be examined to avoid alkaline reactions in the concrete structure.

3) Asphalt Aggregate and Base/Sub-base

For road pavement work, the above mentioned andesite and granite are suitable materials for asphalt, base/sub-base course materials.

4) Sand Material for Earth Work

The Long Xuan and Soc Trang river sands appear to be suitable for concrete casting, especially for PC concrete; however, they can also be used for earth work such as sand mat and/or drainage material.

5) Road Embankment Material (Subgrade)

Since suitable borrow areas can not be found close to the Project site, subgrade material will have to be obtained by side borrow excavation. Moreover, the borrow soil type is a very soft and compressive clay, and therefore sand mixing will be required. Long Xuan and Soc Trang river sand will be used for this purpose. In case that side borrow is insufficient, the use of river dredged material will be considered.

6.3.3 Subsoil Survey Program for the Detailed Design

Testing and examination items, which will be required in the detailed design stage, are listed as follows:

1) Rock Materials

- Specific Gravity
- Water Absorption
- Uniaxial Strength
- Abrasion Loss
- Flakiness Degree
- Degree of Alkaline Reaction

2) Sand Material

- Specific Gravity
- Grain Size
- Fineness Modulus

- Degree of Alkaline Reaction
- Salt Content

3) Concrete Mixing Tests

Especially for PC work, testing will be done on many trial mixes using the most appropriate materials available.

4) Road Embankment Material

- Boring and sounding in the potential borrow areas (including the riverbed).
- Physical Properties
- Uniaxial Compressive Strength
- Triaxial Compressive Strength
- Consolidation
- Compaction
- CBR Test

6.4 Hydrological and Hydraulic Survey

The Mekong Delta is very susceptible to flooding during the rainy season each year. Due to the increase of the river water level, and the velocity of the river flow, bank erosion and riverbed scouring occur. For these reasons, the planning of the bridge site should consider factors such as the inundation area, planform changes, potential of changes, riverbed and bank erosion, and sedimentation. These factors have to be carefully studied before deciding on the bridge location, length of the bridge, structural requirements, safety of the structures, etc. In this study, the flooding characteristics of the Mekong Delta including the Can Tho bridge site, and as well the erosion and sedimentation of the Hau and Tien Rivers were investigated prior to planning of the bridge site. Factors investigated in this study are given below;

a) Collection of hydrological, hydraulic data, and analysis
b) River velocity and water depth survey
c) Flood inundation area using satellite remote sensing data
d) State of the river planform and its changes using satellite remote sensing data

6.4.1 Data Collection and Analysis

(1) Outline of Satellite Remote Sensing Technology

Remote sensing is the process that obtains information about an object without making physical contact with it. It can be visualized in two different ways; (a) the technology of acquiring the data through some form of device which is located away from the object or (b) the phenomena of interest, and the technology that is required to analyze the gathered information so as to interpret the physical attributes of the object.

(2) Data Collection

Data collection was carried out visiting the area as well as obtaining relevant information from the respective agencies (PMU - My Thuan etc.). Data described in the following categories was collected for the hydrological and hydraulics analysis.

a) Topographic and Geographical data
b) Hydrological and hydraulics data
c) River survey data (Velocity, Water Depth etc.)
d) Satellite remote sensing data
e) Field survey information

(3) Hydrological and Hydraulic Conditions

Hydrological and hydraulic conditions of the Hau and Tien Rivers that drain through the Mekong Delta were investigated.

- General Condition

The Mekong River separates into two near Phnom Penh, which is located about 70 km away from the Viet Nam-Cambodian border. These two river branches are referred to as the Hau and Tien rivers upon entering Viet Nam.

The width of the Hau River extends from 1.2 to 2 km from Can Tho city to the estuary. Discharge of the river is 18,000 - 28,000 m^3/sec

in the wet season. Erosion is predominant, scour is complicated, and quite deep.

The characteristics of the Tien River selected for the My Thuan bridge site has a river width of 1 km, and its discharge is 16,000 - 24,000 m^3/sec. Erosion and scour characteristics are almost similar to the Hau River.

- Flood Phenomenon

There is a high variation in the water flow in the rivers of the Mekong Delta due to well defined wet and dry periods. During the wet season, the river water level increases and large scale inundation occurs in the north. Generally, flooding in this area starts in July or August, and extends up to November or December. The inundation also occurs in the southern part of the delta, and in the areas where the drainage facilities are poor the water is logged for as long as five months.

Past flood incidents occurred in the Mekong Delta are tabulated in the Annexure. In the Can Tho area, the largest flood occurred on 25th October 1961 with a record water level of 2.09 m.

Water level data records of the Can Tho station of the Hau River and the My Thuan station of the Tien River together with the maximum annual discharge data are shown in the Annexure.

- Tidal Range

The daily tidal change in the vicinity of the estuary is considerably large, and the range of high tide varies considerably. The monthly average tidal range (1979-1983) is shown in the Annexure. The effects of tides are less pronounced in the upper reaches of the river. It is also observed that the tidal changes are higher in the dry season (December to July) than during the flood season.

- Stream Flow

The velocity of the river flow increases in the flood season, and its maximum is 2.5 m/sec recorded at the Can Tho and the My Thuan gauging stations. In the dry season, sea water enters into the river, and in My Thuan 0.5 m/sec reverse flow was observed. During the wet season, the reverse flow is not observed as the river water level increases.

In the vicinity of the Can Tho ferry port, a whirlpool has been created due to the high changes in the local water flow. Riverbed and bank erosion will increase in this area due to this phenomenon.

- Erosion and Sedimentation

The Mekong Delta was formed from the sediment carried by rivers and deposited over a period of time. This phenomenon is still continuing, and the increase of water level during the wet season, together with the increased water speed further accelerates the erosion and sedimentation in the region. This phenomenon creates changes in river channels, which are still in their natural form, and applies to the Hau and Tien rivers, which are susceptible to erosion and sedimentation.

- Scour

Scour has been occurring in the riverbed due to water flow in the vicinity of the Can Tho bridge site in the Hau river according to the historical water level data and river surface change information. Specially, during the flooding season where the water level and velocity increase causes more scour. Therefore, it is required to take extra precautions to maintain the durability and safety of the piers and abutments of the bridge during the planning stage.

6.4.2 Velocity Survey

From September 18th to September 25th 1997, the hydrological survey team conducted the current velocity survey along the centerlines of the 3 route alternatives of the Can Tho bridge. The survey work was implemented during the flood season of the Hau River.

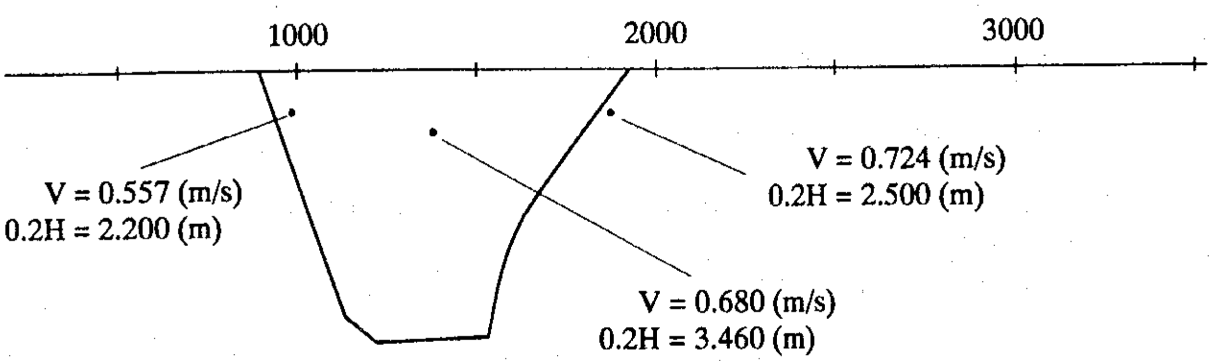
(1) Method and results of the current velocity measurement

a) Method of measurement:

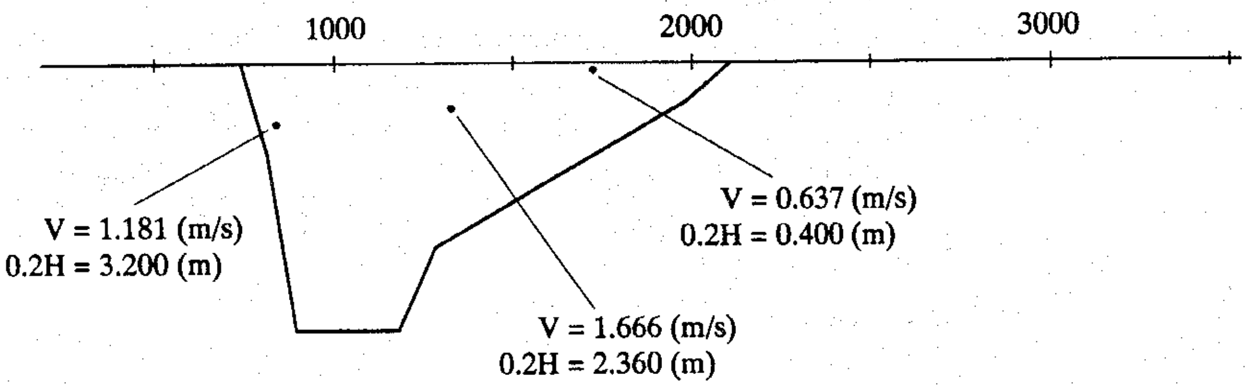
- To measure the velocity distribution, an engine powered boat was anchored at a predetermined position throughout the survey period.
- An electronic distance meter located at a benchmark was used to control the position of the boat.
- During the time of the current velocity measurement, the water level was measured at the same moment for the calculation of the riverbed elevation. The elevation of the water gauges, which were used for collecting water level data at each route, was measured from the benchmark of the cross sections, III-3. DB2, and CC1.

b) Results of the measurement:

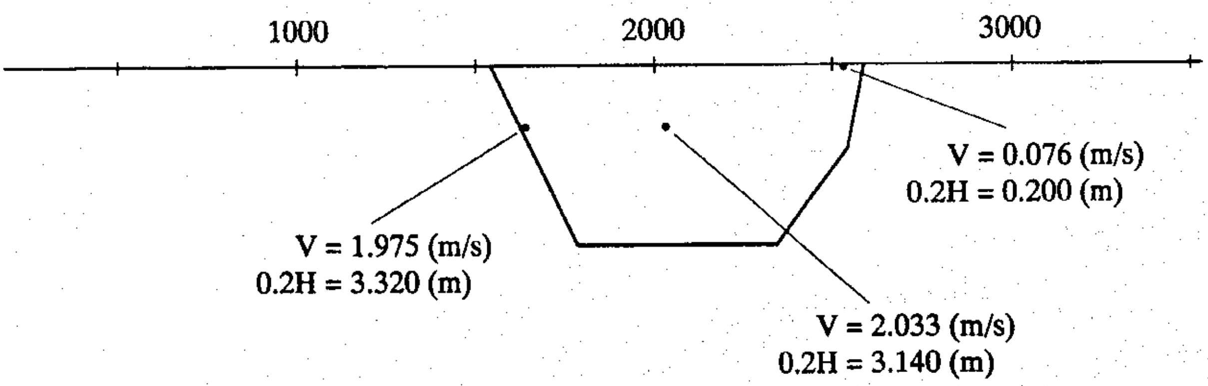
- The results of the water velocity survey along with related information are presented in Fig. 6.6.
- The locations and the results of the verticals of the 3 routes are shown in Fig. 6.6.



ALTERNATIVE (A)



ALTERNATIVE (B)



ALTERNATIVE (C)

THE FEASIBILITY STUDY ON THE CAN THO BRIDGE CONSTRUCTION IN SOCIALIST REPUBLIC OF VIET NAM	Fig. 6.6 Velocity Results
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6.4.3 Survey of the Flood Conditions

(1) Objective of the Survey

In planning a bridge site and its access roads, it is required to consider (a) the inundation area in the event of flooding, (b) the availability of access roads, (c) cutting and filling in of the bridge and connecting road and (d) the open space required to guarantee safety from scour.

To understand the above factors, the flood inundation area, and its characteristics were investigated using satellite remote sensing data and an interview survey was carried out in the field.

(2) Methodology

An analysis of the satellite remote sensing data was carried out by using an image analysis and processing software (ERMapper), and geographical information analysis software (arc/info). Processed and analyzed satellite data in its raster form was their integrated into a GIS database.

The flood area was estimated by JERS-1 SAR data in a wet season, and the Landsat TM data was used as ancillary data for further refinement. The data analysis flowchart is shown in Fig.6.7.

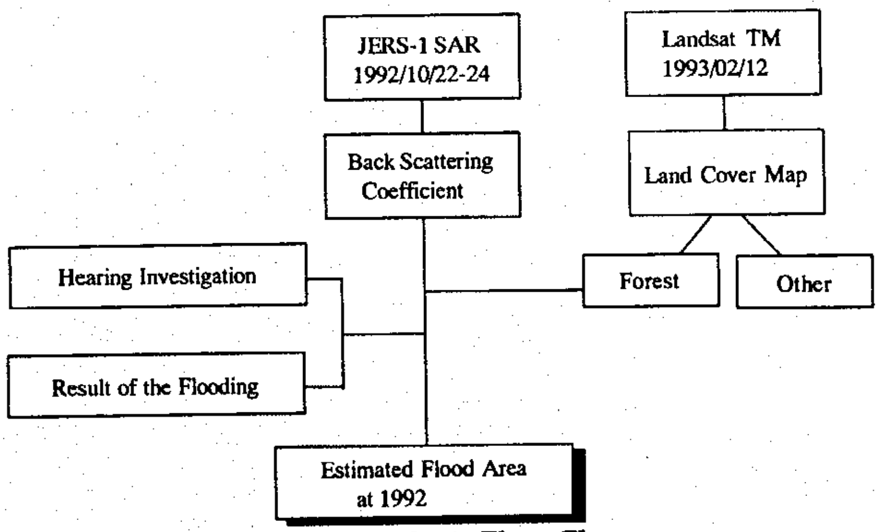


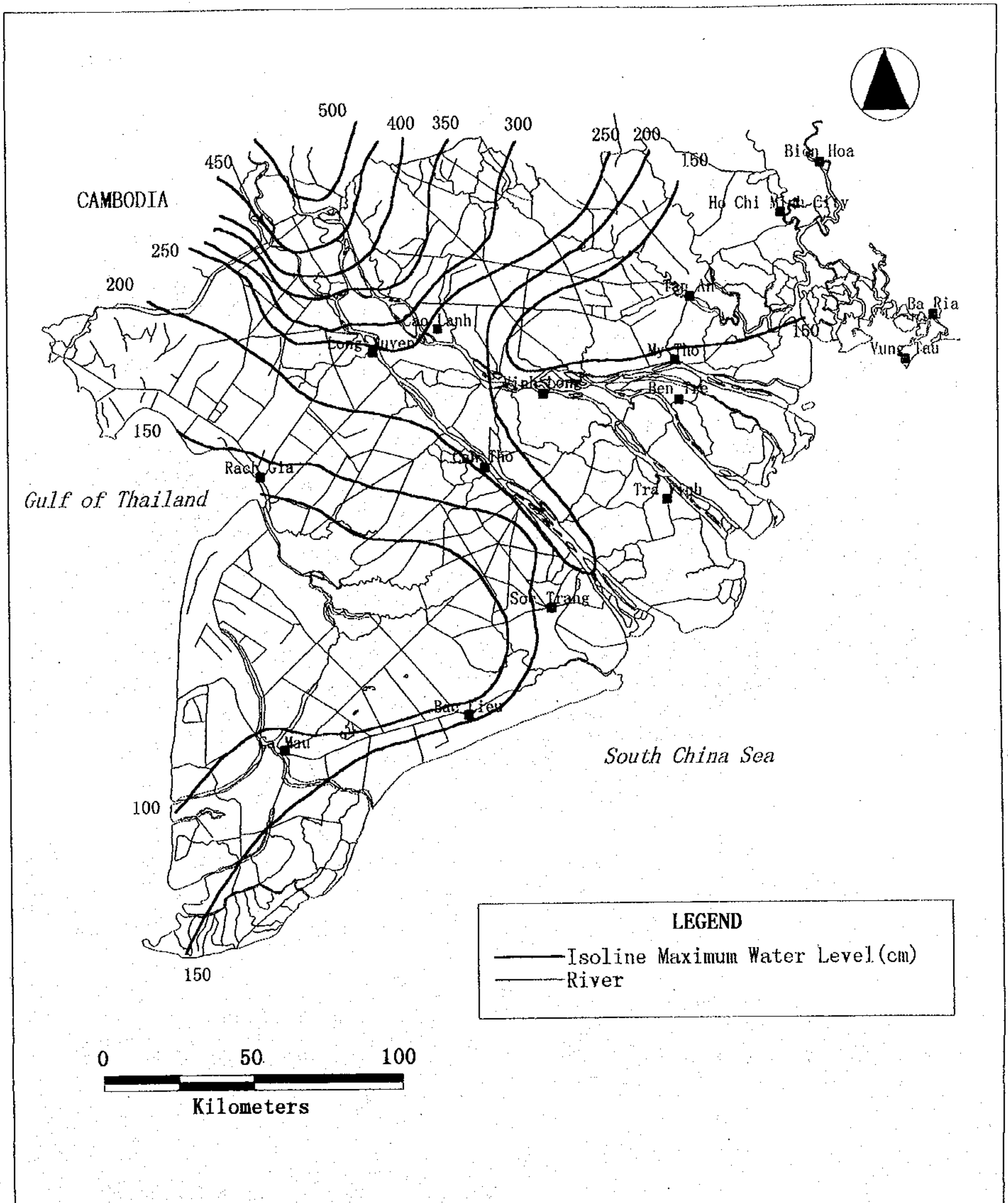
Fig. 6.7 Data Analysis Flow Chart

The maximum water level contour of the 1984 flood and the 1992.10 flood map using JERS-1 SAR data are shown in Fig. 6.8, 6.9 and 6.10.

(3) Interview Survey

An interview survey was carried out along the three Routes, A, B, and C. Inhabitants of the area were interviewed to comment on the flooding status of the area. The information collected on the flood inundation of the Can Tho bridge site can be enumerated as follows;

- The flood is experienced once or twice a year between September to November
- The flood duration is relatively short, and generally is about 2 hours (it was told however that the flood duration continued for 5 days in some years)
- Inundated depth is low, and it was told that no dwelling was affected by flooding.
- It was told that the largest flood occurred in 1984 (1 person), 1988 (1 person), 1993 (1 person), 1996 (2 persons), and 1997 (1 person).



Prepared by Ministry of Agriculture & Rural Development Center for Transferring Technology & Environmental Engineering

Fig. 6.8 Maximum Water Level Contour of the 1984 Flood

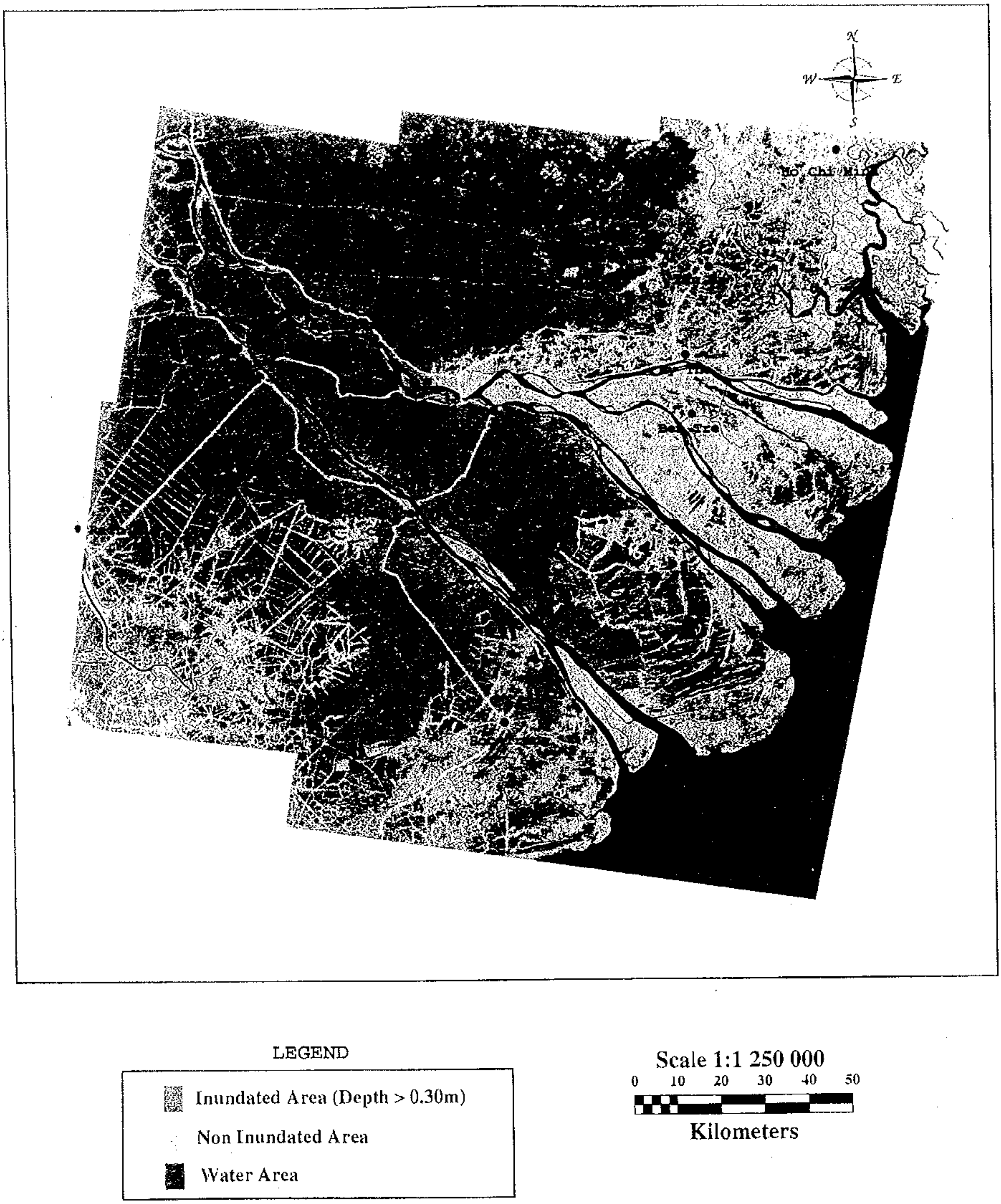


Fig. 6.9 Flood Map using JERS-1 SAR Data in 1992.10

LEGEND

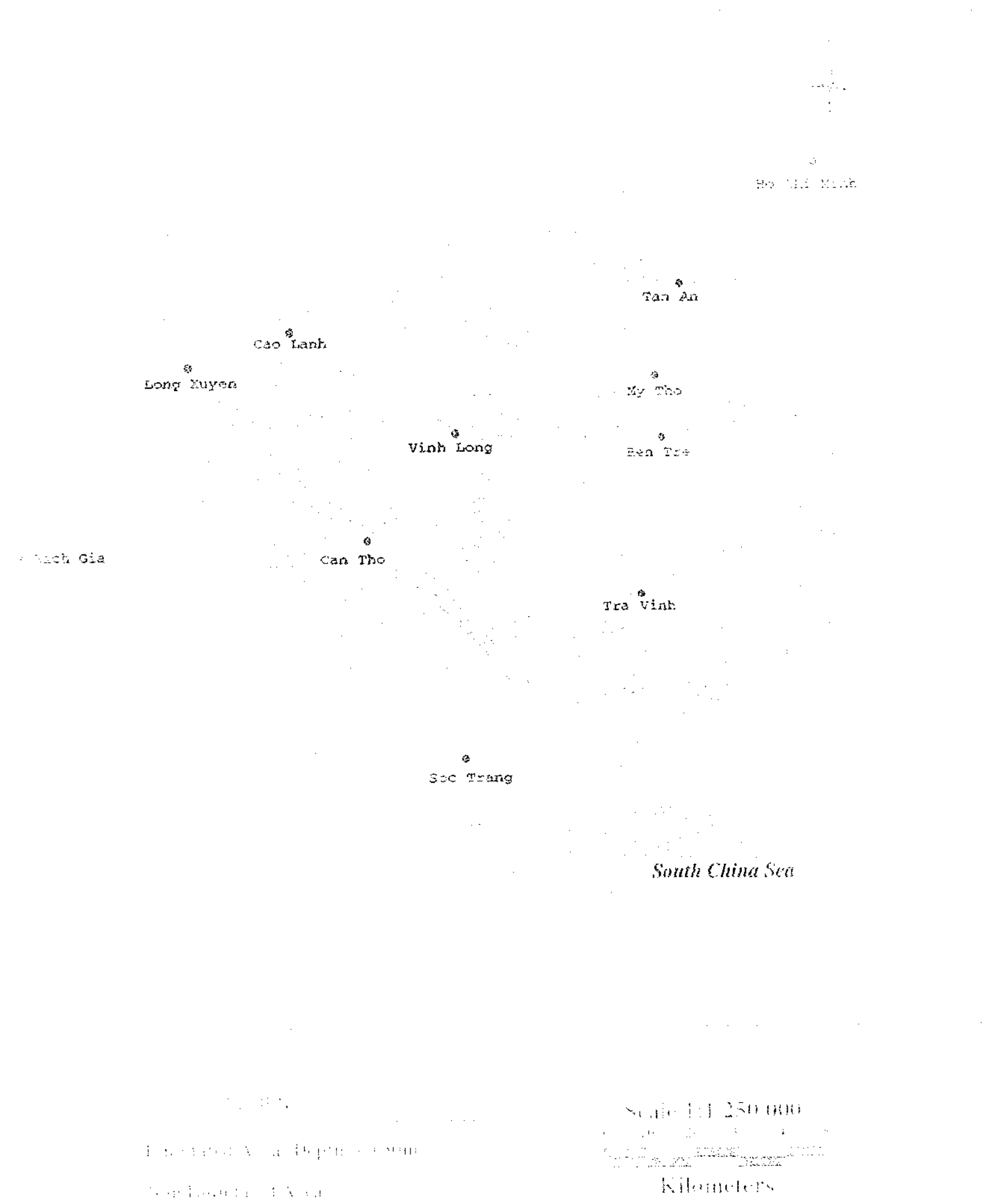
Inundated Area (Depth > 0.30m)
Non Inundated Area
Water Area

Scale 1:100 000

0 1 2 3 4 5

Kilometers

Fig. 6.10 Flood Map using JERS-1 SAR Data around the Can Tho on 1992.10


Tan An
Cao Lanh
Long Xuyen
My Tho
Vinh Long
Ben Tre
Can Tho
Tra Vinh
Soc Trang
South China Sea
Kilometers

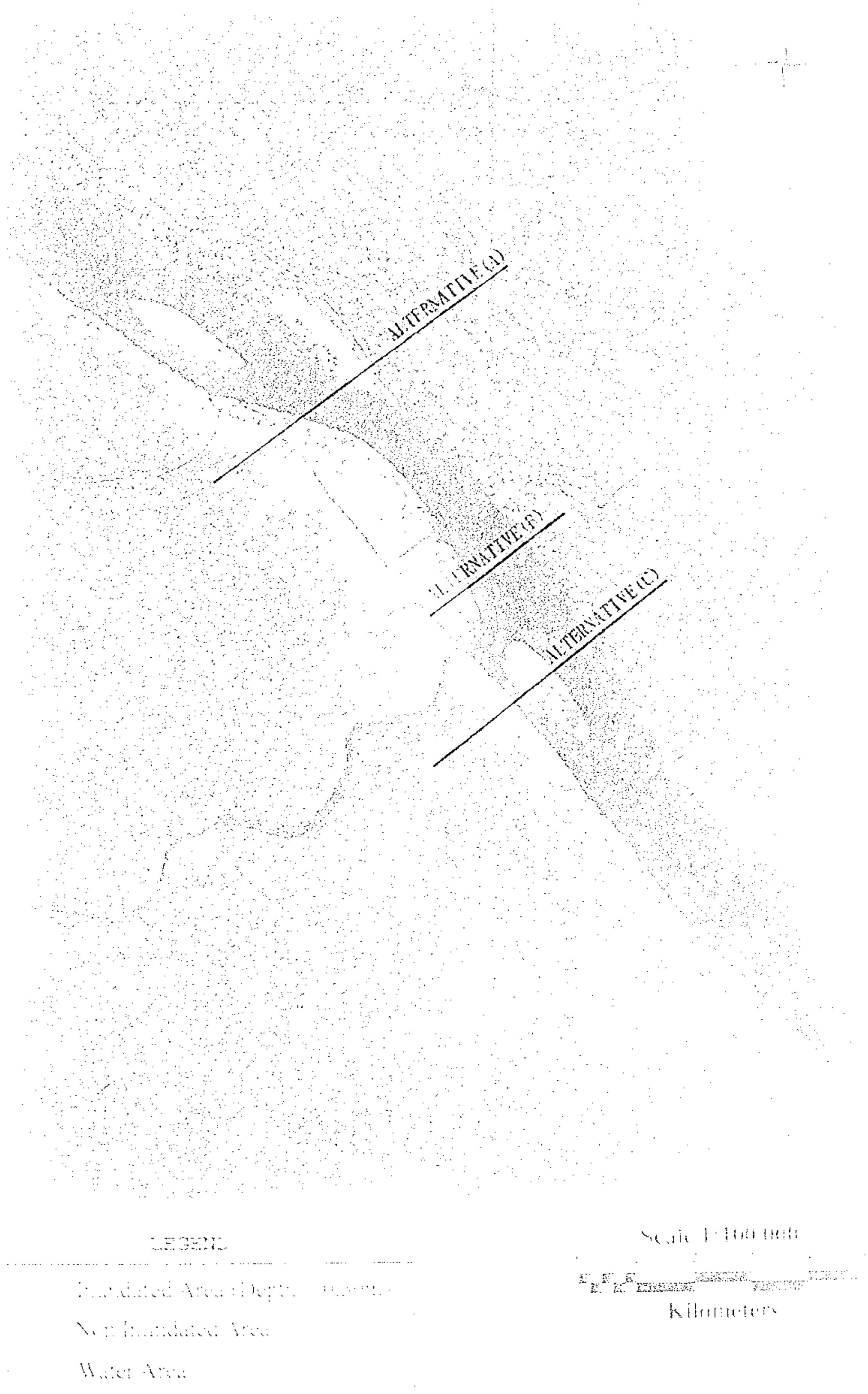


Fig. 6.1? Flood Map using ERS-1 SAR Data [illegible]

(4) Flood condition

Investigation of the flood inundation area in 1984, 1992, and 1993 is described below;

- In the 1984 flood, the maximum water level was 2.0m and its duration was 3 to 5 months at Can Tho.

- During the past three years the whole area of An Giang and Dong Thap provinces were inundated. In 1984 and 1992 Kien Giang, Can Tho, Vinh Long, and Tien Giang provinces were almost flooded, and 50% of the Long An, Tra Vinh, and Soc Trang provinces were flooded. The inundation area of Ben Tre province was relatively small. Also, in 1994 about 50% of Kien Giang, Can Tho, Vinh Long, Tien Giang and Long An provinces were flooded, with flooding in the rest of the areas minimal.

- When comparing 1984 and 1992 inundated areas, paddy fields of Tra Vinh were classified as flooded areas in 1992. The rest of the areas were similar to the 1984 classification. This was probably due to the similarity in the water level pattern, and it was observed that the monthly average maximum water level change showed a similar pattern according to the measurements at the Can Tho measuring station.

- From the water depth comparison for the years 1984 and 1994 where data was available, it was found that the water depth of the inundated area was above 1 meter in areas up to 120 km away from the estuary. This area was in the vicinity of Long Xuyen, and northwest of the upper catchment. However, a water depth of more than 0.5 meters in 1984 covered the whole area of the Hau river, and was only 15 km away from the Can Tho bridge site. Further, it was observed that the depth of the inundation area was higher than at the estuary in the upper section of the river. This is because the Hau watershed is almost flat, but the differences in the depth of the inundated areas could be due to the better drainage in the vicinity of the estuary than at the upper river sections.

- Investigation of flood inundation areas using field investigation would be the best way of acquiring accurate information, but the cost, safety, transportation facilities involved is quite considerable in a developing country, and field investigation cannot be considered as general method of investigation. In the present study, SAR data that is applicable to all weather conditions was used to extract the low roughness areas, and by integration with optical sensor data (Landsat TM) it was possible to accurately map the flood inundated areas. Though the sensor data is not able to estimate the depth of the inundation, this potential in surface estimation and monitoring was in a highly appreciable. Therefore, the present method can satisfactorily be used in future monitoring of inundation and used in other field of studies as well.

6.4.4 Planform Changes Analysis

(1) Objective of Analysis

Historical records and hearing surveys showed that the study area is a flood prone area, and as a consequence of these floods planform changes of the river had occurred. Therefore, it is required to identify and establish the planform changes that had occurred in the past in establishing the appropriate bridge site. Three Landsat data sets, 1972, 1973, and 1993, were acquired in recognizing the planform changes between 1972-73 and the 1993 periods. (see Fig. 6.11)

(2) Methodology

Spectral reflectance of the river in the visible and infrared region is very low, and this characteristic was observed in other form of photographs, such as aerial and normal photography. Using this characteristic, the best spectral band for delineating the river from the other areas was investigated and selected. Subsequently, the selected bands were used for image processing of the three dated Landsat images, and the Hau river area was classified for the three dates. These three dated Hau river images were fused using two images at a time to create two river change images representing the river planform change in 1972-73, and 1993.

Three change patterns were identified; river expansion, no river change, and shrinking river areas.

The Hau and Tien rivers planform changes are shown in Fig. 6.12 and 6.13, (that had occurred during the 1972-73, and 1993 periods in the defined three patterns as estimated by the Landsat TM data). The yellow, red and blue color in these images represents the river shrink, river expansion, and no river change areas, respectively.

(3) Planform Features and Changes

a) Planform changes in the Can Tho bridge site

The interpreted changes of the river in the two-time periods, 1972-73, and 1993 is shown in Fig. 6.12. Characteristics of these changes can be enumerated as below;

- The Hau River in this area is almost linear
- The sand bar in point 1 is almost oval in shape, and extends from the northwest to southeast. The sand bar of the north-west upper stream, which is facing the flow of the river is being eroded, and on the other side, deposition is observed in the northeast of the down stream side. The rate of erosion is 4.5 m/year, and the deposition is 1.5 m/year.
- In point 2, the riverbed is facing the river flow, and erosion is occurring. The rate of this erosion for the period of 1972-73, and 1993 is 3 m/year.
- The sand bar in point 3 was flooded in 1973, but this has been integrated into a land area in 1993.
- The south area in the figure has been classified as river, but in 1993 a new sand bar was found to have developed when compared with 1972-73. There was a tendency in the riverbed area of decrease, and a large rate of shrink, of 6 m/year was observed. This could be due to the river flow change, draining

more into the main river in the west during 1993, and a corresponding decrease of water flow in the branch rivers.

b) River planform changes in the surrounding of the My Thuan bridge site

The interpreted changes of the river in the two periods, 1972-73, and 1993 are shown in Fig. 6.13.

The interpreted charges can be enumerated as below;

- In this area, an expansion in the left bank of the river, and a shrinking of the right bank was observed. This indicates that during the past 20 years the planform changes in this area were quite considerable. Sand bars present in right bank of the river in 1972-73 period showed an expansion in their lower part in the 1993 image, and the rate of this expansion was about 40m/year. In contrast to this, the left bank showed a tendency to erode, and the rate of erosion was as large as 8.6m/year.

c) River planform changes in the surroundings of the Vam Nao Pass

The interpreted changes of the river in the two periods, 1972-73, and 1993 are shown in Fig. 6.14.

The interpreted charges can be enumerated as below;

- In this area, the planform changes have been quite considerable during the past 20 years, especially on the west side of the river. A planform change of more than 10 m/year could clearly be confirmed at 5 points.

- In point 1, two islands, which are about 0.75 sq.km and 0.36 sq.km in area disappeared, and two islands appeared in a down stream direction, of about 0.16 sq.km and 0.04 sq.km in area.

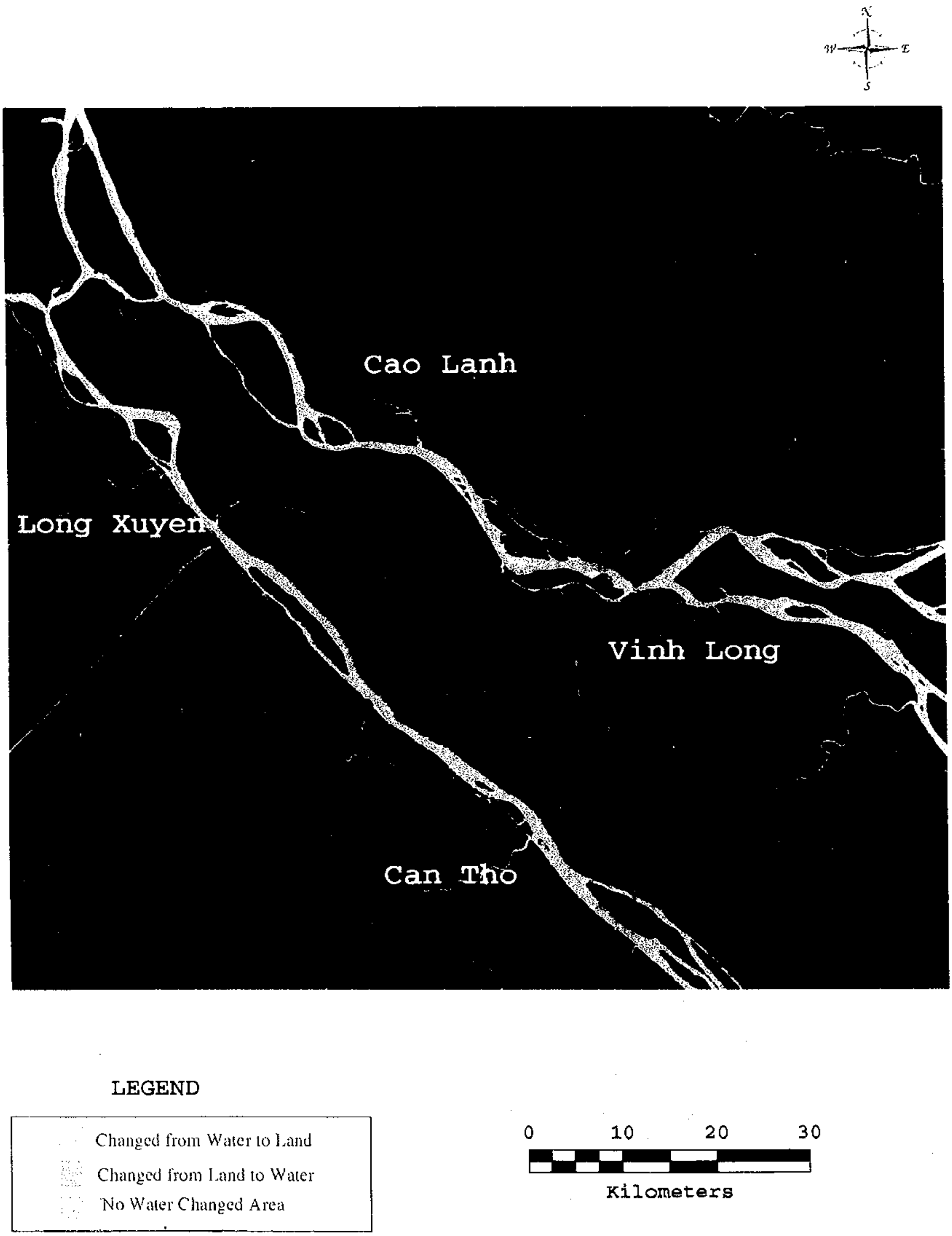


Fig. 6.11 Planform change of the Mekong Delta between 1973.01 to 1993.02

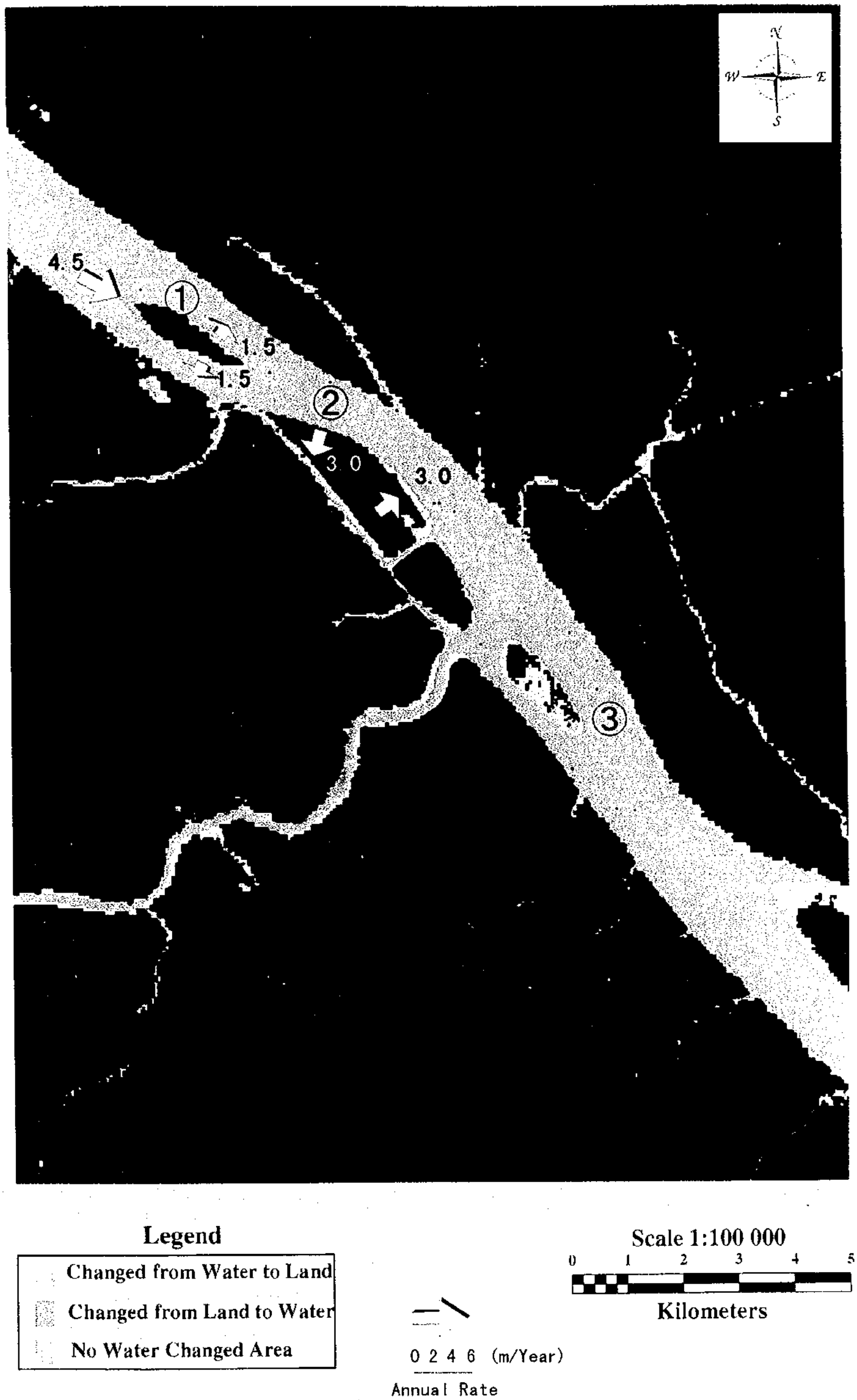


Fig. 6.12 Planform Change of the Hau River at Can Tho between 1973.01 to 1993.02

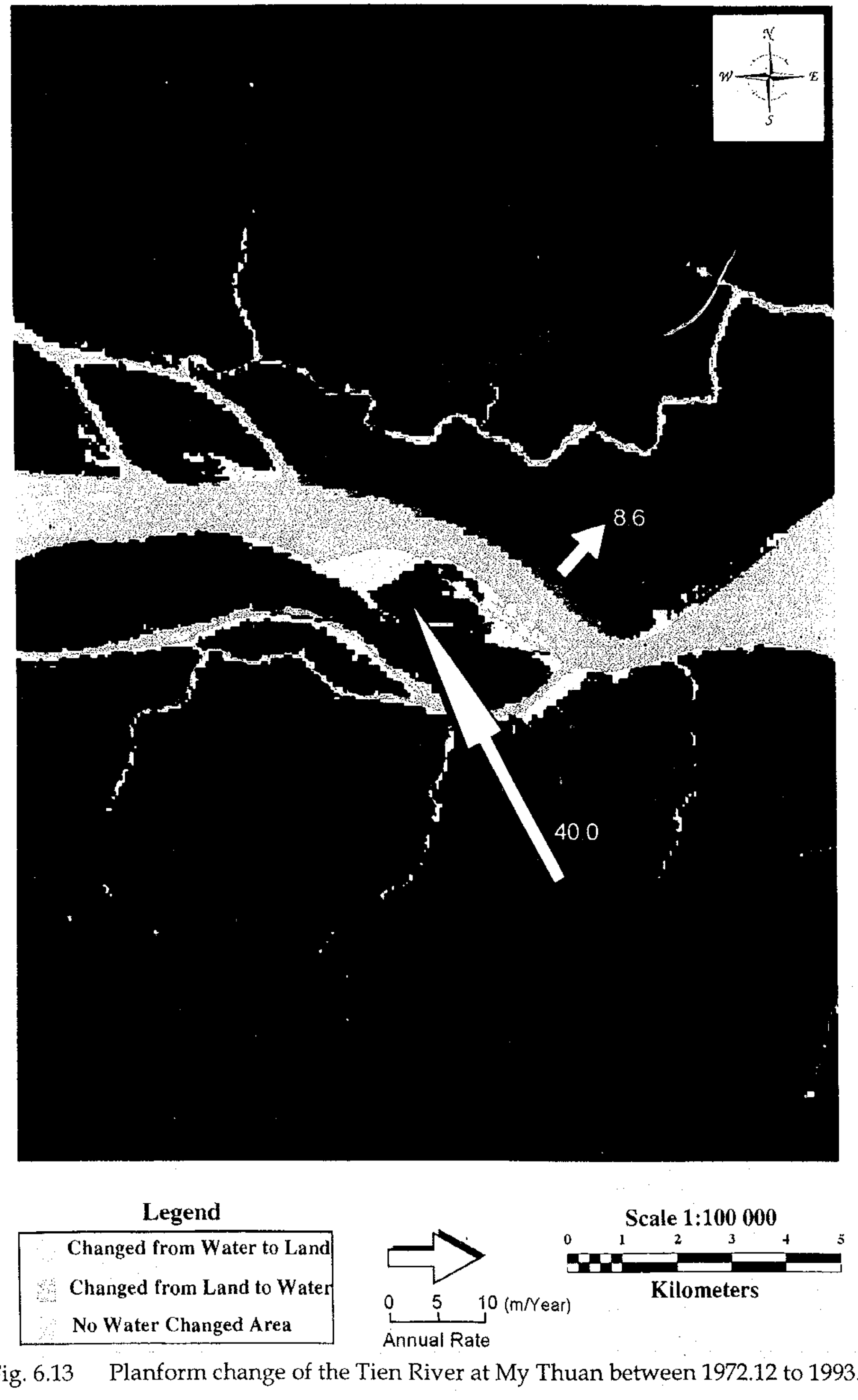


Fig. 6.13 Planform change of the Tien River at My Thuan between 1972.12 to 1993.02

Fig. 6.14 Planform change of the Vam Nao Pass between 1972.12 to 1993.02