powered boats, and the fish landings are smaller than 10 years ago because this is put down to competition from the larger boats from Pattani and Songkhla. GRBDS explains that some 60 percent of the marine fishermen had income from sources other than fishing, and most of this employment was found locally showing a fact that there is a high degree of the residential and occupational stability among this group.

It is of the opinion that catches of the present fishing fleet may be improved by the proposed establishment of an artificial reefs offshore of the Tak Bai lagoon bar. Such reefs may probably increase the available resources to allow its exploitation as a trap fishery and discourage the inshore trawling by larger fleets from Pattani and Songkhla. The likely benefits from such reefs are being assessed by the National Institute of Coatal Aquaculture (NICA) in Songkhla under DOF. When affirmative, it will benefit the marine fishermen who are one of the specific target groups in the Study area.

(3) Brackishwater Aquaculture

The Thai Government has laid a strong emphasis on the development of brackishwater aquaculture. In the Study area, some scope for cage culture is offered in the Tak Bai lagoon which is sheltered from the ocean waves and has an access to the supplies of trash-fish from Pattani. DOF has started the construction of a Brackishwater Research Station at Ban Pulachi Budor on the southeastern shore of the said lagoon to conduct an extensive programme of the research and development. The major limiting factor in determining the scope for cage culture on this lagoon appears to be the water quality for, which some of the solutions are being examined.

(4) Freshwater Fisheries

Swamps, rivers and seasonally inundated flood plain area would have some potential for use of a capture fishery. Productivity is determined by a combination of the nutrient level and an extent of the shallow water areas. The swamps which seem to be of very low productivity may support a very minor subsistence fishery with hook and line or traps. The rivers have in general no great potential for the fish production on anything more than a very small scale. There is an increase in the fishing activities when the flood recedes, however, this is still at a subsistence level. There is very little activity in the fish farming sector which ranges from the intensive pond culture to cage culture and homestead ponds.

It is unlikely that the possibility of increasing the productivity of natural inland waters in the Study area by (1) stocking with local fish species or (2) introducing fish species which are not existing, will significantly increase the yield for same reasons. The natural production level is mostly very low due to the acidic nature of water and the low level of nutrients available for the production process, while this low productivity comes from lack of the fishing activities by the local inhabitants. It is assumed that the cost of stocking would be far greater than the benefit to be accrued because of a very high natural mortality.

It is important to understand that the lack of fish farming tradition in the Study area is contrasted with the extent of freshwater fish production in the neighbouring Changwat Pattani where it is in competition with the considerable amount of fish landed at Pattani port. It is also noted that there is a very active promotion of fish culture with the DOF fish hatchery-training and production unit near Pattani, and a small hatchery and demonstration ponds in the Pikul Thong center near Narathiwat.

(5) Fisheries along Mae Nam Bang Nara

The hydro-biophysicochemical survey along Mae Name Bang Nara to investigate the aquatic environment of the river was carried out by NICA during the non-flood season in 1984 in response to the RID request including five items of water properties, fish population and standing crop, soil pH, Phytoplankton distribution and abundance, and fisheries conditions. The DOF report explains that the fisheries activities excluding the river mouths at Narathiwat and Taba are considered very poor as compared with the rest of Thailand due to the water quality that is low in pH and generally not suitable for the aquatic life. There are, however, a few fishing activities especially during the flood season from November to February with about 20 set bag nets and a few long lines for fishing gear accounting for fishermen not more than 40. A fish catch per night by one family is only 2 kg which serve for their own consumption or for sale on the local markets, although a total annual production was not surveyed.

The fish population and standing crop survey was done with a nylon net, 200 m long, 3 m high and 1 inch in mesh size which was laid in a circle with about 700 sq.m. 29 species with Amabassis kopsii of 64 percent, Leioganathus brevirostis of 7.2 percent, L. equulus of 7.1 percent, Puntius fasciatus of 5.7 percent and others of 16 percent were recorded. The fish standing crop as shown in Table 3-22 specifies that except for the Narathiwat estuary, it amounts to less than 40 gr per 700 sq.m that is quite low, and the middle reaches of Mae Nam Bang Nara are occupied with the freshwater species in connection with the saline water intrusion.

Table 3-22 Fish Standing Crop along Mae Nam Bang Nara

Survey Site	Location	Standing Crop	Estuary Species		Fresh Water Species	
			Carnivorus	Plant Feeder	Canivorus	Plant Feeder
		(gr/700 sq.m)	(%)	(%)	(%)	(%)
1.	Narathiwat Mouth	240	84	16	-	-
2.	UTR	100	28	72	-	-
3.	Kl. Ban Kheng	30	-	-	-	100
4.	Ban Ka Lu	40	-	-	-	100
5.	Ban Bang Po	-	-	-	-	-
6.	Pileng Gate No.1	20	-	-	67	33
7.	Pileng Gate No.2)					
8.	Nam Baeng Channel)	not surveyed				
9.	Kl. Bang Toei)					
10.	Ban Taling Sung	30	38	62	-	-
11.	Ban Rai	30	86	14	-	-
12.	Mae Nam Pu Yu	30	88	12	-	-
13.	Kolok Mouth	10	74	26	-	-
	Average	53				

The Phytoplankton biomass was determined by chlorophyll-a concentration at 13 sites as shown above. Its distribution ranged from 0.4416 mg per cu.m at sites No.4 and 5 to 2.0358 mg per cu.m at No.9. 62 genera of the Phytoplankton and two groups of Zooplankton were observed including such dominant species such as green and blue-green algae (No.4), diatoms (highest genera richness and total numbers, especially at No.13), Copepoda (No.1), Rotifera (at No.9) and Protozoa Cladocerans (at No.13).

3.4.7. Forest Reserves

(1) General

The total forest area in Thailand is estimated to be some 15.6 million ha of which 15.5 million ha is classified as inland forest and the remaining as mangrove. The total forest area in the Study area is estimated at 12,710 ha or 27.2 per cent of the total area. The forest area has been reduced by about few per cent in the last decades to land clearing for permanent and shifting cultivation in turn caused by agricultural development.

(2) Administration

Forestry is under the Government responsibility in Thailand and RFD has the principal responsibility of managing and conserving the national forests, and promoting the forest industries. RFD changwat office works through the Amphoe offices to supervise the forestry operation including issuing of permits for log movements, measurement of logs for assessment of royalities and enforcement of forest regulations.

(3) Forest Reserves

Two divisions of RFD, the National Reserve Forest Management Division and the Watershed Management Division, are mainly responsible for improvement of the National Forest Reserves. Both are responsible for three matters, i) survey and proclamation; ii) control on utilizing forest reserve for purposed other than for wood production and conservation; and iii) control on utilizing forest reserve for resettlement or forest village schemes.

In the Study area, three Forst Reserves have been designated; (1) Kok Mai Rua (2,636 ha, 23 November 1971), (2) Laem Nam Bang Nara I (5,060 ha, 10 August 1971) and (3) a part of Lae Nam Bang Nara II (28,600 ha in total, 31 December 1964). Illegal agricultural intrusions including villages, rubber plantations and paddy field development have occurred on all sides within these boundaries, for which the land titles have not been issued.

After comparison of the Forest Reserve's maps with the DLD's semi-detailed soil map (1984) in terms of organic soils and acid sulphate soils has been made, it appears that majority of the forest reserves would be underlain by such problem soils; therefore, the new land development in these forest reserves would not be subject to discussion in the foreseeable future, and it is recommended that rationalization of the present land use and status as well as the

setting of new boundaries to delineate the preservation and conservation zones are a priority together with the development zone with mitigating actions and controls to supplement the management of preservation and conservation zones.

(4) Forest resources

As mentioned previously, forests account for some 27 per cent of the Study area. And the forests consist mainly of hill forest and swamp forest covering about 13,000 ha. The hill forest occupies the steep slopes of the western part of Amphoe Muang Narathiwat, and are predominantly evergreen forest which forms part of the Dipterocarp forest.

The lowland swamp forest in the Study area consists of Melaleuca/grassland associations and the high mixed rain forest of the To Daeng swamp. The Melaleuca grassland forest falls mainly outside the forest reserve. The mixed rain forest of the To Daeng swamp falls mostly within the Laem Nam Bang Nara 11 Forest Reserve. The forest within the To Daeng swamp is seen by Thai authorities as a unique ecological phenomenon that should be preserved. (Refer to Appendix XII.)

3.4.8. Agricultural Extension and Credit Services

(1) Agricultural extension

DOAE is the organization directly concerned with the farmer families in the process of agricultural development. DOAE has developed its structure and functions suitable to the tasks to cope farmer needs and problems in a changing social and economic situation. A large-scale extension operation system officially called the National Agricultural Extension Project (NAEP) is in its present stage of systems development. NAEP has operated in Thailand since 1977 with a part of its financial support obtained from the International Bank for Reconstruction and Development (IBRD). The purpose of establishment of NAEP is to

reorganize existing extension services to farmers residing in 50,333 Muban in the entire 73 Changwat of the country.

The actual extension service is organized according to Changwat and Amphoe which generally do not coincide with the RID's subdivision of irrigation and drainage projects. In 1978, the National Extension Program started. This program aims at establishment of demonstration plots in each Muban. The Study area comprises of 15 Tambol of which five are located in Amphoe Muang Narathiwat, four in Amphoe Rangae, five in Amphoe Tak Bai and one in Amphoe Yingo. All Tambol have an officer at present. The extension service supplies new seed varieties and organizes farmers credit groups.

In the field, individual Muban-based extension agent is responsible for about 10 Muban and conducts visiting some 100 selected contact farmers each of which responsible for 10 neighbours. The visit is made on a fixed daytime-place basis. Out of this fixed schedule, the process of systematic visit system helps diffuse the agricultural technical information to the group-based farmer families. This certainly implies that the ratio of extension agent to farmer clientele is 1 to 1,000.

One field officer has to cover not less than 3,000 farm families in some part of the Study area. The ratio is obviously inadequate for the promotion of agricultural extension activities. The agent performs his extension role on a two-week schedule basis, viz., eight days in the field visiting both contact farmers, one day at fortnightly training session and another reserved day for special activities or revisiting farmers being faced with unexpected problems. The following figure shows

"Typical Fortnightly Training and Field Operation Schedule for Muban-Based Extension Agents" being applied also in the Study area.

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	FT	3/4*	5	WE	WE
	6	7	RD	8/9*	10	WE	WE

Note:

1-10 : Number of Muban to be visited through contact farmers

FT : Fortnightly training session

RD : Reserved day for special problems/activities

WE : Weekend

* : Two small Muban to be visited on the same days, one in the morning and one in the afternoon

There is an agricultural college at Rangae, and at present the agricultural education and extension training is conducted there.

(2) Credit Services

The lack of an equitable system and its suitable operation of the agricultural credit has been one of the major factors limiting the development of agriculture in the Study area. A credit system, suited to the farmer's needs and integrated with a system of efficient marketing, is essential to enable farmers to get the most out of their land and labor. Sound agricultural credit is necessary for agriculture to produce the Changwat's food supply, provide raw materials for agricultural industries, increase incomes and export earnings and thus form capital from savings for the development of Changwat Narathiwat.

In Changwat Narathiwat, the main institutional sources of credit for farmers are BAAC which is supported by the Government, and another source is the Agricultural Cooperatives (AC). Commercial banks and local merchants or money lenders are also important credit sources for the farmers.

BAAC and AC have similar loan requirements and BAAC is also a credit source for AC. These institutions provide three kinds of loans a) short-term loan, and b) medium-term loan, and c) long-term loan. An individual farmer who is a member of the Farmers Association and also a customer of BAAC or AC can use every kind of services provided by these institutions except investment loan. Short-term, medium-term and long-term loans are offered to each farmer. Land title or person is required as the security for the loan, however, a loan secured by land title is provided in case of larger amounts of money.

Besides BAAC and AC, other private credit sources, particularly local merchants and rice mill owners play quite a limited role in Amphoe Muang Narathiwat and Rangae. However, commercial banks have an important role in providing a loan to a farmer who holds land title or bank saving account.

3.4.9. Input Supply, Storage, Processing and Marketing

(1) Input supply

Agricultural input supply is generally provided by several sources. MOF which is the largest input supply source provides its services through local agricultural institutions. Originally, MOF was established for the provision of fertilizers to farmers. A large amount of fertilizers are sold to farmers associations, agricultural cooperatives or other established groups through MOF. Besides these institutions, MOF also provides fertilizers to other groups such as water users associations.

Individual farmers who meet the qualifications set by MOF are also able to receive this service.

In the Study area, local merchants are also another main fertilizer supply source. It is noted that in the Study area a role of local merchants is strong. Farmers who do not belong to any agricultural group or those who are not able to buy fertilizers from MOF depend on

local merchants. Usually local merchants sell fertilizers to their customers on credit, and seeds and pesticides are also provided by them to large extent. However, the prices of inputs provided by them are generally higher than from other sources. As mentioned above, usually input supplies originate in MOF, Bangkok and are distributed through a network of Changwat, Amphoe and Muban dealers at the Government-fixed prices.

Various kinds of fertilizers are available in the Study area, but the amount is limited. Of various fertilizers, compound 16-20-0 is the most famous one recommended for paddy by DOAE, Narathiwat, and it is commonly used by farmers. Urea and ammonium sulphate with relatively lower price are not available at muban level.

Seed production is the responsibility of DOAE. Under the National Program, DOAE is required to multiply seed supplied by DOA via contract growers, and to process, package and distribute to farmers via MOF, dealers or by direct sales. And there is also provision for a seed exchange program. Farmers can exchange their own seed for seed of the recommended varieties.

Due to lack of an outstanding main-season variety, there is limited demand for the recommended varieties in the Study area. Farmers are generally not well informed nor convinced regarding the advantages of better seed. Presently, the majority of farmers retain their own seed for planting or purchase from or exchange with other farmers when they need new seed.

(2) Storage

In the Study area, storages play an important role to reduce the post harvest losses particularly in fruits, vegetables, etc. Though storage and warehousing facilities are being provided by different agencies, a gap still exists between the availability and demand for it.

Generally, large godowns belong to the primary cooperative societies, the market committees or the Government corporations. Cooperative storage provides an essential part for agricultural inputs, for marketing of farm produce and also for distribution of consumer goods at Amphoe and Muban levels.

(3) Processing

In the Study area, farmers produce some kinds of food crops, vegetables and fruits which are perishable for further distribution and need the processing and preservation. However, food processing is not so active there except for rice milling. It is mainly due to non-availability of the raw materials for the growth of food processing.

On the other hand, rubber processing is popular, but the standards of on-farm processing are rather low. Many farmers use sulphuric acid rather than formic acid for coagulation and use inadequate filtering methods resulting in dirty rubber. Most rubber is processed only to unsmoked sheets(USS) on-farm and sold via middlemen for further processing of ribbed smoked sheets(RSS). There have been efforts to encourage the group processing as a means to improve the quality of rubber, but these have so far reached only a small number of producers.

(4) Marketing

Markets for farm produce in the Study area are divided into two, local and assembly. Local markets are located in the production areas. The produce is sold at farm gates and/or in Muban. Usually, they have no fixed spatial dimension. A number of middlemen operate in these markets including local merchants, brokers, shippers, agencies, retailers, etc. Most important at this level of marketing is that the traders do not only purchase farm produce but also provide to the farmers such services as money lending and sometimes delivery of inputs, or farming advice.

The assembly market usually has a fixed buying and selling place, located in towns and cities like Narathiwat with better transportation and communication networks. Merchants, shippers, brokers, retailers, agencies, etc. serve as collection agents for the produce that originate in Muban concerned. They deal with much larger quantities than the local merchants and buy either directly from the farmers or from local market merchants. Besides buying, they also provide cash loans and furnish the basic link between the local markets and the terminal markets. One of the main functions they perform is the grading of produce.

Trade policy is based on free trade both internally and externally. Two public organizations are involved in trade activities; one is the Public Warehouse Organization, and another is MOF. These organizations manage the price guarantee programs for the selected produce.

3.5 Rural Infrastructure

3.5.1 General

Collectively, "Rural Infrastructure" forms an integral component of each of the three basic facets of development such as (1) human settlement functions, (2) production oriented functions and (3) area or regional development functions. In most cases, the provision of rural infrastructure follows demand; however, once established, infrastructure would provide the catalyst for expanding developmental functions. In general, the rural infrastructure is, therefore, defined as those social and physical facilities and services that contribute to the well-being of the community, including the roads, public transport and communications, electricity, water supply and sanitation, health and education facilities, and related development.

In the Study area, the provision of rural infrastructure has received some strengthening in recent years due to its location adjacent to the Malaysian border and to a fact that this is recognized as a security sensitive area. While it has been explained that the level of infrastructure in Changwat Narathiwat still remains below that of the Kelantan State of Malaysia, the Changwat Narathiwat is progressively developing towards the Thai national average for rural areas with respect to its infrastructural characteristics. Acceptance of the social benefits by rural people from improved health, sanitation, education and other social services is a prerequisite for successful infrastructural implementation of these sectors. It appears that the apparent contradiction between the rural people's expression of interest in additional facilities and the Government's emphasis upon promotion of changing traditional behavior patterns than on the provision of new infrastructure needs to be resolved by closer liaison between the Government and the rural communities.

It seems that the Central Government would have no plan to enhance the settlement hierarchy in Changwat Narathiwat, however, Sg.Kolok's position as the focal point of the region is certain to continue because of the range of services available there, its location at the principal border crossing to Malaysia, and its distance from higher order centers. In addition, the on-going development of a ferry terminal between Malaysia and associated infrastructure of Taba as well as the private development of Taba New Town will surely enhance the range and role of various services in the Tak Bai area and adjoining eastern part of the Study area.

It has been understood through a thorough review of the current situations that the measures to overcome dificiencies in the social and physical infrastructure in the Study area are being incorporated into departmental plans and proposals, however, the delay in implementation is recognized due to the budgetary constraints on one hand and to the local conservation viz. inactive villagers' cooperation and cultural reluctance to change from the traditional mode on the other, as compared with the lack of policy and planning.

3.5.2 Taba New Town Development Scheme

It has been explained that the Department of Town and Country Planning in the Ministry of Interior is currently preparing the zoning plans for future development of municipal areas in Narathiwat and Sg. Kolok as well as Tak Bai/Taba. No details would not yet be available, but the plans will be concerned with ensuring the orderly development of urban areas rather than with development per se.

Of more immediate interest to the subject Project study is the private sector development of Taba New Town on the foreshore 1 km north-west of the ferry terminal linking Thailand and Malaysia located at the Kolok estuary. Phase I Development Scheme (7.5 ha) will be fully operational in the near future comprising 273 shop-houses, a permanent roofed market structure for 89 traders, a 120 room first-class hotel, a small second-class hotel and other sundry facilities with electricity, telephone and potable water supply network services. Phase II Development Scheme (22 ha) will subsequently be constructed being immediately adjacent to Phase I towards Tak Bai and include housing, schools, mosque, cinema and other urban-related services. A separate privately-funded group of 30 shop-houses is on the point of completing in Taba, close to the proposed new ferry terminal. Once the new ferry service is operational, it is anticipated that further private sector investment in developing the Tak Bai/Taba foreshore would be promoted to cater for the demands of a foreseeable substantial increase in tourist from Malaysia and business trade between Malaysia.

3.5.3 Existing Irrigation and Drainage Projects

There are the following three types of existing irrigation and drainage projects in the Study areas given below:

- Medium Scale Irrigation Project under RID (MSIP)

  Medium scale refers to schemes costing between ฿ 4 million and ฿ 200 million.

- Small Scale Irrigation Project under RID (SSIP)

  Small Scale refers to schemes costing between ฿ 500,000 and ฿ 4 million.

- Koh Soh Choh Project (Rural Employment Generation Project) under the Office of Prime Minister.

The outlines of each project are described below and these detailed information are compiled in Appendix VII.

(1) Medium Scale Irrigation Project

(i) Klaiban Project

This is combined with four projects, i.e. one medium scale irrigation project and three small scale irrigation projects. This project aims to supply irrigation water to the paddy field and to eliminate excess water from the area in and around the Pikultong Research Center.

(ii) Nam Baeng Project

This aims to eliminate the inundated water as quickly as possible at the middle of Mae Nam Bang Nara which has two river mouths in Narathiwat and Tak Bai.

(iii) Pileng Project

This is the agricultural development project for the new settlers. Its area belong partly to the low land which is located along Mae Nam Bang Nara. The construction of dike and four regulators along Mae Nam Bang Nara for flood prevention are close to completion.

(2) Small Scale Irrigation Project

In the Study area, eleven projects are classified into the following three categories:

Irrigation 2
Drainage and Conservation 8
Fisheries 1

These are almost well functioning. However, in a few projects, for example Ku Bae Ya Hae and Pru Kab Daeng, over-drain is appearing due to the inappropriate operation of regulator.

(3) Koh Soh Choh Project

In the Study area, fourteen projects have been identified and are classified into the following three categories:

Irrigation canal 5
Drainage ditch 2
Pond (Fisheries) 7

Almost all are well functioning. However, some of the pond projects do not reach the initial targets because of insufficient size of the pond and lack of the release of fingerlings.

3.5.4 Transport and Communications

(1) Roads

The Study area and its environs have a fairly well developed highway and local access road system, involving the activities of several Government agencies such as DOH, ARD, Amphoe and Tambol authorities, RID, RFD and the Military.

- DOH is in charge of the construction and maintenance of the national highways with classification of six types, only two of which are represented in the area - asphaltic concrete and double surface treatment with the pavement width of 5.5 m and 5.0 m, respectively. There are five routes numbered 42, 4055, 4056, 4084 and 4057, with no current plans for new road construction. (See Figure 3-22.) The current situations of these highways are summarized below:

Route	Length in the Study Area	Width	Type of Pavement	Traffic Density (vehicles a day)
42	6 (km)	5.5 (m)	A.C.	1,800 (Narathiwat - Sai Buri)
4055	15	5.0	D.S.	1,300 (Narathiwat - Rangae)
4056	17	5.5	A.C.	1,100 (Sg. Kolok - Sg. Padi)
4084	30	5.5	A.C.	1,500 (Narathiwat - Tak Bai)
4057	0	5.5	A.C.	2,100 (Tak Bai - Sg. Kolok)

A.C.: Asphaltic Concrete, D.S.: Double Surface

Source: Department of Highway, Narathiwat

- ARD is concerned with the roads of rural distribution importance including three types, and designs, constructs and maintains the roads under its responsibility.

  o ARD Standard Road ------ linking Tambol centers or large Muban to Amphoe headquarters with a design capacity to carry 250 to 300 vehicles a day. This road has a 6 m-pavement with 20 cm-laterite thickness and 1 m-drainage ditches.

o Development Road Type 1 ------- linking two or three Muban to a higher access road with a carrying capacity of 160 to 250 vehicles a day and a design to pave a 5 m-width and 15 cm-thickness of laterite.

o Development Road Type 2 ------- providing access to one Muban only with 3 m wide, earth road. While some roads of this type still exist, this has been no longer part of the ARD's programme.

ARD currently constructs about 10 km a year in Changwat Narathiwat being short of its construction capacity of 30 km a year due to lack of fund. In the Study area, there are existing roads with a total length of 78 km, under construction of 11 km and future plan of 28 km. (See Figure 3-22 and Table 3-23.)

Table 3-23 ARD Roads in the Study Area

Item	No. of Route	Total Length (km)
Complete	18	78.2
Under Construction /1	4	10.9
Total	22	89.1
Future Plan /2	3	28.0

/1 Route 11011, 12022, 12023, 12024 (as of 1985)
/2 Route 11010, 11024, 11025

Source: ARD, Narathiwat

- Amphoe and Tambol authorities construct the road of local importance which contribute to the overall rural accessibility, with a design of 4 m-width and 30 cm-uncompacted laterite costing about ฿ 100,000 per km. The roads are financed from taxes and with the MOI's assistance and are partly maintained with Muban self-help projects.

- Other departments such as RID, RFD and the Military are also involved in rural road development particularly concerned with their own projects, and are generally of less significance in the Study area.

- Along Mae Nam Bang Nara, there are two permanent concrete made bridges under DOH located at Ban khai near Narathiwat municipality and at Ban Tha Phraek near Tak Bai Amphoe headquarters, and one ARD concrete bridge at Ban Ku Cham near the RID Pileng project. Two local ferry services are available along Mae Nam Bang Nara in Amphoe Tak Bai. As far as Mae Nam Yakang is concerned, there are two highway bridges near Narathiwat and Rangae and one suspension wooden bridge near the intake for Narathiwat water work.

(2) Transportation

The Narathiwat Police Department has explained that the 1983 cumulative number of vehicle registrations in Changwat Narathiwat is 912 of private car, 259 of taxis and 41,788 of motors cycles, and its growth in the last eight years has been dominated by motor cycles by nearly 420 percent which is about twice the increase rate in the private licensed car.

The DOH data indicate that average two-way traffic excluding motor cycles on the Bang Nara basin's highway network ranges 1,100 to 2,100 vehicles a day including 1,800 on the Route 42 (Narathiwat to Sai Buri) leading towards Hadyai and Bangkok. Generally speaking, traffic between Narathiwat and Sg.Kolok is heavier than that of the Route 42, and the former on the Routes 4084 and 4057 via Tak Bai is about twice as heavy as compared with the alternative Routes 4055 and 4056 via Sg. Padi.

The Government-owned Express Transportation Organization provides commercial transportation between Sg.Kolok, Narathiwat and the rest of Thailand, and competes with the private sector for commodity transports. Local bus services are licensed by the Department of Land Transport and are operated by the private sector on principal roads

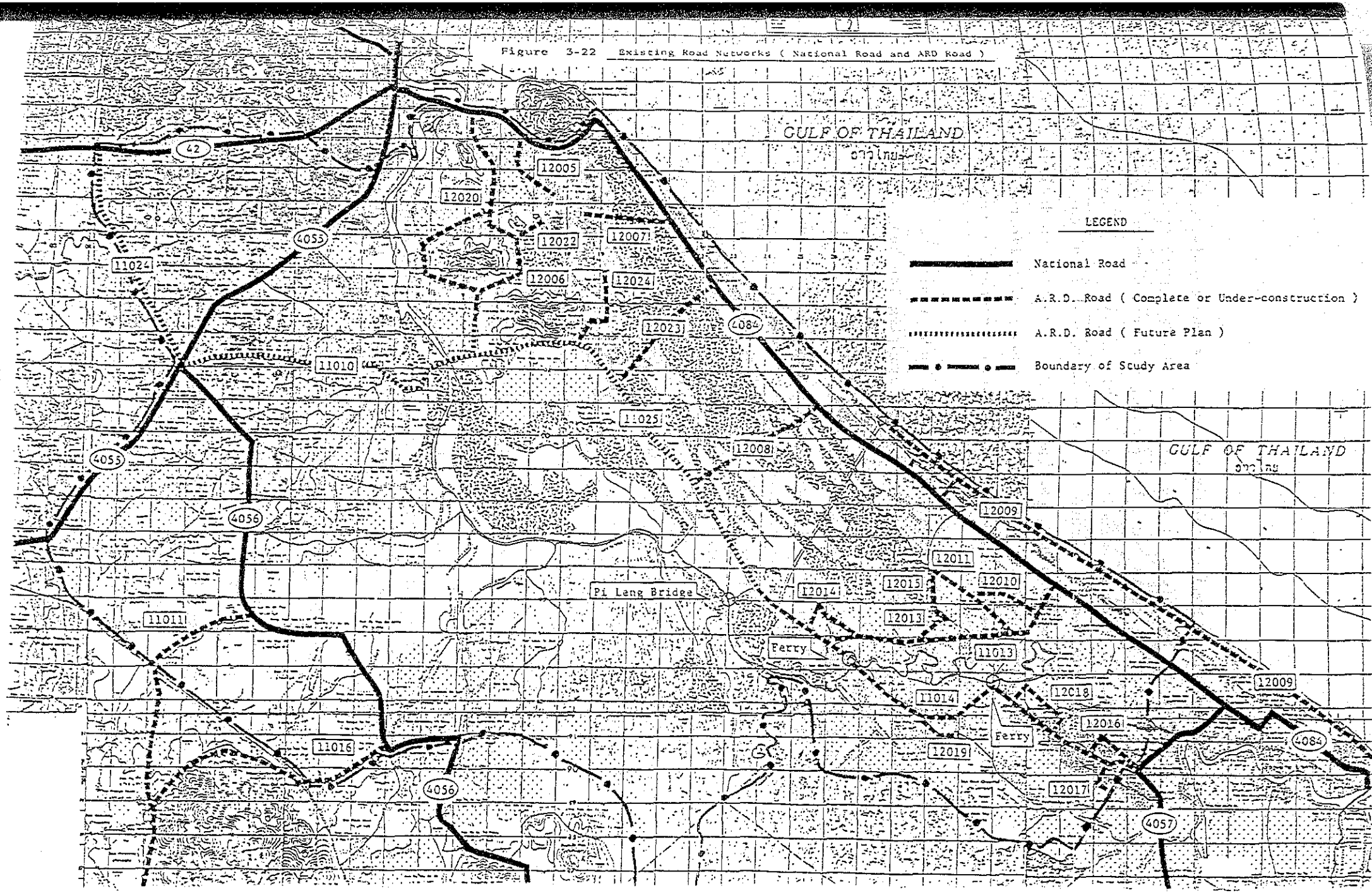


Figure 3-22 Existing Road Networks (National Road and ARD Road)

between Amphoe headquarters towns with the bus terminals at Narathiwat, Tak Bai and Sg.Kolok. These bus services are supplemented by licensed and unlicensed taxis and other passenger carriers which operate on main and some rural roads, and further supplemented in towns by motorcycle carriers and pedal rickshaws. It has been explained that the number of licensed buses and other passenger carriers appears to decline in recent years due to an increase in the number of unlicensed operators or new vehicles registered at the point of purchase elsewhere.

The State Railway of Thailand runs six local trains per day along the southern periphery of the Study area, stopping Tan Yong Mat (closest to Narathiwat), Cho Ai Rong, Ban Bukit, Ban Ai Satia, Ban To Daeng, Sg.Padi, Ban Khok Saya and Sg.Kolok. In addition, four express trains from Bangkok per week stop at Tan Yong Mat, Sg.Padi and Sg.Kolok. Inter-province express passenger traffic is said to be increasing at 10 percent per year, while local passengers numbering about 25,000 per year have remained unchanged but account for less than 4 percent of the total passenger traffic by rail. Inter-station passenger movement by rail is insignificant as compared with the road transport.

While there are one road bridge and one railway bridge across Mae Nam Kolok linking Sg. Kolok with Rantan Panjang in Malaysia for the cross-border traffic at present, the informal ferry services currently operate between Taba and Pengkalan Kubor in Malaysia. The plan to establish a formal service including the site work for new terminal building is under implementation, and the service by using two vessels (one for each country), each with a carrying capacity of 2 trucks and 4 cars will be operational in the near future. Although it is not possible to identify a future increase of the cross-border traffic at present, the Thai authorities are confident that both of traffic and the area's income and development potential will increase substantially when the formal ferry service starts, and it is considered that the proposed Project should be designed in response to the increasing capacity of cross-border traffic between Malaysia.

(3) Postal and Telephone Services

The Department of Post and Telegraph manages that every Amphoe headquarters has one post office which is responsible for mail collection and delivery services within its Amphoe by a network network of post boxes.

The Telephone Organization of Thailand operates two telephone exchanges in Narathiwat and Sg. Kolok. At present, Tak Bai is served by 100 milliwatt repeater radio from Narathiwat, while other Amphoe offices concerned are in radio contact with Narathiwat. There are plans to start rural long distance telephone services via VHF radio between the Amphoe headquarters and expand the exchange capacity during the late 1980s.

3.5.5 Electricity, Water Supply and Sanitation

(1) Electricity

PEA supplies the electricity from a 115 KV substation at Yala with a 115 KV single circuit transmission line to Narathiwat where it is dropped down to 33 KV in three phase to supply urban areas such as Tak Bai and Sg. Kolok and then to 19 KV in single phase to rural areas. PEA expects that 95 percent of Muban in Changwat Narathiwat will be served by the end of the 1980s with electricity network available on a 24-hour basis except for small Muban less than 20 houses located away from all-weather roads, because this region has received priority for electrification for the reasons of security and proximity to Malaysia. There is no generator in use for the domestic supplies in Changwat Narathiwat.

PEA is its own construction agency. The consumers pay for the transmission line to the point of consumption at ฿5 per m with a meter charge from ฿450 for 3 amperes to ฿700 for 5 amperes. Tariff rates vary both based upon the amount of electricity consumed and the category of consumption such as domestic, business, industry, agriculture and so on, and the statistics show that most households average about ฿ 1 per KWH.

Current situations in four Study Amphoe have been explained that about 90 percent of Muban are provided with electricity as favorably compared with the Changwat average of 80 percent; however, proportion of the households is greatly reduced to 60 percent, as shown in Table 3-24:

Table 3-24 Electrification in Muban & Households, 1984

Amphoe	Muban		Households	
	Total No.	No. of Mubans with Electricity	Total No.	No. of Households with Electricity
Muang	43	39 (90.7)	15,080	10,010 (66.4)
Yingo	39	36 (92.3)	6,492	3,384 (52.1)
Rangae	55	45 (81.8)	11,271	6,324 (56.1)
Tak Bai	44	41 (93.2)	8,029	4,537 (56.5)
Total/Average	181	161 (89.0)	40,872	24,255 (59.5)
Changwat Total/ Average	312	252 (80.8)	n.a	n.a

Note: Figures in parentheses show the rate of electrification.

Source: Provincial Electricity Authority, Narathiwat

(2) Water Supply and Sanitation

Although a general policy is to provide 70 percent of the people with at least 2 litres of safe water per head per day by the year 1986, this objective is far from realization. In Changwat Narathiwat, Narathiwat, Sg. Kolok and Sg.Padi have a piped water supply system, while Tak Bai plans to draw water from the confluence of Mae Nam Bang Nara and Mae Nam Puyu to serve the Sanitary District area including Tak Bai and Taba in connection with Taba New Town development scheme. It has been reported that the domestic water demand from the piped supplies is not increasing as much as the authorities considered, due to unfavorable water rates to small users as well as the poor quality and reliability of supply below untreated well water.

For the rural inhabitants, water is obtained from private and community hand-dug shallow wells, tubewells and surface water with a general situation which is regarded unsatisfactory particularly given the relatively high morbidity rate and incidence of preventable water - borne diseases, as is shown in Table 3-25. There is no wastewater treatment in the region, and the wastewater is discharged directly to nearby Klongs; while a higher proportion of the urban and semi-urban households have a septic tank, and a few rural households have pour-flush W.C. or other formal sanitation arrangements.

Table 3-24. Domestic Water Supply in the Study Area

(Unit: %)

	Drinking Water		Other Domestic Water	
	Wet Season	Dry Season	Wet Season	Dry Season
1. Source				
Rainwater	8	7	6	1
Shallow Well	92	92	94	98
Canal Water	0	1	0	1
2. Distance to the Source				
0 - 100^{m}	98	97	98	97
100^{m} -	2	3	2	3
3. Labor Requirement				
0 - 30 man/days	98	94	97	95
30man/days -	2	6	3	5
4. Quality				
Good	91	88	91	89
Bad Color	3	3	3	3
Bad Smell	1	1	1	1
Acid	2	2	3	2
Bitter	2	2	2	1
Muddy	1	4	1	4

Note: Sample Size: 144 households

Source: Farm Economic Survey

The Government recognizes the causal relationships between the environmental sanitation consisting of safe drinking water and the health situation of rural population, therefore, improved water supply and sanitation and related promotional measures to educate villagers form an important programme of the Department of Public Health (DPH), Ministry of Health and ARD. To date, however, the Government's impact on the quality of environmental sanitation in the Study area has been much limited. The main constraints to an increasing progress with respect to providing safe water to rural areas would be both attitudinal and budgetary in nature.

DOH is responsible for about 70 percent of the rural water supply and sanitation programme with a policy in the 1980s to encourage and assist in providing individual sanitary wells and rainwater storage tanks or jars since these are cheaper than rural piped supply scheme. The sanitary wells as designed to the WHO standards have an average depth of 5 m costing ฿3,000 by hand pump or ฿5,000 by electric pump, while the rainwater storage in 3 to 5 cu.mtank or small jar costs ฿3,000. The pour-flush WC requires the cost of ฿1,500 excluding that of superstructure.

ARD has a program to provide deep wells with a minimum depth of 40 m, a service up to 150 households and a cost of ฿70,000 including filter and hand pump, as well as shallow wells with an average depth of 10 m and a cost of ฿12,000 to serve up to 15 households.

DOH has commenced in 1981 a programme of establishing Muban cooperatives to prompte the environmental sanitation with demonstration schemes. This encompasses a material grant and a ten-day training in the DOH's regional office in Songkhla to enable one householder in a selected Muban to construct relevant facilities to disseminate the Government policy to other villagers. When they wish to follow, a cooperative is formed to administer a loan fund consisting partly of

the Government grant and of joining fees levied by the cooperative on its members. To date, only 61 water supply and sanitation cooperatives have been organized in Changwat Narathiwat, because the cultural reluctance to change from the traditional water sources in terms of taste, colour and smell would be a problem factor, and it would take a time-consuming process to join a cooperative loan scheme.

(3) Provincial Water Work for Narathiwat Municipality

It has not been identified to take water from Mae Nam Bang Nara and Mae Nam Yakang in the Study area. The inhabitants in the area do not take water from the both rivers at present. They, usually, are taking drinking water from shallow and deep wells around their houses or village, but they, sometimes, are using river water for washing daily goods. However, they can not get water for drinking from Mae Nam Bang Nara because of poor water quality.

The intake facility equipped with two sets of pumps (ϕ200 mm, lift head of 131 ft, four-stages, 1,500 rpm) and motors (75 Hp) was constructed by PWWA in 1975 for a domestic water supply for Narathiwat municipality. According to the PWWA future development plan, the present water distribution program will be enlarged up to 1.55 MCM per annum of sale water by 1995 for 21,200 persons which is estimated based on the present and future intake water volume.

PWWA has taken an amount of sale water of 0.84 MCM per annum for 11,500 persons for Narathiwat municipality at present. The 1995 amount of maximum daily water demand including losses (main pipe loss of 10 percent and distribution pipe loss of 15 percent) and daily peak factor of 1.5 would be calculated at about 0.1 cu.m per sec. Since the intake facility has no weir or gate to lift the water level in Mae Nam Yakang, the intake losses would be large. Considering the present conditions of the facility, the minimum amount of water of 1.0 cu.m per sec in the river would be kept under any development program of the Yakang river basin.

According to PWWA, water quality of Mae Nam Yakang would have no problem for domestic use even in the drought period. For example, PH of 7.45 to 8.0 and EC of 23 to 34 were surveyed in the years 1983 to 1984.

3.5.6 Health and Education

(1) Health Facilities

Although the health status in Changwat Narathiwat is reportedly better than the rest of Thailand and steadily improving, the relatively high incidences of diarrhoea, malaria, conjunctivitis, filariasis, dysentry and others are detected being more or less equally widespread. As a sensitive indicator of the health, infant and maternal mortality rates in Changwat Narathiwat were 6.4 and 1.9 per 1,000 live births in 1984 which are reportedly double the rates in Kelantan State of Malaysia.

DOH is fully aware of the relationship between low health status and poverty, under-nourishment, and poor housing, water supply and sanitration situations. Therefore, the promotion of preventive measures forms an important part of the DOH's public health programme which comprises urban and rural health services, training and development of health personnel, nutrition, family planning, material and child health, prevention and control of communicable diseases, environmental health, dental health, health education, public health laboratory, planning, management and information services, primary health care, and school health.

It has been explained by DOH that more strong campaign needs to promote the primary health care that is an innovative approach to achieve "Health for all by the Year 2000" with radio broadcasts, deployment of the mobile units and intensification of the support to Muban health volunteers. The introduction of Muban health volunteers and Muban health communicators to deliver the primary health care services was made in Changwat Narathiwat in 1978, and such service network was 64 percent of the target level in 1983 for 100 percent coverage programme

in 1986. While some aspects of the primary health care are instructed in the primary schools, additional emphasis would be placed upon introducing similar classes for adults after school hours in the Jawi language.

As far as the health facilities under the Ministry of Public Health are concerned, there are (1) a health office and a hospital in each Amphoe, (2) Tambol level health center with 2 staff capable of the first-aid treatment and public health promotion, and (3) health posts single staffed in large Muban and/or remote from existing health facility. In addition, some of Amphoe have private clinics, dentists and pharmacies. It is reported that one doctor and one dentist cover the population of 20,000 and 80,000, respectively, and these ratios are inadequate to achieve the Government public health programme in Changwat Narathiwat. DOH explained that the provision of additional health facilities in Changwat Narathiwat is considered as the second importance as compared with the need of primary health care.

Data and information on the cases of disease as well as the health institutions and services have been collected from the Changwat health office and supplemented by the field survey, which are compiled in Tables 3-26 to 3-30.

Table 3-26 Reported Cases of Disease, 1984

	Narathiwat		Muang	Yingo	Rangae	Tak Bai
	1979	1984	1984	1984	1984	1984
Chlorera	1	-	-	-	-	-
Diarrhoea	2,093	6,759	1,299	484	1,206	523
Malaria	829	881	76	14	208	9
Dysentry	9	646	90	55	142	25
Typhoid/Enteric Fever	233	363	89	15	84	31
Food Poisoning	76	156	47	1	12	8
Conjunctivities	88	1,370	253	171	248	125
Influenza	225	885	226	21	46	22
Venereal Disease	n.a	2,723	1,233	17	105	106
Pneumonia	n.a	845	128	14	132	19
Yaws	n.a	9	-	-	-	8
Tuberculosis	71	284	39	12	56	12
Measles	25	141	32	4	19	5
Infectious Hipatitis	48	105	18	5	17	4
Filariasis	75	13	13	-	-	-

Source: Department of Public Health, Narathiwat

Table 3-27 Major Causes of Death in Narathiwat

Cause	1978	1979	1983	1984
Senility, General Debility	1,394	1,269	1,557	1,504
Tuberculosis	1	1	-	2
Acute Diarrhoea	12	10	7	4
Malaria 5	5	3	1	4
Diptheria	-	-	1	-
Homorraghic Fever	-	-	-	-
Hepatitis	2	3	-	-
Pneumonia	-	-	5	9
Rebies	-	-	1	-
Encephalitis	1	1	-	-
Tetanus	4	2	-	1
Total	1,149	1,289	1,572	1,524
Total No. of Death	2,249	2,365	2,726	2,261

Source: Department of Public Health, Narathiwat

Table 3-28 Health Facilities, 1980 & 1984

Facility	Narathiwat		Muang		Yingo		Rangae		Tak Bai	
	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984
Hospital-No.	5	7	1*	1*	0	0	0	1	0	1
-Beds	575	595	350	360	0	0	0	10	0	10
Health Office	11	12	1	1	1	1	1	1	1	1
Health Center	2	2	1	1	0	0	0	0	0	0
Health Post	1	1	1	1	0	0	0	0	0	0
Midwife Center	69	71	7	9	6	6	15	15	8	8
Private Clinic	10	9	6	5	0	0	0	0	0	0
Pharmacy-Modern	9	11	3	4	0	0	1	1	0	0
-Old	32	29	5	5	1	1	3	3	3	3
-Traditional	10	9	4	4	0	0	2	1	0	0

Note: *Provincial level hospital

Source: Department of Public Health, Narathiwat

Table 3-29 Public Health Personnel, 1984

Personnel	Narathiwat		Muang	Yingo	Rangae	Tak Bai
	1979	1984	1984	1984	1984	1984
Physician	26	24	11	-	1	1
Dentists	3	10	2	-	-	-
Pharmacists	3	4	3	-	-	-
Health Assistants	90	176	39	9	1	3
Midwives	116	80	8	6	3	-
Nurses-Senior	109	158	74	-	5	4
-Junior			15	-	5	5
Nurse assistants	215	206	136	-	5	6

Source: Department of Public Health, Narathiwat

Table 3-30 Population Served by the Different Health Services, 1980 & 1984

(Unit: 1,000 persons)

Health Personnel	Narathiwat		Muang		Yingo		Rangae		Tak Bai	
	1980	1984	1980	1984	1980	1984	1980	1984	1980	1984
Physicians	17	20	n.a.	7	n.a.	-	n.a.	86	n.a.	48
Dentists	147	48	n.a.	40	n.a.	-	n.a.	-	n.a.	-
Pharmacists	147	121	n.a.	26	n.a.	-	n.a.	-	n.a.	-
Health Assistants	5	3	n.a.	2	n.a.	3	n.a.	86	n.a.	16
Midwives	4	6	n.a.	10	n.a.	5	n.a.	29	n.a.	-
Nurses	4	3	n.a.	1	n.a.	-	n.a.	9	n.a.	5
Nurse Assistants	2	2	n.a.	1	n.a.	-	n.a.	17	n.a.	8
Health Institutions										
Hospitals	88	69	72	79	-	-	-	86	-	48
Persons per bed	1	1	1	1	-	-	-	9	-	5
Health Offices	40	40	72	79	29	29	87	86	45	48
Midwife Centers	6	7	10	9	5	5	6	6	6	6
Private Clinic	44	54	12	16	-	-	-	-	-	-
Pharmacy	9	10	6	6	29	29	14	17	15	16

Source: Compiled from Tables 1-31 and 1-32 and Population Data from DOLA

(2) Education

Changwat Narathiwat is recognized as a lower level of the primary education by the national standards ranking the 65th out of 72 Changwat, partly due to a high proportion of smaller schools (91 percent of the Changwat's total number of schools) and additionally due to a high pupil failure rate (20 percent) requiring a repeat year.

Although attendance at primary school at aged six that is the starting point for six years is compulsory, the farm economic survey in the four Study Amphoe indicates that only 55 percent are enrolled, and there is some evidence that the drop-out rate during the primary school would be significant. The Jawi-speaking Muslim children are encouraged to

enroll for a preliminary year at aged seven to learn the Thai language that is the principal medium of teaching thereafter. Apart from municipal and private schools, the primary schools which are administrated by the Changwat Education Authority are distributed on the basis of one large school (100 to 300 pupils) per Tambol acting as the focal point for a group of 6 to 8 smaller schools in Tambol. The pupil/teacher ratio of 19:1 is favorably compared with the national standard of 30:1 by the Ministry of Education, and there is an average of 24 pupils accommodated in one class.

Table 3-31 School Enrollment

(Unit: Persons)

	School Age				Not-School Age	Total
	Enrolled		Not-Enrolled	Sub-Total		
	Primary	Secondary and Above				
Paddy Farmers	27(52)	6(12)	19(36)	52(40)	79(60)	131(100)
Mixed Farmers	44(40)	27(25)	39(35)	110(42)	154(58)	264(100)
Total (Average)	71(44)	33(20)	58(36)	162(41)	233(59)	395(100)

Note: Figures in parentheses refer to the percentage distribution

Source: Farm Economic Survey

Table 3-32 Primary Schools, 1985

Amphoe	No. of Primary Schools ≥100 Pupils	<100 Pupils	Private	Total	No. of* Class Rooms	No. of* Teachers	No. of* Pupils
Muang	15	39	3	57	353	430	7,952
Yingo	4	21	0	25	201	281	4,890
Rangae	4	51	2	57	521	647	13,358
Tak Bai	9	29	0	38	284	361	6,868
Total	32	140	5	177	1,359	1,746	33,068

Note: * excludes private schools

Source: Changwat Education Authority, Narathiwat

Table 3-33 Secondary Schools, 1985

Amphoe	Grade	No. of Schools	No. of Students	No. of Teachers
Muang	M1 - M3	5(4)	2,322	73
	M1 - M6	2(0)	3,241	191
Yingo	M1 - M3	8(6)	788	55
	M1 - M6	0(0)	0	0
Rangae	M1 - M3	13(12)	3,116	147
	M1 - M6	2(0)	2,028	95
Tak Bai	M1 - M3	4(4)	377	21
	M1 - M6	1(0)	910	58
Total	M1 - M3	30(26)	6,603	296
	M1 - M6	5(4)	6,179	344

Note: Figures in parentheses indicate the number of Muslim schools out of the total number of schools.

Source: Changwat Education Authority, Narathiwat

Students may commence up to six years of the secondary school education from age 12 which is not free. It has been surveyed that about 25 percent of the children at school age are enrolled in the Study area. Secondary schools in the Study Amphoe number 35, of which 30 are classified as the lower secondary at the M1 to 3 grades, and it is noted that of the 35 secondary schools, 30 are Muslim schools. The student/teacher ratio is 20:1 which is almost equal to that of the primary schools. The education authority is concerned about the low level of secondary school attendance, and considers that the promotion to improve the situation should form the main thrust of the Changwat's plan for secondary education. As a matter of fact, many families cannot afford the cost of school fees, uniforms and transport fares amounting to about ฿1,200 a year, and also require their children to work to supplement family income as quickly as possible. In addition, students attending the upper secondary school (M1 to 6 grades) are facing the problem of lengthy daily travel to schools, thus some lives away from their families.

Some vocational trainings are conducted by mobile units operating out of Narathiwat. Courses range in duration from short specialist training (5 to 30 hrs), medium length basic skills training (150 hrs) to more comprehensive skills training (300 hrs), which enable certificated students to offer their services in small business sector, including dress making, carpentry, vehicle repair, cooking, radio, hair dressing, building, wearing, instruction in Thai language and other activities. Training programmes are available to both men and women over the age of 15 who have completed their primary education and, for some courses, Grade 3 secondary school. Muban committees request the Changmat Education Authority to conduct training in their Muban for applications which are usually granted when classes of 20 or more could be guaranteed. Unfortunately, off-farm employment opportunities in Changwat Narathiwat for the certificated students are rare.

3.5.7 Community Development

About 80 percent of the Study area population are Muslim, and this reveals that mosques significantly outnumber the Buddhist temples, while over 90 percent of Muban have a mosque and/or a temple.

Amphoe	Mosques		Temples	
	No.	(%)	No.	(%)
Muang	44	(81)	10	(19)
Yingo	27	(93)	2	(7)
Rangue	79	(94)	5	(6)
Tak Bai	30	(61)	19	(39)
Total	395	(88)	56	(12)

Source: Amphoe offices, 1984

Attitude to religion forms a component of the Central Government's policy with respect to the human development that is under the responsibility of CDD including the activities of pre-school child care, status/role of women, youth training, Muban level organization and cooperatives, development of local commercial skills, voluntary services for development and so forth. Every Tambol has one community development officer with a role to provide the advisory assistance with respect to those aspects of human development.

In 1984, there are 43 Muban-level community development projects in Changwat Narathiwat which were implemented by self-help means without any Government financial assistance. It appears that most of these projects oriented towards the development of women's role in society and commercial interests.

Table 3-34 Community Development Projects, 1984

Type	Narathiwat	Muang	Yingo	Rangae	Tak Bai
Childcare	6	0	2	0	0
Youth	6	0	2	0	2
Women	19	3	3	0	0
Commercial	0	0	0	0	0
Environment	4	3	0	0	0
Voluntary	0	0	0	0	0
Cooperative	0	0	0	0	0
Occupation	8	3	1	0	1
Total	43	9	6	0	3

Source: Community Development Department, Narathiwat

3.5.8 Rural Industry

Data on the industrial development and employment in Changwat Narathiwat is limited due to the condition that the factories with an engine of more than 2 HP or seven or more employees need to register with the Division of Factory Control, Department of Industry. Distribution of the industrial establishments and employment in Changwat Narathiwat and Study Amphoe as well as newly registered industries by year and number of employees in Changwat Narathiwat are explained in Tables 3-35 and 3-36, respectively.

Table 3-35 Industrial Establishments & Employment, 1983

Type	Narathiwat		Muang		Yingo		Rangae		Tak Bai	
	Est	Emp	Est	Emp	Est	Emp	Est	Emp	Est	Emp
Ricemill	385	418	49	97	53	107	66	125	55	89
Coconut Oil	4	43	0	0	0	0	0	0	3	43
Smoke Rubber	14	1,187	7	1,187	0	0	0	0	0	0
Sawmill	0	0	0	0	0	0	0	0	0	0
Bricks	17	227	10	174	0	0	2	25	2	28
Stone Crushing	3	23	1	23	0	0	0	0	0	0
Batik	4	0	0	0	0	0	0	0	0	0
Ice	5	22	3	22	0	0	0	0	0	0
Bread/Biscuits	6	14	0	0	0	0	2	14	0	0
Noodles	11	22	6	19	1	0	0	0	0	0
Plastic Bag	1	0	0	0	0	0	0	0	0	0
Wood Product	27	152	2	7	1	10	13	135	0	0
Steel Windows/Doors	4	0	0	0	0	0	0	0	0	0
Printing/Paper	6	17	3	11	0	0	2	6	0	0
Turning/Welding	10	18	4	13	0	0	1	5	0	0
Car/Motorcycle Repair	50	110	10	53	0	26	8	26	3	5
Others	3	n.a	0	0	0	0	0	0	0	0
Total	550	2,253	95	1,606	55	143	94	336	63	165

Note: Est; No. of establishment, Emp; No. of employee

Source: Department of Industry, Narathiwat

Table 3-36 Newly Registered Manufacturing Industries by Year and Number of Employees in Changwat Narathiwat, 1975-1983

Year	Number	Employee		
		Male	Female	Total
1975	16	273	131	404
1976	18	74	20	94
1977	10	57	57	114
1978	18	174	82	256
1979	30	343	110	453
1980	14	n.a	n.a	284
1981	40	n.a	n.a	247
1982	25	n.a	n.a	322
1983	25	n.a	n.a	166
Total	196	(921)	(400)	2,340

Source: Department of Industry, Narathiwat

It is observed that the rice mills make up the majority of the industrial establishments, and the large establishments in terms of employment are concerned with smoking rubber and, to a lesser extent, saw mills, brick making, noodles and manufacturers of wood products. It can be mentioned that the industrial base is quite narrow being confined to the processing of primary products, and related employment effect is also very limited especially in the Amphoe concerned.

The Statistical Report of Changwat Narathiwat indicates that there were 4,896 registered commercials or 11 per 1,000 population in Changwat Narathiwat in 1982, majority of them are located in Amphoe Muang Narathiwat and Sg.Kolok - Sg.Padi corridor. As far as the Study Amphoe are concerned, the 1982 registered commercials per 1,000 population were 16 in Muang, 11 in Yingo, 6 in Rangae and 2.8 in Tak Bai. All Amphoe hold at least one daily market, and one or more weekly markets are available at Tambol level.

CHAPTER 4. PLAN FORMULATION

4.1 Objectives and Development Components

4.1.1 Objectives

The Study area where the rural sector is the corner stone of the area's economy has been identified to be socially and economically depressed as compared to the rest of the Southern region and the kingdom as a whole; therefore, particular attention has been paid to the planning and formulation of an agricultural development plan in quick yielding manner in line with the prime objective related to the social welfare, poverty alleviation and national rural development policy as are revealed in para. 2.3. of Chapter 2.

The Bang Nara Irrigation and Drainage Project proposed in the Study area has been formulated in line with a strategy that the water resources in the Mae Nam Bang Nara basin should be made available for irrigation development while the annual inundation during the heavy rains should be alleviated to a possible extent. In order to attain this strategy, it would be essential to build, in addition to existing Nam Bang tidal regulator, a tidal regulator (or a salinity barrier) at each side of Narathiwat and Tak Bai along Mae Nam bang Nara for the purpose of exclusion of the saline intrusion and provision of water storage for irrigation development, and concurrently to reduce the annual inundation over the low-lying area along Mae Nam Bang Nara through proper operation of the relevant tidal gates.

The next step would be to provide the irrigation and drainage facilities for the possible service area with an aim to enhance the agricultural productivity in existing farm land of the Study area and to stabilize this area from the socio-economic-political viewpoint in such manner that the irrigation distribution system would be planned to be capable of actual delivery of water to the maximum number of farmers

within a scope that the national socio-economic policy would permit. And, at the same time, a full support from the Government agencies concerned would be extended to the Muban families who could get the maximum benefits at the earliest practicable date.

4.1.2. Development Components

The following development components have been worked out on the feasibility study level for agricultural development of the Study area in line with the development strategy as explained above, and have been incorporated into the Project.

(1) Tidal Regulators and Bang Nara Water Storage

In addition to existing Nam Baeng drainage canal and its outlet tidal regulator with a total gate opening width of 24 m, the most appropriate plan has been proposed to establish the Upper Tidal Regulator (UTR) with a total gate opening width of 120 m to be located some 6 km upstream of the Narathiwat river mouth and about 1 km downstream of Mae Nam Yakang's confluence and of the Lower Tidal Regulator (LTR) with a total gate opening width of 24 m some 7 km upstream of Mae Nam Kolok connection. These two sites have been identified by RID with a top priority for the urgent construction, and RID has already completed the topographical survey and geological and soil mechanics investigations required even for the detailed design work.

During the course of regulators' site selection, some of the possible alternative sites have been thoroughly examined from the viewpoints of development potential of the utilizable water resources, probable influence to the regulators' downstream reaches and river mouths, proper operation of the relevant facilities and required cost. As far as the structural alternatives of tidal regulators are concerned, a type of the vertical lift gated concrete structure and non-overflow typed embankment closure has been employed taking an advantageous structural stability in comparison with an alternative type composed of

the ungated overflow typed embankment closure and water level drawdown control structure by vertical lift gates. Then, a total gate opening width of each tidal regulator has been given on the basis of existing river width in the vicinity of each site taking into account a relationship between the construction cost and the extent to alleviate the annual inundation, with additional investigation of such supplemental ways as river channel excavation, removal of the sand bar at Narathiwat river mouth and so on.

It has been experienced that the ocean outlet of the Nam Baeng drainage canal with the regulator about 400 m upstream from its canal end has been open sometimes during the high flood season and soon been blocked from the ocean side by sand bar generated with approximately 2.5 million cu.m per annum of the longshore sediment moves along the coast. The current procedures to open the sand bar by digging a narrow ditch across the bar and then adding the Bang Nara flood flow for flushing sand would be continued taking into account the technical difficulty to maintain the entrance even with the provision of a breakwater or training wall system; therefore, it has been proposed that no structural improvement of the existing Nam Baeng Tidal Regulator and its ocean outlet has been incorporated in the Project.

The above proposed tidal regulators' arrangement would achieve the following effects in terms of the Bang Nara water storage with respect to the proposed irrigation development for agricultural development as well as of the alleviation of annual inundation:

- Water storage effect:

  With the proper operation of the regulators' tidal gates, a fixed impounding water level of Mae Nam Bang Nara as compared to its present tidal variation could be maintained after storing the rainwater during the final period of the rainy season, and this results in the establishment of a water storage necessary for supplementary irrigation of the main season paddy and full irrigation of the newly introduced field crops and vegetables during the off season.

It would be possible to raise a full water level of the Bang Nara water storage upto EL+1.1m of the UTR's gate top that is the lowest among the three; however, this requires the right-of-way for the submerged area including 2,700 ha of the paddy field and 60 ha of the rubber area. When a long dike along both the sides of Mae Nam Bang Nara with 25 check gates at its tributaries is provided to eliminate the above mentioned land loss, this arrangement would invite such disadvantages as high cost for the initial construction, difficulty in the operation of such many gates and poor drainage in the farm land adjacent to the dikes.

Taking into consideration the environmental constraints of existing swamp forests in the Laem Nam Bang Nara II Forest Reserve as well as the wildlife and riverside regimes which are quite different from the usual reservoirs on hilly side, a normal impounding water level of the non-bunded water storage has been given at EL+0.4m that any farm land is not submerged. In view of a perspective that excessive drawdown of the impounding water level for long period in the critical dry years would cause irreversible environmental damage to the ecology of swamp forests as well as the unfavorable dehydration of potential acid sulfate soils in the tributaries, the lower limit of the impounding water level has been taken at EL-0.2m. To this end, the water balance simulations for irrigation has been based upon this water abstraction management.

Dimensions of the proposed Ban Nara water storage which is established immediately after the completion of two tidal regulators are summarized below:

Impounding Water Level and Water Storage:

	Water Level	Water Storage
Full Water Level	EL + 0.4 m	15.8×10^6 cu.m
Low Water Level	EL - 0.2 m	11.3×10^6 cu.m
Difference:	Effective Water Depth = 0.6 m	
	Effective Water Storage = 4.5×10^6 cu.m	

Water Storage Surface Area: 1,390 ha
of which : river course, 510 ha
swamp forest, 880 ha

Catchment Area: 1,401 sq.km
of which: Mae Nam Bang Nara, 677 sq.km
Mae Nam Yakang, 724 sq.km

Annual Average Inflow: $1,834.3 \times 10^6$ cu.m (1956 to 1985)
of which : 700.6×10^6 cu.m from Mae Nam Bang Nara
$1,133.7 \times 10^6$ cu.m from Mae Nam Yakang

- Effect of the inundation alleviation on the low-lying land:

The hydraulic flood simulations study indicates that approximately 160 ha of the paddy field and 60 ha of the rubber area which are low-lying along Mae Nam Bang Nara would be protected from the current inundation when the target heavy rainfall with a five-year return period is applied. More particularly, a significant effect has been given to a conclusion that the Lower Tidal Regulator would function to eliminate the current flood invasion into Mae Nam Bang Nara due to the flooding of Mae Nam Kolok. This flood invasion amounts to 10 million cu.m which would be equivalent to the channel storage volume of Mae Nam Bang Nara.

(2) Control of Acidic Water Inflow into the Bang Nara Water Storage

In the vicinity of the bifurcation of the Nam Baeng drainage canal from Mae Nam Bang Nara as well as the service area of the Klaiban project, the sulfate ions are dissolved from the leachate of actual acid sulfate soils with pH value less than 4 in connection with the dehydration of potential acid sulfate soils in the state of swamp by drainage. Such basins would include that of the Pileng land settlement scheme and those of its vicinity including six small rivers and drains called "Khlong Sg. Padi", "Khlong Bang Toei", "Ku Bae Ya Hae drain", "Khlong To Lang", "Pru Kap Daeng drain" and "Khlong Ya Bi".

The following countermeasures to protect the Bang Nara water storage from acidification have been established:

- During the rainy season, the sulfate ions which are formed during the previous dry season are dissolved by heavy rainfalls and then flushed away in a form of floods to the sea.

- During the dry season, it is essential to keep the groundwater level at about 0.4 m below the ground surface with the provision of well-designed water level control facilities so called "Acidic Water Flow Check Facilities".

At present, RID has completed the sluice gates at 4 sites of the Pileng area, one at Khlong Bang Toei, one at Khlong To Lang, one at Khlong Ya Bi and one at Pru Kap Daeng drain and is presently constructing one sluice gate at Khlong Ya Bi in order to raise the water level upstream during the dry season. Following this, RID has a plan to provide the check structures for the remaining two rivers such as Ku Bae Ya Hae drain, Khlong Bang Toei and Khlong Sg. Padi and to complete a series of the acidic water flow check facilities at 17 sites covering the above mentioned seven target basins. When proper control mode and operation rule are observed by the RID operators with the completion of such facilities in connection with the effort to neutralize the acidity in the Bang Nara water storage by mobilizing a large amount of the Yakang fresh water inflow through operation of the tidal regulators, there would be fundamentally no problem with respect to the effect on the water quality of the Bang Nara storage for irrigation.

The agricultural development covering the area where the sulfate ions are currently dissolved would be left over for future consideration, taking into account the less benefit to be derived from the development and also the relative difficulty in water conveyance from the Bang Nara storage when the acidic water flow check facilities are operated.

(3) Agricultural Development Plan

(i) Land Use Plan

The land use plan which has been delineated from the proposed irrigation and drainage schemes in the Study area is shown below:

(Unit = ha)

Land	Total in the Study Area	Irrigation Development and Drainage Improvement 1/			Drainage Improvement		Conversion to Fruit		Outside the Project
		Paddy Field	Right-of-Way	Total	High-lying	Low-lying	Total		
Paddy Field	12,430	9,980	340	10,320	520	-	520	-	1,590
Rubber Area	8,320	-	-	-	6,190	60 2/	6,250	-	2,070
Coconut Area	4,380	-	-	-	-	-	-	-	4,380
Orchard	1,180	-	-	-	-	-	-	-	1,180
Forest Reserve	12,400	-	-	-	-	-	-	-	12,400
Communal Copse	600	-	-	-	-	-	-	60	540
Others	7,390	-	-	-	-	-	-	-	7,390
Total	46,700	9,980	340	10,320	6,710	60	6,770	60	29,550

1/.....Including that for irrigation development only.
2/.....With operation of the tidal gates.

The prospective for new land development in the Study area is limited to minor extent involving the rehabilitation of land on the fringes of swamp forests and ridge depression. The proposed Project would not incorporate any component to reclaim the swamp forests for paddy field because of poor soil conditions and related high development cost.

(ii) Irrigation Development

- It would be a basic principle to make supplemental irrigation for the main season paddy and full irrigation for the off-season field crops and vegetables in existing rainfed paddy field.

- The irrigated cropping patterns composed of 98 percent of the main season paddy, 2 percent of perennial forage crops and 25 percent of the off-season field crops and vegetables have been introduced. Increased production of the main season paddy in the Project area would contribute to overcome the current rice deficit in the Study area. Extent of the off-season field crops and vegetables which would take a form of the collective cultivation on the basis of a Muban cooperative has been worked out at the realizable level taking into account he availability of farming labor and the possible marketing of such products to the neighboring Malaysia in connection with completion of the on-going Taba New Town Development Scheme (refer to para. 3.5.2 of Chapter 3) as well as the increasing local demand including that of Hadyai/Songkhla region. In view of the current Government policy to reduce the rice production due to the depression of its export and the unfavorable farm gate price, the production of off-season paddy has not been incorporated into a plan.

- With the target to maximize the irrigable area on the basis of the water storage balance simulations in line with the objective as mentioned in para. 4.1.1, existing rainfed paddy field of 9,800 ha would be converted into the irrigated one by pumping up water from the proposed Bang Nara storage and its upstream Mae Nam Yakang. In the water storage balance simulations, the minimum river maintenance flow of 5 cu.m per sec for the lower reaches of Mae Nam Bang Nara in terms of water environment and river entrance sand bar at Narathiwat estuary and the future demand of 1 cu.m per sec including the domestic water supply for Narathiwat Municipality have been taken into consideration.

- With a view to diverting the available stream flow in the Bang Nara tributaries, existing rainfed paddy field of 180 ha in the upstream of Khlong Maru Bo would be irrigated in the gravity manner taking into account the conversion of rainfed field as much as possible.

In consideration of the impounding water level at the proposed Bang Nara water storage, the proposed irrigation schemes would depend upon the pumping method as a whole. Under this circumstance, two modes of the pumping irrigation have been delineated:

Portable pumping scheme:

° Existing paddy field largely below EL +2 m which is distributed on the fringe of the Bang Nara water storage with an irrigable area of 3,870 ha would be irrigated by portable lift pumps utilizing existing small tributaries and drains reversely from the water storage. It could be mentioned that this type of the small pumps have been procured and operated by many farmers or their groups in the Mae Nam Chao Phraya Basin and Northeastern Region.

° As soon as the Bang Nara water storage is established, the above mentioned irrigable area would be in a possible situation to be serviced by a series of portable pumps (self-priming centrifugal pump directly coupled with gasoline engine on common base) when the water users' groups are properly organized and the on-farm work including the pump procurement is provided under the Government technical and financial assistance. This arrangement would correspond to the planning and formulation of a quick yielding project as are emphasized in para. 4.1.1.

° Local procurement of such small pumps, construction of on-farm work and subsequent Q&M would be the responsibility of the water users' groups under the technical and financial assistance of the Government agencies concerned. This is hereinafter referred to as the WUG pumping irrigation scheme.

Fixed pumping scheme:

° Existing paddy field with the elevation of +2 to 13 m would be irrigated by fixed type pumps with some improvement of existing

small tributaries and drains from the Bang Nara water storage. Following this, the main and lateral canals would be provided upto the outlets into each terminal service unit with a standard size of 20 ha.

° RID would be responsible for the construction and O&M of fixed type pumping stations and subsequent canal systems for 10 schemes to irrigate 5,930 ha of existing paddy field (hereinafter referred to as RID pumping irrigation scheme), while the water users' groups would be responsible for the terminal irrigation on-farm work and related services.

- The service area proposed for irrigation development as mentioned above is summarized below:

(Unit: ha)

. Pumping irrigation from the Bang Nara Water Storage and Mae Nam Yakang			
Paddy field, below EL +2m on an average by portable pump	3,870	(40)	(39)
Paddy field, EL +2 to 13m by fixed pump	5,930	(60)	(59)
Sub-total	9,800	(100)	(98)
. Gravity irrigation from the Bang Nara tributary	180		(2)
Total	9,980		(100)

(iii) Drainage Improvement

Apart from the effect of flood mitigation over the low-lying land along Mae Nam Bang Nara by the tidal regulators, appropriate drainage improvement scheme would be provided for 7 sub-areas over the high-lying land covering the western part of the Project area where the overtoppings of Mae Nam Yakang occurs and the eastern part with the flood

originating from the Bang Nara tributaries. This scheme which intends not to prevent the flooding but to alleviate deep and prolonged inundation and impeded drainage would serve existing paddy field of 4,850 ha and rubber planted area of 6,190 ha with the improvement of existing river tributaries and drains by widening and deepening.

RID would be responsible for the construction and subsequent O&M of 7 drainage improvement subprojects.

(iv) The Project Service Area

With the components of drainage improvement and irrigation development, there is the duplication of each service area. The breakdown of two components by function is given below, with a total service area of 16,750 ha under the proposed Project which is classified into the paddy field of 10,500 ha and the rubber planted area of 6,250 ha:

(Unit: ha)

	Drainage Improvement	Irrigation Development				Total
		Portable Pump	Fixed Pump	Gravity	Total	
(1) Drainage Improvement Only						
Rubber Area	6,250	-	-	-	-	6,250
Paddy Field	520	-	-	-	-	520
Sub-total	6,770	-	-	-	-	6,770 1/
(2) Drainage Improvement + Irrigation Development						
Paddy Field	-	350	3,940	40	4,330	4,330 2/
(3) Irrigation Development Only						
Paddy Field	-	3,520	1,990	140	5,650	5,650 3/
Total	6,770	3,870	5,930	180	9,980	16,750

. Drainage improvement service area includes 60 ha of rubber area to be derived from the operation of tidal regulators:

1/ + 2/ = 11,100 ha
of which : Rubber , 6,250 ha and Paddy, 4,850 ha

. Irrigation service area

2/ + 3/ = 9,980 ha
of which : Rubber , 0 ha and Paddy, 9,980 ha

(v) Demonstration Farms

It has been understood that an irrigated agriculture demonstration scheme would be decisive for quick yielding of the proposed Project to demonstrate to the Project farmers an advanced agricultural technology coupled with an efficient irrigation water management at field level and also to apply for the staff training of Special Task Force Unit as specially proposed to organize under the Project as well as the training of agricultural extension workers and on-farm development design/water management engineers.

In view of the Changwat administration network and the convenience of the Project farmers, three demonstration farms in each of Amphoe Muang Narathiwat, Rangae and Tak Bai have been tentatively selected to locate with a logical size of the area to be covered by a tertiary service unit. It is suggested to establish such scheme with a temporary water source such as tube well in the very beginning of the Project and to manage the operational activities of such scheme by the Special Task Force Unit which is described in para. 6.3 of Chapter 6.

(4) Water Storage Fisheries

With the construction of two tidal regulators and acidic water flow check facilities for the strategic basins, the Bang Nara water storage would have a potential for freshwater capture fisheries under extensive low input farming with the review of storage morphometry, water quality still being slightly acidic and nutrient increases. Management of this water storage fisheries would be promoted with the stocking and restocking of appropriate fish species at adequate levels if the fisheries are sufficiently productive and economic.

(5) Rural Infrastructure

As mentioned in para. 3.5. of Chapter 3, the provision of rural infrastructure in the Project area has received some strengthening in recent years due to its location adjacent to the Malaysian border and to a fact that this is recognized as a security sensitive area. While the Changwat Narathiwat is progressively developing towards the Thai national average for rural areas, the measures to overcome deficiencies in the social and physical infrastructure in the Project area are already being incorporated into the departmental plans and proposals. Under this circumstance, any component of the rural infrastructure sector related to the Project has not been included in the Project.

4.1.3. Staging of the Project Development

(1) Concept for the Staged Development

It has been worked out to implement the proposed Project in two stages within the RID's responsibility taking into account the elevation of irrigable areas for existing rainfed paddy field by pumping, scope of the initial construction cost required for major work of the associated irrigation and drainage schemes, and the quick accrual of the anticipated benefits to be derived from the investment for two tidal regulators, in line with the proposed implementing arrangement for the Project as is explained in detail in Chapter 7:

- Stage I Development:

  (1) Construction of the upper and lower tidal regulators to be supplemented with that of the acidic water flow check facilities at 8 sites.

  (2) Construction of the major work relevant to the fixed pumping irrigation and associated drainage improvement schemes in the relatively low-lying areas.

- Stage II Development:

  Construction of the major work related to the drainage improvement and fixed pumping and gravity irrigation schemes in the high-lying areas.

(2) Stage I Development

° As soon as the two tidal regulators are completed by RID, the Bang Nara water storage with a strict control of the acidic water inflow would be established after the first rainy season and be ready to bring irrigation. It has been envisaged that 3,870 ha of existing paddy field below about EL +2m on an average which is distributed on the fringes of the water storage would be commenced to irrigate with portable pumps under the water users' groups for agricultural development.

° In addition, it has been contemplated that a proper arrangement for early construction of the major work for some of the RID pumping irrigation schemes in the relatively low-lying areas which are located in the vicinity of the proposed demonstration farms and are qualified with the completion of detailed design for short period as well as with the comparatively procurable budget for the construction would be made by the Government in view of the quick yielding of the Project. These schemes would involve 3 subprojects of the RID pumping irrigation at Pu Ta, Sala Mai and Ko Sawat covering the irrigable area of 1,240 ha in total and associated drainage improvement subprojects at 3 locations such as Ban Lo Mo, Ban Sala Pradu and Khlong Sala Mai covering the service area of 700 ha for paddy field and 50 ha for rubber area in total.

° Construction period of the RID facilities in the Stage I would take 3 years, which would develop the irrigated agriculture covering existing rained paddy field of 5,110 ha that is equivalent to 51 percent of the total Project service area.

(3) *Stage II Development*

° It has been considered that RID would commence the construction of major work for the irrigation and drainage facilities in high-lying areas required for the Stage II agricultural development at adequate period being subject to the Government financial arrangement after the completion of two tidal regulators in the Stage I development. It would be desirable that the commencement date of major work construction for the Stage II development by RID be given immediately after completion of the tidal regulators because of quick accrual of the full benefits to be realized from the tidal regulators as well as in due consideration of the progress on the formation of the water users' groups concerned and the subsequent development of on-farm work.

° RID would be responsible for the construction of 7 pumping irrigation schemes and one gravity irrigation scheme in the higher-lying areas above the WUG pumping scheme covering the irrigable area of 4,690 ha by pumps and 180 ha in gravity. These irrigation schemes would be constructed in closer connection of the drainage improvement schemes concerned over 4,850 ha of existing paddy field and 6,190 ha of rubber planted area.

° Construction of the RID facilities in the Stage II which would service the irrigated agriculture over 4,870 ha of existing rained paddy field would need a period of 5 years, while the water users' groups would be responsible for the terminal irrigation on-farm work and related services.

4.1.4 Development Options Examined

The development plan in the Study area requires a combination of the measures to promote some control of the water resources, to increase the productivity in rural sector and to protect the environment. Major development options considered in the Study area during the course of the Project formulation are, among others, given below:

(1) Annual inundation/flooding impede more intensive development for majority of the Study area in agricultural and socio-economic terms, for which appropriate measures to alleviate this problem has been given special attention. On the other hand, drought is a limiting factor to the productivity of main-season paddy and the crop production during the off-season, for which proper irrigation facilities would be imperative for development of the Study area.

(2) The water resources in the Study area have not been developed, for which the Bang Nara water storage including its major tributary called Mae Nam Yakang would be provided with the construction of two tidal regulators. This water storage which has a small capacity is highly blessed with much inflow; however, due to its location at the bottom of the Project area, there would be only a pumping method in expanding the irrigation potential in terms of water level. Other water resources development plans so far examined are outlined below:

- Water storage at the To Daeng swamp with the bund would have a potential to promote the flood alleviation and/or to equip the irrigation supply capability which is larger than that of the proposed Bang Nara storage; however, this should be left over in line with the GRBDS's recommendation in terms of the environmental issues. Reference is made to Appendix XII "Present Position of the To Daeng Swamp".

- Major water storage in the upsteam basin of Mae Nam Yakang to be combined with the Bang Nara storage would contribute to a greater expansion of the irrigation potential in the Study area in terms of water level and quantity; however, such possible site has not been identified due to the densely populated area except for the small scaled reservoirs for local supply.

- Potential of the deep groundwater exploitation to a certain extent has been forecasted mainly in the flood plain in the southwestern part of Mae Nam Bang Nara; however, higher operation cost would not be permissive for irrigation practices from the national economic point of view.

(3) In addition to three tidal regulators, it has been conceived that the release of part of the flood water directly from the Bang Nara flood plain to the Gulf of Thailand through construction of new flood diversion channels would be a final solution to alleviate the inundation over the low-lying land along Mae Nam Bang Nara taking into account the advantages to reduce friction loss due to the shortening of drainage pass length. However, with the experience in operation of the Nam Baeng regulator, it would be quite difficult to maintain the entrance of such flood diversion channels to the ocean. This concept has not been materialized in the Project due to high investment and also to technical uncertainty even with a provision of the breakwater system, therefore, this has been left over for future consideration.

(4) Water-related environmental concerns along the river reaches downstream of the proposed tidal regulators should be taken into account in terms of the freshwater contribution in the estuaries especially in Narathiwat side. It has been, therefore, considered that the minimum river maintenance flow of 5 cu.m. per sec for the Narathiwat estuary should be at all times released from the Upper Tidal Regulator.

(5) There are relatively large areas of the problem soils such as organic and acid sulfate soils; however, when developed, amelioration and rehabilitation of such soils would take very difficult and much expensive steps. For the already cleared swamp surrounds, the groundwater level control system would be provided with a proper operation mode to prevent the Bang Nara water storage from acidification.

(6) The proposed in-situ development under the Project aims to raise the productivity of farm land already under cultivation including some of the currently idle land, and this requires the introduction and adoption of a new, higher productivity technology in connection with the infrastructural investment in water facilities as well as the use of commercial inputs.

The traditional southern land inheritance system coupled with large family size and limited land resources has resulted in small farm size and land fragmentation with a limitation on prospects for increasing farm incomes. Consolidation (intensification or reorganization) of the farm plots may be a basic necessity before the introduction of a fully reticulated distribution system could be expected to operate efficiently. Greater effort would be continued to demonstrate the benefits of land organization to permit the optimum alignment of canals as well as the adoption of scale sensitive technology for productivity increase; however, this option would not be directly linked to the immediate viable benefits in the Study area.

4.2 Bang Nara Water Storage

4.2.1 Tidal Regulators' Sites Considered

The proposed water storage which should be the key facilities to develop the Study area for agricultural development as a whole would be provided with the construction of tidal regulators on two sides of Narathiwat and Tak Bai in addition to existing Nam Baeng tidal regulator called "NBR". As a matter of fact, this storage is inevitably located at the bottom of the Study area. Prior to the subject Study, RID has planned to locate one regulator at the upper Bang Nara site called "UTR-1" about 6 km upstream of Narathiwat river mouth (refer to Figure 4-1) and another regulator at the lower Bang Nara site called "LTR" about 7 km upstream of Mae Nam Kolok connection and about 9 km upstream of Taba, mouth of the Kolok (refer to Figure 4-2).

Since it is essential to construct a tidal regulator at its lower downstream water level during the flood, an alternative site for UTR has been investigated in its downstream course; however, it has been judged that there would not be a possible site in view of the construction in Narathiwat urban area. Moreover, another attention has been paid to a possible reduction of the flood inflow into the proposed water storage in order to lower its water level with a particular emphasis upon Mae Nam Yakang which has a drainage area at about half of that of Mae Nam Bang Nara. This alternative site called "UTR-2" which is located about 2 km upstream of UTR-1 and about 1 km upstream of Mae Nam Yakang's confluence (refer to Figure 4-1) has been taken up for the Study.

As far as LTR is concerned, there would be no alternative site other than the RID plan when the location and function of Pu Yu tidal regulator recently constructed in the Mu No Project are kept in mind.

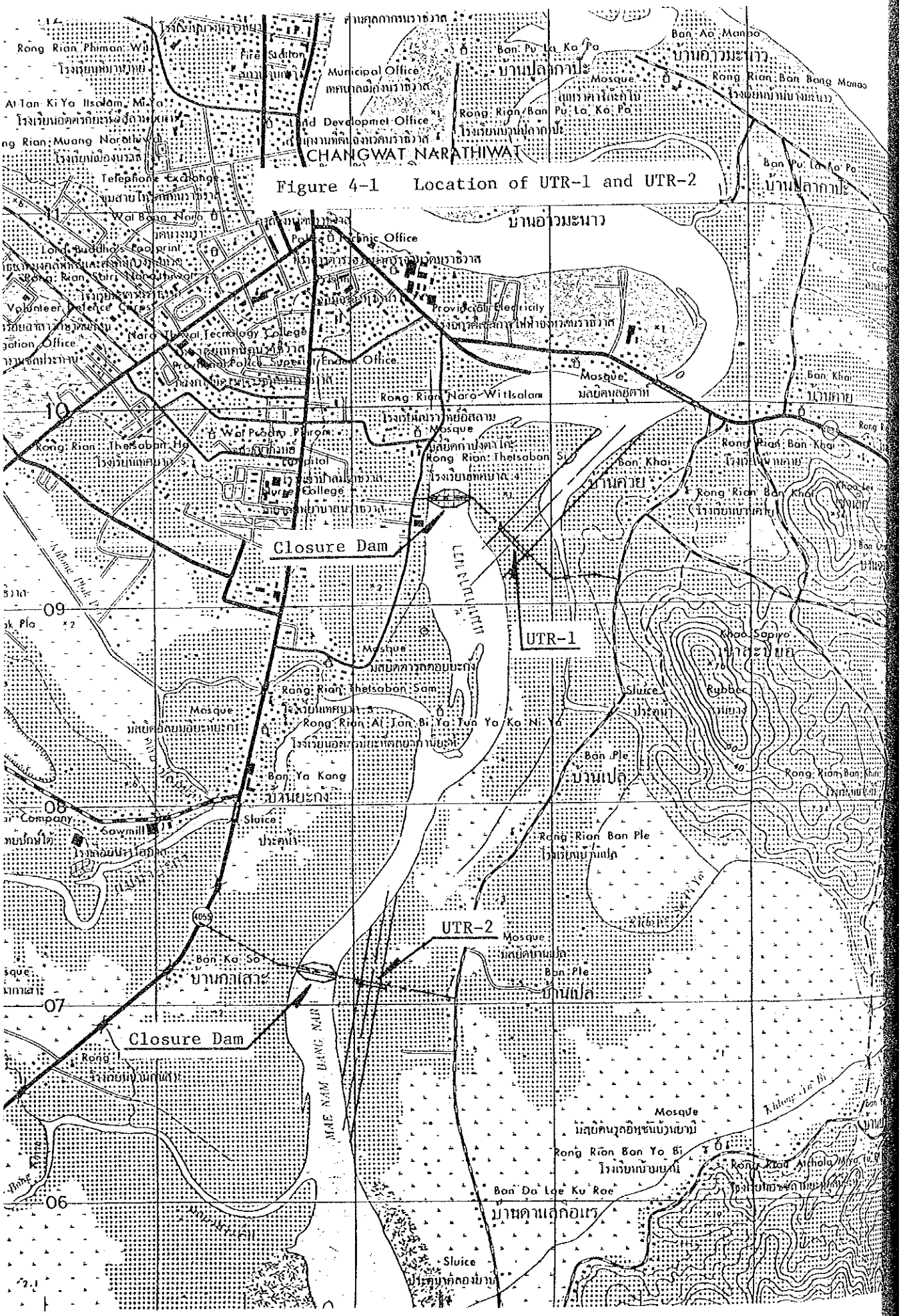
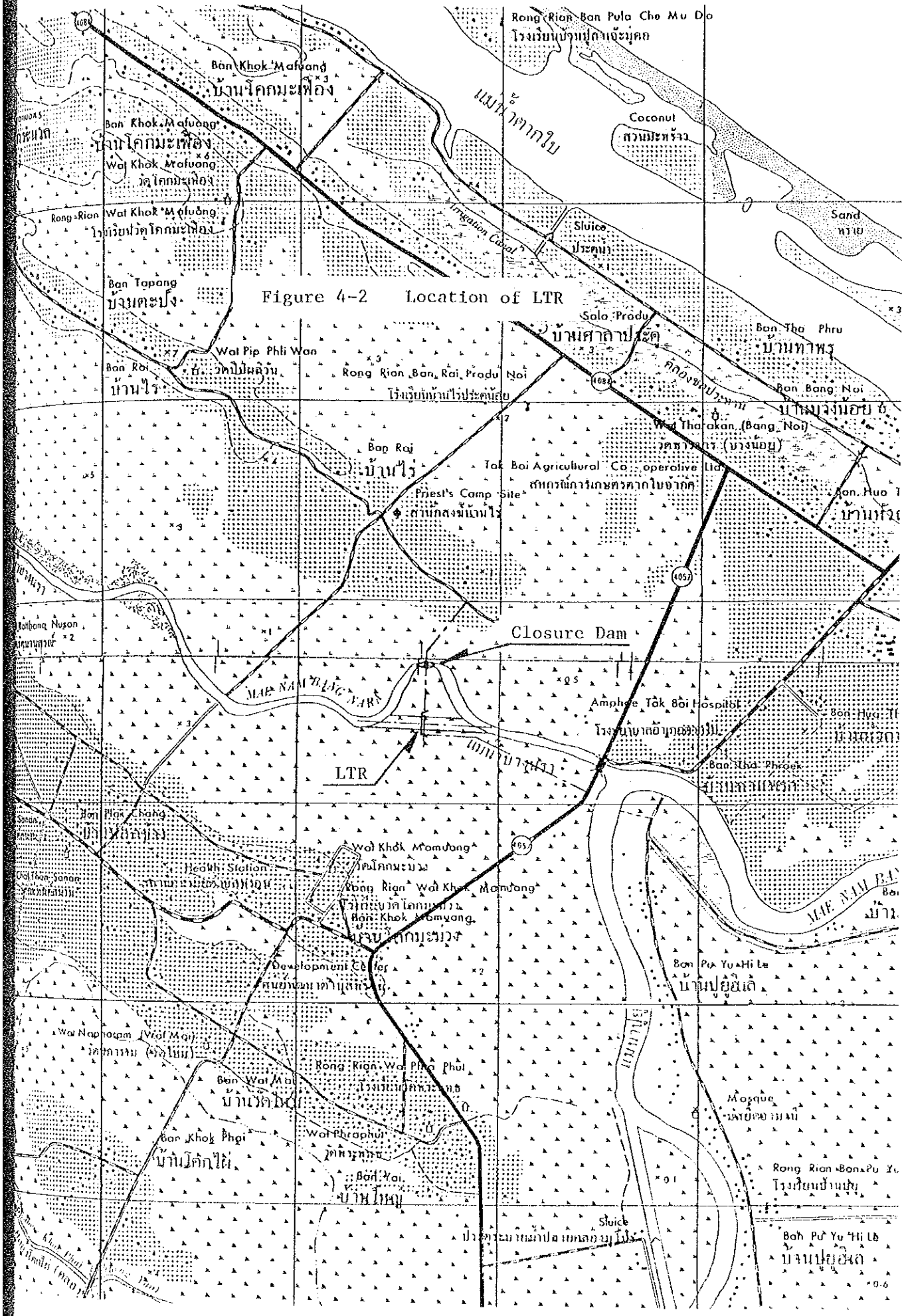


Figure 4-1 Location of UTR-1 and UTR-2


Rong Rian Ban Pula Cho Mu Do
โรงเรียนบ้านปูลาเจ๊ะมูดอ
Ban Khok Mafuang
บ้านโคกมะเฟือง
Coconut
สวนมะพร้าว
Wat Khok Mafuang
วัดโคกมะเฟือง
Rong Rian Wat Khok Mafuang
โรงเรียนวัดโคกมะเฟือง
Irrigation Canal
Sluice
ประตูน้ำ
Sand
ทราย
Ban Tapang
บ้านตะปัง
Figure 4-2 Location of LTR
Salo Pradu
บ้านศาลาประดู่
Ban Tha Phru
บ้านท่าพรุ
Wat Pip Phli Wan
วัดวิปผลิวัน
Ban Rai
บ้านไร่
Rong Rian Ban Rai Pradu Noi
โรงเรียนบ้านไร่ประดู่น้อย
Ban Bang Noi
บ้านบางน้อย
Wat Tharakan (Bang Noi)
วัดท่าระเข้ (บางน้อย)
Tak Bai Agricultural Co operative Ltd.
สหกรณ์การเกษตรตากใบจำกัด
Ban Rai
บ้านไร่
Priest's Camp Site
สถานที่ลงหลักบ้านไร่
Closure Dam
MAE NAM MANG WARE
Amphoe Tak Bai Hospital
โรงพยาบาลอำเภอตากใบ
LTR
Ban Tha Phraek
บ้านท่าแพรก
Ban Plak Chang
บ้านปลักช้าง
Wat Khok Mamuang
วัดโคกมะม่วง
Health Station
สถานีอนามัยบ้านปลักช้าง
Rong Rian Wat Khok Mamuang
โรงเรียนวัดโคกมะม่วง
Ban Khok Mamuang
บ้านโคกมะม่วง
Development Center
ศูนย์พัฒนาที่ดินตากใบ
Ban Pu Yu Hi La
บ้านปูยูฮีลา
Wat Naphatam (Wat Mai)
วัดนาทาม (วัดใหม่)
Rong Rian Wat Phra Phut
โรงเรียนวัดพระพุทธ
Ban Wat Mai
บ้านวัดใหม่
Mosque
มัสยิด
Ban Khok Phai
บ้านโคกไผ่
Wat Phraphut
วัดพระพุทธ
Ban Nai
บ้านในนุ
Rong Rian Ban Pu Yu
โรงเรียนบ้านปู
Sluice
ประตูระบายน้ำคลองบางโกระ
Ban Pu Yu Hi La
บ้านปูยูฮีลา

4.2.2. Hydraulic Simulations

(1) Introduction

The low-lying land in the Study area has been inundated and suffered from flood by heavy rainfall occurring from November to next January every year. The annual inundations have resulted from the following major causes:

- The flood inflow from Mae Nam Yakang and other tributaries which flow through the river basin of Bang Nara;
- The adverse flow from Mae Nam Kolok;
- The generation of sand bars near the river mouths at Narathiwat and Taba;
- The backwater by high tide along the river; and
- The smaller water retention and flowing capacity of Mae Nam Bang Nara.

There is the unsteady flow analysis which catches such inundation phenomena on hydraulics in numerical manner. This study has adopted the Leap-Frog method which is one of the explicit method. By this method, it has been made possible to reproduce the flood phenomena and also to obtain the hydraulic dimensions of the proposed tidal regulators numerically.

(2) Input Materials

(i) River Channel

Longitudinal profile of Mae Nam Bang Nara which forms very irregular slope is shown in Figure 4-1. Cross-sections of

the Bang Nara employed for hydraulic simulation are shown in Figures 4-2 to 4-4. In order to establish a hydraulic model which has steady computing processes and is appropriately employed to analyze the flood condition, each of the cross sections is simplified with the particular reference to the topographical maps and river profile. A series of the levelling works for relevant benchmarks and water level recorders were carried out during the first half of the field work.

(ii) Tide Level

At the Narathiwat mouth, the tide table calculated by the Hydrographic Department, Royal Thai Navy has been used, of which the calculated high tide and low tide at Bang Nara in 1985 are shown in Figure 4-5. Observed tide level which is located in the upstream of the river entrance sand bar at Taba and calculated ocean tide level at Narathiwat which are used for verification study for a proper understanding of the non-flood flow stage in Mae Nam Bang Nara are shown in Figure 4-8. Figure 4-9 shows both water levels as mentioned above in December 1984 which are used for flood stage verification study and flood simulation options.

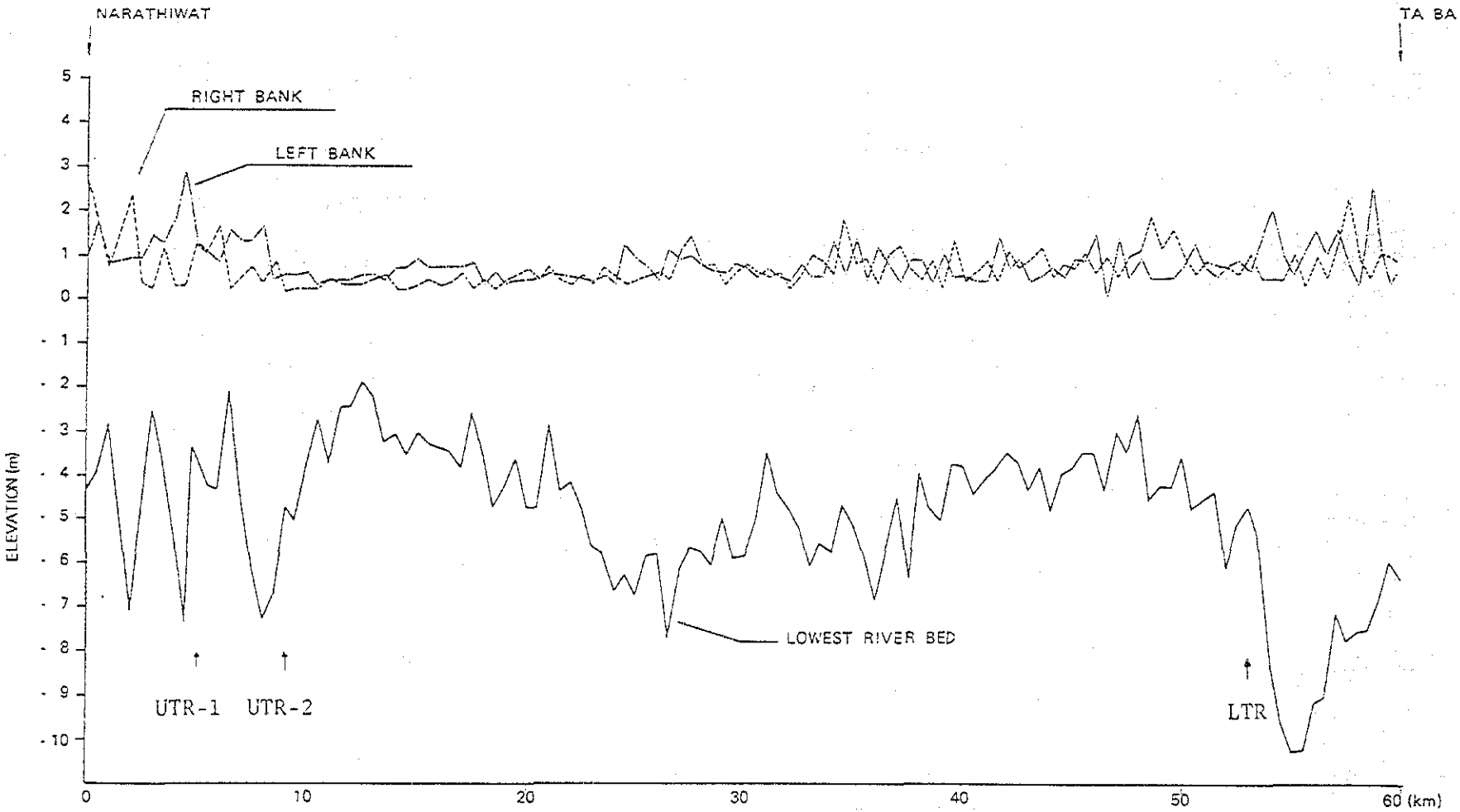
During the Phase II Field Work in December 1985, a small flood occurred in the Bang Nara basin. In this period, water level observed at JICA-provided gages (X160, X162 and X161) are shown in Figure 4-16 and the estuary water level observed by HD and RID which are located in the upstream of the river entrance sand bar at Narathiwat and at Taba are shown in Figure 4-10. As the boundary conditions of a verification, these estuary water levels are employed.

(iii) Relevant Factors

The flood planning for the proposed water storage has been made taking a design heavy rainfall with 5-year return period that is very close to 543 mm of the consecutive 5-day rainfall actually observed at Narathiwat during the period of 20 to 24 December 1984 as explained in para.3.3.2 of Chapter 3. The flood inflow into the Bang Nara including those of the Yakang have been estimated by using the Nakayasu's formula with the above specified rainfall. And, the rainfall recorded in December 1985 which is also used for a model verification is shown in Figure 4-16.

To achieve the degree of accuracy in hydraulic simulations, all of the information on topographical elevation should be made common on the basis of a proper datum line. In this Study, all of the elevations concerned have been based on RTSD shown in para.3.3.1 of Chapter 3.

FIGURE 4-3. PROFILE OF BANG NARA RIVER



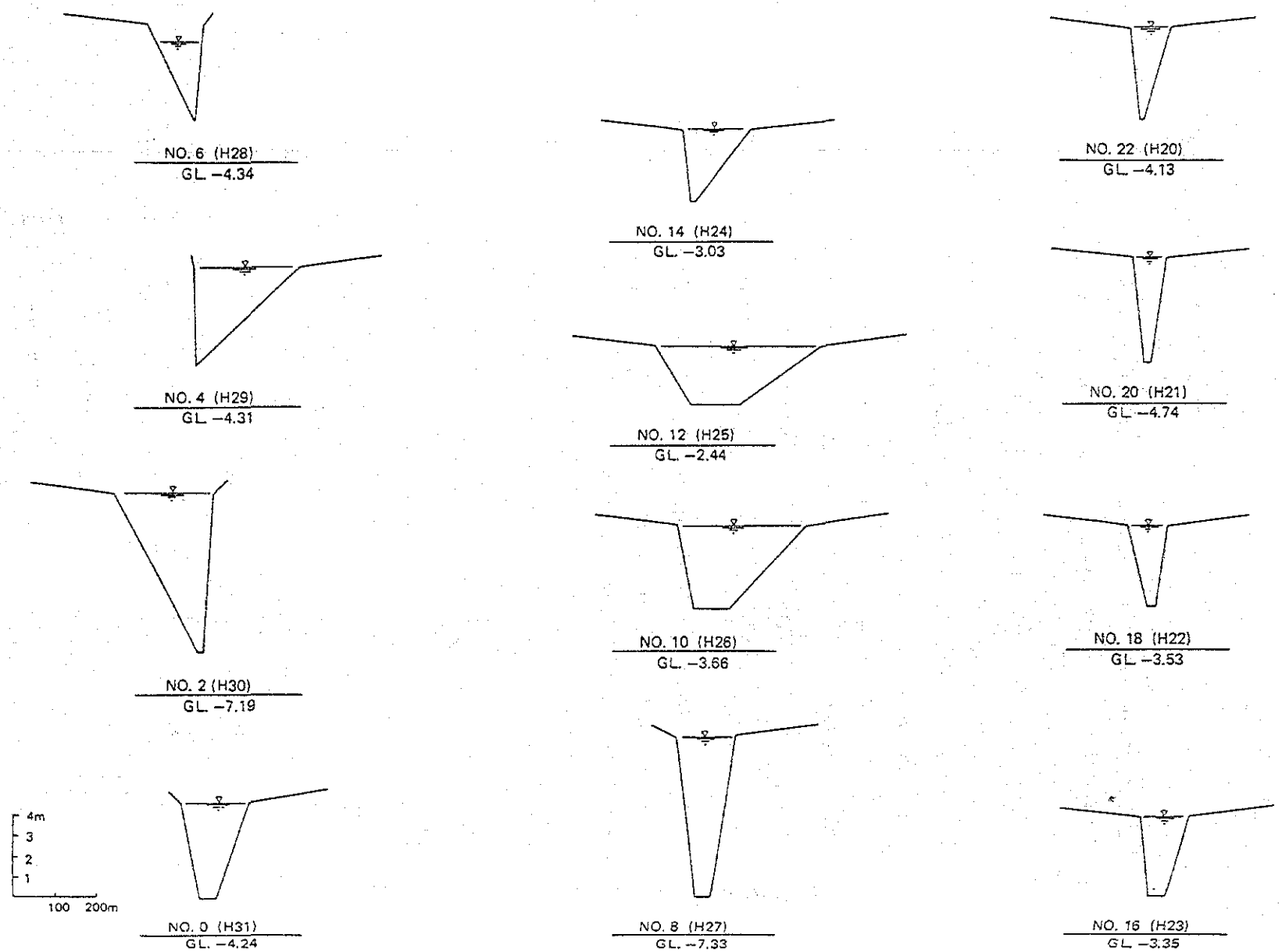


FIGURE 4-4. CROSS SECTION OF BANG NARA RIVER EMPLOYED FOR HYDRAULIC SIMULATION

FIGURE 4-5. CROSS SECTION OF BANG NARA RIVER EMPLOYED FOR HYDRAULIC SIMULATION

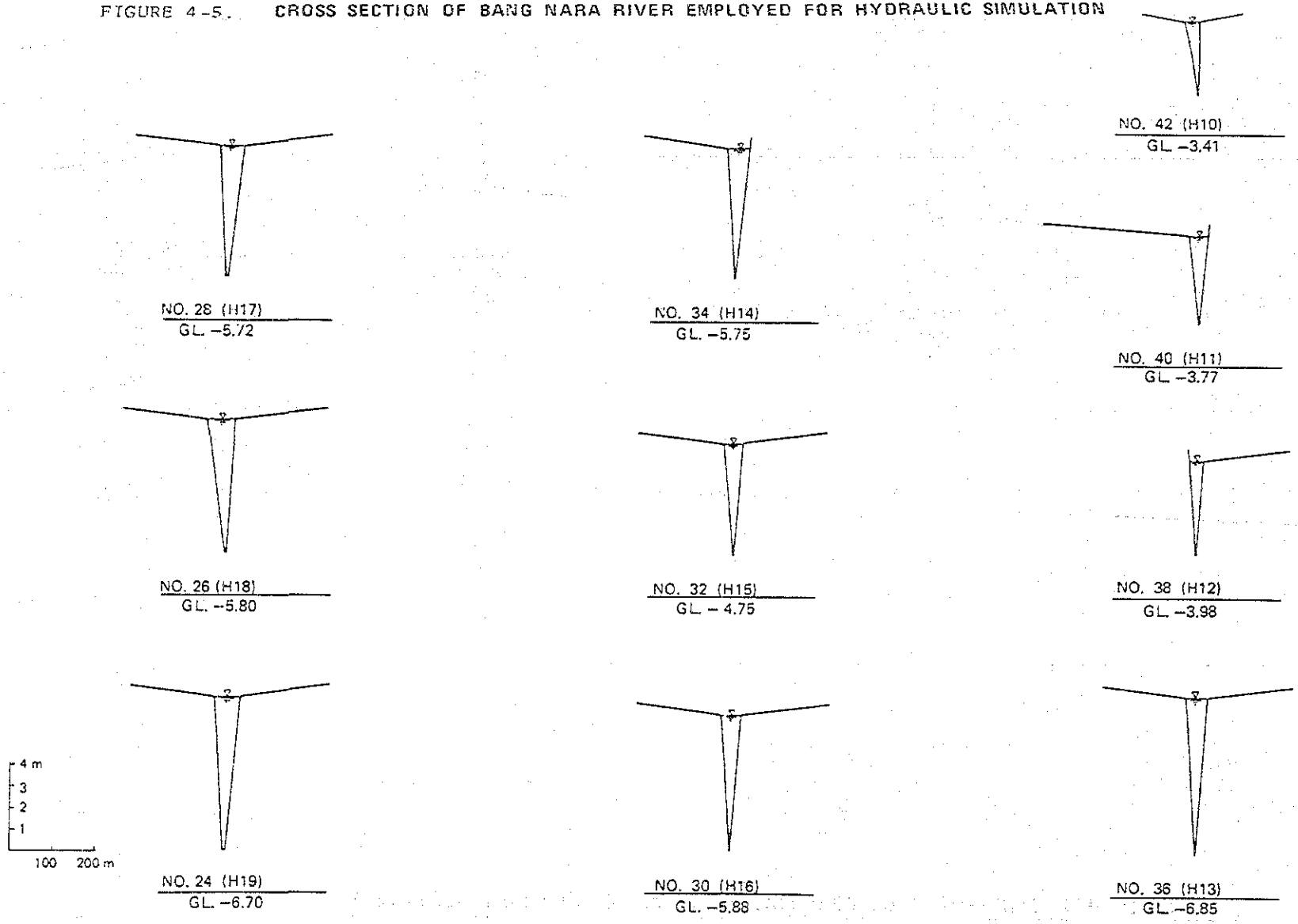
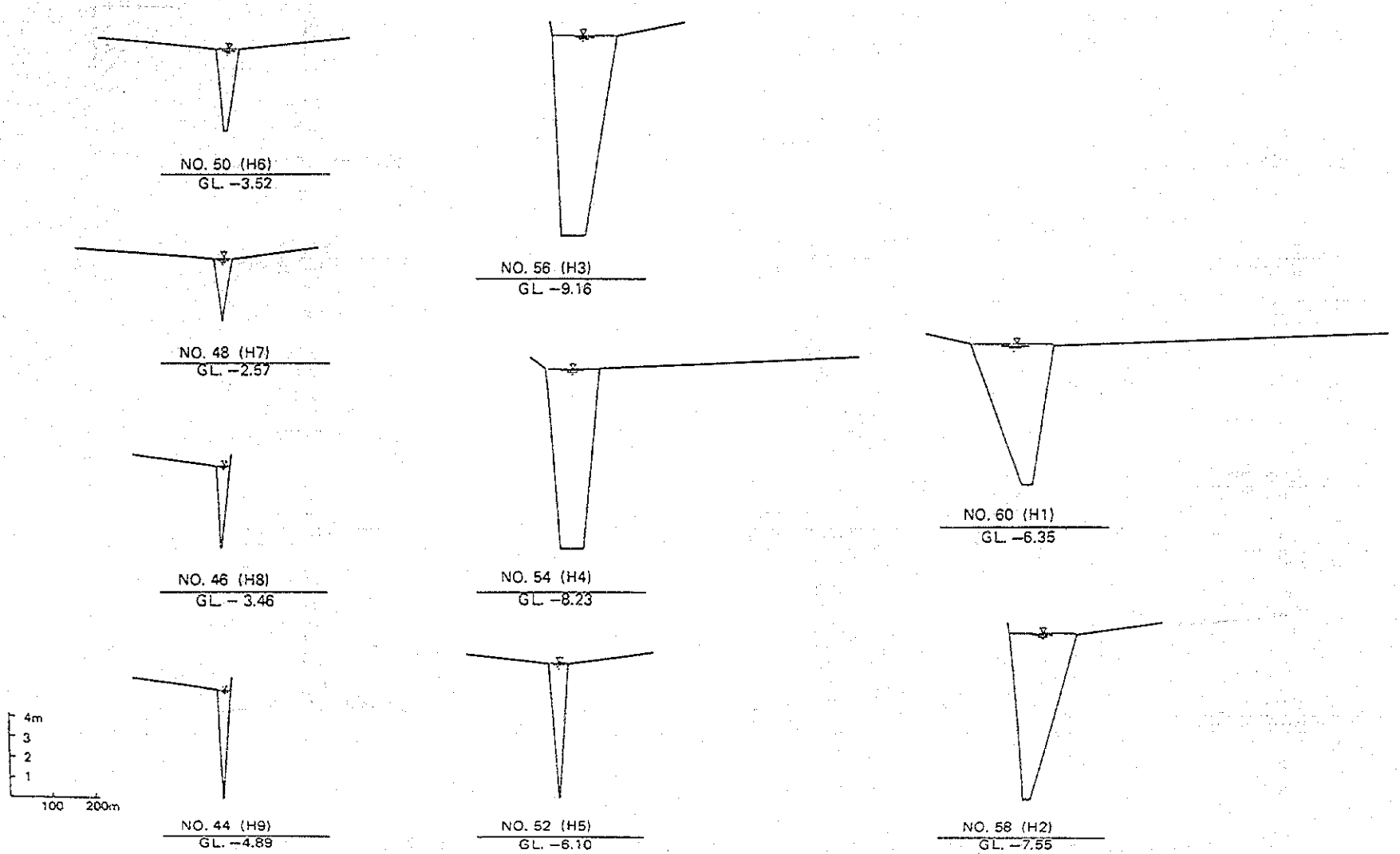


FIGURE 4-6. CROSS SECTION OF BANG NARA RIVER EMPLOYED FOR HYDRAULIC SIMULATION



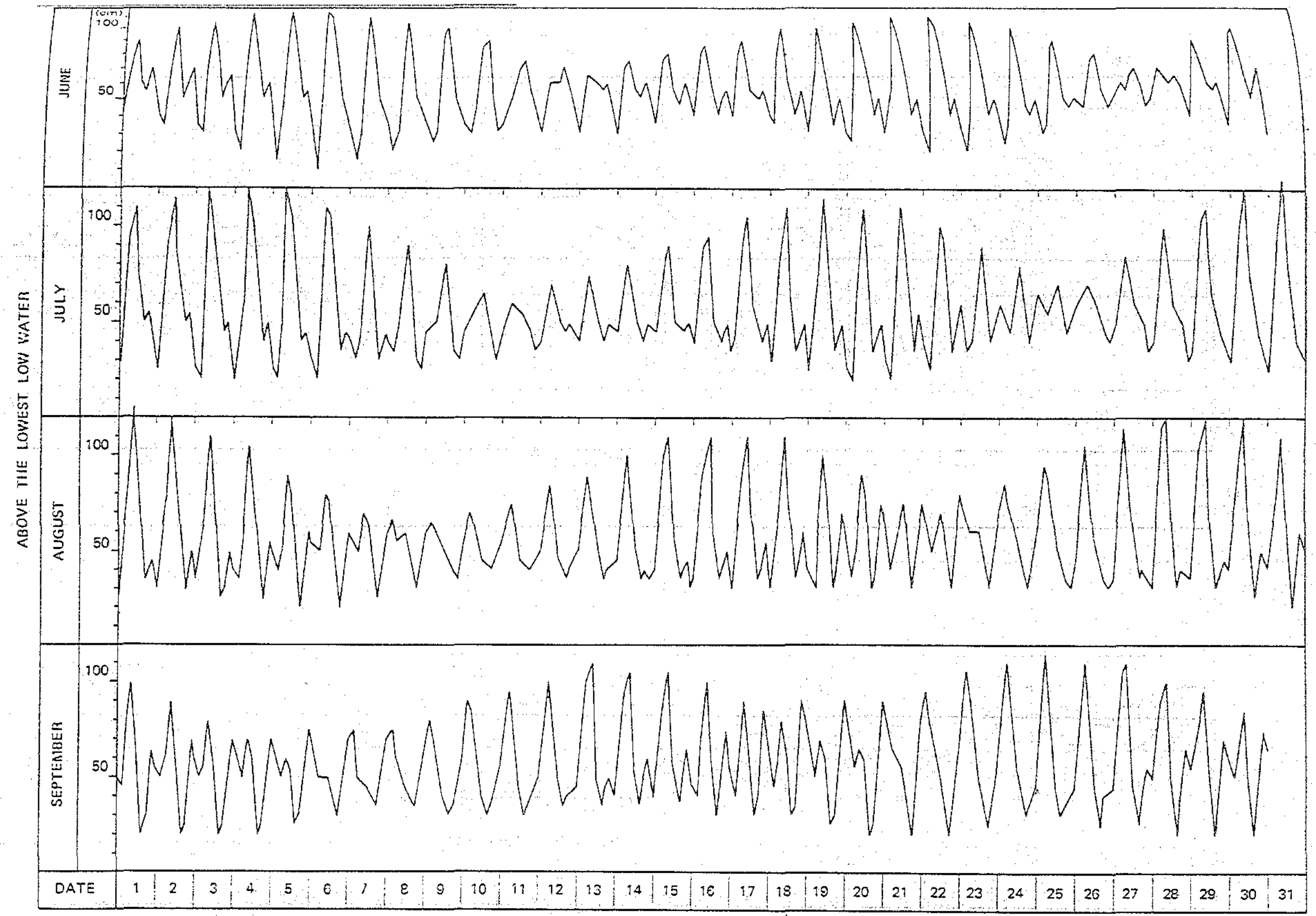


FIGURE 4-7. **CALCULATED HIGH TIDE AND LOW TIDE AT BANG NARA IN 1985**

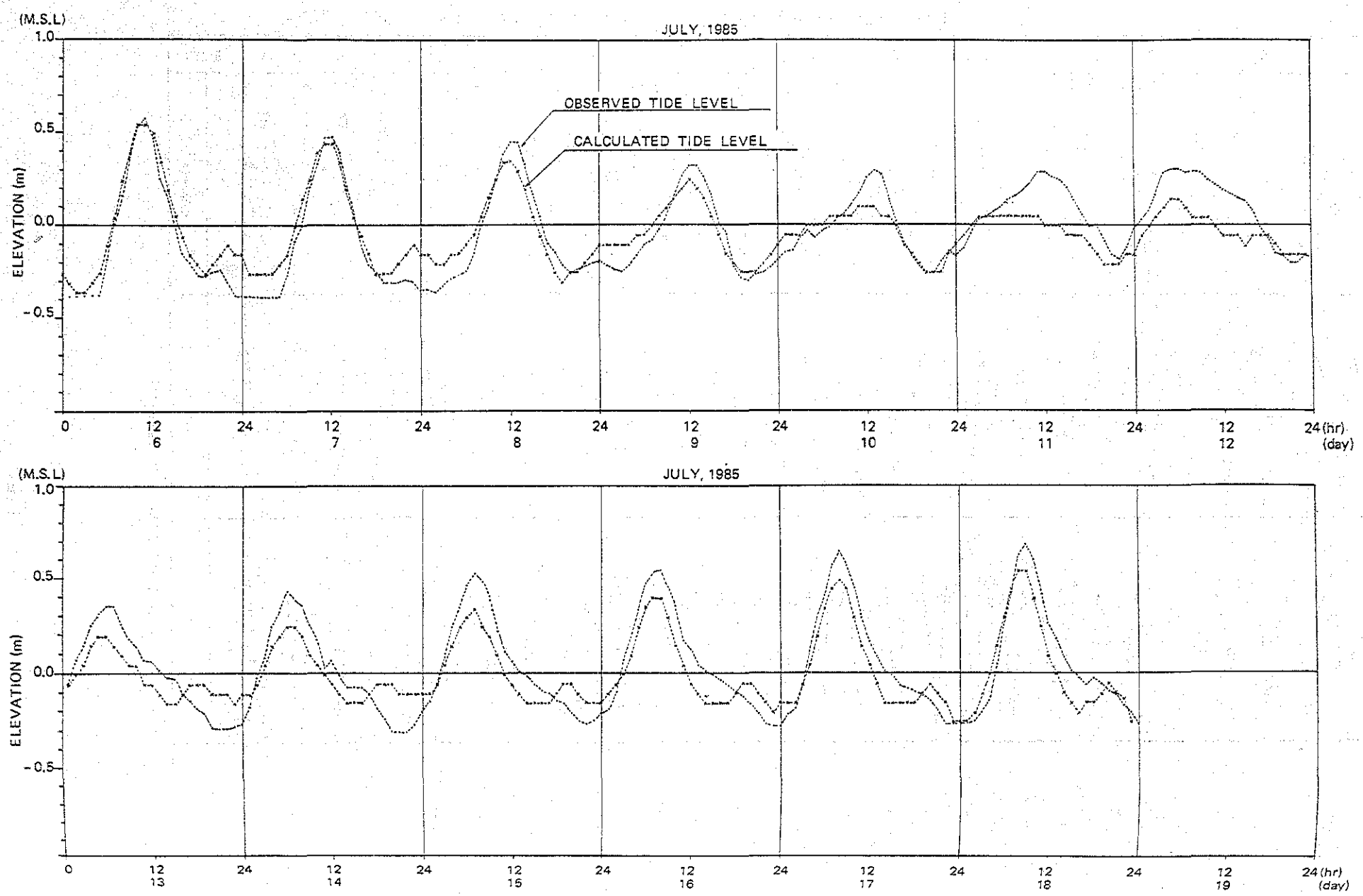


FIGURE 4-8. OBSERVED TIDE LEVEL AT TA BA AND CALCULATED TIDE LEVEL AT BANG NARA

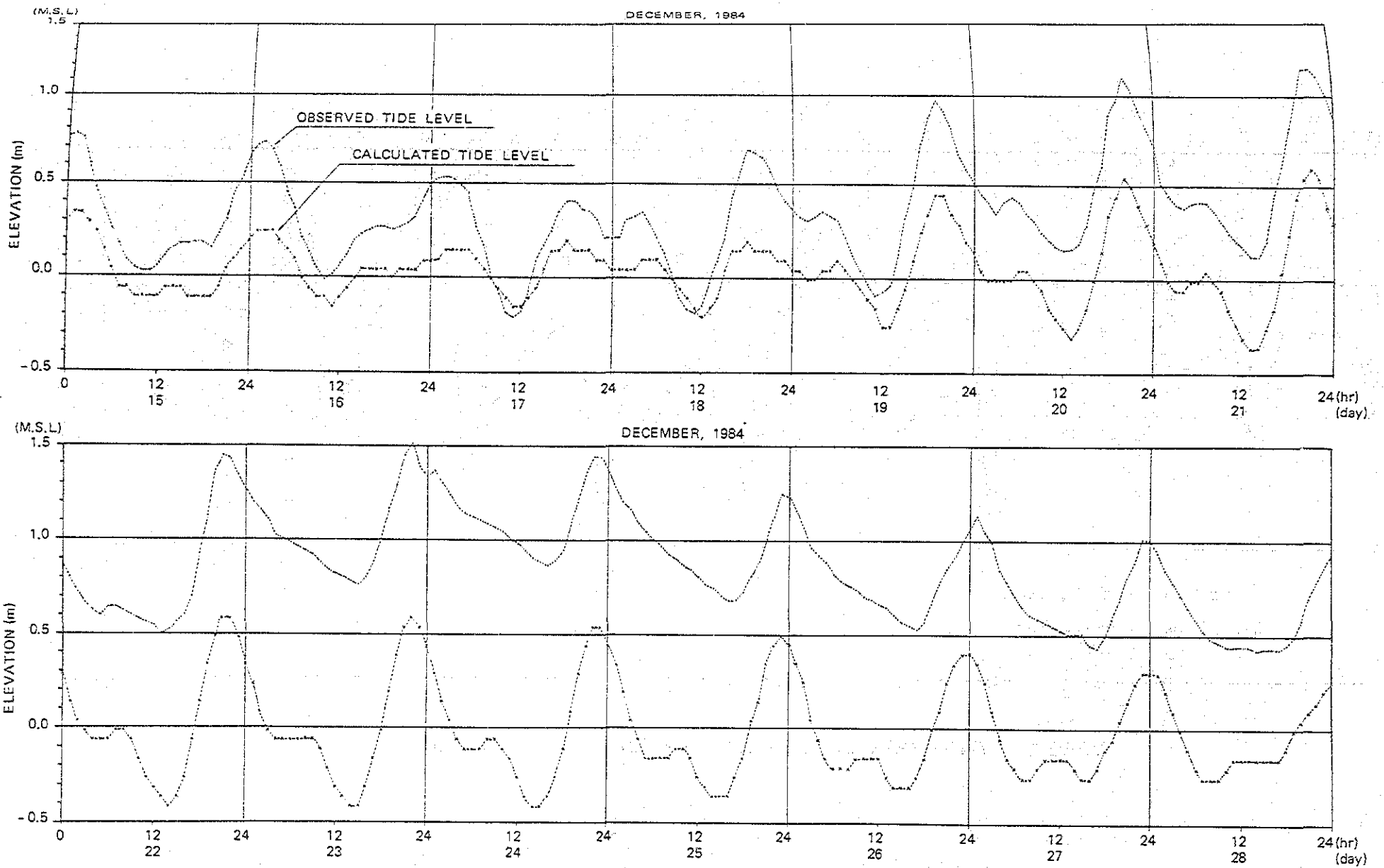
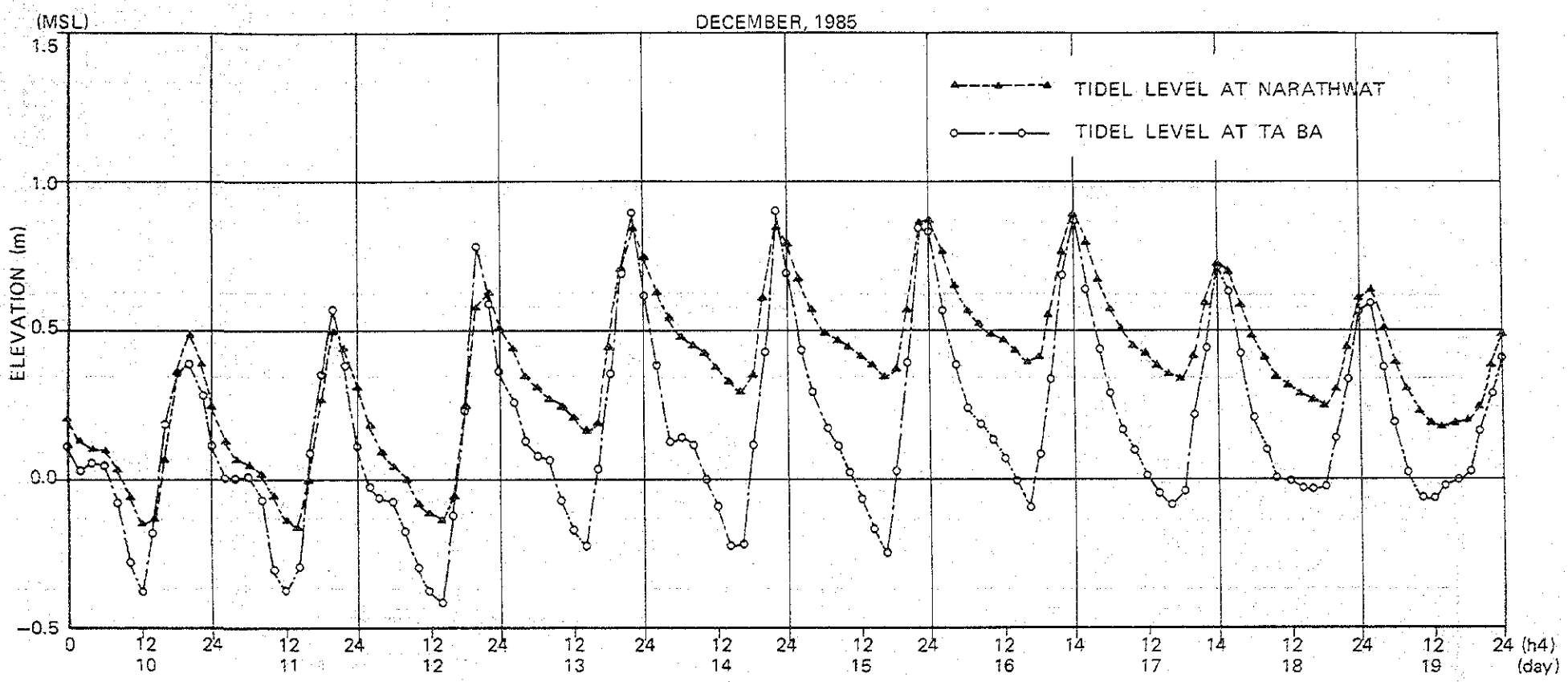


FIGURE 4-9. OBSERVED TIDE LEVEL AT TA BA AND CALCULATED TIDE LEVEL AT BANG NARA

FIGURE 4-10 **OBSERVED TIDE LEVEL AT NARATHIWAT AND TA BA**



(3) Mathematic Model

(1) Basic Equation

In the flow status of river, there are two physical phenomena, viz. one is a steady flow that is constant with time, and the other is an unsteady flow that is changeable with time. The following unsteady flow equation shows the change of channel flow with time in the open channel:

$$\frac{1}{g}\cdot\frac{\partial v}{\partial t} + \frac{v}{g}\cdot\frac{\partial v}{\partial x} + \frac{\partial h}{\partial x} + \frac{v}{gA}\cdot q - I + \frac{n^2|V|V}{R^{4/3}} = 0 \qquad (1)$$

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \qquad (2)$$

At a given section, V = Q/A; thus Eq. (1) becomes

$$\frac{1}{gA}\cdot\frac{\partial Q}{\partial t} - \frac{Q}{gA^2}\cdot\frac{\partial A}{\partial t} + \frac{Qq}{gA^2} + \frac{Q}{gA^2}\cdot\frac{\partial Q}{\partial x} - \frac{Q^2}{gA^3}\cdot\frac{\partial A}{\partial x} + \frac{\partial h}{\partial x} - I + \frac{n^2|Q|Q}{A^2R^{4/3}} = 0 \qquad (3)$$

Since Eq. (1) is equal to

$$\frac{\partial A}{\partial t} = -\frac{\partial Q}{\partial x} + q \qquad (4)$$

And also

$$-I + \frac{\partial h}{\partial x} = \frac{\partial H}{\partial x} \qquad (5)$$

$$\frac{\partial A}{\partial x} = B\cdot\left(\frac{\partial H}{\partial x} + I\right) \qquad (6)$$

where B is width of channel section at the free surface above a datum, A is water area and H is water level.

Substituting these equation into Eq. (3) and simplifying,

$$\frac{1}{gA}\frac{\partial Q}{\partial t} + \frac{2Q}{gA^2}\cdot\frac{\partial Q}{\partial x} + \left(1 - \frac{Q^2B}{gA^3}\right)\cdot\frac{\partial H}{\partial x} - \frac{Q^2B}{gA^3}I + \frac{n^2|Q|Q}{A^2R^{4/3}} = 0 \qquad (7)$$

Eq. (7) is dynamic equation for unsteady flow in natural irregular channel.

Since $\partial A/\partial t = B \cdot \frac{\partial H}{\partial t}$, Eq.(2) may be written as

$$\frac{\partial Q}{\partial x} + B\frac{\partial H}{\partial t} = q \qquad (8)$$

The above equation is in the form of the continuity for unsteady flow in open channel.

where
- Q : discharge (m^3/s)
- g : gravity acceleration (m/sec^2)
- A : cross-sectional area of the flow normal to the direction of flow (m^2)
- t : time (sec)
- x : distance to direction of flow
- B : width of channel section at the free surface (m)
- I : channel slope
- R : Hydraulic radius (m)
- q : side inflow or outflow (m^3/s)

(ii) The Finite Difference Expression Basic Equation by Leap Frog-Method

In analysis of an unsteady flow, it is necessary to solve the differential equation. But this equation is a non-linear type, so it is very difficult to solve it directly. Then, it is solved by means of numerical analysis, which is one of the mathematical simulations. Here, Leap-Frog method has been adopted that is one of the explicit methods.

Hydraulic characteristics of an unsteady flow as a mathematical model are given by simultaneous solution of both the equation of motion and that of continuity. Dynamic equation Eq. (7) may be written in the finite difference expression as follows:

$$ {}_n\left(\frac{1}{gA}\right)_{(I+1)(I-1)} \cdot \frac{{}_{n+1}Q_I - {}_{n-1}Q_I}{2\cdot\Delta t} - {}_n\left(\frac{1}{gA^2}\right)_{I-1} \frac{\left(\frac{{}_{n-1}Q_I + {}_{n-1}Q_{I-2}}{2}\right)\cdot\left({}_{n-1}Q_I - {}_{n-1}Q_{I-2}\right)}{2\cdot\Delta x} $$

$$ + \left(1 - {}_n\left(\frac{B}{gA^3}\right)_{(I+1)(I-1)} \cdot {}_{n-1}Q_I^2\right) \cdot \frac{{}_nH_{I+1} - {}_nH_{I-1}}{2\cdot\Delta t} $$

$$ - {}_n\left(\frac{B}{gA^3}\right)_{(I+1)(I-1)} \cdot {}_{n-1}Q_I^2 \cdot \frac{Z_{I+1} - Z_{I-1}}{2\cdot\Delta x} + \frac{\left|{}_{n-1}Q_I\right| \cdot {}_{n+1}Q_I}{(K^2)_{(I+1)(I-1)}} = 0 \qquad (9) $$

Therefore,

$$ {}_{n+1}Q_I = \frac{\left({}_nH_{I-1} - {}_nH_{I+1}\right)\cdot(1-T) - {}_n\left(\frac{1}{gA^2}\right)_{I-1}\cdot\left({}_{n-1}Q_I^2 - {}_{n-1}Q_{I-2}^2\right) + T\cdot\left(Z_{I+1} - Z_{I-1}\right) + P\cdot {}_{n-1}Q_I\cdot\frac{\Delta x}{\Delta t}}{P\cdot\frac{\Delta x}{\Delta t} + {}_n\left(\frac{2}{K^2}\right)_{(I+1)(I-1)}\cdot\left|{}_{n-1}Q_I\right|\cdot\Delta x} \qquad (10) $$

where $$ T = {}_n\left(\frac{B}{gA^2}\right)_{(I+1)(I-1)} \cdot {}_{n-1}Q_I^2 $$

$$ P = {}_n\left(\frac{1}{gA}\right)_{(I+1)(I-1)} $$

The continuity equation Eq.(6) is expressed as follows.

$$ \frac{{}_{n+1}Q_I - {}_{n+1}Q_{I-2}}{2\cdot\Delta x} + {}_nB_{I-1} \cdot \frac{{}_{n+2}H_{I-1} - {}_nH_{I-1}}{2\cdot\Delta t} = {}_{n+1}q_{I-1} \qquad (11) $$

Therefore

$$ {}_{n+2}H_{I-1} = {}_nH_{I-1} - \frac{\Delta t}{\Delta x\cdot {}_nB_{I-1}} \cdot \left({}_{n+1}Q_I - {}_{n+1}Q_{I-2} + {}_{n+1}q_{I-1}\right) \qquad (12) $$

where

n : suffix showing time scheme

I : suffix showing location scheme

Δt : calculation time interval

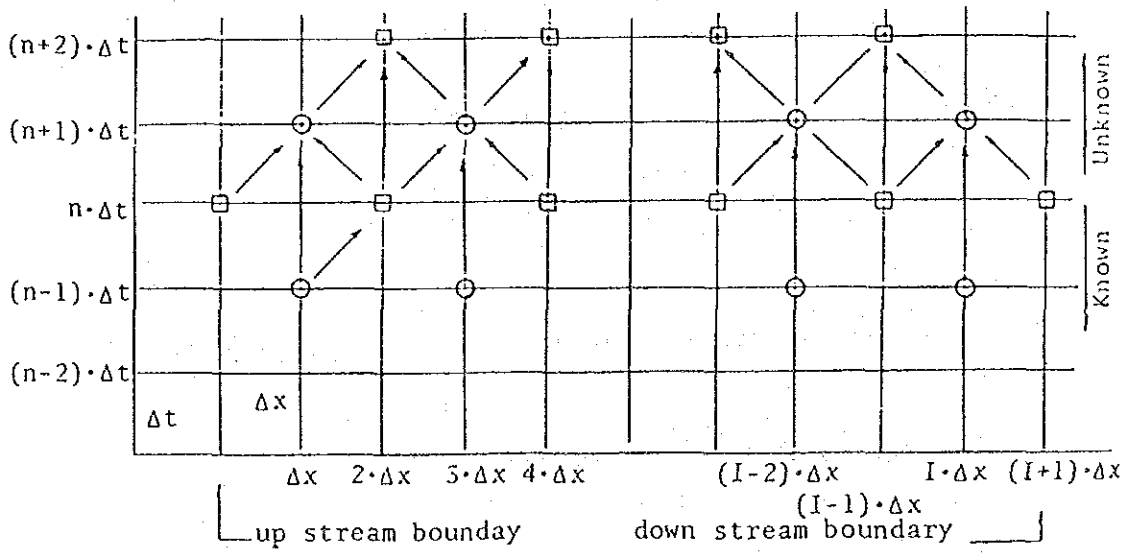
Δx : longitudinal distance interval along the channel

K : hydraulic conveyance

K^2 : $A^2 \cdot R^{4/3}/n^2$

iii) Method of Analysis

Eq. (10) and Eq. (12) as expressed in the gride-figure as follows:



⊙ Discharge calculation point

⊡ Water level calculation point

Gridé figure for Simulation

In the above figure, the direction of x-axis is positive from upstream to downstream and the direction of t-axis is positive from past time to future time.

In the case of Leap-Frog Method scheme, discharge and water level calculation point are existing one after another in the gride figure, which expresses the hydraulic simulation procedure. Therefore, water level point is only needed as the upstream and downstream boundary condition. This is the reason why this method is convenient to simulate the hydraulic behavior in the river channel which is related to tide level at the upstream and downstream. The calculation progress from downstream to upstream with distance interval x and from past time to future time with time interval t.

With the concept that the river flow passes through the river course and that the flow over the river course inundates the surrounding area in case of the Bang Nara, a hydraulic model of the unsteady flow with tidal oscillation at three mouths has been conceived with the application of simultaneous solution of "Equation of Motion" for river channel and "Continuity Equation" for entire flow cross-sectional area.

Then, for the given initial condition, boundary condition and geometric conditions, the numerical intergration is performed. It is desirable to constitute the efficient and economic grid system from the point of the electronic computer performance. The selection of the time interval to be used is not arbitrary. It is well-known that solving by finite differences method does not produce a stable solution unless the distance interval and the time interval are related to the velocity of the long wave, such as

$$\Delta t < \frac{\Delta x}{| V_{max} \pm \sqrt{g\, h_{max}} |} \qquad (13)$$

If the value of t exceeds that given above, the transmission of the hydraulic phenomena goes beyond the tracing speed in the mathematical model and the solution is led to unconvergence. The value of t and x must be determined to satisfy the expression (13), by speculating in advance the maximum possible velocity and water depth.

(4) Hydraulic Simulation Options

(i) Verification of Unsteady Flow in the Bang Nara River

To build the suitable hydraulic model, some observed hydraulic dimensions such as water level and water velocity with time in the river are helpful. In this point, one observation was executed during the field work. In verificating the mathematical model, the flow resistance of river course is one of the important elements that gives the flow characteristics, for which the manning's roughness coefficient has been used (See Table 4-1 and Figure 4-15)

The verification data collected in Figure 4-14 for the purpose of building the hydraulic model cover the short duration records of the water level such as half day record in normal stage and peak water level which is shown in Figure 4-13. In December 1985, there was a flood with about one-year return period and, the water level was recorded continuously at three stations (JICA-provided gages; X160, X162 and X161) along the Bang Nara river and at two river mouths of the Narathiwat and Taba. The applicability of the hydraulic model structure has been studied and verified with these water level records. Figure 4-14 shows comparison between the observed values and the simulated values at X160, X162 and X161.

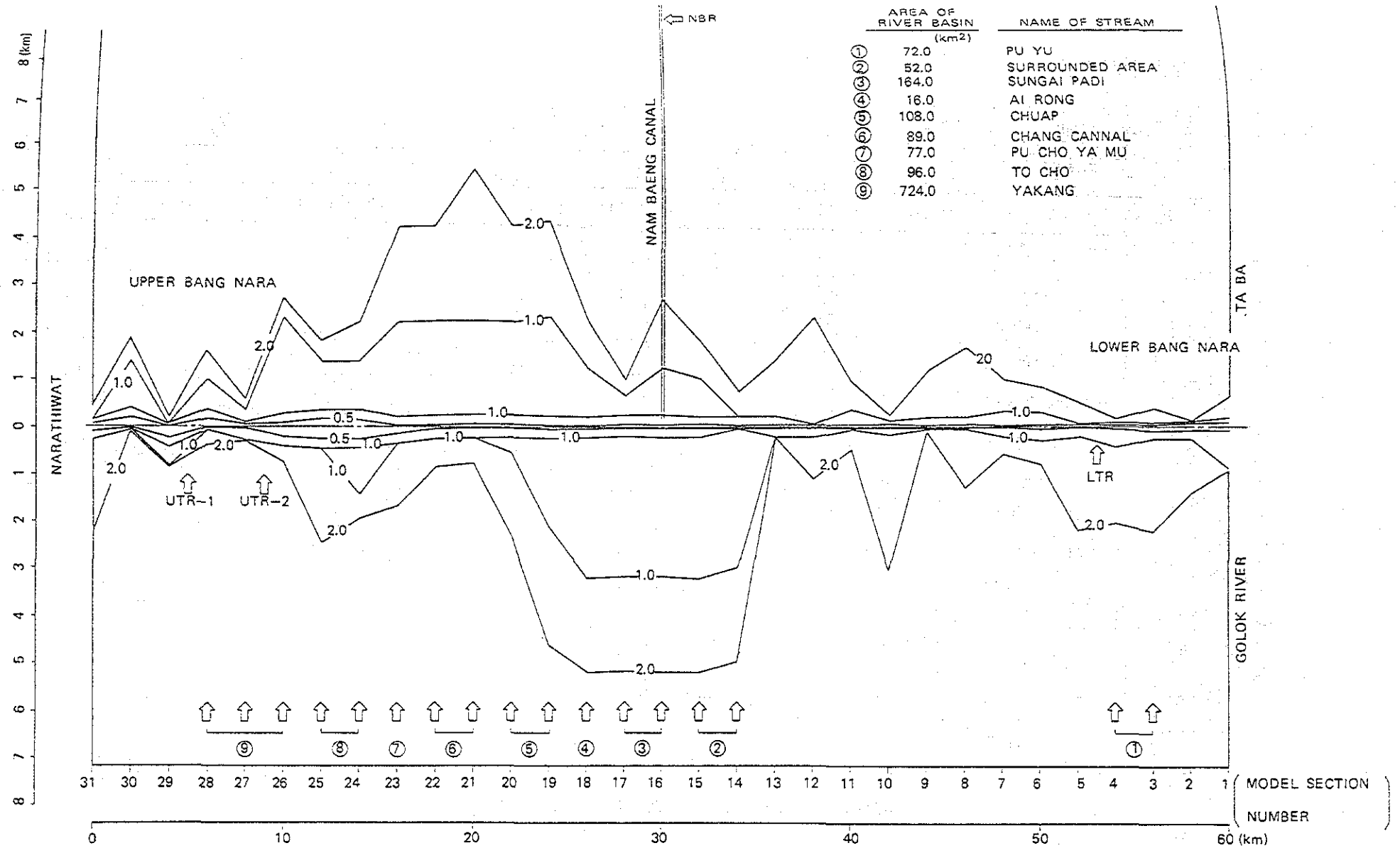


FIGURE 4-11. **SCHEMATIC PLAN OF BANG NARA RIVER BASIN FOR SIMULATION MODEL**

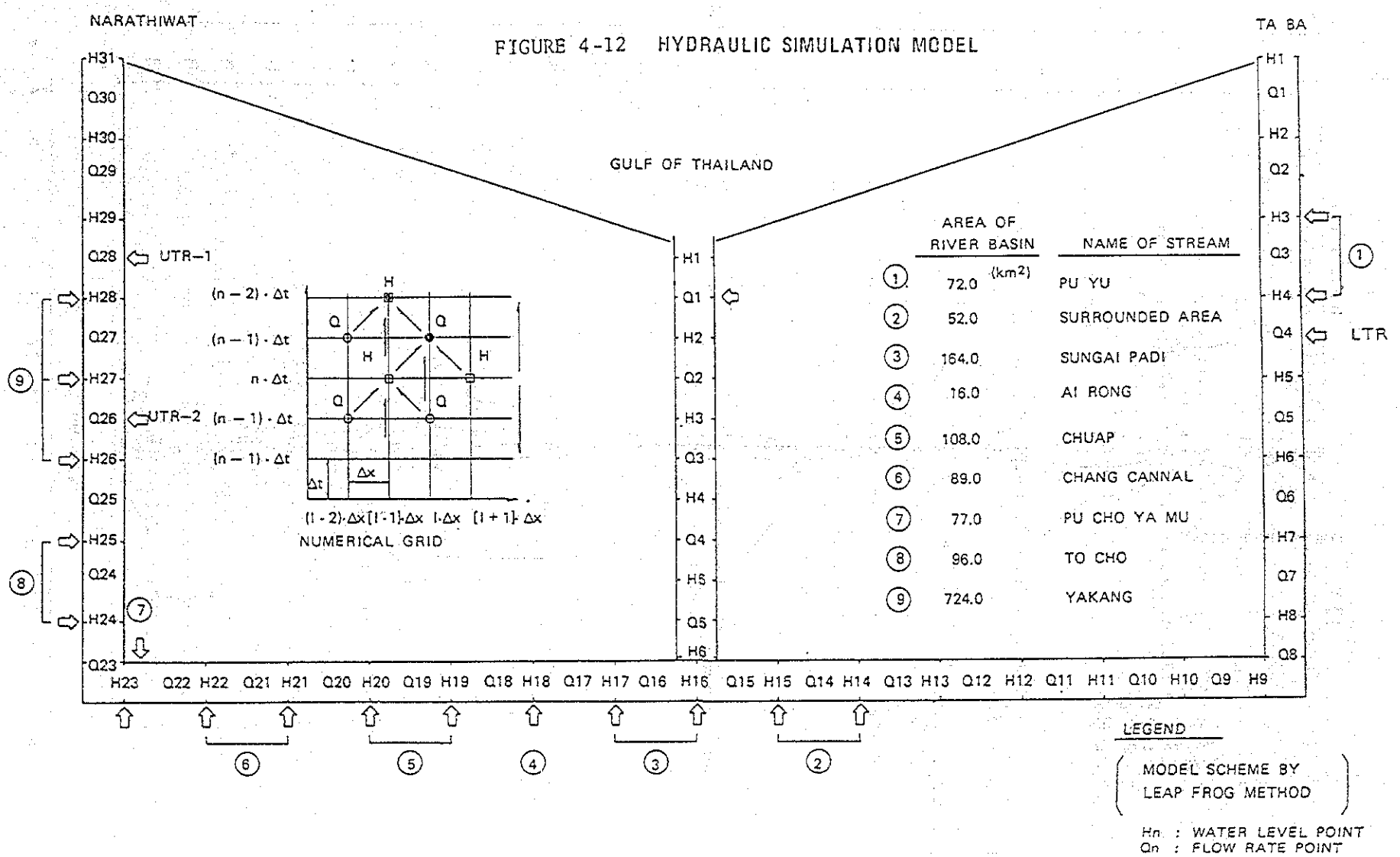


FIGURE 4-12 HYDRAULIC SIMULATION MODEL

The duration of the simulation has been taken at 10 days. However, the influence of previous rainfall runoff remains in the water level record fluctuating until three days after simulation is started, and it is recognized that the simulated values adequately coincide with the observed values as a whole. Since the simulated values in Figure 4-16 much coincide with the observed values at three stations on the 10th day that the influence of the last rainfall runoff vanishes, it can be explained that the river channel model in the hydraulic simulations would have a high reliability.

The outlet of the Nam Baeng channel was closed by sand bar of the river-mouth during the flood stage in December 1985. For the purpose of confirming construction effect of the Nam Baeng channel, it is assumed that during the flood the outlet of the Nam Baeng channel is opened. And then the hydraulic simulation is executed and the both results are compared in Figure 4-17. As a conclusion, it is identified that the Nam Baeng channel would make a enough contribution to alleviate the inundation along Mae Nam Bang Nara with a fact that the inundation duration shortens and its depth is reduced.

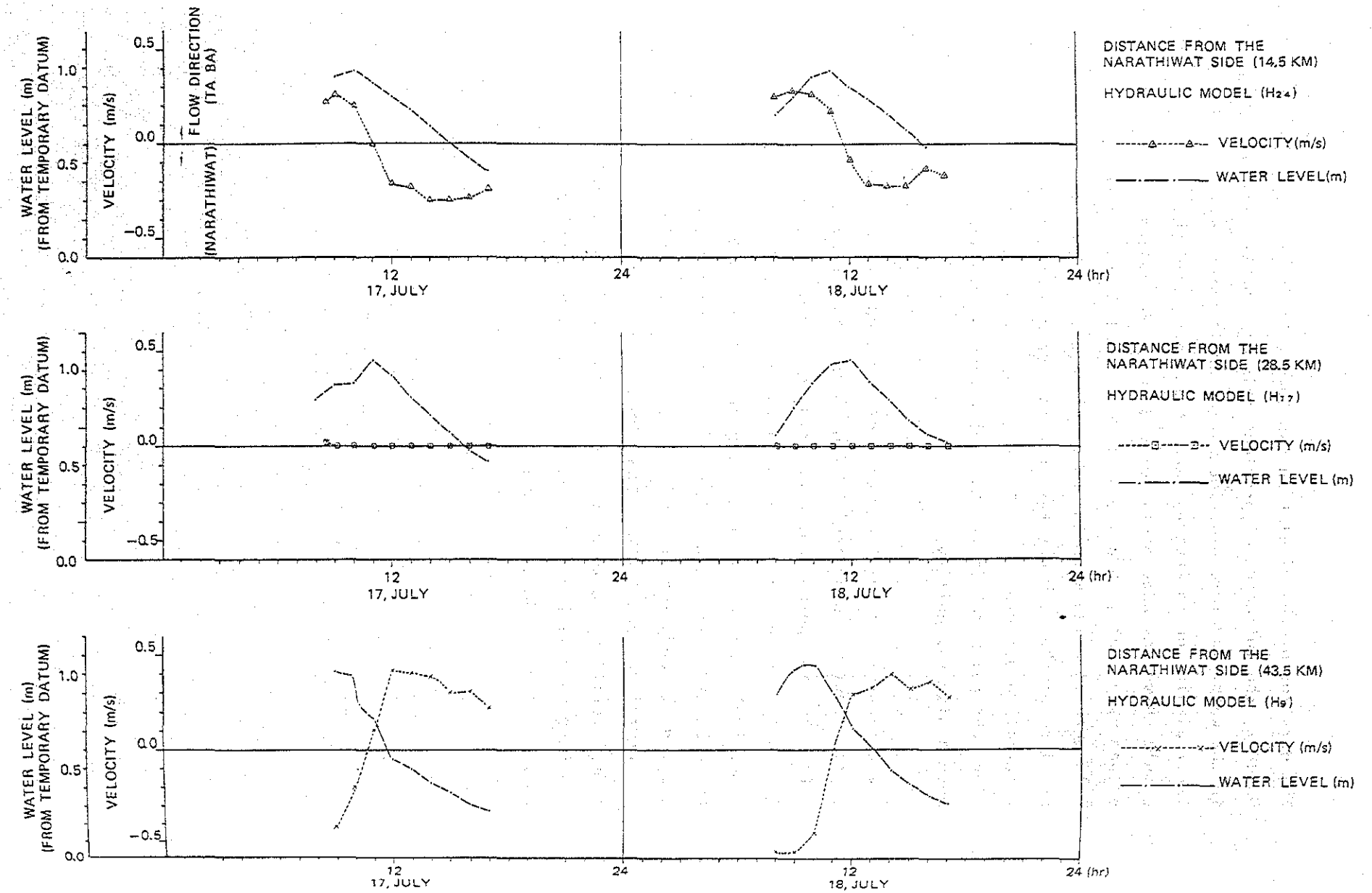


FIGURE 4-13. **OBSERVED WATER LEVEL AND VELOCITY OF BANG NARA RIVER**

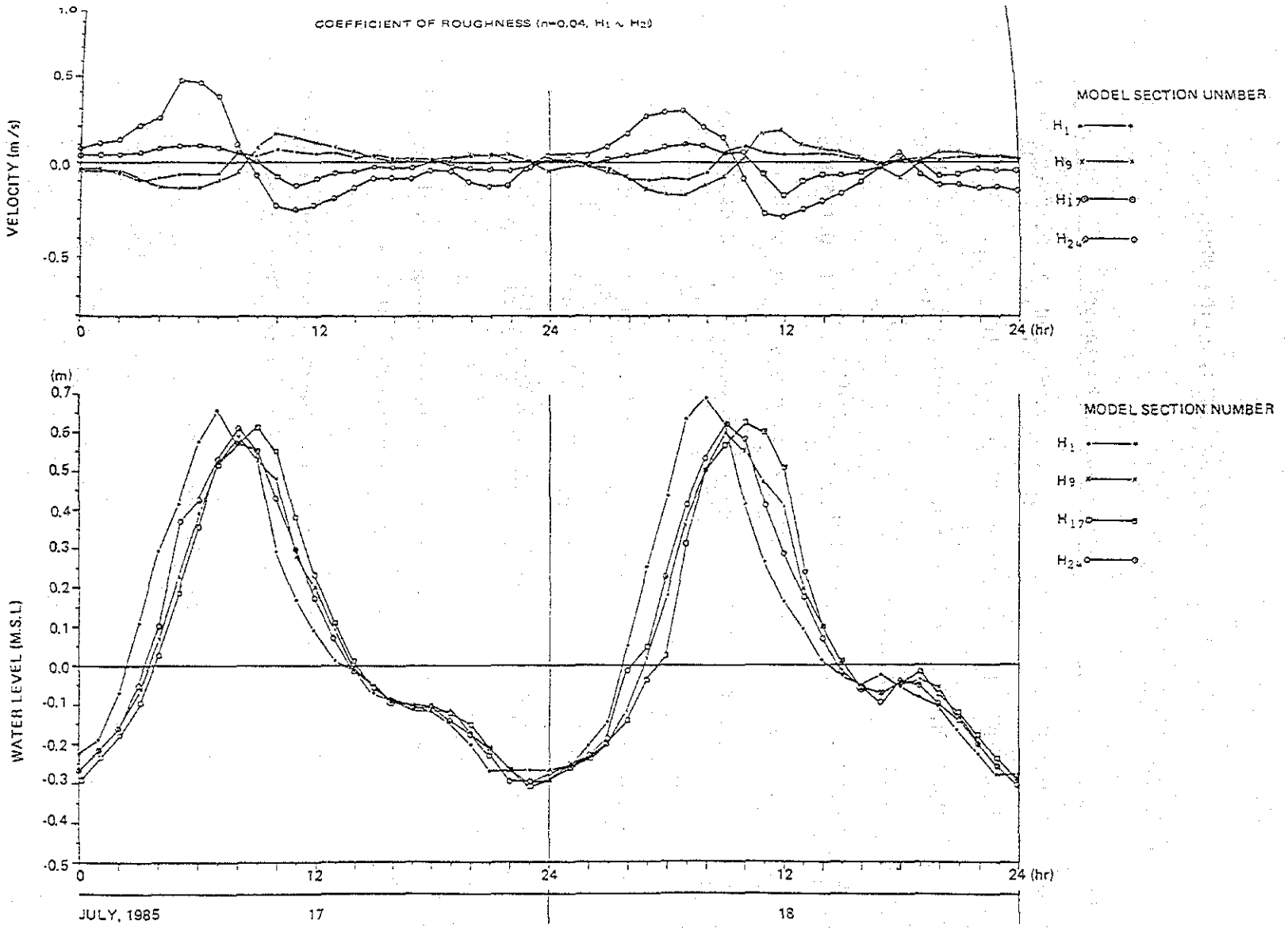


FIGURE 4-14. **VERIFICATION OF ORDINARY WATER LEVEL STAGE ALONG THE BANG NARA RIVER**

Table 4-1. CASES OF VERIFICATION STUDY

Case	Coefficient of Roughness
1	$0.035(H_1-H_4)$, $0.045(H_5-H_{10})$, $0.110(H_{11}-H_{14})$, $0.125(H_{15}-H_{16})$ $0.110(H_{19}-H_{20})$, $0.045(H_{21}-H_{23})$, $0.035(H_{24}-H_{31})$
2	$0.035(H_1-H_4)$, $0.045(H_5-H_{10})$, $0.110(H_{11}-H_{14})$, $0.125(H_{15}-H_{16})$ $0.110(H_{17}-H_{20})$, $0.045(H_{21}-H_{23})$, $0.035(H_{24}-H_{31})$
3	$0.035(H_1-H_4)$, $0.045(H_3-H_{10})$, $0.110(H_{11}-H_{14})$, $0.125(H15-H_{16})$ $0.110(H_{17}-H_{20})$, $0.045(H_{21}-H_{23})$, $0.035(H_{24}-H_{31})$
4	$0.035(H_1-H_4)$, $0.045(H_5-H_{10})$, $0.070(H_{11}-H_{20})$, $0.045(H_{21}-H_{23})$ $0.035(H_{24}-H_{31})$
5	$0.035(H_1-H_4)$, $0.045(H_5-H_{23})$, $0.035(H_{24}-H_{31})$
6	$0.035(H_1-H_4)$, $0.045(H_5-H_{23})$, $0.035(H_{24}-H_{31})$
7	$0.035(H_1-H_4)$, $0.045(H_5-H_{23})$, $0.035(H_{24}-H_{31})$

Note; 1. Difference of the models among case 1, case 2 and case 3 is the lateral inflow.

2. Difference of the models among case 5, case 6 and case 7 is the cross sectional area.

3. CASE-7 : CASE-P

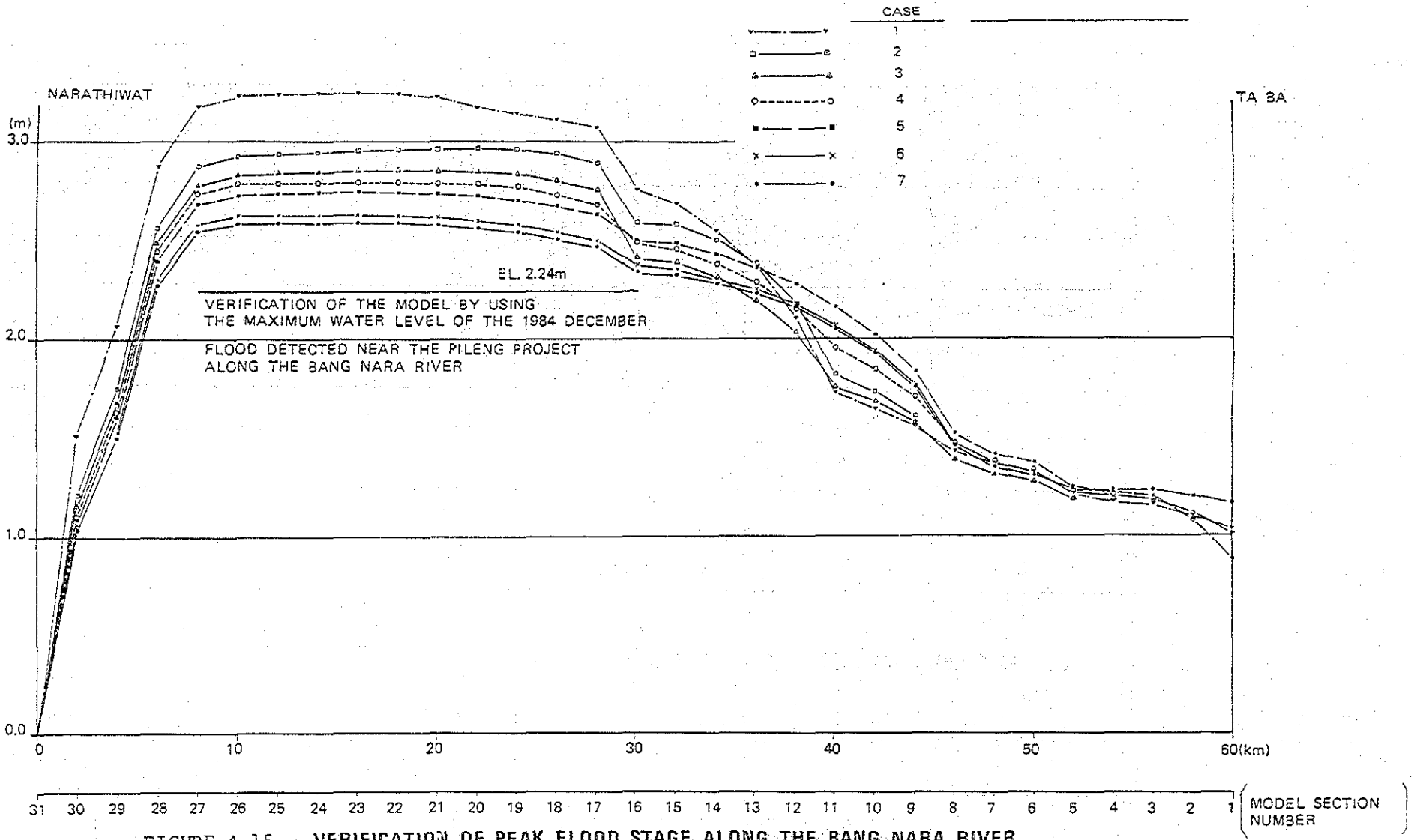


FIGURE 4-15. **VERIFICATION OF PEAK FLOOD STAGE ALONG THE BANG NARA RIVER**

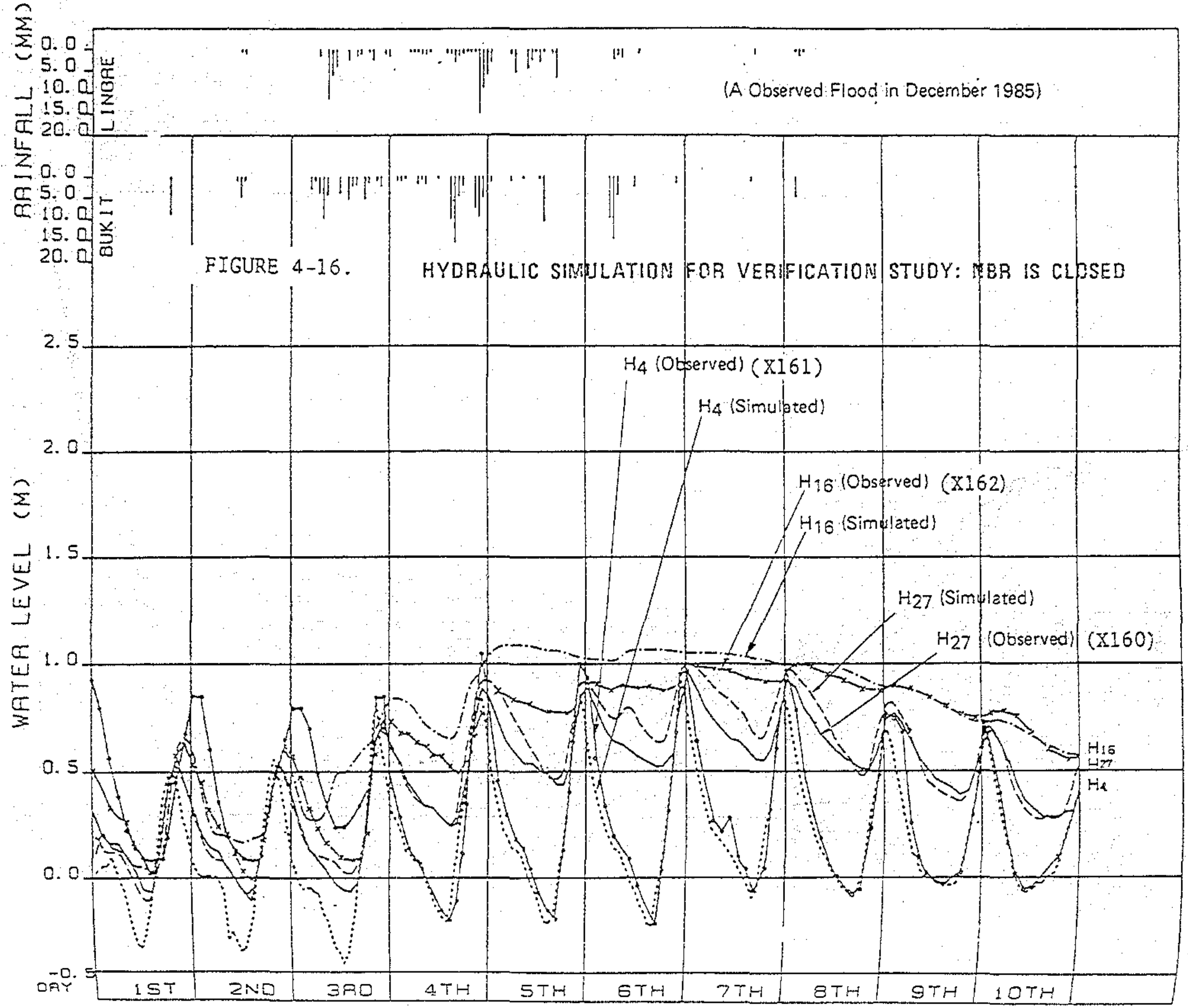


FIGURE 4-16. HYDRAULIC SIMULATION FOR VERIFICATION STUDY: MBR IS CLOSED

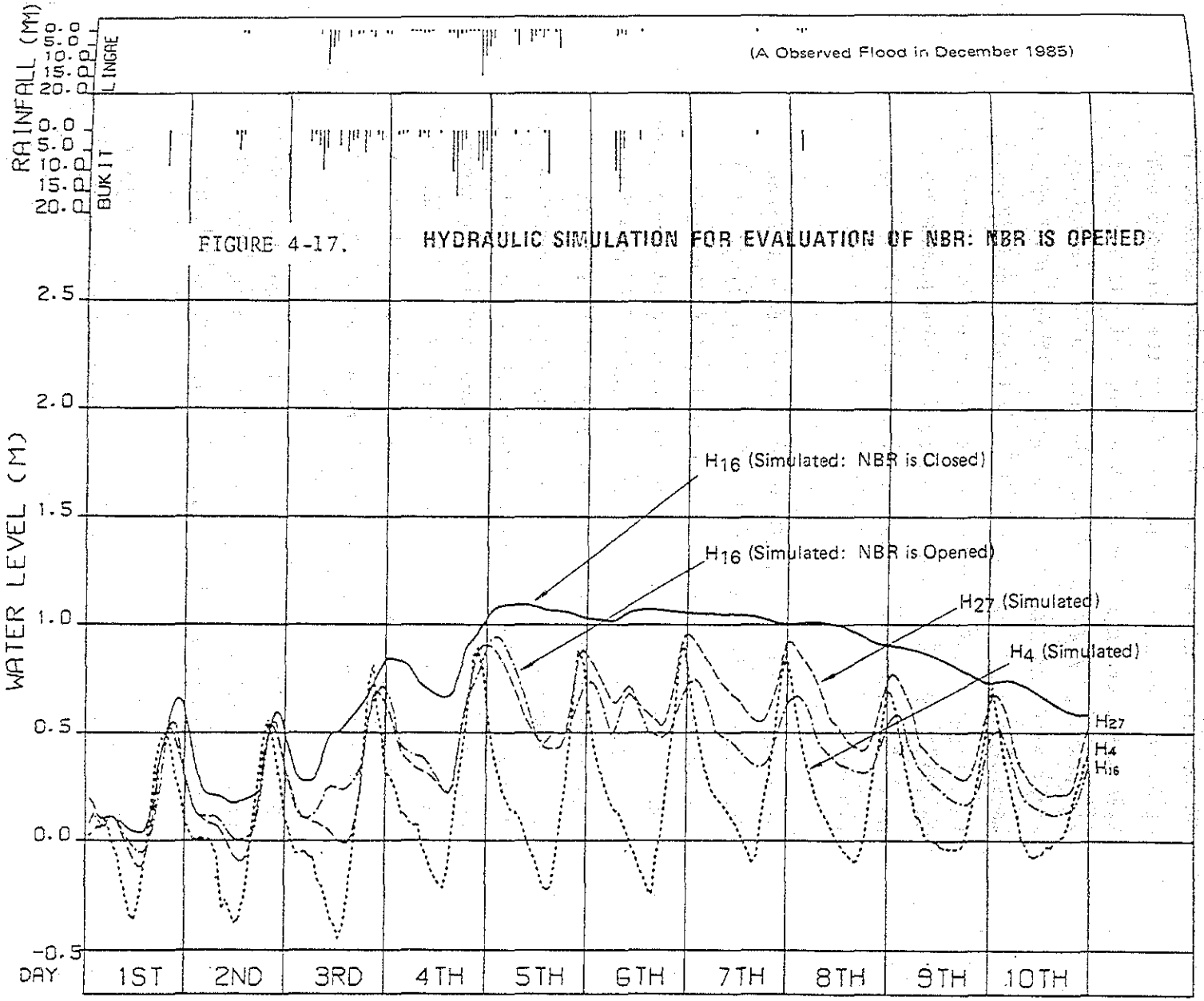


FIGURE 4-17. HYDRAULIC SIMULATION FOR EVALUATION OF NBR: NBR IS OPENED

(ii) Hydraulic Simulations Options

The objective of the hydraulic simulations model is to study the engineering feasibility of the proposed Bang Nara water storage from the hydrological and hydraulic viewpoints. A conclusion of the hydraulic simulations model with the function of existing NBR which computes the maximum water level of EL + 2.35 m near Pileng by using the target rainfall with 5-year return period observed in December 1984 has been obtained, and subsequently this model has been designated "Case P" which is the case at present.

At present, RID has a schedule to complete the flood embankment on the periphery of the Pileng project after two years. This would be another input to the model taking the conditions before construction of the proposed tidal regulators. This boundary conditions have been incorporated into the verified model "Case P". The maximum water level of Mae Nam Bang Nara as computed near Pileng is EL + 2.27 m resulting in the water level reduction of 0.08 m. It appears that the Pileng flood embankment could play a role in temporarily impounding the incoming flow. This has been called "Case W/O" which is the condition without the tidal regulators.

The major study item is to carry out the hydraulic design of tidal regulators in terms of its locating and sizing in the target flood case, which is called "Case W".

And in order to study the non-rainy condition in the Bang Nara storage and the various floods condition in the Bang Nara basin, the following cases have been simulated:

- Normal case for the operation of UTR, LTR and NBR during the non-rainy period. (Planned impounding water leveL; EL + 0.4 m)

- Normal case for the operation of LTR and NBR during the non-rainy period. (Planned impounding water level: EL + 0.4 m and UTR is completely closed)

- Flood simulation for the heavy rainfall at 3 yr-return period during the rainy season. (Case P and Case W)

- Flood simulation for the heavy rainfall at 3 yr-return period during the dry season. (Case P and Case W)

- Flood simulation for the heavy rainfall at 50 yr-return period. (Case P and Case W)

- Flood simulation for the heavy rainfall at 100 yr-return period. (Case P and Case W)

- Flood simulation for the heavy rainfall at 200 yr-return period. (Case P and Case W)

Detailed information for the above various floods cases are presented in Appendix III.

Abbreviations Used

Case P ("At Present")

- Without the Pileng embankment to be constructed in near future.
- Verification of the model by using the maximum water level of the 1984 December flood detected near the Pileng Project along the Bang Nara river.

Case W/O ("Without the Project")

- With the Pileng embankment to be constructed in near future.

Case W ("With the Project")

- With the Tidal Regulators

ALT U-1,120 + L,24 + N,24

ALT ..... Alternative
U-1,120 .... Upper Tidal Regulator including Mae Nam Yakang with 120 m of a total gate width

L,24 ..... Lower Tidal Regulator with 24 m of a total gate width

N,24 ..... Existing Nam Baeng Regulator with 24 m of a total gate width

ALT U-1, G-100 with W-200 + L,G-24 with W-500 + N,24

U-1, G-100 with W-200 .....
Upper Tidal Regulator with 100 m of a total gate width and 200 m of a fixed weir length

L,G-24 with W-500 .....
Lower Tidal Regulator with 24 m of a total gate width and 500 m of a fixed weir length.

RMI	River mouth improvement at Narathiwat - to protect the river mouth by a breakwater -
RCI, H28-16	River channel improvement for a section of H28 to H16 along Mae Nam Bang Nara
U-1	UTR-1 ..... Upper Tidal Regulator including Mae Nam Yakang
U-2	UTR-2 ..... Upper Tidal Regulator excluding Mae Nam Yakang
L	LTR ..... Lower Tidal Regulator
N	NBR ..... Nam Baeng Tidal Regulator

Table 4-2. Flood Simulations for Each Case
- Max. Water Level and Inundation Duration -
(Rainfall: 5yr - Return Period)

Case	Water Level (EL-m, RID Datum)	Model Section Number										
		H_{29}	H_{28}	H_{27}	H_{26}	H_{25}	H_{23}	H_{16}	H_{12}	H_9	H_5	H_4
		UTR-1		UTR-2			NAM BAENG CHANNEL				LTR	
Case-P	Max. Water Level (m)	1.73	2.28	2.49	2.54	2.55	2.54	2.33	2.17	1.91	1.60	1.59
	> + 1.0 m (Hrs)	102	151	159	162	169	191	215	210	200	90	88
	> + 1.5 m (Hrs)	22	116	128	131	133	150	161	154	122	17	15
	> + 2.0 m (Hrs)	-	44	81	92	93	98	72	57	-	-	-
Case-W/O	Max. Water Level (m)	1.69	2.24	2.44	2.48	2.49	2.48	2.30	2.13	1.88	1.66	1.59
	> + 1.0 m (Hrs)	100	151	160	163	165	193	215	210	200	90	88
	> + 1.5 m (Hrs)	11	113	127	130	132	143	157	153	104	17	15
	> + 2.0 m (Hrs)	-	39	67	72	73	79	70	51	-	-	-
Case-W ALT U-1, 180 + L,24 + N,24	Max. Water Level (m)	1.81	2.11	2.24	2.30	2.31	2.31	2.21	2.05	1.81	1.55	1.59
	> + 1.0 m (Hrs)	117	131	137	139	141	172	200	198	183	91	85
	> + 1.5 m (Hrs)	42	92	103	112	115	128	141	135	84	5	12
	> + 2.0 m (Hrs)	-	21	37	43	45	54	44	26	-	-	-
Case-W ALT U-1, 120 + L,24 + N,24	Max. Water Level (m)	1.67	2.24	2.43	2.47	2.47	2.46	2.28	2.11	1.85	1.55	1.59
	> + 1.0 m (Hrs)	106	145	153	155	157	189	215	210	200	87	88
	> + 1.5 m (Hrs)	10	109	122	125	127	140	154	149	98	7	12
	> + 2.0 m (Hrs)	-	39	62	68	69	75	64	47	-	-	-
Case-W ALT U-2, 60 + L,24 + N,24 + RCI, H28	Max. Water Level (m)	1.71	2.11	2.27	2.42	2.45	2.45	2.28	2.11	1.85	1.55	1.59
	> + 1.0 m (Hrs)	102	133	151	158	165	190	215	210	200	93	86
	> + 1.5 m (Hrs)	18	93	114	127	133	144	155	150	98	7	12
	> + 2.0 m (Hrs)	-	18	39	67	73	76	65	47	-	-	-

Table 4-3. Flood Simulations for Each Case
- Max. Water Level and Inundation Duration -
(Rainfall: 5yr - Return Period)

Case	Water Level (EL-m, RID Datum)	Model Section Number										
		H_{29}	H_{28}	H_{27}	H_{26}	H_{25}	H_{24}	H_{16}	H_{12}	H_{9}	H_{5}	H_{4}
			↑ UTR-1		↑ UTR-2			↑ NAM CHANNEL			↑ LTR	
Case-W	Max. Water Level (m)	1.71	2.27	2.35	2.40	2.41	2.41	2.26	2.08	1.84	1.55	1.58
ALT U-1, G-120 with W-600 +	> + 1.0 m (Hrs)	86	137	160	153	155	187	212	209	190	87	86
L,G-24 with W-500 +	> + 1.5 m (Hrs)	16	110	116	121	123	135	149	144	93	8	12
N,24	> + 2.0 m (Hrs)	-	40	52	58	61	70	57	39	-	-	-
Case-W	Max. Water Level (m)	1.70	2.27	2.37	2.42	2.42	2.42	2.26	2.09	1.84	1.55	1.58
ALT U-1, G-100 with W-620 +	> + 1.0 m (Hrs)	85	138	151	154	156	188	215	212	193	87	86
L,G-24 with W-500 +	> + 1.5 m (Hrs)	14	112	117	123	125	137	152	146	94	8	12
N,24	> + 2.0 m (Hrs)	-	42	55	61	65	72	59	42	-	-	-
Case-W	Max. Water Level (m)	1.66	2.32	2.42	2.47	2.47	2.47	2.28	2.11	1.85	1.55	1.58
ALT U-1, G-80 with W-640 +	> + 1.0 m (Hrs)	76	150	154	158	160	191	221	217	200	87	86
L,G-24 with W-500 +	> + 1.5 m (Hrs)	9	115	123	127	128	143	156	150	99	8	12
N,24	> + 2.0 m (Hrs)	-	51	61	67	69	77	68	48	-	-	-
Case-W	Max. Water Level (m)	1.67	2.27	2.41	2.46	2.46	2.47	2.28	2.11	1.85	1.55	1.58
ALT U-1, G-100 with W-200 +	> + 1.0 m (Hrs)	85	142	152	155	157	189	216	214	200	87	86
L,G-24 with W-500 +	> + 1.5 m (Hrs)	9	111	119	124	126	149	154	148	97	8	12
N,24	> + 2.0 m (Hrs)	-	44	58	66	68	74	66	46	-	-	-

Table 4-4. Flood Simulations for Special Cases
- Max. Water Level and Inundation Duration -
(Rainfall: 5yr - Return Period)

Case	Water Level (EL-m, RID Datum)	Model Section Number										
		H_{29}	H_{28}	H_{27}	H_{26}	H_{25}	H_{23}	H_{16}	H_{12}	H_{9}	H_{5}	H_{4}
		↑ UTR-1		↑ UTR-2			NAM BAENG CHANNEL				↑ LTR	
Case W/O	Max. Water Level (m)	1.69	2.24	2.44	2.48	2.49	2.48	2.30	2.13	1.88	1.60	1.59
No Improvement	> + 1.0 m (Hrs)	100	151	160	163	165	193	215	210	200	90	88
	> + 1.5 m (Hrs)	11	113	127	130	132	143	157	153	104	17	15
	> + 2.0 m (Hrs)	-	39	67	72	73	79	70	51	-	-	-
Case W/O	Max. Water Level (m)	1.50	2.16	2.39	2.44	2.44	2.44	2.27	2.10	1.86	1.60	1.59
+ RMI	> + 1.0 m (Hrs)	58	134	155	158	160	190	215	210	200	90	88
	> + 1.5 m (Hrs)	-	92	120	124	126	140	152	148	98	17	15
	> + 2.0 m (Hrs)	-	31	58	64	66	73	61	45	-	-	-
Case W/O	Max. Water Level (m)	1.75	2.15	2.32	2.37	2.37	2.37	2.26	2.10	1.86	1.60	1.59
+ RCI, H28-16	> + 1.0 m (Hrs)	111	151	156	160	164	176	193	192	182	90	88
	> + 1.5 m (Hrs)	29	108	122	126	129	134	142	138	92	17	15
	> + 2.0 m (Hrs)	-	28	52	58	61	66	57	42	-	-	-
Case W/O	Max. Water Level (m)	1.56	2.05	2.25	2.31	2.32	2.32	2.21	2.07	1.83	1.60	1.59
+ RMI +	> + 1.0 m (Hrs)	79	124	151	154	158	166	187	186	178	90	88
RCI, H28-16	> + 1.5 m (Hrs)	5	81	114	118	120	125	135	131	86	17	15
	> + 2.0 m (Hrs)	-	13	42	51	53	56	49	33	-	-	-
Case W	Max. Water Level (m)	1.47	2.14	2.34	2.39	2.39	2.39	2.25	2.09	1.84	1.55	1.59
ALT U-1, 120 + L,24	> + 1.0 m (Hrs)	64	136	154	157	162	172	191	190	179	88	88
+ N,24 + RMI +	> + 1.5 m (Hrs)	-	96	117	122	125	131	141	137	90	6	15
RCI, H28-16	> + 2.0 m (Hrs)	-	28	54	57	60	64	58	42	-	-	-
Case W	Max. Water Level (m)	1.53	2.07	2.26	2.32	2.32	2.33	2.21	2.06	1.81	1.55	1.59
ALT U-1, 150 + L,24	> + 1.0 m (Hrs)	74	122	145	153	156	165	185	185	175	90	88
+ N,24 + RMI +	> + 1.5 m (Hrs)	3	81	113	117	119	125	134	130	84	6	15
RCI, H28-16	> + 2.0 m (Hrs)	-	17	43	51	53	56	50	31	-	-	-
Case W	Max. Water Level (m)	1.61	1.99	2.13	2.21	2.12	2.23	2.15	2.01	1.78	1.55	1.59
ALT U-1, 180 + L,24	> + 1.0 m (Hrs)	87	119	133	138	142	157	174	173	162	83	86
+ N,24 + RMI +	> + 1.5 m (Hrs)	10	73	92	101	106	117	125	121	74	3	15
RCI, H28-16	> + 2.0 m (Hrs)	-	-	27	36	38	42	36	7	-	-	-

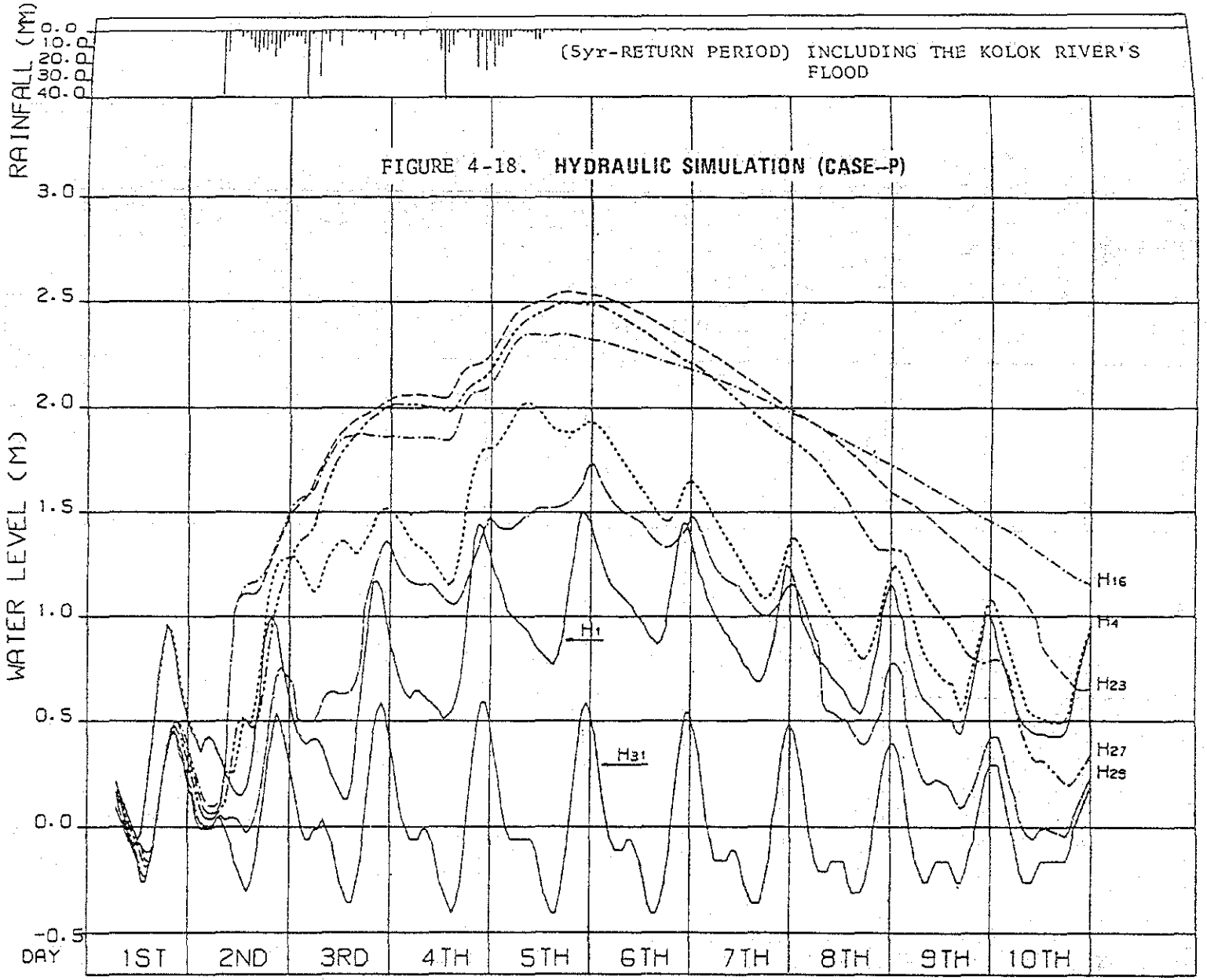
Table 4-5. Flood Simulations for Inclusion or Exclusion of LTR
- Max. Water Level and Inundation Duration -
(Rainfall: 5yr - Return Period)

Case	Water Level (EL-m, RID Datum)	Model Section Number										
		H_{29}	H_{28}	H_{27}	H_{26}	H_{25}	H_{23}	H_{16}	H_{12}	H_9	H_5	H_4
		UTR-1		UTR-2				NAM BAENG CHANNEL			LTR	
Case-P	Max. Water Level (m)	1.73	2.28	2.49	2.54	2.55	2.54	2.33	2.17	1.91	1.60	1.59
	> + 1.0 m (Hrs)	102	151	159	162	169	191	215	210	200	90	88
	> + 1.5 m (Hrs)	22	116	128	131	133	150	161	154	122	17	15
	> + 2.0 m (Hrs)	-	44	81	92	93	98	72	57	-	-	-
Case-W/O	Max. Water Level (m)	1.69	2.24	2.44	2.48	2.49	2.48	2.30	2.13	1.88	1.60	1.59
	> + 1.0 m (Hrs)	100	151	160	163	165	193	215	210	200	90	88
	> + 1.5 m (Hrs)	11	113	127	130	132	143	157	153	104	17	15
	> + 2.0 m (Hrs)	-	39	67	72	73	79	70	51	-	-	-
Case-W	Max. Water Level (m)	1.67	2.24	2.43	2.47	2.47	2.46	2.28	2.11	1.85	1.55	1.59
ALT U-1, 120 +	> + 1.0 m (Hrs)	106	145	153	155	157	189	215	210	200	94	88
L,24 + N,24	> + 1.5 m (Hrs)	10	109	122	125	127	140	154	149	98	8	12
	> + 2.0 m (Hrs)	-	39	62	68	69	75	64	47	-	-	-
Case-W	Max. Water Level (m)	1.67	2.25	2.43	2.47	2.47	2.47	2.29	2.21	2.20	2.20	1.59
ALT U-1, 120 +	> + 1.0 m (Hrs)	107	150	154	157	166	198	<234	<234	<234	<234	88
L,0 + N,24	> + 1.5 m (Hrs)	11	110	124	128	133	147	181	195	190	200	15
	> + 2.0 m (Hrs)	-	39	63	69	73	78	87	88	85	82	-

Table 4-6. Flood Simulations for Proposed Case
- Max. Water Level and Inundation Duration -
(Rainfall: 5yr - Return Period)

Including the Kolok River's Flood

Case	Water Level (EL-m, RID Datum)	Model Section Number										
		H_{29}	H_{28}	H_{27}	H_{26}	H_{25}	H_{23}	H_{16}	H_{12}	H_9	H_5	H_4
		↑ UTR-1		↑ UTR-2				↑ NAM BAENG CHANNEL			↑ LTR	
Case-P	Max. Water Level (m)	1.74	2.28	2.49	2.54	2.55	2.55	2.35	2.25	2.10	2.02	2.02
	> + 1.0 m (Hrs)	106	151	160	163	165	192	215	210	200	148	146
	> + 1.5 m (Hrs)	23	116	128	131	133	151	164	157	135	60	58
	> + 2.0 m (Hrs)	-	45	82	92	93	99	76	64	36	5	5
Case-W ALT U-1, 120 + L,24 + N,24	Max. Water Level (m)	1.67	2.25	2.43	2.47	2.47	2.47	2.28	2.15	2.01	1.89	2.14
	> + 1.0 m (Hrs)	107	147	153	156	158	190	215	210	200	145	147
	> + 1.5 m (Hrs)	10	110	73	126	127	142	156	151	127	57	58
	> + 2.0 m (Hrs)	-	39	63	68	70	77	70	55	9	-	8
Case-W ALT U-1, 120 + L,24 + N,48	Max. Water Level (m)	1.63	2.19	2.36	2.40	2.39	2.39	2.02	1.89	1.83	1.79	2.14
	> + 1.0 m (Hrs)	100	136	150	152	152	174	164	166	158	135	144
	> + 1.5 m (Hrs)	7	105	118	121	123	132	100	81	64	42	54
	> + 2.0 m (Hrs)	-	33	54	61	63	67	4	-	-	-	8


RAINFALL (MM)
0.0
10.0
20.0
30.0
40.0
(5yr-RETURN PERIOD) INCLUDING THE KOLOK RIVER'S FLOOD
FIGURE 4-18. HYDRAULIC SIMULATION (CASE-P)
WATER LEVEL (M)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
H16
H4
H23
H27
H29
H1
H31
DAY
1ST
2ND
3RD
4TH
5TH
6TH
7TH
8TH
9TH
10TH

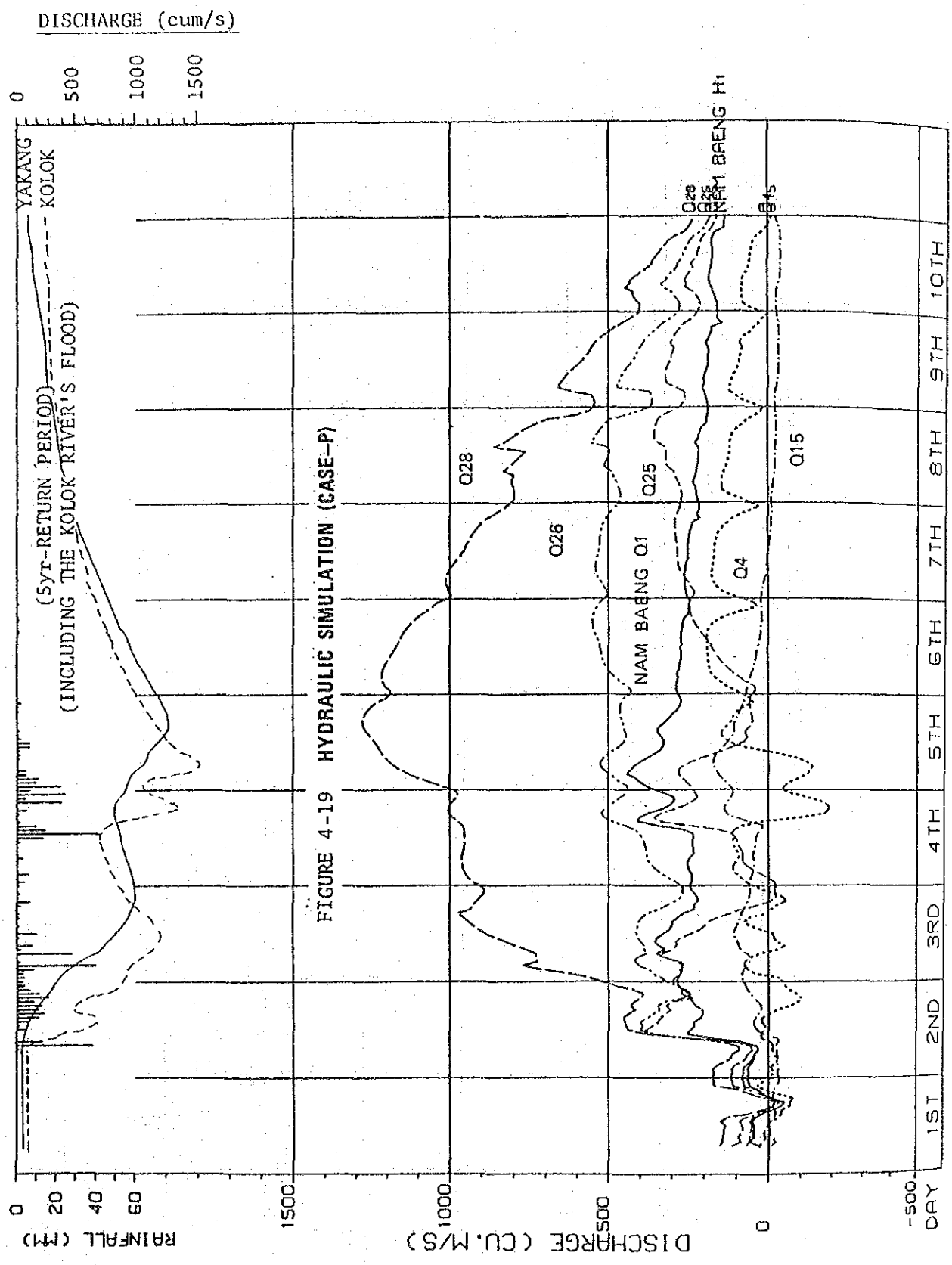
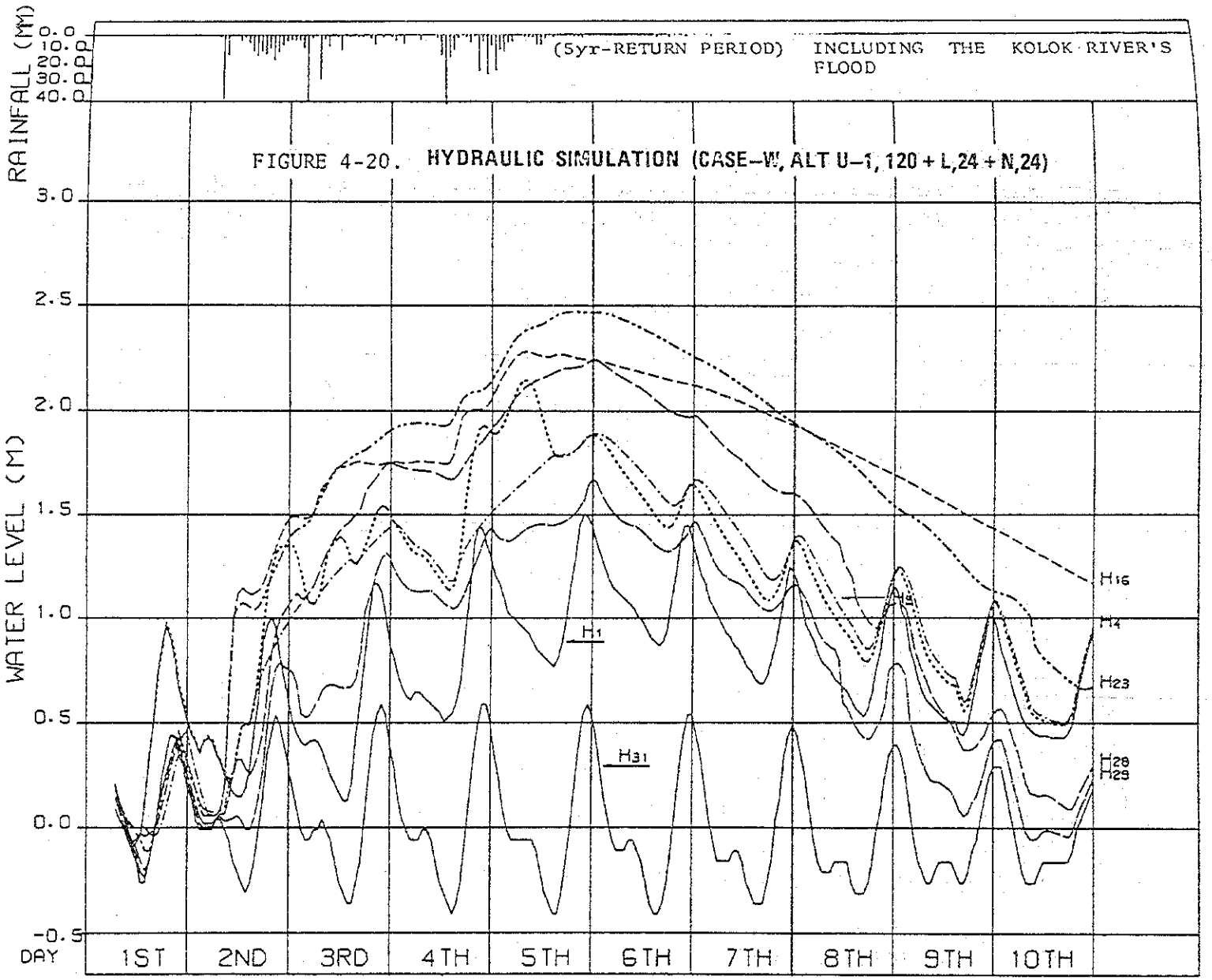


FIGURE 4-19 HYDRAULIC SIMULATION (CASE-P)


RAINFALL (MM)
0.0
10.0
20.0
30.0
40.0
(5yr-RETURN PERIOD) INCLUDING THE KOLOK RIVER'S FLOOD
FIGURE 4-20. HYDRAULIC SIMULATION (CASE-W, ALT U-1, 120 + L,24 + N,24)
WATER LEVEL (M)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
H16
H4
H23
H1
H31
H28
H29
DAY
1ST
2ND
3RD
4TH
5TH
6TH
7TH
8TH
9TH
10TH

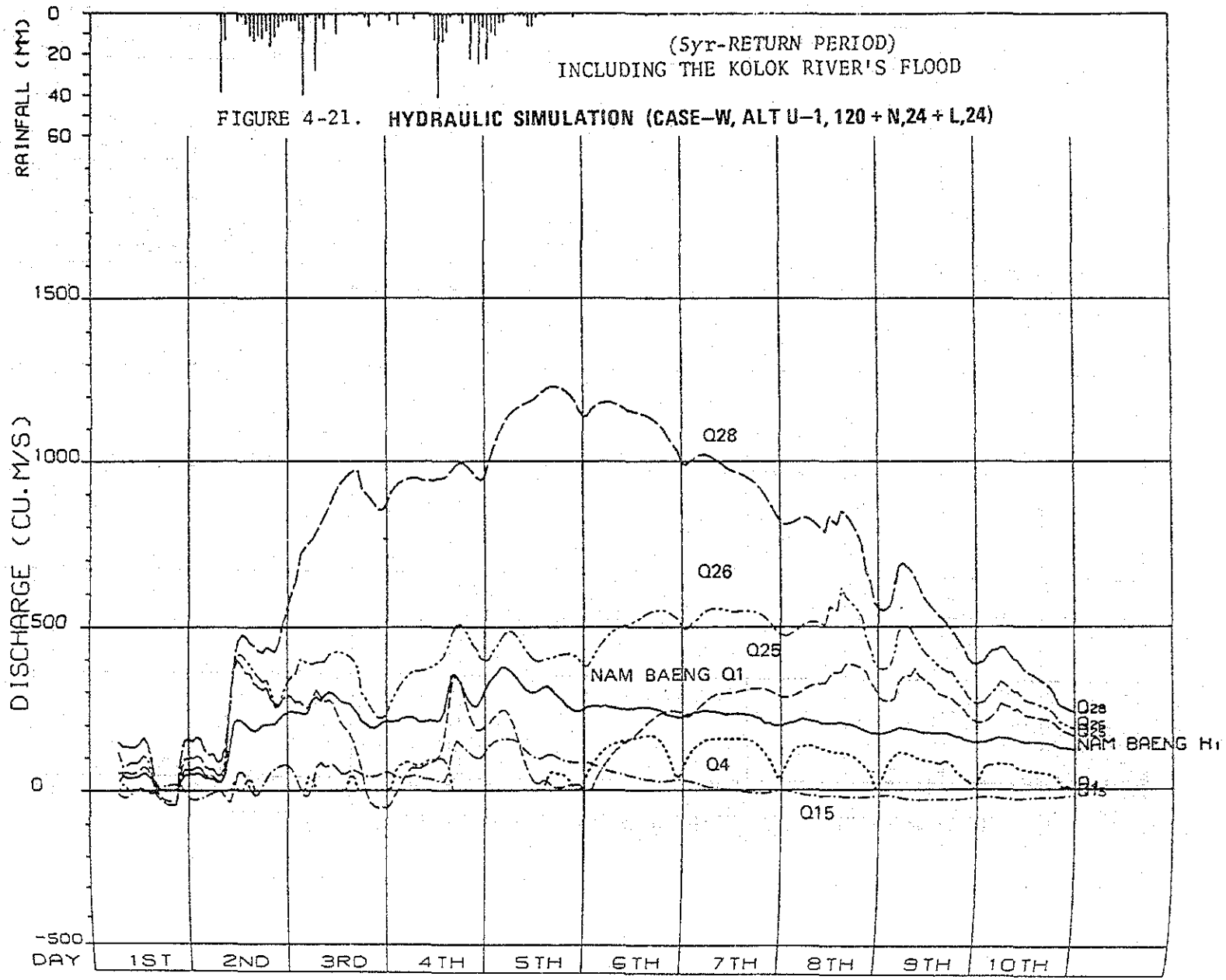
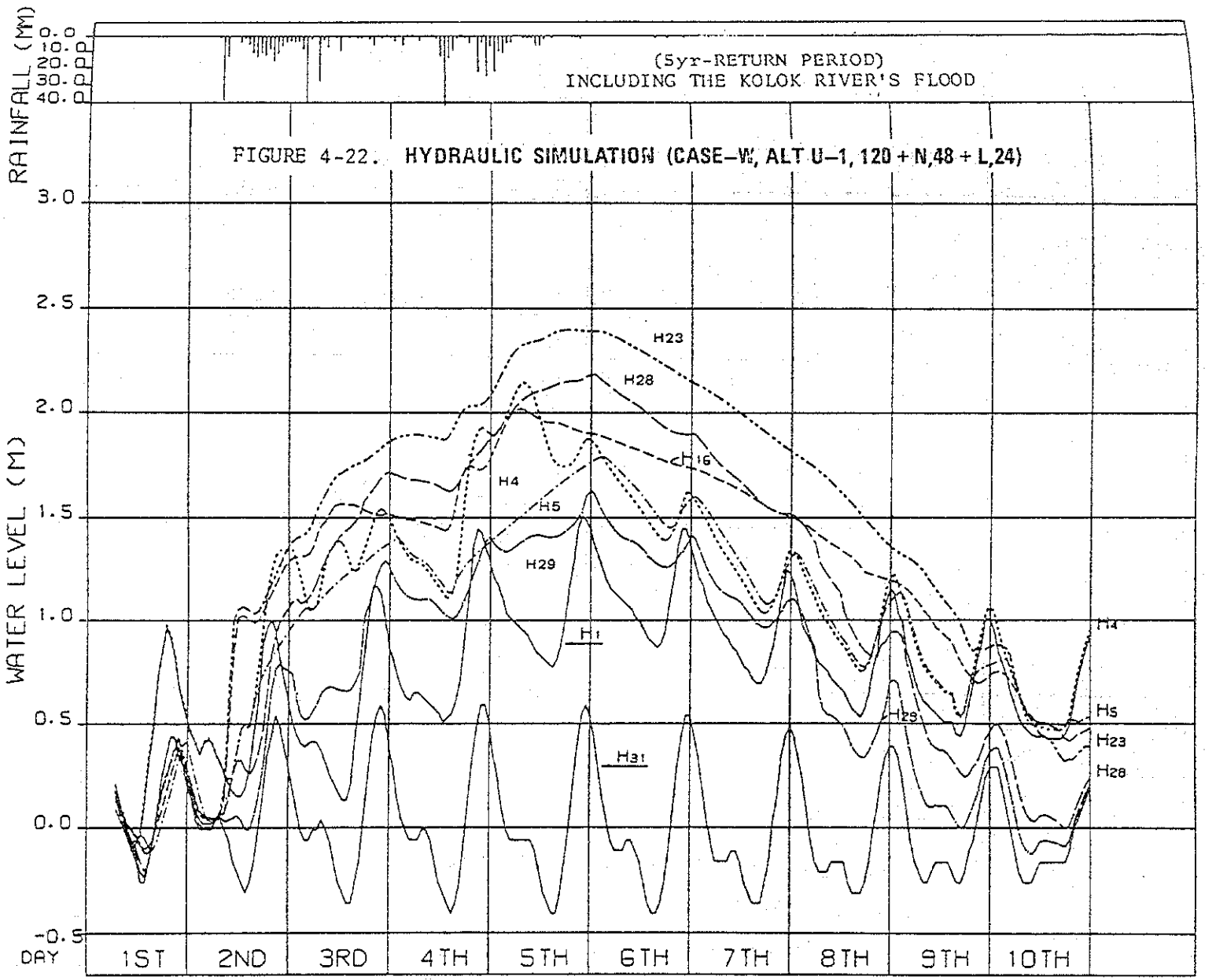


FIGURE 4-21. **HYDRAULIC SIMULATION (CASE–W, ALT U–1, 120 + N,24 + L,24)**


RAINFALL (MM)
0.0
10.0
20.0
30.0
40.0
(5yr-RETURN PERIOD)
INCLUDING THE KOLOK RIVER'S FLOOD
FIGURE 4-22. HYDRAULIC SIMULATION (CASE-W, ALT U-1, 120 + N,48 + L,24)
WATER LEVEL (M)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
H23
H28
H16
H4
H5
H29
H1
H31
H4
H5
H23
H28
H29
DAY
1ST
2ND
3RD
4TH
5TH
6TH
7TH
8TH
9TH
10TH

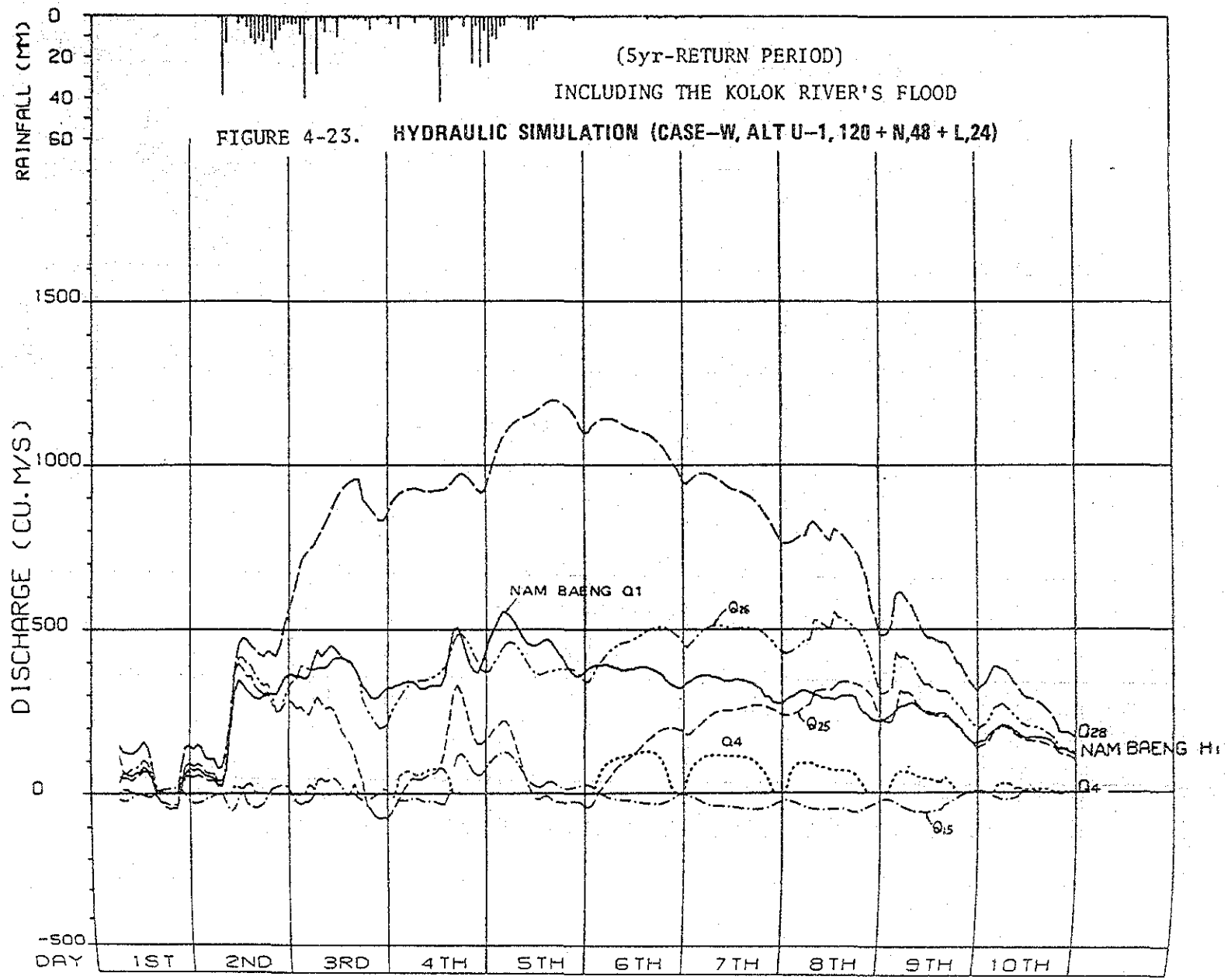


FIGURE 4-23. **HYDRAULIC SIMULATION (CASE–W, ALT U–1, 120 + N,48 + L,24)**

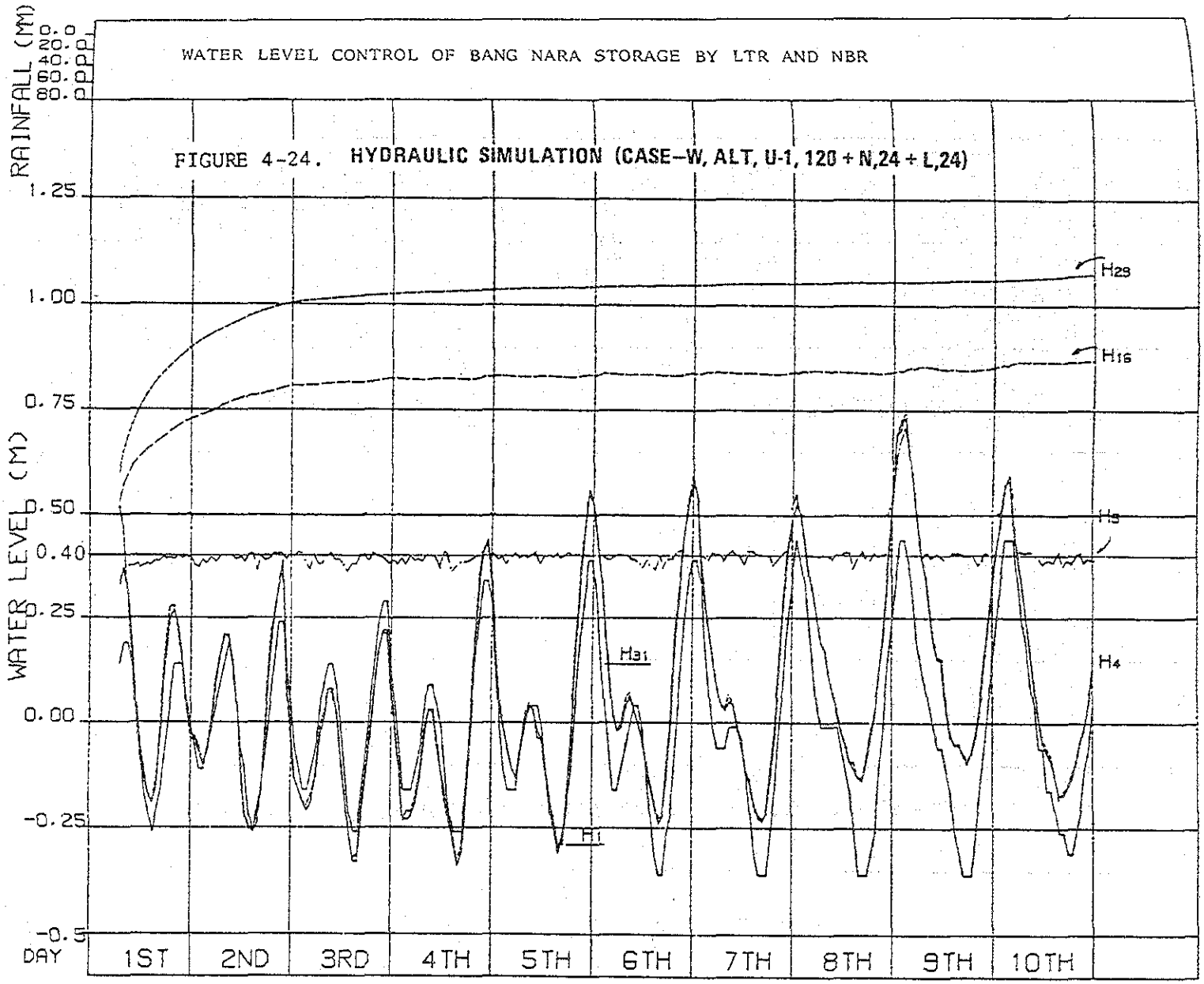


FIGURE 4-24. HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 120 + N,24 + L,24)