2. FLOOD MITIGATION MASTER PLAN

2.1 Principles for Formulation of Master Plan

(1) Objective of Master Plan

Objective: The Master Plan aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned. In the present study, flood mitigation always means the mitigation of damages due to flood and sediment induced disasters.

Master Plan: Flood mitigation measures generally needs long and continuos periods of efforts to accomplish. Therefore, all of these efforts must be directed in an orderly manner toward flood mitigation targets described in the Master Plan. The Master Plan includes the following contents:

1) Present conditions and problems
2) Flood mitigation measures: The measures consist of watershed management, river control and community development components.
3) Master Plan: A conceptual plan for flood mitigation is prepared to cope with basin's flood and sediment disasters. Discussions on the technical details are left for future studies.
4) Action program: Activities to be performed by the target year are clarified and actions toward the target year are detailed. Execution methods and procedures for the implementation are also discussed.

(2) Target Year

In line with the national development plan, target year was set at the end of Twelfth Plan in 2017.

(3) Objects to be Protected

According to the investigation of flood and sediment disasters, the major causes of damage in the Terai plain are:

1) Bank erosion,
2) Sedimentation in the riverine areas, and
3) Flooding and inundation.

Owing to these, the following objects in the flood prone area have been affected by damage:

1) Human being: Injury and loss of life
2) Settlements: Houses and household effects, public buildings such as school and hospital, etc.
3) Public facilities: Highway and roads, bridges, electric cables, irrigation canals, river training works, etc.
4) Farm lands and livestock: Paddy and other crops, livestock, etc.

Such people, land and facilities in flood prone areas located along the rivers shall be protected from flood and sediment disasters.

(4) Approach to Flood Mitigation

Considering the natural and social conditions of the Study Area and the financial situation of HMG/N, the following matters are taken into consideration in planning the flood mitigation of the rivers in Terai plain:

1) **Maximum use of local materials and human resources:** The proposed plan should fit in with the financial situation of the country. The proposed project must be practical and sustainable, low cost for both construction and in the maintenance. In this regard, consideration is given to the use of local materials in parallel with the participation of local residents as much as possible.
2) **Provision of safe lands:** Expansion of rural towns and isolated farmhouse is taking place due to migration and population increase in the Terai plain. Some of the new residents live on the land which are flood prone. Provision of safe and productive land is one of the important tasks of the flood mitigation projects in the Terai plain, and the prevention of loss of human life is a top priority.
3) **Comprehensive measures:** Flood mitigation measures should be inclusive adopting non-structural measures as well as structural measures.
4) **Technical Model:** The proposed flood mitigation plan should be a technical model for other river basins of similar nature.

2.2 Flood Mitigation Measures and Project Components

(1) Conceivable Flood Mitigation Measures

In order to mitigate damage due to flood and sediment disaster, it is necessary to employ all the possible measures. The flood mitigation measures are broadly classified into four, according to their functions, as follows:

1) Erosion and sediment control by watershed management
2) Storage or detention of flood water
3) Smooth transport of flood water and sediment
4) Damage mitigation by flood plain management

These flood mitigation measures are shown in Fig. A2.1. Considering the characteristics of the river and the existing situation of the basin, measures applicable to the rivers in the Terai plain are also shown in the Figure.

(2) Project Components

In order to undertake the project in a practical and sustainable manner, it is important to implement the watershed management and river control measures in combination with community development activities. Therefore, the flood mitigation is composed of three components, i.e., watershed management, river control and community development components.

2.3 Watershed Management Component

Enhancement of the living standard of the resident is the premise for preventing soil erosion and the watershed management. Therefore, it is preferable to adopt countermeasures for promotion of watershed conservation together with community development activities.

For the conservation of watershed, construction of erosion control facilities, encouragement of afforestation and land use control are recommended as primary measures. In order to materialize the measures, publicity activities mobilizing local community, and governmental and non-governmental organization are also essential. The Department of Soil Conservation and Watershed Management (DOSCWM) and Water-induced Disaster Prevention Technical Center (DPTC) are expected to take the

leading role in this regard.

(1) Erosion Control Facilities

As remedial measures, the following erosion control facilities, solely or in combination with bioengineering technology, could be applied considering topographical, geographical and social situation of the site:

1) Construction of check dam
2) Revetment works along river banks
3) Protection of hillside slope by revetment work and small terracing with vegetation
4) Protection of small-scale channel with gully plugging and surrounding slopes by planting shrubs and grasses.

(2) Afforestation/Reforestation and Land Use Regulation

Afforestation/reforestation and land use regulation aim to foster physical strength of the watershed area against land erosion. The followings are the recommended measures for the watersheds under study:

1) Afforestation and reforestation artificially and fostering natural regeneration of trees.
2) Promoting farm tree and shrub planting by growing commercial crops such as fruit trees, medicinal herbs, aromatic plants and natural dyes. Well-managed commercial crops prevent land erosion in watersheds and promote sustainable watershed management activities through income generation. The cultivation of medicinal and aromatic plants has been one of the main programs of Nepalese forestry policy. Root crops should not be chosen.
3) Planting of fodder grasses on slopes, fodder trees on terraces, and restricting the number of livestock within permissible limits for sustaining the pasture and forest.
4) Conservation of wild medical herbs, by protecting from over-collect, thus allowing a sustained yield.
5) Reducing energy use through the promotion of improved stoves.
6) Training the local leaders in land use and woodland management, and exchanging know-how among other communities.

(3) Publicity Activities

Afforestation and reforestation have already been carried out in Nepal. However, public people have little knowledge on this matter. In order to promote watershed management, the understanding and cooperation of communities, local and central governments and other organizations are indispensable. In this regard, publicity activities should be extended employing all possible means as follows:

1) Establishing a specific date or dates for tree planting activities as a national and/or local level events and conducting tree planting campaign for afforestation, reforestation, form tree planting and forest conservation.
2) Commemorative tree planting for any ceremonies and memorial events by residents, and local and national leaders.
3) Environmental education, tree nursery and small arboretums in school.
4) Enactment of a system of commendation for excellent tree planting projects, including agro-forestry, riverside plantings and other community activities.
5) Combination of natural regeneration and/or afforestation project with tourism and local development project.
6) Campaign by mass media for planting trees.
7) Establishment of foundations and solicitation of funds to encourage tree planting.
8) Organizing tree-planting volunteer groups and facilitating volunteers from the overseas countries to participate as well.
9) Conducting of study tours to on-going projects to learn from past initiatives.

2.4 River Control Component

2.4.1 Design Discharge

The probable peak discharges at a specific section of the river were estimated by the following equation:

$$Q_n = (Q_n / Q_2) \cdot q_2 \cdot A$$

$$q_2 = C \cdot A^{(A^{-0.05}-1)}$$

where

Q_n : Probable discharge of n-year return period (m^3/s)
(Q_n/Q_2) : Ratio of n-year probable discharge to 2-year discharge
q_2 : Probable specific discharge on 2-year return period ($m^3/s/km^2$).

C_2 : Coefficient of Creager's formula for 2-year return period

C_2-value for the Babai river basin was assumed to be C_2 = 11.1 based on the result of probability analysis of the Babai river data (sta. code: 290). The values of Q_n/Q_2 for the Babai river were estimated, based on the same results of analysis as shown in the following table:

(Q_n/Q_2-values for Babai River)

C_2	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2
11.1	1.00	1.72	2.20	2.66	3.26	3.70

Probable discharges of 2, 5, 10, 20 and 50-year return periods at the lower end (Indian border) of the river basin are shown below:

River	Catchment (km^2)	Probable discharge (m^3/s)				
		Q_2	Q_5	Q_{10}	Q_{20}	Q_{50}
Babai	3,425	2,500	4,300	5,500	6,660	8,160

2.4.2 River Segments and Channel Characteristics

The river is generally divided into four segments with similar characteristics mainly based on river slope and bed materials, i.e., Segment M for mountain reaches, Segment 1 for alluvial fan, Segment 2 for natural levee zone, and Segment 3 for delta.

Segment-3 does not exist in the Terai plain rivers. The Segment 2 is divided further into Segments 2-1 and 2-2. River control measures should be discussed based on the channel characteristics of respective segments.

River channel of the Babai was divided into three stretches depending on the channel slope, grain size distribution, river width, surrounding topography, etc. as follows:

1) BA-1: Reaches from Indian border to Sta. 30 km
2) BA-2: Reaches from Sta. 30 km to Sta. 38.0 km
3) BA-3: Reaches from Sta. 38.0 km to Babai barrage (Sta. 48 km)

Grain size and other channel factors are worked out for respective stretches as follows:

River stretch	River segment code	Ground elevation		Ground slope (1/I)	Grain size		River width Bm (min-max) (m)
		From (m)	To (m)		d_{60} (mm)	d_R (mm)	
Babai R.							
BA-1	2-2	137	150	2,310	0.26	0.26	427(88-724)
BA-2	2-1	150	159	890	43	63	592(338-700)
BA-3	1	159	190	320	38	71	858(325-1325)

2.4.3 River Boundary Line (RBL)

Necessity of River Boundary Line: Stabilization of river course is a fundamental task to achieve river control. As a reference datum for the river course stabilization, the river boundary line (RBL) should be first designated and authorized for the flood mitigation activities, identifying the lands and objects to be protected. The RBL must be fixed and protected from movements of the river courses.

Use of the RBL: All the river-related facilities for flood mitigation and water use should be planned and designed in consideration of the authorized RBL. By so doing the efforts for flood mitigation to be carried out when the occasion demands would be accumulated and the safety level of the river would be enhanced gradually in line with the plan.

Setting the RBL: The RBL should be set satisfying the following requirements:

1) Protection of properties: The RBL should be placed to protect important lands and objects from flood and sediment disasters.
2) Enough channel capacity: The river width between the right and left RBLs should be more than average width of the existing river and enough to transport of flood water and sediment.
3) Free from erosion: The RBL itself should be free from erosion keeping enough distance from riverbank or providing appropriate bank protection measures.

Procedure of Setting RBL: Therefore, the RBL is designed and authorized through the following procedures:

1) To study river width necessary to transport design flood water and sediment
2) To investigate erosion width along the both river banks. The erosion width discussed here is total erosion width of riverbank throughout a flood season.

Design erosion width (B_e) is determined as the maximum value for respective river reaches based on the investigated data.

3) To draw initial RBLs on both banks keeping distance more than B_e from river bank. The RBL should be set on a smooth alignment for floodwater flow.
4) The initial RBLs are examined from the viewpoints of property protection and channel capacity. The RBL will be revised partially, if the result of examination demands.
5) The RBLs are fixed and authorized finally after getting consent of government authorities and local communities concerned.

The RBL should be clearly marked in the field by permanent objects such as stakes, planted trees, dike road or dike embankment.

The design erosion width (B_e) was assumed, tentatively for the present study, to be B_e = 50 m based on the information obtained in the field.

2.4.4 Facility Plan

(1) Channel Treatment

1) **Tributary works:** Treatment of tributaries by diversion structure, closing dike, and connecting channel works, to fix the river system and catchment boundary.
2) **Branch/anabranch works:** Treatment of branches and anabranches by closing dike works with diversion structure, if necessary, to prevent river course shifting and flood water spreading.

(2) Bank Protection

Bank protection aims to protect the banks from erosion and accordingly to stabilize the river course.

1) **Spur (or groin) works:** A series of spurs to prevents bank erosion, primarily by two functions, namely to retard flow velocity near the bank and to change the flow direction away from the bank. Spur and revetment works are the primary bank protection measures. These measures can be planed independently or jointly. Various types of bank protection works have been developed empirically over the world, and the works should be selected

considering the channel characteristics of the river.

2) **Revetment works:** Revetment works prevent bank erosion by covering bank slopes and protecting their foundations.
3) **Preventive bank protection works:** Grass and trees planted on the riverbanks to resist and retard erosion. These bioengineering technologies can be used as preventive measures against bank erosion, not as direct bank protection works.

Design of Spur: For the purpose of Master Plan study, spur works were tentatively selected for bank protection, since river section data were not available. The following assumptions were also introduced mostly based on the data in Japan:

1) Total length of a series of spurs (L):
   L = X/4.0 for Segment 1
   L = X/3.0 for Segment 2-1
   L = X/2.0 for Segment 2-2
   where X : Bank length to be protected
2) Crown height of spur (h_{sp}) from bank level:
   h_{sp} = 0.0 h_L for Segment 1
   h_{sp} = 0.3 h_L for Segment 2-1
   h_{sp} = 0.5 h_L for Segment 2-2
   where h_L: Mean depth of low water channel
3) Type of spur:
   Gabion spur for Segments 1 and 2-1
   Pile groin for Segment 2-2

Classification of riverbank: In order to identify the sites in critical conditions and prioritize the work sites for protection, riverbanks should be classified in the following types (Fig. A2.2) based on the relationship between the distance from river bank to the river boundary line (B_b) and design erosion width (B_e):

1) Type-C bank: $B_b \geqq B_e$ and bank erosion is not active due to topographical and geological reasons.
2) Type-B bank: $B_b \geqq B_e$ and bank erosion is active.
3) Type-A bank: $B_b < B_e$ and bank erosion is active.
4) Type-A_s bank: $B_b < 0.5\ B_e$ and bank erosion is active.
5) Type-A_{ss} bank: $B_b < 3h_{ll}$, $7h_{ll}$ and $10h_{ll}$ for Segment 1, Segment 2-1 and

Segment 2-2, respectively, where h_{II} : design water depth in high water channel.

Periodic monitoring: Conditions of riverbank shall be monitored every year after the flood season and the necessity of protection works shall be examined based on the following criteria depending on the types of river bank:

1) Type-C bank: No bank protection works are needed.
2) Type-B bank: Preventive measures for bank erosion are needed.
3) Type-A bank: Bank protection works are desirable as far as the fund is available. Preventive measures for bank erosion are needed immediately.
4) Type-A_s bank: Bank protection works are needed immediately.
5) Type-A_{ss} bank: Protection works of dike slope are needed.

(3) Dike Works

Dike works aim to prevent floodwater and sediment from spreading over the land.

1) **Forest and grass belts:** Trees and grass planted along the river course are not strictly dikes. However, these grass and tree belts would alleviate flood damages in the flood prone areas, retarding the flood flows and promoting the formation of a natural levee along the belt (Fig. A2.3).
2) **Dike road:** Road embankment constructed along the river as rural road and flood dike as well. Even if the embankment height is lower than the design level, the road embankment would protect nearby lands from flooding and sedimentation most of the time.
3) **Local dike:** A local dike is applicable to protect a specific area from flooding in such places as the confluence of tributaries, the bifurcation site of an old river course and other local sites of low elevation.
4) **Ring dike:** A ring dike is applicable to protect sporadic important objects like settlements in flood prone areas. A facility for interior drainage is also required.
5) **Continuous dike:** A continuous dike along the river course is an effective measure for the prevention of flooding. However, a continuous dike was not proposed considering the present land use of the flood prone area, the anticipated difficulties in maintenance under the uncontrolled sediment yield in watershed area and the necessity of coordinating the plan with India.

These dikes are aligned, in principle except for the ring dike, on the river boundary line (RBL). The river zone between the RBLs on both banks is planed considering the water and sediment transport capacity and existing river width. Various types of dike works are conceivable. Selection of these works should be made considering the channel characteristics, land use in flood prone areas, etc.

For the purpose of the Master Plan study, following dike works are tentatively selected:

1) Forest belt for Segment 1
2) Grass belt for Segments 2-1 and 2-2
3) Local dike
4) Ring dike

(4) Excavation of Low Water Channel

Channel excavation works primarily aims to increase channel capacity and to normalize the river courses.

1) **Channel excavation:** Intensive channel excavation is not recommended for the rivers in the Terai plain, since the sediment in the upper watershed is not controlled yet. Therefore, channel excavation may be executed only for channel normalization in extremely narrow sections and for collecting materials for earth dikes.
2) **Collection of bed material:** Collection of riverbed material also contributes to the increase of the channel capacity, as far as the amount and places of collection are planned appropriately from a river control viewpoint. The collection can be undertaken on the coarse material bed such as in the alluvial fan.

Channel section: Wide channel has large capacity for floodwater transport but small capacity for sediment transport, which may result in silting up of channel sections. The designed width of the low water channel should be checked with the empirical relationship developed by Dr. Koichi Yamamoto (Fig. A2.4). Since this relationship was prepared based on the data of rivers in Japan, it is recommended to reproduce the relationship using data from Terai rivers in future.

(5) Realignment of Channel

1) **Cut-off Channel (COC):** This will ensure smooth flood and sediment flows by shortening and steepening the channel in meandering sections, and keep away the river course from the site to be protected. The COC may not be applicable to the channels in alluvial fan, since the river course is braided and unstable. The COC is planed considering the following:
   - Cut-off channel was planned for the severe by meandering channel.
   - Cut-off channel section was designed with the average width and depth of the existing river.
   - Closing dike shall close the head of the existing channel.
2) **Diversion Channel:** The primary functions of a diversion channel are to divert all or a part of the river water to alleviate flood discharge in the lower reaches, or to keep the river course away from the objects and areas to be protected. However, appropriate sites for diversion channels are difficult to locate for the rivers in the Terai plain, since these rivers take routes in parallel to each other, in a south-east direction, and the trans-basin of the flood water may cause another problem in the receiving river.

(6) Storage or Detention of Flood Water

1) **Dam Reservoir:** Dam reservoir to control flood and sediment flows is not applicable in class-III river basins, because of the poor geological conditions in the Siwalik hills. Single purpose dam for flood mitigation would not be economically feasible. As to multi-purpose dams, promising projects are not proposed at present for the river basins in the Study Area. Therefore, the dam schemes were not incorporated at present.
2) **Retarding Basin:** In order to reduce flood peaks in the downstream reaches, a retarding basin by conserving natural flood storage function can be considered. The retarding basin can be planned at the confluence of tributaries. It will (1) reduce runoff peak by spilling floodwater into the retarding basin; (2) collect flood water from the upper reaches; and (3) join tributaries without a drainage sluice, thereby as a back-water levee.

2.5 Community Development Component

The "Community Development Component" will consist of three sets of activities (Fig. A2.5). The "Community Mobilization" intends to build up organizational bases for the

Plan implementation. The "Local Coping Measures" will enable the communities to "live with flooding". The "Community-based Sustainable Measures" will motivate the local people to maintain and sustain the flood control structures.

This Master Plan will address both hazards (e.g., inundation, sedimentation, and bank erosion) and people's vulnerability (e.g., lack of awareness and motivation for flood mitigation, inadequate resources to adjust to flooding, lack of access to alternative sources of livelihoods) as shown in Fig. A2.5. The hazard control will be addressed by the "River Control" component (and partly by "Community-based Sustainable Measures" with some structural measures). The "Community Development" will promote vulnerability reduction in itself (by enhancing the people's capabilities to adjust to hazards, through "Local Coping Measures"), and also will bring the "River Control" component to impact on vulnerability (by linking the physical structures with community development, through "Community-based Sustainable Measures"). In this way, the "Community Development" component will contribute towards Comprehensive Flood Mitigation (tackling both hazards and vulnerability).

2.5.1 Community Mobilization

The "Community Development" will start with the "Community Mobilization" component, to strengthen the organizational bases for local flood mitigation initiatives (Fig. A2.6). Unlike the past practices in which the people are hastily "organized" primarily for the construction of physical facilities, more focus will be placed on awareness-raising and capacity-building of the communities themselves.

(1) Workshops for Local Government Institutions (LGIs)

There are specific set of "Community Development" activities that will be entrusted to the LGIs. Although the DIO even presently seeks the LGIs' cooperation in mobilizing the communities in flood control projects, the LGIs contribute only to labor hiring, with little regard to awareness-raising of the local people. In order to upgrade the LGIs' capacities to perform the full-fledged "Community Mobilization" tasks, a series of training workshop will be undertaken at the inception of the "Community Development" activities. The subjects to be taken up in the workshops are as follows:

1) Technicalities of Flood Control Measures (functioning of various measures)
2) Local Initiatives for Flood Mitigation (actions expected of communities)
3) Community Mobilization Processes (procedures for community mobilization)

4) Facilitative Roles by LGIs (roles and responsibilities of LGIs)

(2) Creation of Organizational Bases at the Community

Formation of Community Organizations (COs)

1) **Step 1: Organize Settlement-wise Meetings:** An initial meeting will be held in each settlement, inviting all the households.
2) **Step 2: Dialogues with Communities:** This step is to enable the communities to understand the potential benefits of the Plan through a) Presentation of "Flood Control" Component, and b) Relating "Flood Control" with Other Local Needs
3) **Step 3: Establishment of COs for Forest/Grass Belts:** To develop and maintain the forest/grass belts, settlement-wise COs will be established, through a) Formalization of COs, b) Preparation of Forest/Grass Belt Operational Plan, and c) Registration of CO with the District Authority.
4) **Step 4: Strengthening of COs for Other Flood Control Works:** Where additional structures (other than forest/grass belts) are proposed, the CO will be strengthened, through a) Formation of Inter-CO Groups, where necessary, and b) Formulation of "Community Development" Action Plans.
5) **Step 5: Enter into Agreement with CO Groups:** Finally, a formal agreement is signed with COs, which stipulates project activities, time-frames and budgets, as well as responsibilities of both sides.

Promotion of Public Awareness, Knowledge & Skills

Once the COs are formalized, formal training will be conducted on the following topics:

1) **Technicalities of Flood Control Measures:** to understand how various measures are to function and are to be maintained, and also why continuous dikes are not opted.
2) **Skills in Masonry and Gabion-netting:** to gain employment during the construction stage, and also to obtain skill necessary for the maintenance activities.
3) **Community Participation in Flood Mitigation:** to understand modalities of "participation", e.g., labor/in-kind/cash contributions, as well as local practice.

Generation of Financial Resources by COs

The COs can generate financial resources through a) Forest/Grass Belt Products, b) Nursery Products (in case the communities run nurseries), and c) Group Savings. Savings will primarily be used as capital to for regular maintenance and minor repair of flood control structures, and/or for undertaking community-based flood mitigation activities. At the same time, it is important to assist COs in establishing a record keeping system, and in acquiring skills in running it in a transparent manner.

2.5.2 Local Coping Measures

Since it is not possible to contain all flooding through river control facilities alone, it is important for people also to take coping measures on their own, to complement the physical structures. The Plan component for "Local Coping Measures" will be undertaken on a community-by-community basis (Fig. A2.7). The following are a menu of support, in assisting local communities to enhance their local coping measures.

(1) Flood Proofing

The following are examples of flood proofing measures observed in the Terai plain:

1) **Agricultural Adjustments:**
   - Immediately after the summer crops are damaged, cultivate fast-growing crops (e.g., certain types of vegetables, Arun maize) which can even harvested in a few months' time - even in time for farmers to start winter crops;
   - Grow sweet potatoes if as a result of floods their farming lands are covered by thick sand, thus preventing them from cultivating other crops;
   - Where feasible, change from maize growing to rice cultivation which is less vulnerable to inundation, and in other words, more flood-resistant; and
   - Set aside rice seedlings, in order that they can re-plant paddies, even in case rice fields are destroyed due to flooding.

2) **Housing Structures:**
   - Construct houses on plinths, so that flood water flows underneath;
   - Raise grain stores on stilts, while build escape areas under roofs for family members and other valuables; and,

- Concentrate houses on higher grounds of the communities, to prevent residential shelters from being inundated during floods.

3) **Other Possible Flood Proofing Measures:**
   - Afforestation/reforestation on the riverbanks will serve to curtail the speed of overflow water in case of emergencies;
   - In low-lying areas, drainage will serve to reduce the level of inundation as well as to improve hygienic conditions during the monsoon; and,
   - Small-scale reservoirs (e.g., creation/expansion of new/existing ponds) on community-owned barren land.

One modality of possible support is to introduce the above-mentioned practices to localities where they are feasible but still unknown. Some communities may be facing the resource constraints, which can be supported with the supply of those lacking materials. Moreover, support will also be provided even to existing flood proofing efforts, when there is scope for further improvements.

(2) Forecasting, Warning, & Evacuation

The following are some of such examples of local measures:

1) **Forecasting and Warning:** Some people anticipate floods when they observe;
   - Changes in the water flow (e.g., rising levels of water, river water mixed with mud, leaves floating on the water, increasing number of fish);
   - Unusual sound/smell of rivers (e.g. rumbling sounds coming from the river, muddy smells of the stream); and,
   - Continued rainfall in surrounding areas, or in the upper watersheds.

2) **Evacuation:**
   - Stay in under-roof areas/ on rooftops, until floodwater subsides;
   - Stay on trees (e.g., bananas, and mangoes) planted around houses;
   - Evacuate to neighbors' second-story houses, or to others' houses in surrounding areas on higher grounds; and,
   - Shift valuables (e.g., money, grain, and livestock) to safer areas, before the monsoon season starts.

For both "forecasting/warning" and "evacuation", a possible strategy is to improve upon

local measures (e.g., it is fairly common that warning and evacuation are undertaken individually, which can be organized as joint efforts). More systematic approaches to forecasting/warning simply by utilizing existing facilities, such as P.C.O. (Public Call Office). In localities that find it difficult to secure suitable evacuation sites, support will be provided, e.g., in developing accessible roads to safer areas.

(3) Flood Fighting

The following are examples of local flood fighting measures:

1) Install bamboo piles as bank protection works;
2) Grow indigenous shrubs on the land-cutting sites;
3) Plant bamboo on river banks as protective works;
4) Construct temporary spurs made of logs;
5) Use sandbags with bamboo piles; and
6) Place boulders and tree trunks, where embankments are being breached.

However, such village-level measures often lack technical soundness. In such cases, the faults will be corrected with the provision of technical advice. Where certain materials are not available locally, support will be extended for the local communities themselves to procure or produce those materials locally. Only for those materials beyond the reach of the local populations will be donated to the local communities.

2.5.3 Community-based Sustainable Measures

The "Community-based Sustainable Measures" component is to derive additional benefits from the physical facilities, and to motivate the beneficiaries to sustain the structures (Fig. A2.8). (1) forest/grass belts, (2) preventive bank protection works will derive tree/grass products out of the flood control measures, while (3) access improvements, (4) bed material collection will produce other additional benefits. These additional values will motivate the COs to sustain the physical structures, through (5) operation and maintenance (O&M) of flood control structures, and (6) land use management.

(1) Forest/Grass Belts as Dike Works

The flood mitigation plan envisages the development of forest/grass belts. Table A2.1 shows a list of potential candidate trees/shrubs/grass that can be used as part of the Belts. The belts will also serve various necessities of the local residents. As illustrated in

Table A2.2, there are various local trees, shrubs, and grass that are of multi-purpose (e.g., fuel, timber, roofing, etc). The COs can sell surpluses of forest products in the market. Moreover, in case the local communities choose those species that require nurseries, the COs can sell extra seeds/seedlings that are produced in their nurseries.

In addition to these direct opportunities, there are also multitude of indirect benefits that farmers can tap into. Certain trees/grasses can be used to promote livestock farming, i.e., as fodder for domestic animals (e.g., buffaloes, goats, and cows). In places where bioengineering strategies include forestry development, bee keeping, ginger/turmeric farming, and coffee growing could also be initiated near/in the forests.

(2) Preventive Bank Protection Works

There are broadly two types of bank protection works that the local communities can undertake using their own resources. One is the construction of flood control works entirely relying upon local materials (e.g., bamboo and sandbags). In some cases, the communities attempt to contain bank erosion and/or flooding by installing revetments/spurs using local materials such as bamboo and sandbags. These will be disseminated where the velocities are not high. Local communities will also be assisted to generate their own resources, e.g., the plantation of bamboo, group savings to purchase sandbags themselves. The government agencies will also be encouraged to refrain from handing out those materials, to the extent possible.

Another modality of local bank protection works is the plantation of trees/shrubs/grass, usually to supplement engineering structures. Bioengineering will help derive at long-term stability of the river control measures, by stabilizing the land that adjacent to the engineering structures. It will be used to derive tree/grass products. As Table A2.2 shows, there exist two categories of income-earning opportunities, i.e., one emanates from sales of extra seeds and seedlings produced in nurseries, and the other from the supply of tree products, e.g., fuel wood, fodder, and timber. In addition to extension activities, support will also be extended to those localities that already practice bioengineering, but still have room for improvements (e.g., introduction of higher-value species).

(3) Access Improvements using Flood Control Structures

Flood mitigation projects, when dikes are constructed, provide opportunities to simultaneously develop rural road networks. In some places, the dikes alone will be

designed as access roads. In other areas, short-distance unpaved roads (gravel, or earthen) will be constructed, to link embankments with outside road networks. Where revetments will be constructed, it is expected that the riverbanks are also stabilized. Therefore in places where access improvements are required, gravel and/or earthen roads will be developed along those banks.

In doing so, it is important to take into consideration a variety of expectation people may have concerning accessibility improvements, e.g., to transport agricultural products, to send children to school, to go to health clinics, or to attend village meetings. One critical issue, in the context of flood mitigation, is the damages to roads during flooding which prevent the people for evacuating to safer sites. In such places, support will be extended to link road development with the evacuation requirements.

Community-based approaches have been extensively tested for rural road construction at various locations in Nepal. Such approaches can encourage people to contribute their own resources to the rural road projects (e.g., land, labor, construction materials, and cash). This way, local road projects contain unit costs of road construction, usually ranging from 50,000 to 80,000 Rs/km for gravelling earthen roads.

(4) Bed Material Collection as Channel Excavation Works

Many rivers in the Terai are being mined for sand, gravel and boulder, which serves as one important source of revenues for many District Development Committees (DDCs). More importantly, sand/gravel/boulder collection from a riverbed can be part of a river training scheme, which serves to increase the transport capacity of a river. It can also provide employment opportunities for rural people in the Terai plain.

It is to be noted bed material collection is not feasible in all the areas along the rivers. Certain localities face the constraints of (a) unavailability of sand/gravel, (b) low quality of sand /gravel, (c) lack of roadways from outside to excavation sites, (d) distance to transport to markets, (e) lack of flexible/clear-cut rules and regulations, and (f) objections from community members. However, efforts can be made to redress the above-mentioned constraints except (a) and (b).

Despite the high demands for sand/gravel/boulder, riverbed extraction should not be promoted *laissez-faire*. On the contrary, tighter control should be exercised over contractors, to minimize the extraction of sand/gravel/boulder in accessible locations

(near riverbanks or bridges). Generally speaking, it is necessary to dig in the middle part of the river where the sediments are deposited and which generally causes the diversion of river flow towards the banks.

(5) Operation and Maintenance of Flood Control Structures

The local communities will be responsible to constantly monitor the sites, and when necessary, seek external support for rehabilitation. For revetment works made of galvanized iron (G.I.) wire boxes, community will be instructed to monitor the river bed, and when it is scoured, to place stones and rubbles on the river bed. When the gabion wire is cut, the local residents will request the DIO, through the DDC/VDC, for additional nets. It is also necessary, on a regular basis, to remove objects which may be hooked to the G.I. wire boxes.

Gabion spurs and permeable types of pile spurs, similarly, require monitoring of the riverbeds. When the surface of the riverbeds are washed off, it is crucial to stabilize the foundation of the spurs by placing stones and rubbles on the riverbeds. Moreover, the local residents need to ensure that any objects hooked to the piles or the gabion should be removed. In case of gabion spurs, it is also desirable to plant grass or shrubs on the sand-deposit areas, to stabilize the land adjacent to the structures.

Dike works are subject to scouring of their slopes, given its objective to counteract the flood forces. It is therefore critical to ensure that the local communities undertake timely repairs of slope failures. Moreover, it is expected that the dikes are also used as rural roads throughout the year. In this respect, another maintenance task required is to watch the conditions, and whenever necessary to flatten the bumps of the dike roads.

(6) Land Use Management

The purpose of land use management is to ensure flood risks are not worsened by ill-conceived land uses, by conserving the land adjacent to the rivers. Along the target rivers, the following types of poor land use are observed.

1) **Over cultivation:** Farmers with land adjacent to the rivers cultivate right on the riverside. This exacerbates soil compaction, thus accelerating bank erosion.
2) **Over grazing:** Pastureland along the target rivers is usually used freely by herdsmen, which cause overgrazing problems. This leads to the reduction of vegetation cover, which also stability of the riverbank.

3) **Deforestation:** Not all the forests along the rivers are properly managed. Some are being deforested, while others are maintained but not in a manner conducive to soil conservation.

Against this background, it is crucial for the local communities to agree on local rules and practices that will stop the above-mentioned poor land use management. Those with landholdings on the riverside will be encouraged to stop over cultivation. This can be promoted, through the introduction of high yield crops, or other income-generating activities, e.g., livestock raising. It is important for the farmers to gain alternative sources of income to compensate for the loss of cultivated land. To curb over grazing, more organized systems of pasture land management will be initiated, e.g., rotational grazing, and fodder plantation. Planting of trees near the rivers will be also promoted, both on community land as well as on private farmlands.

2.6 Flood Mitigation Plan

Based on the discussions and analyses made so far, Master Plan for flood mitigation activities by the target year 2017 was worked out. The Master Plan still remains at the concept level, since the planning was made on the topographic map basis (scale 1/25,000 and partly 1/50,000) and the river survey data were not available. In future the Master Plan should be upgraded based on a river survey to be conducted, in line with the concept of flood mitigation described here.

(1) Present Conditions and Problems

1) River basin:
   - Class-II river in Mid-western Development Region
   - Basin area: 3,316 km^2 in total consisting of mountainous basin 2,993 km^2 and plain area 323 km^2.
   - Babai barrage exists at the upper end of the plain area and supply water to the left bank (east side) areas including flood prone areas of the Babai.
   - There is a scheme to convey irrigation water from the east canal to west side area across the Babai by siphon. This scheme will be implemented soon.
   - A study is being carried out by JICA to divert a part of water from the Bheli river to the Babai river for power generation and irrigation purposes. This scheme would not affect significantly the flood flows of the Babai river.

2) River system: There is no major tributaries joining in the downstream reaches of the barrage. It is said that the Babai river shifted to the present course about 40 years ago.
3) River channel: At downstream of the barrage the Babai river expands its width abruptly and forms a braided channel. In the lower reaches, river course meanders severely. Grain size of the riverbed materials changes clearly from sand (fine to medium) in the lower reaches to gravel (coarse to very coarse) in the upper reaches.
4) River segments:
   - Segment 2-2: From 0.0 km (Indian border) to 30.0 km
   - Segment 2-1: From 30.0 km to 38.0 km
   - Segment 1 : From 38.0 km to 48.0 (Barrage)
5) Flood and sediment disasters:
   - Recent major floods: 1995, 1987 and 1996 floods in order of severity.
   - Kinds of damages: Bank erosion, flooding over farm lands and sedimentation
   - Suffering areas: 7 wards in Gulariya municipality and 4 VDCs in Bardiya district.
   - Conditions and mechanism of flooding: Gulariya municipality and Mahamadpur VDC suffer from inundation almost every year. During the 1995-flood, about 470 families of Gulariya municipality were evacuated to the public facilities like schools. After the flood, epidemic disease attacked the Gulariy municipality and two VDCs, 12 human lives were lost.

(2) Principal Measures to be Taken

1) Right bank from 42.5 km to 45 km will be protected securely to protect farmer's irrigation canal and further to prevent river course shifting toward the Karnali river.
2) Old Babai river will be closed securely at 19.5 km by closing dike.
3) Anabranches will be closed securely at 12.3 km, 22.0 km and 29.8 km with diversion facilities if necessary.
4) Forest and grass belts will be formed in Segments 2-2 and 2-1.
5) Alternative study will be carried out for the meander stretches from 24.6 km to 25.9 km and from 2.2 km to 6.7 km to protect road bridge and near-by villages.
6) Bank protection works by a series of spurs will be implemented based on the

monitoring result of riverbanks. Preventive measures for bank erosion will also be taken by adopting bioengineering approach.

7) Watershed management will be carried out for erosion and runoff control.
8) Flood plain management will be carried out for mitigation of damages due to flood and sediment disasters.

(3) Layout Plan

Layout of the flood mitigation Master Plan is shown in Fig. A2.9.

(4) Project Works and Cost

Quantities of works for the Master Plan were estimated based on the standards and assumptions discussed in the previous sections, and preliminary cost required for the project implementation was estimated under the following conditions:

1) Price Level: The project cost and other related unit costs are expressed under the economic conditions prevailing in October 1998.

2) Exchange Rate of Currencies: Exchange rate of currencies are assumed as follows:

   US$1.00 = Rs.67.93 = ¥115.14 (Rs.1.00 = ¥1.69)

3) Constitution of Project Cost: Project cost is the sum of construction base cost, land and compensation cost, administration cost, engineering, physical contingency and value added tax. Calculation is carried out based on the following:
   (1) Construction base cost = (Work volume) x (Unit work cost)
   (2) Land and compensation cost = (Area of land to be acquired and number of houses to be relocated) x (Unit cost)
   (3) Administration cost = 5% of (1)
   (4) Engineering service cost = 10% of (1)
   (5) Sub-total = (1) + (2) + (3) + (4)
   (6) Physical contingency = 10% of (5)
   (7) Price contingency =Assumed annual escalation rate at 3% for foreign currency portion, and 10% for local currency portion
   (8) Value added tax = 10% of (5) + (6) + (7)

Quantity of work, unit work cost and amount of project cost are shown in Table A2.3. Annual disbursement of investment cost was estimated on the basis of the implementation schedule. The annual disbursement schedule of financial and economic costs for Babai river are shown in Table A2.4.

CANDIDATE SPECIES FOR BIOENGINEERING WORKS IN TERAI

	Naturally Grown Species	Nursery Species
Grasses	- Arundo clonax (Narkato) - Cymbopogon microtheca (Khar) - Cymbopogon pendulus (Dangre Khar) - Cynodon dactylon (Dhubo) - Eulaliopsis ninanta (Babiyo, Sabai Grass) - Neyraudia arundinacea (Sito) - Neyraudia reynaudiana (Dhonde) - Pennisetum clandestinum (Kikuyu, Thulo Dhubo) - Pogonatherum paniceum (Musekharuki) - Saccharum spontaneus (Kans)	- Desmodium intortum - Pennisetum purpureum (Napier) - Setaria anceps - Thysanolaena maxima (Amliso) - also in forests - - Stylo - Molasess grass
Shrubs & Non-Plantation Trees	- Adhatoda vasica (Assuro) - Butea minor (Bhujetro) - Calatorpha giganteum (Aak) - Colebrookea oppositifolia (Chusun) - Ipomoea fistulata (Saruwa --- Beheu) - Lantana camara (Phul Kanda) - Phoenix humilis (Thakal) - Trema orientalis (Kunyelo) - Vitex negundo (Simali) - Wedlandia species (Tilka) - Woodfordia fruticosa (Dhanyero)	
Trees	- Acacia catechu (Khayer) --- also in nursery - Acacia auriculiformis - Albizia julibrissin - Ficus semicordata (Khasre Khayu, Khanayo) - Shorea robusta (Sal) -- also in nursery	- Bauhinia purpurea (Tanki) - Delonix regia (Gulmohar) - Leucaena species (Ipil Ipil) - Bamboo species

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

INCOME GENERATION OPPORTUNITIES THROUGH BIOENGINEERING

From:	Species Used	Income-generating Products
Nursery	Trees	
	- Acacia catechu (Khayer)	- saplings
	- Shorea robusta (Sal)	- saplings
	- Bauhinia purpurea (Tanki)	- saplings
	- Delonix regia (Gulmohar)	- seeds/saplings
	- Leucaena species (Ipil Ipil)	- seeds/saplings
	- Bamboo species	- roots
	Grasses	
	- Desmodium intortu	
	- Pennisetum purpureum (Napier)	- seeds
	- Thysanolaena maxima (Amliso)	- cutting
	- Stylo	- seeds/cutting
	- Molasess grass	- seeds
		- seeds
Bio-Engineering Facility	Grasses	
	- Desmodium intortum	- fuel wood
	- Pennisetum purpureum (Napier)	- fodder/mulching
	- Thysanolaena maxima (Amliso)	- fodder/broom
	- Stylo	- fodder/seed
	- Molasess grass	- fodder/seed
	- Arundo clonax (Narkato)	- fencing
	- Cymbopogon microtheca (Khar)	- roof thatch
	- Cymbopogon pendulus (Dangre Khar)	- roof thatch
	- Cynodon dactylon (Dhubo)	- fodder
	- Eulaliopsis ninanta (Babiyo)	- rope
	- Saccharum spontaneus (Kans)	- roof thatch/rope
	Shrubs	
	- Adhatoda vasica (Assuro)	- green manure/medicine
	Trees	
	- Bamboo species	- furniture/timber
	- Bauhinia purpurea (Tanki)	- fodder/fuel wood
	- Delonix regia (Gulmohar)	- fuel wood
	- Leucaena species (Ipil Ipil)	- fodder/fuel wood
	- Acacia catechu (Khayer)	- timber/fuel wood/medicine
	- Shorea robusta (Sal)	- leaf plate

source: "Vegetation Structures for Stabilizing Highway Slopes", Dept. of Roads, 1991

PROJECT COST FOR MASTER PLAN

BABAI RIVER (unit: 1000NRs)

Item	Unit	Quantity	Unit Cost	Amount
I . Construction Base Cost				265,885
1. Preparatory Works	L.S.	1.00		24,171
2. Bank Protection Works				167,558
2-1 Pile Spur (Type-B)	km	13.10	7,289	95,486
2-2 Gabion Spur (Type-B)	km	7.00	10,296	72,072
3. Cannel Works				52,182
3-1 River Boundary Line	km	76.00	27	2,052
3-2 Tree Belt	ha	40.75	68	2,771
3-3 Grass Belt	ha	243.25	126	30,650
3-4 Closing Dike/structure	place	7.00	2,387	16,709
4. Dike Road				0
4-1 Dike Embankment	km	0.00	2,506	0
4-2 Gravel Metaling	km	0.00	1,102	0
5. Miscellaneous Works	L.S.	1.00		21,974
II . Compensation Cost	L.S.	1.00		68,160
III. Administration Cost	L.S.	1.00		16,702
IV. Engineering Service	L.S.	1.00		39,883
V . Physical Contingency	L.S.	1.00		37,393
Poject Cost				428,022

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

ANNUAL DISBURSEMENT SCHEDULE OF BABAI RIVER PROJECT FOR MASTER PLAN

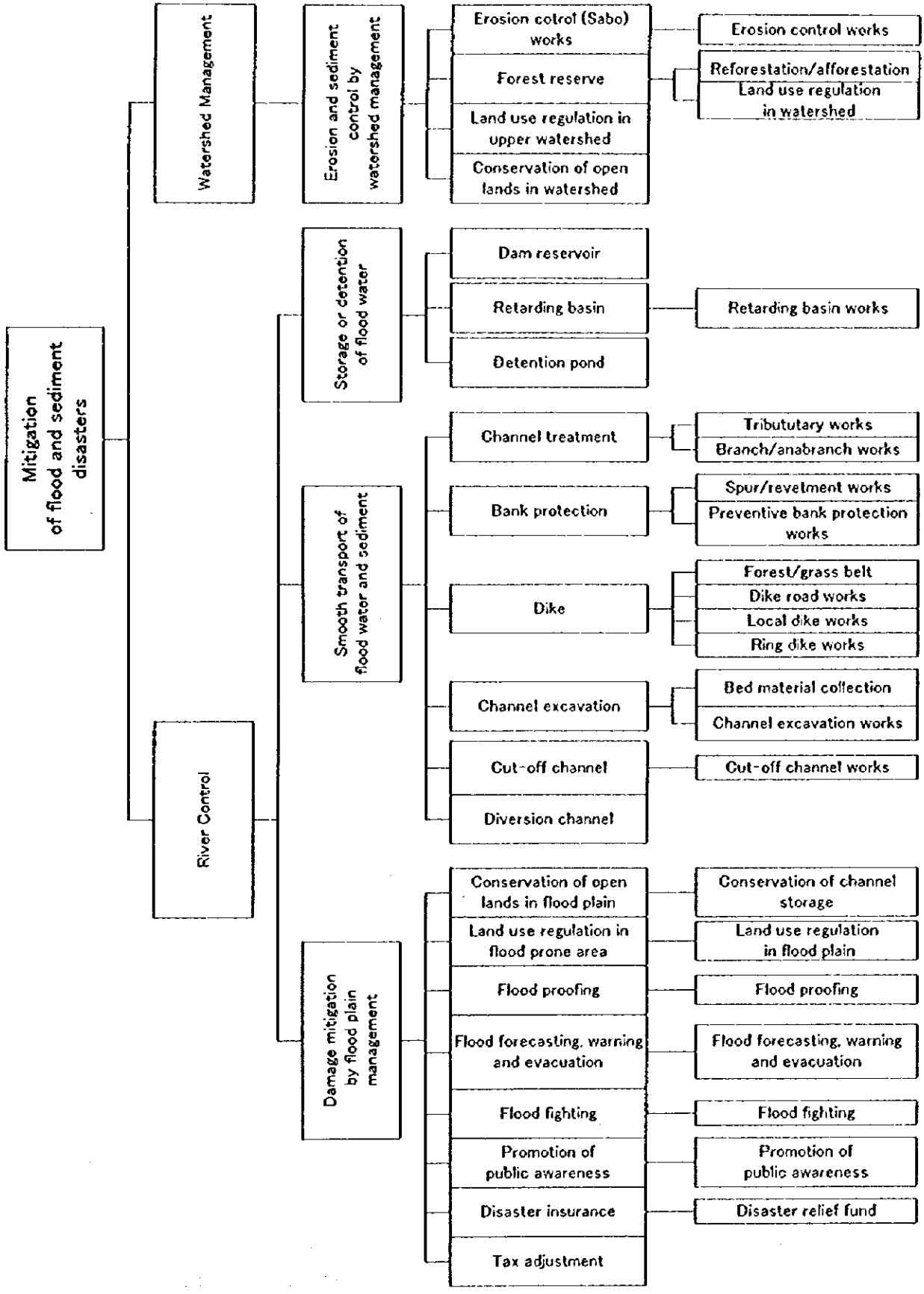
(Financial Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I. Construction Base Cost	265,885	0	0	0	23,164	23,164	23,164	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107	15,107
1. Preparatory Works	24,171	0	0	0	8,057	8,057	8,057	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	167,558	0	0	0	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472	10,472
3. Channel Woks	52,182	0	0	0	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261	3,261
4. Dike Road Works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Miscellaneous Works	21,974	0	0	0	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373	1,373
II. Compensation Cost	68,160	0	0	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	4,260	0
III. Addministration Cost	16,702	0	0	213	1,371	1,371	1,371	968	968	968	968	968	968	968	968	968	968	968	968	755
IV. Engineering Cost	39,883	6,647	6,647	6,647	1,737	1,737	1,737	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133
1. F/S, D/D etc.	19,941	6,647	6,647	6,647	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	19,941	0	0	0	1,737	1,737	1,737	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133	1,133
V. Physical Contingency (10% of Items I, II &IV)	37,393	665	665	1,091	2,916	2,916	2,916	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	2,050	1,624
VI. Total	428,022	7,312	7,312	12,211	33,449	33,449	33,449	23,518	23,518	23,518	23,518	23,518	23,518	23,518	23,518	23,518	23,518	23,518	23,518	18,619

Note: *1 Price Level in October 1998
*2 Convertion Rate US$ 1.00 = NRs 67.93, 1.00 Yen = NRs 0.59
*3 Cost do not include Price Contingency and Value Added Tax
*4 Figures may not add up to totals due to rounding

(Economic Cost) (1,000NRs)

Discription	Total	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I. Construction Base Cost	239,296	0	0	0	20,848	20,848	20,848	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596	13,596
1. Preparatory Works	21,754	0	0	0	7,251	7,251	7,251	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Bank Protection Works	150,802	0	0	0	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425	9,425
3. Channel Woks	46,963	0	0	0	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935
4. Dike Road Works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Miscellaneous Works	19,777	0	0	0	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236	1,236
II. Compensation Cost	61,344	0	0	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	3,834	0
III. Addministration Cost	15,032	0	0	192	1,234	1,234	1,234	872	872	872	872	872	872	872	872	872	872	872	872	680
IV. Engineering Cost	35,894	5,982	5,982	5,982	1,564	1,564	1,564	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
1. F/S, D/D etc.	17,947	5,982	5,982	5,982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Construction Supervision	17,947	0	0	0	1,564	1,564	1,564	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
V. Physical Contingency (10% of Items I, II &IV)	33,653	598	598	982	2,625	2,625	2,625	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,462
VI. Total	385,220	6,581	6,581	10,990	30,104	30,104	30,104	21,167	21,167	21,167	21,167	21,167	21,167	21,167	21,167	21,167	21,167	21,167	21,167	16,758



FLOOD MITIGATION MEASURES

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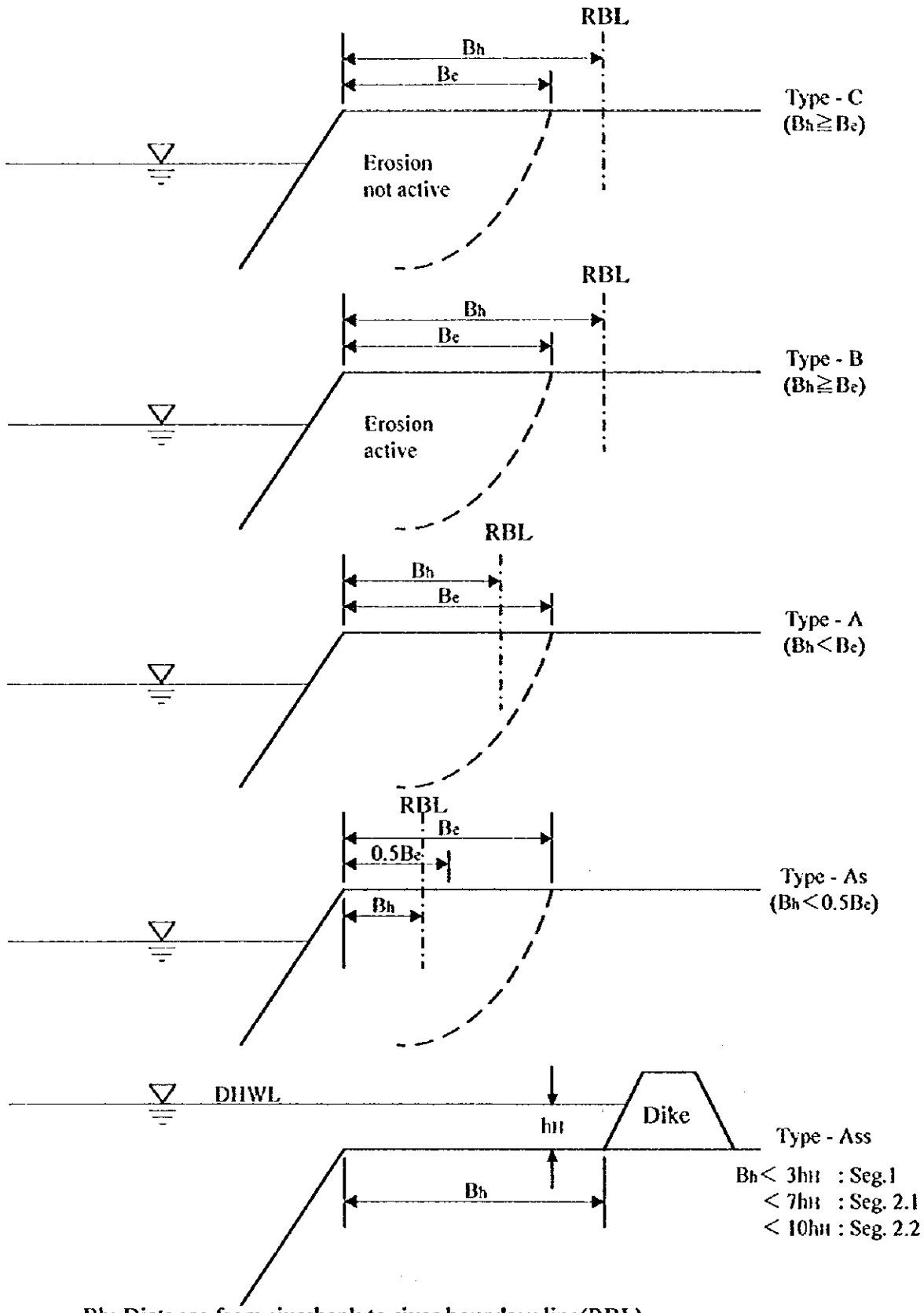
Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY



Bh: Distance from riverbank to river boundary line(RBL)

Be: Design erosion width (Assumed maximum annual erosion width)

CLASSIFICATION OF TYPES OF RIVER BANK

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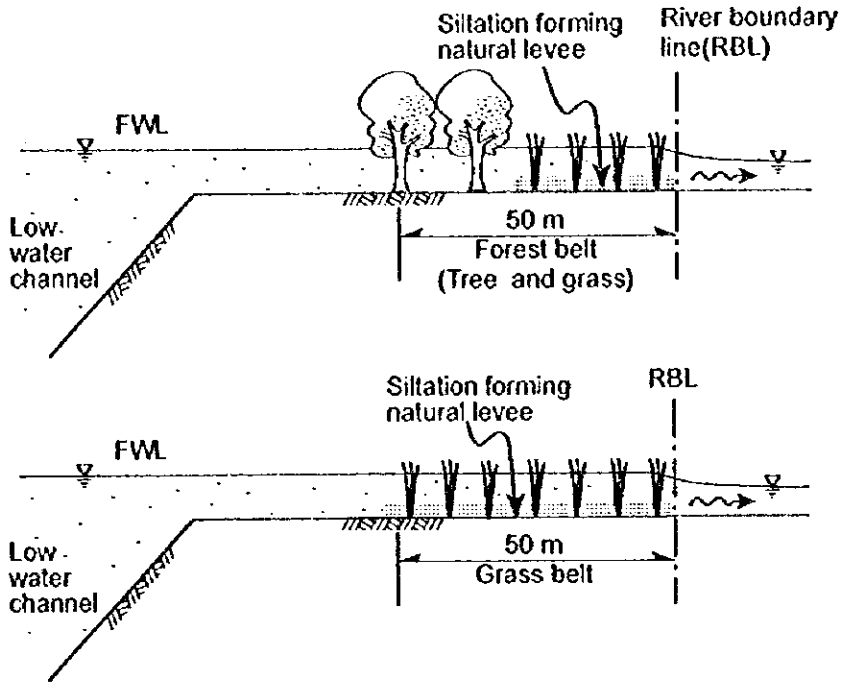
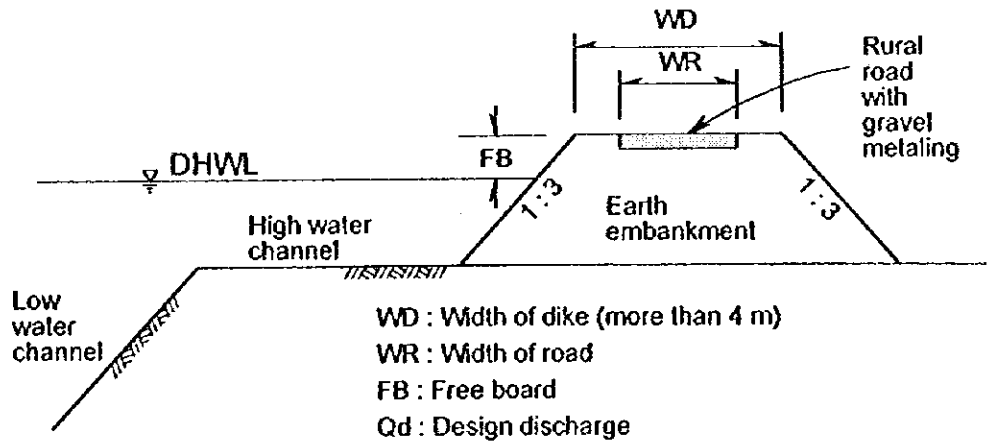
Forest and Grass Belt



Earth Dike / Road



WD : Width of dike (more than 4 m)
WR : Width of road
FB : Free board
Qd : Design discharge

Qd (m^3/s)	FB (m) (Not less than)	WD (m, Not less than)	
		Dike only	Dike road
Less than 200	0.6	3	5
200 to 500	0.8	3	5
500 to 2,000	1.0	4	5
2,000 to 5,000	1.2	5	5
5,000 to 10,000	1.5	6	6
More than 10,000	2.0	7	7

DIKE WORKS

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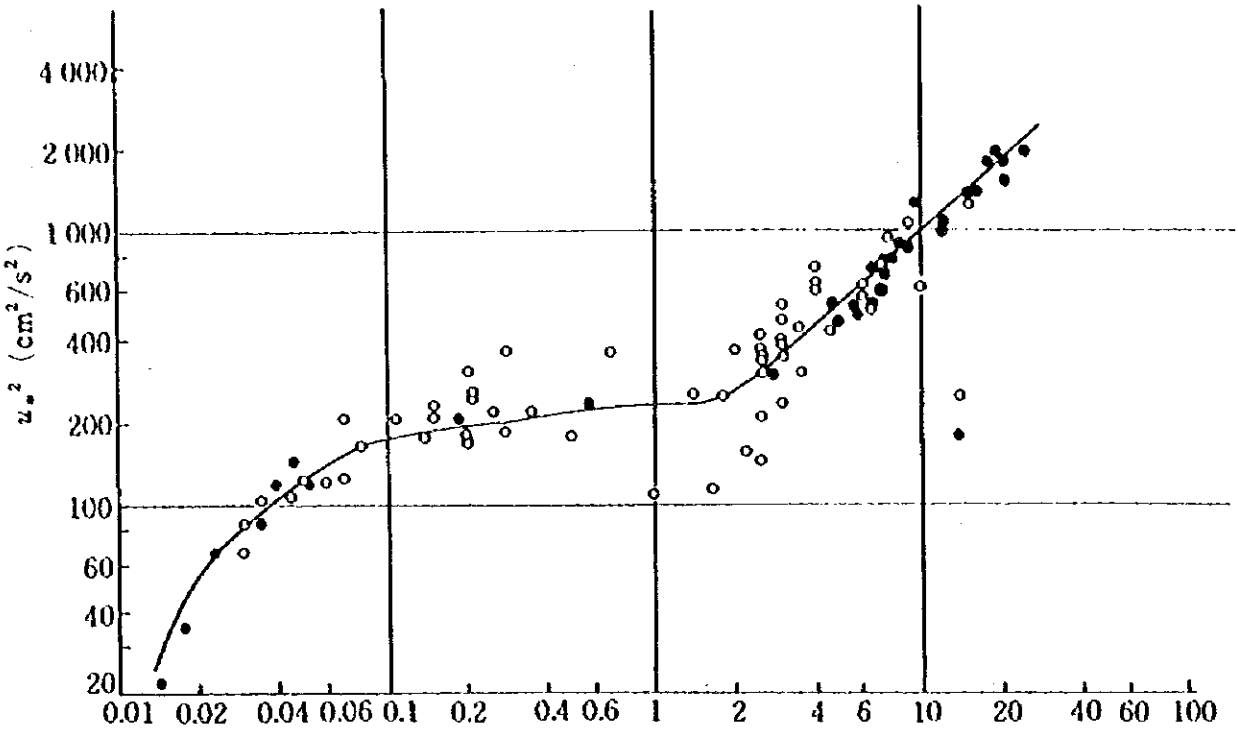

$$Q_2 = A \cdot V = \frac{B \cdot h_L^{5/3} \cdot I^{1/2}}{n} \quad \Rightarrow \quad h_L = \left\{ \frac{Q_2 \cdot n}{B \cdot I^{1/2}} \right\}^{3/5}$$

$$u_*^2 = g \cdot h_L \cdot I \quad \Rightarrow \quad I = \frac{u_*^2}{g \cdot h_L}$$

$$B = \frac{n \cdot Q_2}{h_L^{5/3} \cdot I^{1/2}} = \frac{n \cdot g^{1/2} \cdot Q_2}{u_* \cdot h_L^{7/6}} \qquad (m, \text{sec})$$

n : Manning's coefficient of roughness

g : Acceleration of gravity (m/sec^2)

Q_2 : Two-year probable discharge (m3/s)

u_* : u_*-value obtained from d_R-u_* diagram for a given representative grain size (d_R) (m/s)

h_L : Mean depth of low water channel (m)

B : Low water channel width

RELATIONSHIP BETWEEN BED MATERIAL SIZE AND FRICTION VELOCITY

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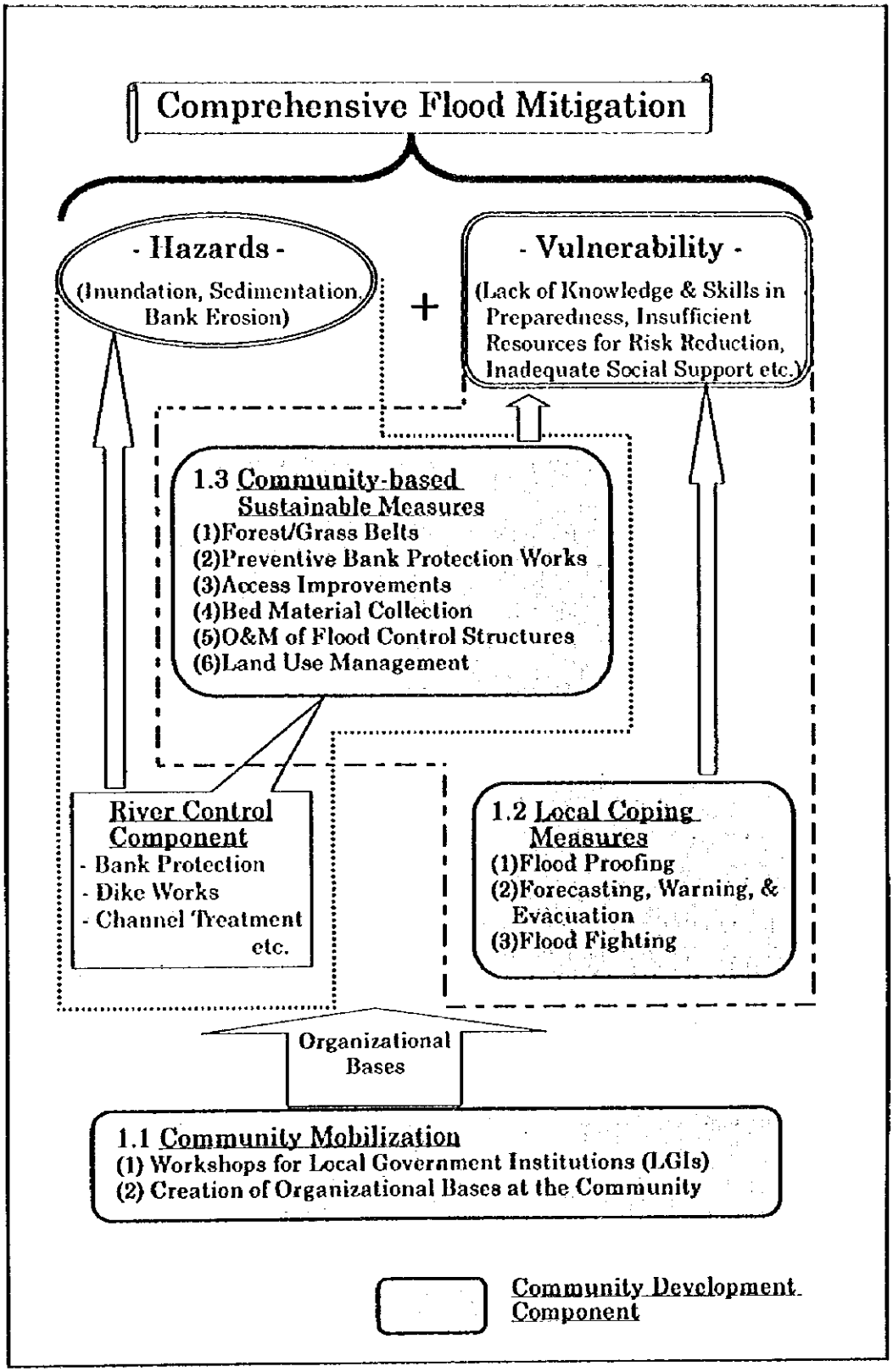

COMPREHENSIVE FLOOD MITIGATION

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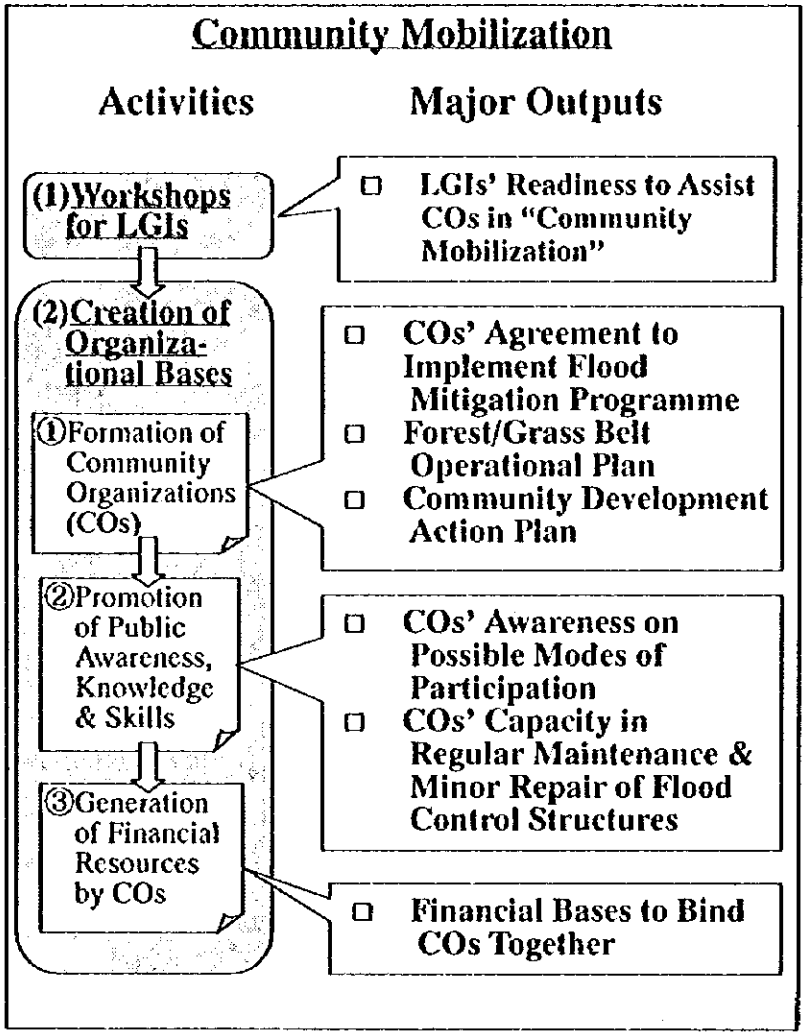

COMMUNITY MOBILIZATION

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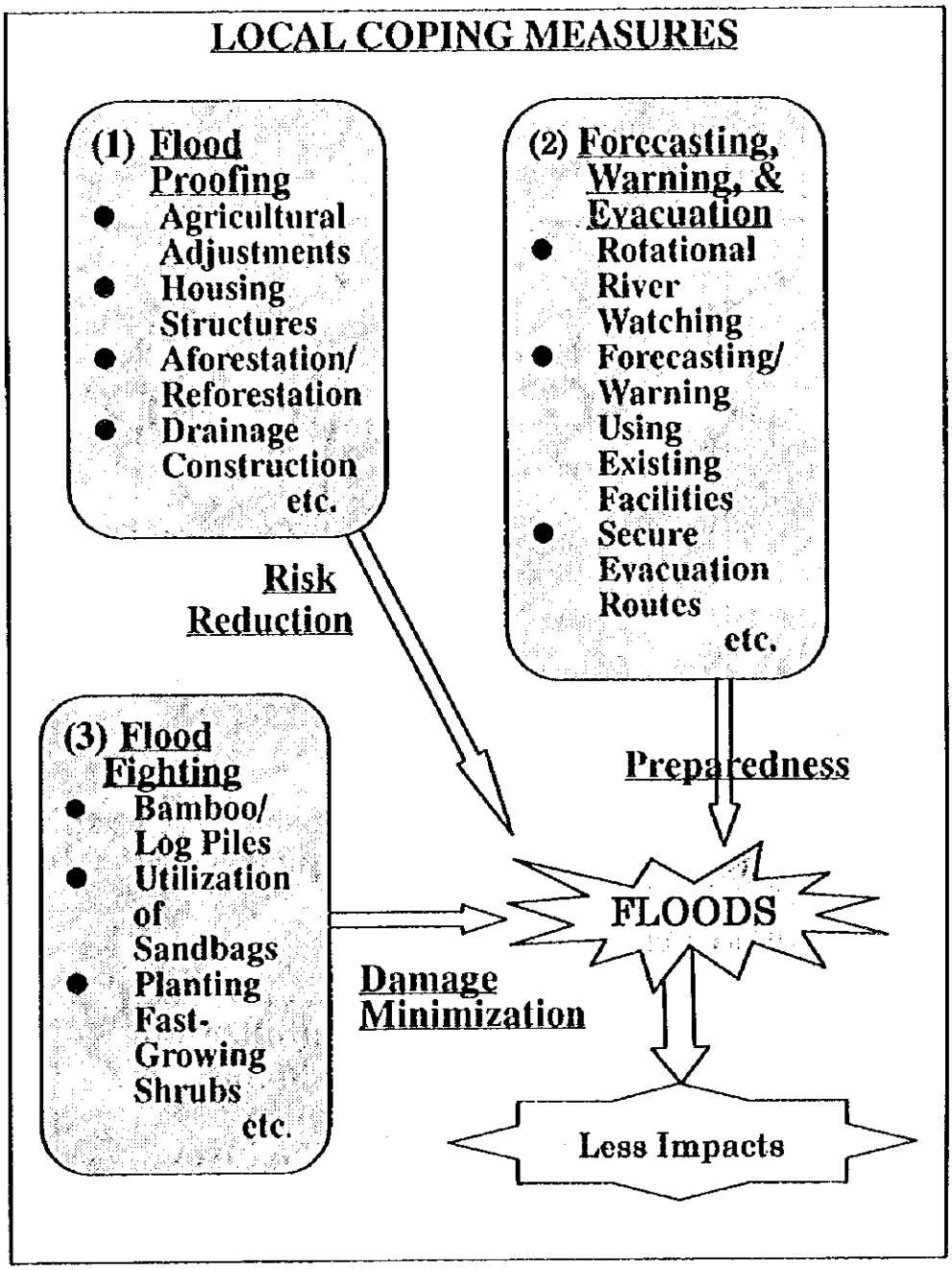

LOCAL COPING MEASURES

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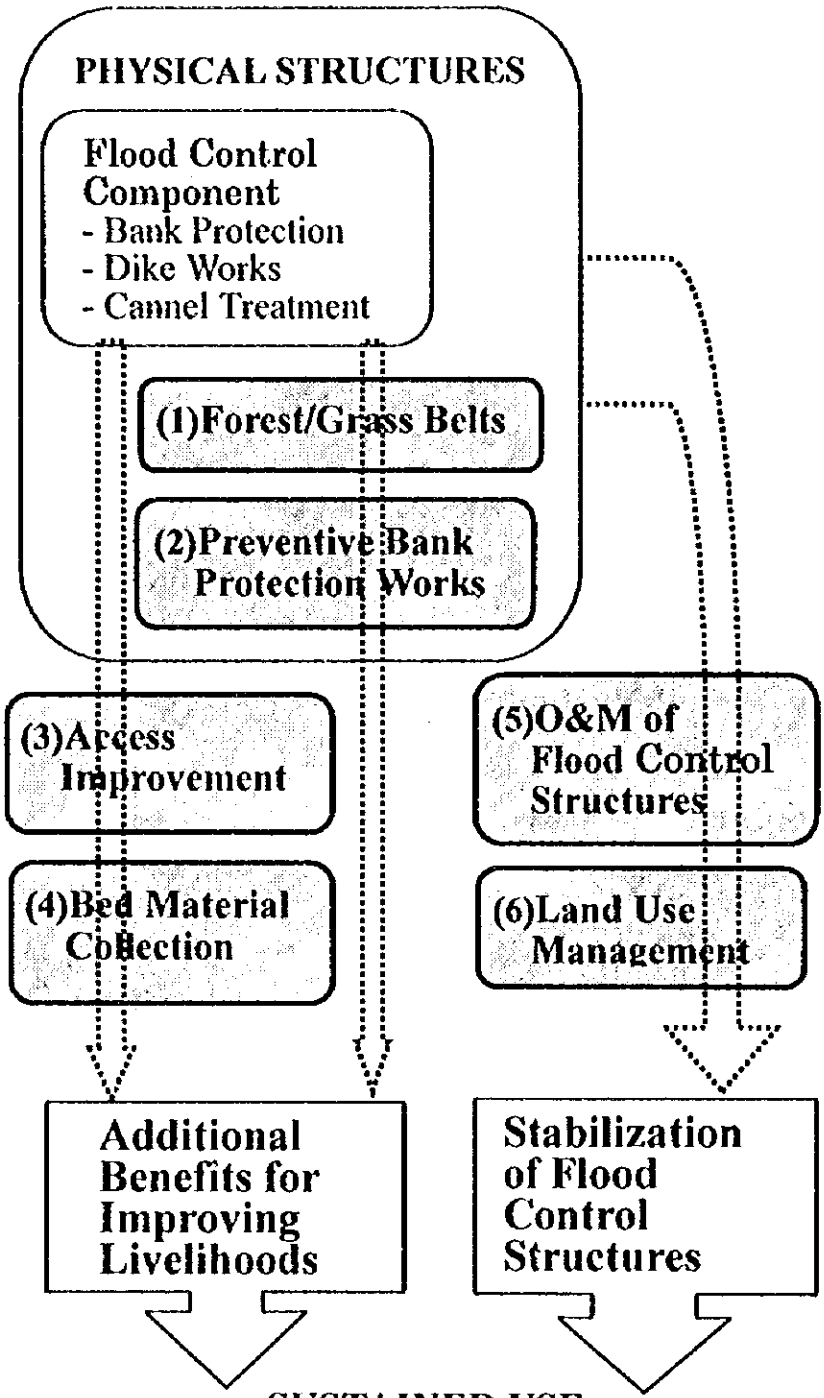
Community-based Sustainable Measures



COMMUNITY-BASED SUSTAINABLE MEASURES

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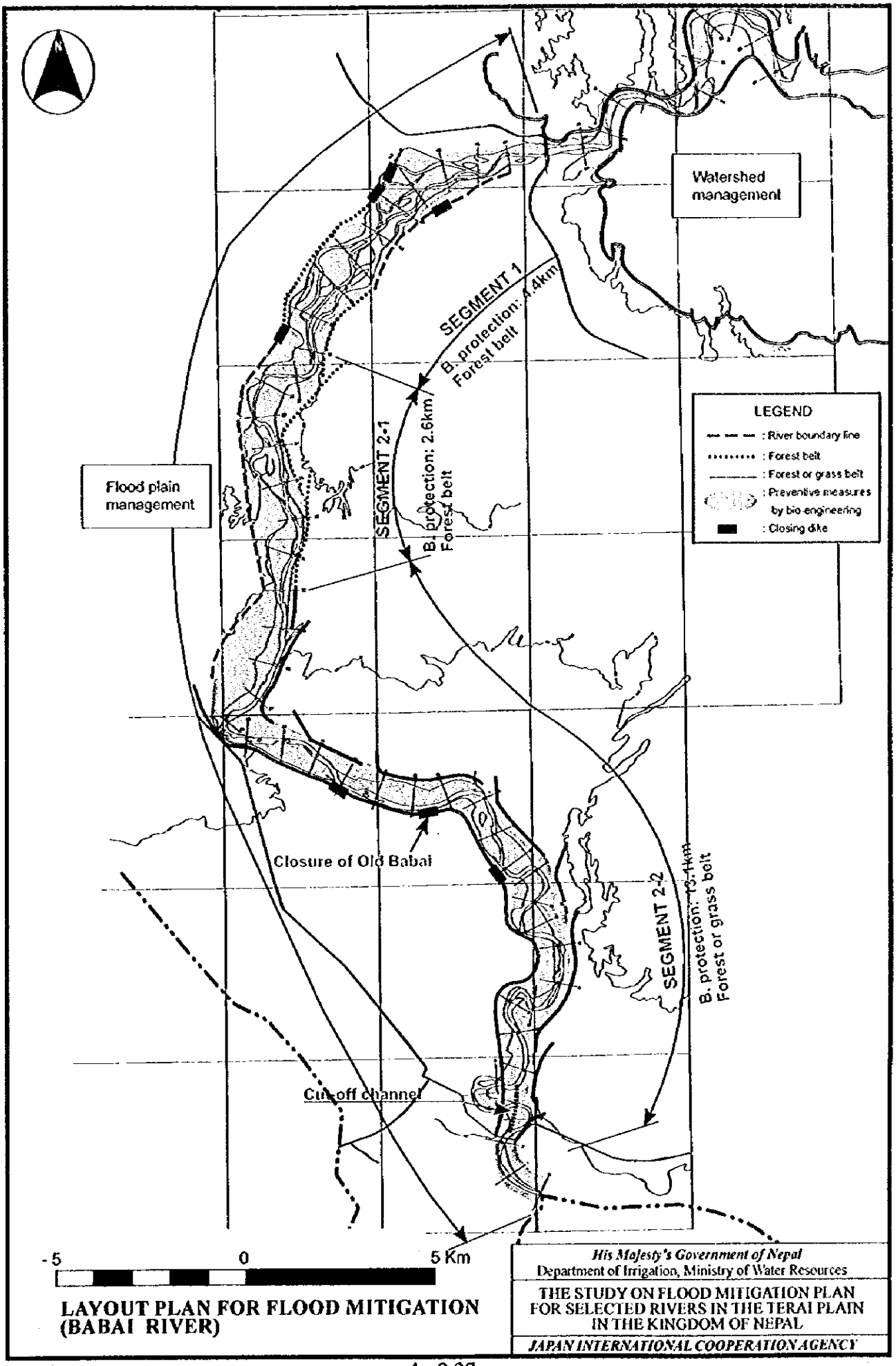


LAYOUT PLAN FOR FLOOD MITIGATION (BABAI RIVER)

3. ACTION PROGRAM TOWARD TARGET YEAR

3.1 Sequence of Works

The Master Plan is proposed for the implementation by the target year of 2017. The project works must be carried out effectively in orderly manner toward the target year. It is also important to realize the flood mitigation effects, in the course of implementation, corresponding to the progress of work. In view of the above, consideration was given to the sequence of work as presented below.

(1) Preparatory Works

1) **Feasibility Study:** A Feasibility Study will be conducted immediately, mainly covering the following:
   (a) **River Survey:** To obtain topographic maps along the river with smaller contour intervals, longitudinal river profiles and cross sections.
   (b) **Restudy of Master Plan:** Based on the river survey result, the Master Plan proposed at the present stage should be subject to in-depth study.
   (c) **Feasibility Study:** The study will cover discrete environmental studies as well, in order to obtain approval for project implementation from MOPE.
2) **Fund Arrangement:** The project cost estimated in the Feasibility Study is allocated between the central and local governments, and local communities, taking into consideration the nature of work and the capability of funding.
3) **Definite Plan/Detail Design:** A definite plan of the flood mitigation works, including the river boundary line (RBL), will be drawn up after getting consent of the central and local government agencies and local communities concerned. A detailed design will be prepared of the project facilities.
4) **Preservation of Lands:** Population in the Terai is growing rapidly. Because of this, more and more people live in the flood prone areas close to the rivers. Therefore, it is essential to preserve the lands for flood mitigation facilities, and this should start immediately after the preparation of definite flood mitigation plan. Appropriate land use should also be encouraged as outlined in the definite plan and detail design.
5) **Research and Investigation:** In parallel with implementation of the specific flood mitigation projects, research and investigation activities are needed to support the projects. Among these following are included, but not limited to:
   (a) **Hydrological Study for Class-III Rivers:** Flood runoff and sediment yield to be studied and analyzed especially for class III rivers originating

at Siwalik hills. Observations on a designated model basin would serve this purpose.

(b) **Investigation of Bank Erosion Characteristics:** Characteristics of bank erosion in the Terai have yet to be investigated. Mechanisms of bank erosion, erosion speed/width, etc. should be investigated in relation with the river segment, riverbed and bank materials, river flow condition, etc.

(c) **Development of Bank Protection Works:** Various types of bank protection works should be introduced in each of the river segment, hared on effectiveness, materials available and cost-performance. Recommended bank protection work for rivers in the Terai should be made through hydraulic model tests in the laboratory and prototype models in field.

(d) **Research on Application of Bio-engineering Technology:** In order to introduce bio-engineering technology as a component of flood mitigation, research works and accumulation of experience are necessary, mainly for the selection of plant species, type and function of work applicable, cultivation techniques, and contribution to income generation.

(2) Coordination For Flood Mitigation

Coordination to mobilize watershed management and flood plain management should be taken as soon as possible in combination with the community development activities.

(3) River Works

1) **Channel Treatment Works:**

(a) **Tributary Works:** Tributary work to stop inflow/outflow from/to adjacent river basins will be implemented soon after the preparation of the definite plan.

(b) **Branch/Anabranch Work:** Closing works of branches and anabranches, with diversion structure if necessary, will be carried out soon after the preparation of definite plan.

(c) **Channel Connection Works:** Unification and normalization by connecting tributaries and drainage can be executed at any time before dike work commences.

2) **Bank Protection Works:**

(a) **Spur/Revetment Work:** Riverbank classified as Type-As bank needs

protection works immediately and works are desirable for Type-A bank as well. The bank protection works will be executed continuously, primarily for Type-As banks identified by the periodic monitoring after every flood seasons.

(b) **Preventive Bank Protection Measures:** Preventive bank erosion measures by bioengineering are required immediately for Type-A bank and are desirable for all the riverbank between river course and boundary line of river zone.

3) **Dike Works:**

(a) **Forest and Grass Belts:** Forest belt will be formed inside of the river boundary line (RBL) in Segment 1 (alluvial fan) and grass belt in Segments 2-1 and 2-2 (natural levee zone). The work can be carried out at any time and any place, but for the purpose of marking the RBL it is best to do it quickly.

(b) **Local Dike and Dike Road:** The local dike and the dike road will be constructed inside along the RBL to protect the land locally and serves as rural road as well. These works should be started soon from the places where possible so as to realize the flood mitigation.

(c) **Ring Dike:** Ring dike work will be executed at the critical site.

(d) **Retarding Basin:** It is important to preserve the lands for the retarding basin, confining by forest belt, grass belt or earth dike.

4) **Channel Excavation and COC Works:**

(a) **Channel Excavation:** Channel excavation will be executed for channel normalization in extremely narrow sections.

(b) **Bed Material Collection:** Bed materials can be collected for construction materials soon after the preparation of definite plan according to a regulation to be prepared for bed material exploitation.

3.2 Action Plan

Implementation of the Master Plan project is programmed, in principle, by the phases of the national development plan from the ninth through twelfth plans as follows:

1) **1st Phase (Ninth plan: 1997-2002):**

(a) Preparatory works such as feasibility study, fund arrangement, definite

plan/detail design, preservation and of lands will be performed.

(b) Research and investigation, and coordination for watershed management and flood plain management will be started in combination with community development activities.

(c) Bank protection and ring dike works will be executed at the critical sites.

(d) Preventive bank protection works by bioengineering, and bed material collection are also started in this phase.

2) **2nd Phase (Tenth plan: 2002-2007):**

(a) Channel treatment works which are the key to stabilize the river system will be executed.

(b) Forest belt will start for its work in field. Grass belt will be completed for Segment 2-1 and 2-2.

(c) Local dikes and dike roads will be constructed where they are required.

3) **3rd Phase (Eleventh and twelfth plan: 2007-2017):**

(a) All the works and activities targeted for the Master Plan will be completed.

General action plan for the implementation of the Master Plan project is shown in Fig. A3.1.

ACTION PROGRAM TOWARD TARGET YEAR

River: **BABAI RIVER**

Activities	Phasing			
Master Plan	1st.	2nd.	3rd.	
National Plan (year)	9th (1997-2002)	10th (2002-2007)	11th (2007-2012)	12th (2012-2017)
(1) Preparatory Works				
1) Feasibility study:				
·River survey				
·Restudy of master plan				
·Feasibility study				
·Environmental study				
2) Fund arrangement				
3) Definite plan/ detail design				
4) Preservation of lands				
5) Rsearch/ investigation				
(2) Coordination for Flood Mitigation				
1) Community development				
2) Watershed management				
3) Flood Plain Management				
(3) River Works in Segment-1				
Channel treatment works:				
·Tributary works				
·Branch/ anabranch works				
Bank protection works:				
· Spur/ revetment				
· Preventive bank protection measurs (by bio-engineering)				
Dike works:				
· Forest belt				
· Ring dike				
Channel excavation works:				
· Bed material exploitation				
Retarding basin				
(4) River Works in Segment-2				
Channel treatment works:				
·Tributary works				
·Branch/ anabranch works				
Bank protection works:				
· Spur/ revetment				
· Preventive bank protection measurs (by bio-engineering)				
Dike works:				
· Grass belt				
· Low dike road w/ drainage sluice				
· Continuous dike w/ drainage sluice				
· Ring dike				
Channel excavation works:				
· Bed material exploitation				
· Widening channel				
Cut-off channel works				
Retarding basin				

4. ECONOMIC EVALUATION FOR MASTER PLAN PROJECTS

4.1 Basin Overview

The Babai basin occupies 32,300 hectares in the plain which include Bardiya wildlife presence. About 45% of the basin is used for agriculture, while 25% is covered by forests. There exist no manufacturing establishment except one tile factory. However, it is anticipated Babai river might change its course, at any time and directly hit the center of Gulariya municipality. The Master Plan should be implemented in time before floods can seriously damage the center of the Bardiya district.

Paddy production occupies the largest area of agricultural land (with the estimated 1996/97 production of 21,400 metric tons), followed by wheat (6,900) and pulse (3,800). Based upon the retail value of 96/97 in the Morang district, paddy production amounted to Rs256 million, and in the case of maize, Rs152 million.

4.2 Effects of Flood Mitigation

Implementation of the flood mitigation Master Plan will primarily safeguard the land and properties in the flood prone areas and also bring about other favorable effects to the Study Area. The potential benefits and effects expected to accrue from the Master Plan, including tangible and intangible ones, are listed below.

1) **Reduction of damage due to flood and sediment:** Inundation and sedimentation will be alleviated and reduce damages of village houses, crop production, public facilities, etc.
2) **Protection of riverbank from erosion:** Loss of lands due to riverbank erosion are averted, and villages and farmlands will be protected.
3) **Indirect effects:** Owing to the reduction in damages in flood prone area, social and economic activities in the surrounding areas will not be interfered.
4) **Land enhancement:** Flood mitigation project ensures the social and economic activities in the flood prone area which enable further investments for the development of the flood prone area and the surrounding areas.
5) **Land reclamation:** Existing low-lying barren lands along the river turn to arable ones. Channel excavation and normalization at severely meandering section may create lands for agriculture and settlement.
6) **Flood-free embankment:** The earth embankment constructed as local dike and ring dike can be used as rural roads and flood-free areas in the flood prone

area. The area will also serve for evacuation and flood fighting activities.

7) **Income generation:** The forest belt and grass belt for flood mitigation will generate community's income. The trees from the forest belt could be used for flood mitigation as well.
8) **Stabilization of residents' livelihood:** Flood free land is the basis of the residents' livelihood in the flood prone areas. Only under such conditions, residents are encouraged to accumulate their immovable and other properties, and accordingly can stabilize their livelihood.
9) **Community development:** The Master Plan places emphasis on flood mitigation through community development. The community-based approaches will forge links among the resident people and may enable other community development activities.

4.3 Preliminary Economic Evaluation for Master Plan Projects

Economic viability of the flood mitigation Master Plan was examined preliminarily. Out of the various effects listed in the previous section, (a) flood damage reduction benefit, (b) bank protection benefit, and (c) indirect benefit were considered as tangible benefit for the evaluation.

Flood Damage Reduction Benefit: Flood damage study by hydraulic analysis is difficult at this stage, since the river section data are not available and available topographic and hydrological data are limited. The flood damage reduction benefit was estimated preliminarily based on the damage data of recent large flood.

Bank Protection Benefit: Benefit accruing from bank protection works was estimated as a product of the land area to be protected from erosion and the amount of property on the unit land area to be protected.

Conditions for Economic Evaluation: Evaluation was made for the existing basin conditions and future basin conditions in target year (2017). The benefit in the target year was assumed in proportional to the population projected. Cash flows of the project cost, maintenance cost and benefit are shown in Table A4.1. With these cash flows, the economic internal rate of return (EIRR), cost-benefit ratio (B/C) and net present value (NPV, or B-C) were worked out.

The results are summarized below, though these should be restudied based on river

survey data.

River	Existing basin			Future basin		
	EIRR (%)	B/C	NPV (10^6Rs)	EIRR (%)	B/C	NPV (10^6Rs)
Babai	9.3	0.94	-11.3	14.8	1.48	89.0

(Note) B/C and NPV were calculated under the discount rate of 10%.

Methodology and procedures of economic evaluation of the project are compiled in SUPPORTING REPORT-C.

COST BENEFIT FLOW FOR MASTER PLAN
(Existing Basin)

River: Babai (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	6,581	0	6,581	0	6,581	0
2 2000	6,581	0	6,581	0	5,983	0
3 2001	10,990	0	10,990	0	9,083	0
4 2002	30,104	0	30,104	0	22,618	0
5 2003	30,101	161	30,265	3,445	20,671	2,353
6 2004	30,104	321	30,425	6,891	18,892	4,279
7 2005	21,167	482	21,619	10,336	12,220	5,834
8 2006	21,167	595	21,762	12,758	11,167	6,547
9 2007	21,167	708	21,875	15,181	10,205	7,082
10 2008	21,167	821	21,988	17,603	9,325	7,465
11 2009	21,167	933	22,100	20,026	8,521	7,721
12 2010	21,167	1,046	22,213	22,448	7,786	7,868
13 2011	21,167	1,159	22,326	24,871	7,114	7,925
14 2012	21,167	1,272	22,439	27,293	6,500	7,906
15 2013	21,167	1,385	22,552	29,715	5,939	7,825
16 2014	21,167	1,498	22,665	32,138	5,426	7,694
17 2015	21,167	1,611	22,778	34,560	4,957	7,521
18 2016	21,167	1,724	22,891	36,983	4,529	7,317
19 2017	16,758	1,837	18,595	39,405	3,344	7,087
20 2018		1,926	1,926	41,323	315	6,757
21 2019		1,926	1,926	41,323	286	6,142
22 2020		1,926	1,926	41,323	260	5,584
23 2021		1,926	1,926	41,323	237	5,076
24 2022		1,926	1,926	41,323	215	4,615
25 2023		1,926	1,926	41,323	196	4,195
26 2024		1,926	1,926	41,323	178	3,814
27 2025		1,926	1,926	41,323	162	3,467
28 2026		1,926	1,926	41,323	147	3,152
29 2027		1,926	1,926	41,323	134	2,865
30 2028		1,926	1,926	41,323	121	2,605
31 2029		1,926	1,926	41,323	110	2,368
32 2030		1,926	1,926	41,323	100	2,153
33 2031		1,926	1,926	41,323	91	1,957
34 2032		1,926	1,926	41,323	83	1,779
35 2033		1,926	1,926	41,323	75	1,617
36 2034		1,926	1,926	41,323	69	1,470
37 2035		1,926	1,926	41,323	62	1,337
38 2036		1,926	1,926	41,323	57	1,215
39 2037		1,926	1,926	41,323	51	1,105
40 2038		1,926	1,926	41,323	47	1,004
41 2039		1,926	1,926	41,323	43	913
42 2040		1,926	1,926	41,323	39	830
43 2041		1,926	1,926	41,323	35	755
44 2042		1,926	1,926	41,323	32	686
45 2043		1,926	1,926	41,323	29	624
46 2044		1,926	1,926	41,323	26	567
47 2045		1,926	1,926	41,323	24	515
48 2046		1,926	1,926	41,323	22	469
49 2047		1,926	1,926	41,323	20	426
50 2048		1,926	1,926	41,323	18	387
Total	385,226	75,262	460,488	1,614,666	184,142	172,874

EIRR: 9.3%
B/C: 0.94
NPV(B-C): -11,268 (NRs.1,000)

COST BENEFIT FLOW FOR MASTER PLAN

(Future Basin)

River: Babai (Unit: NRs. 1,000)

Year	Economic cost/benefit				Discounted (10%)	
	Project cost	Maintenance cost	Total cost	Benefit	(C) Cost	(B) Benefit
1 1999	6,581	0	6,581	0	6,581	0
2 2000	6,581	0	6,581	0	5,983	0
3 2001	10,990	0	10,990	0	9,083	0
4 2002	30,104	0	30,104	0	22,618	0
5 2003	30,104	161	30,265	5,444	20,671	3,718
6 2004	30,104	321	30,425	10,887	18,892	6,760
7 2005	21,167	482	21,649	16,331	12,220	9,218
8 2006	21,167	595	21,762	20,158	11,167	10,344
9 2007	21,167	708	21,875	23,986	10,205	11,189
10 2008	21,167	821	21,988	27,813	9,325	11,795
11 2009	21,167	933	22,100	31,640	8,521	12,199
12 2010	21,167	1,046	22,213	35,468	7,786	12,431
13 2011	21,167	1,159	22,326	39,295	7,114	12,521
14 2012	21,167	1,272	22,439	43,123	6,500	12,491
15 2013	21,167	1,385	22,552	46,950	5,939	12,363
16 2014	21,167	1,498	22,665	50,778	5,426	12,156
17 2015	21,167	1,611	22,778	54,605	4,957	11,884
18 2016	21,167	1,724	22,891	58,433	4,529	11,561
19 2017	16,758	1,837	18,595	62,260	3,344	11,198
20 2018		1,926	1,926	65,290	315	10,675
21 2019		1,926	1,926	65,290	286	9,705
22 2020		1,926	1,926	65,290	260	8,823
23 2021		1,926	1,926	65,290	237	8,021
24 2022		1,926	1,926	65,290	215	7,292
25 2023		1,926	1,926	65,290	196	6,629
26 2024		1,926	1,926	65,290	178	6,026
27 2025		1,926	1,926	65,290	162	5,478
28 2026		1,926	1,926	65,290	147	4,980
29 2027		1,926	1,926	65,290	134	4,527
30 2028		1,926	1,926	65,290	121	4,116
31 2029		1,926	1,926	65,290	110	3,742
32 2030		1,926	1,926	65,290	100	3,402
33 2031		1,926	1,926	65,290	91	3,092
34 2032		1,926	1,926	65,290	83	2,811
35 2033		1,926	1,926	65,290	75	2,556
36 2034		1,926	1,926	65,290	69	2,323
37 2035		1,926	1,926	65,290	62	2,112
38 2036		1,926	1,926	65,290	57	1,920
39 2037		1,926	1,926	65,290	51	1,746
40 2038		1,926	1,926	65,290	47	1,587
41 2039		1,926	1,926	65,290	43	1,443
42 2040		1,926	1,926	65,290	39	1,311
43 2041		1,926	1,926	65,290	35	1,192
44 2042		1,926	1,926	65,290	32	1,084
45 2043		1,926	1,926	65,290	29	985
46 2044		1,926	1,926	65,290	26	896
47 2045		1,926	1,926	65,290	24	814
48 2046		1,926	1,926	65,290	22	740
49 2047		1,926	1,926	65,290	20	673
50 2048		1,926	1,926	65,290	18	612
Total	385,226	75,262	460,488	2,551,372	184,142	273,142

EIRR: 14.8%

B/C: 1.48

NPV(B-C): 88,999 (NRs.1,000)

PART-II: FEASIBILITY STUDY

5. ADDITIONAL INVESTIGATIONS AND STUDIES

5.1 General

The Babai river basin was selected for the Feasibility Study. Supplemental and detailed data necessary for the Feasibility Study were collected for the Babai river.

Members of the Study Team visited the site from time to time, mainly from the middle of July to the end of August in 1998. During the site visits, they inspected rainy season conditions of the rivers and basins, collected verbal information from the residents, and discussed with the local government officials concerned on the flood mitigation plan. In order to inspect the flood conditions, sites were also inspected by helicopter on September 10, 1998 for the Babai river.

Workshops were held on July 20-21, 1998 for the Babai river in Bardiya district. The workshops aimed to seek inputs from district level line agencies, local authorities and communities on the flood mitigation problems, possible roles in effective project implementation and ways for maximizing of participation.

5.2 Topographic Mapping and River Survey

(1) Topographic Mapping

Topographic maps of scale 1/10,000 with the contour intervals at 2.5 meters were prepared for the riverine inundated area along the Babai river. The mapping area measures approximately 145 km^2 for the Babai.

The mapping work was carried out by the following procedures:

1) Reproduction of preliminary maps at the scale of 1/10,000 from the existing topographical maps at the scale of 1/25,000 or 1/50,000 using a precise photomechanical process.
2) Ground survey for the following items:
   - Measurement of spot height by leveling or GPS survey
   - Field verification for such as road width, channel width, riverbanks, and annotation
3) Editing with contour interpolation at every 2.5 m interval
4) Tracing by inking, or another technical procedures

(2) River Survey

River survey was carried out for the Feasibility Study on flood mitigation. The surveys included longitudinal surveying, cross sectional surveying and flood mark surveying along the rivers. Cross sections were surveyed at approximately one (1) kilometer intervals, and the river length for surveying is about 50 km.

The river survey was conducted from May to June in 1998 by the Nepalese Surveying firms, TECHDA (Technical Development Associates) (P) Ltd.

Major work items and quantities for the river surveys are as follows:

1) Installation of section stakes on both river banks: 50 sections
2) Marking of past flood water levels near every section stakes: 50 places
3) Longitudinal leveling: 50 km
4) Cross sectional leveling: 50 sections
5) Drawing and Report: 3 copies and original

5.3 Flood Flow Investigation

Objective: Flood flow investigation of the Babai river basin aims:

1) To collect information on flood flow conditions, by site inspection and interviews with VDC and the village people;
2) To clarify the places and extent of flooding, sediment cover and bank erosion, by site inspection and interviews with VDC and the village people; and
3) To prepare flood and sediment hazard map based on the above results, upgrading the hazard map prepared in the master plan stage.

Field Investigation: Site inspection and interviews with VDC and the village people were performed at more than 50 sites along the entire length of right and left riverbanks, to collect the following data and information relevant to the flood and sediment disasters:

1) Flood Flow Conditions: Time of concentration of flood runoff, places where the floodwater spills/overflows frequently, and photos taken during floods.
2) Inundated Area Survey: Extent of the maximum inundated area, extent of

frequently inundated area, extent of inundated area during recent big flood (1995-flood), source of inundated water, and photos of typical inundated areas.

3) Sedimentation Survey: Extent of sediment cover, sedimentation damages, period required for recovery, effects to next year crops, and photos of typical sediment covered farm land and settlement areas.
4) Bank Erosion Survey: Severely eroded riverbank in recent years, riverbank eroded last rainy season, bank erosion damages, river course shifting, and photos of severe bank erosion sites.

Flood and Sediment Hazard Map: Flood and sediment hazard maps were prepared as shown in Fig. A5.1, based on the field investigation results, upgrading the hazard map prepared in the Master Plan stage. The hazard map indicates active bank erosion sites, sediment suffering lands and the maximum inundated areas.

5.4 Environmental Study

(1) Introduction

Part-I Report (Master Plan Study) has outlined the environmental rules that are pertinent, if and when a project proposal is formulated as a result of the flood mitigation Master Plan, (FMMP). An environmental screening has been done and impacts were listed, both positive and negative, according to the social and natural environment and the possible pollution effects caused by the interventions. The overall conclusion of this screening is that the environmental impacts will be very positive.

(2) Environmental Study

General Environmental Inventory: Because the various proposed interventions may affect the people and their land along the banks of the two rivers, it was decided to undertake an inventory along these banks. Such an inventory would help the engineers and social scientists, as well as indicate to the environmentalist the type of survey required if houses have to be relocated as a result of the proposed interventions. The inventory documented land use, land ownership, houses (by type), other buildings and infrastructure in a belt up to 500 meters wide on either side of the Babai river in the Terai.

Environmental Study (Babai R.): In order to test the Environmental Conservation Rules (ECR) of 1997, it was decided to undertake a study at specific sites on the Babai

river where either an IEE or an EIA will be required, once a project is proposed and funds are allocated. The ECR were followed in as much as the recommended specified surveys were carried out and the environmental impact of each intervention assessed. The views of the local people to the proposed interventions were sought and a survey of the social and economic conditions undertaken. A monitoring plan was proposed; this detailed the measures to be taken to monitor the environmental impacts of the proposed project and the actions to take to negate negative impacts and improve positive ones.

Implementation of Study: The study was put out for tender and the Contract was awarded to GEOCE Consultants (P) Ltd., Consulting Engineers, of Kathmandu. In accordance with the study program prepared by the Study Team, fieldwork for the general environmental study and at the specific sites along the Babai river took place from August to October of 1998.

(3) Results of Studies

The study report prepared as a study result describes the conditions along the river and the anticipated effects of flood mitigation measures in the Terai of the Babai river. These findings are summarized in Table A5.1.

5.5 Additional Findings on Channel Characteristics

The longitudinal profile of the Babai river is shown in Fig. A5.2 based on the results of river survey conducted in May/June, 1998 by the Study Team. The Figure includes the profiles of the lowest riverbed, right and left riverbanks, mean riverbed and flood water levels of 1995-flood according to the information obtained from resident peoples.

Figure A5.3 and Table A5.2 show the principal characteristics of the Babai river such as the overall channel profile, hydraulic mean depth, channel width, flow area, bank-full capacity and profile of the riverbed materials.

From these data the Babai river was divided into three river segments, as follows:

1) Segment 2-2: Sec. No. 0 – No.30
2) Segment 2-1: Sec. No.30 – No.37
3) Segment 1: Sec. No.37 – No.46

Average channel sizes of respective river stretches are summarized below.

River stretch	Bed Slope (I)	River Width (m)	Mean depth (m)	Flow area (m^2)	Bank-full capacity (m^3/sec)
Segment 2-2:					
No.0-No.13	1/3,716	407	3.21	1,264	1,511
No.13-No.30	1/1,820	471	2.42	1,094	1,600
Segment 2-1:					
No.30-No.37	1/1,000	623	2.53	1,534	2,610
Segment 1:					
No.37-No.46	1/436~383	804	2.38	1,796	3,932

5.6 Runoff and Flood Flow Analyses

5.6.1 Runoff Analysis

(1) Sub-basin Area

The basin area of the Babai river is 3,425 km^2 in total and the watershed area upstream from the Babai barrage covers 3,002 km^2 (88% of the total basin area).

The plain basin is further divided into several sub-basins at the confluence of major tributaries and major structure sites for flood flow analysis. The sub-basin areas are shown in Table A5.3.

(2) Probable Peak discharge

The probable peak discharges estimated for the Master Plan study were adopted.

$$Q_n = (Q_n / Q_2) \cdot q_2 \cdot A$$

$$q_2 = C \cdot A^{(A^{-0.05}-1)}$$

The probable discharges of 2-year return period at specific points are shown in Tables A5.3.

(3) Base-flow Discharge

Base-flow discharge was studied based on the runoff records for 20 years at Babai river station (No.290). The base-flow is an assumed constant flow before and during the flood runoff due to rainfall. According to the study:

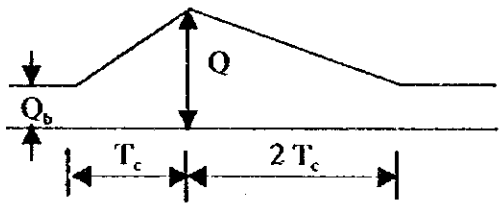
1) Average of annual maximum monthly discharge is 388 m^3/s, and
2) Average of monthly discharge when the annual maximum discharge occurred is 382 m^3/s.

Based on the above, the base-flow at the Babai river station was assumed to be 390 m^3/sec. Base-flow discharges (Q_b) at respective river sections of interest on the Babai river were assumed, applying the same specific base-flow discharge (q_b) estimated at the Babai river data as follows:

q_b = 390 m^3/s / 3,002 km^2 = 0.13 m^3/s /km^2
Q_b = 0.13 m^3/s/ km^2 x A, where A is a basin area in km^2.

(4) Discharge Hydrograph

Since the actual runoff hydrograph was not available, the triangular discharge hydrograph was assumed as shown below for the present study.



Q : Peak discharge
Q_b: Base-flow discharge
T_c : Time of concentration

Recession period of flood is assumed to be twice of time the concentration (T_c). The time of concentration (T_c) was estimated at Babai barrage for the Babai river, using Kraven's empirical formula for natural mountainous basins as follows:

(Items)	(Babai R.)
River length	154 km
Propagation velocity	3.5 m/s
Time of concentration (T_c)	12 hr

Hourly discharges were estimated as shown in Tables A5.3. Runoffs from the residual basins are estimated as a balance of discharges at adjacent river sections for runoff calculation.

5.6.2 Flood Flow Analysis

(1) Methodology

Flood flow analysis was made using a unsteady flow simulation model. The model mainly consists of channel and flood plain models.

Channel Model

1) Fundamental equations:

$$\frac{\eta}{g}\frac{\partial v}{\partial t}+\frac{a}{2g}\frac{\partial v^2}{\partial x}+\frac{\partial H}{\partial x}+\frac{n^2}{R^{4/3}}v|v|=0$$

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=-q$$

2) Boundary conditions:
   - Upper end: Discharge hydrograph
   - Lower end: Water level hydrograph or stage-discharge curve
3) Channel data: Channel sections surveyed

Flood Plain Model

1) Fundamental equations:

$$\frac{1}{g}\frac{\partial v_p}{\partial t}+\frac{\partial H_T}{\partial l}+f_p v_p|v_p|=0$$

$$F\frac{dH_p}{dt}=Q_{in}-Q_{out}$$

2) Boundary conditions: Various types of boundary conditions such culvert, canal, embankment, etc. can be incorporated at the boundary of the plain block.
3) Flood plain data: Plain areas at various elevations for each plain block.

Notations of Above Equations

t	: Time
x	: Distance along river
Q and v	: Channel discharge and velocity
H, A and R	: Water level, flow area and hydraulic mean depth

n : Manning's coefficient of roughness
g : Acceleration of gravity
η, α : Coefficients depending on velocity distribution
v_p : Velocity at the joint of plain blocks
f_p : Energy loss at the joint of plain blocks
$\delta H_T / \delta l$: Surface slope in plain block
F, H_p : Surface area and water level of in plain block
Q_{in} and Q_{out} : Inflow and outflow of the plain block

(2) Results of Simulation

The model was first adjusted for each basin condition using the 1995-flood data. Then the model was run based under the following cases for 1.05, 2, 5, 10, 20, 50 and 100 year probable floods:

1) Flood flow under the present channel conditions
2) Flood flow confined within the present river area.

The results of calculations are shown in Fig. A5.4 and Table A5.4.

PRELIMINARY ENVIRONMENTAL STUDY
for
the Lakhandei and Babai Rivers

People and property close to the rivers in the Terai are most under threat from flooding and flood damage during the monsoons. Therefore, a Survey was undertaken in September of this year (1998) along the narrow strip of land on either side of the Lakhandei and Babai rivers. The purpose of the survey was to determine the number of people, buildings, the land use and the land ownership in this narrow belt. Estimates were made of the damage to property, riverbanks and land. A preliminary assessment of the economic and environmental cost has been made and is presented in the following tables.

Population and Buildings in the Area.

	Lakhandei	Babai
Length of river in the Terai (m)	50960	49840
Average width of strip surveyed (m)	345	409
Number of houses in the area	7748	1908
Number of other buildings	188	29
Number of people	39590	9820
Population density, (people per hectare)	11.3	2.4

The riverbank area is densely populated along the banks of the Lakhandei and at present there is a fairly low population density along the Babai.

Land Use pattern (Units: hectares)

	Lakhandei	%	Babai	%
Cultivated land	3025	85.9	1635	40.1
Barren land	154	4.4	455	11.1
Forest land	254	7.2	1960	48.1
Building area	79	2.2	21	0.5
Road/canal area	11	0.3	8	0.2
Total area	3523	100.0	4079	100.0

Cultivated land, practically all private, accounts for 86% of land use in the Lakhandei, whereas along the Babai river, forest land at 48% is the largest form of land use. Over 40% of the forest land are communal in the Babai, but it is less than 1% in the Lakhandei.

Estimated Damage.

	Lakhandei	%	Babai	%
Houses destroyed or moved in 1998	75	1.0	50	2.6
Houses in danger from flood damage	65	0.8	66	3.5
Length of river bank erosion (m)	11500	11.3	5295	5.3
Length of road damage (m)	1800	4.6	0	0.0

Estimated Area Damaged (hectares).

	Lakhandei	Babai
Riverside land eroded and lost (average depth 10 m)	12	5
Land inundated with coarse material	165	120
Land flooded	1200	520

Estimated Loss of Crops and Land in Weight and Value Terms.

	Lakhandei		Babai	
	t.	$	t.	$
Land permanently lost ($ 4800 per ha)		57600		24000
Permanent crop loss (2.8 t/ha – 2 crops/yr)	67	13400	28	5600
Land inundated with coarse material. Cost of reclamation ($ 1600 per ha)		264000		192000
Temporary loss of crops (5.6 t/ha)	924	184800	672	134400
Flooded land rehabilitation ($ 50 per ha)		60000		26000
Loss of 1 crop (2.8t/ha)	3360	672000	1456	291000
Total	4351	1251000	2156	673200

Note: the loss of crops is given in rice equivalent terms, valued at $ 200/t. ex-farm.

Estimated Loss of Animals.

	Lakhandei		Babai	
	number	$	number	$
Cattle ($ 50 each)	120	6500	55	2750
Goats/sheep ($ 10 each)	260	2600	115	1150
Poultry ($ 1 each)	950	950	410	410
Total	1330	10050	580	4310

Estimated Infrastructure Repair Costs.

	Lakhandei		Babai	
	number	$	number	$
Houses destroyed/removed ($ 1000/house)	75	75000	50	50000
Houses to be reinforced ($ 100 per house)	65	6500	66	6600
Road repair ($ 50/m)	1800 m	90000	0	0
Total		171500		56600

Estimated Total Cost of Flood Damage.

	Lakhandei	Babai
Total Damage in 1998 ($)	1,433,350	734,110

The physical environmental costs include the loss of habitat, pollution of water and land. The social environmental costs include destruction and damage to property and the infrastructure and an increase in the incidence of diseases. Much of the above damage could have been prevented with adequate flood prevention measures. Unless this is done, land will be eroded continually and lost and several houses will be destroyed each year. When a project is proposed, an IEE is required to assess the impact on endangered houses and other buildings.

ENVIRONMENTAL STUDY ALONG BABAI RIVER

The Flood Mitigation master Plan has recommended that protection work be undertaken along the Babai river in the Terai. According to the Environmental Protection Rules, some of these interventions will have to have an environmental assessment undertaken on them, if and when the plan is acted upon and a project is undertaken. In anticipation of a project proposal, four sites along the Babai river, which will require an assessment at the project proposal stage, were studied for possible environmental impacts as a result of the proposed initiatives.

At three sites, bank strengthening over a stretch of more that one-kilometer is proposed, whereas at the other site, it is proposed to straighten the river channel by eliminating two large bends. An alternative to river strengthening at one site is to realign the river from a sharp bend to gradual smooth bend.

The purpose of these various initiatives is to protect irrigation canal intakes, to prevent irrigated land from being damaged, to reduce bank erosion, to stop the river from taking its old course and to reclaim some land.

Environmental Costs and Benefits.

The study found that at all sites the environmental benefits far outweigh the costs. At the first site about 900 hectares of irrigated land will be protected and riverbank erosion will be minimized. There are no environmental costs at this site.

At the second site, the erosion caused a village of about 20 houses to be washed away. These people are living in temporary shelters in a forest plantation. Some farmland was also washed away and other areas covered with coarse sand and gravel. About 5 old protected sal trees, which are stabilizing the southern bank of the river were washed away. This bank is very close to a main gravel road that is in danger of being eroded along this stretch of the river. In addition about 25 trees on the northern bank are being destroyed because of bank erosion.

The river takes a sharp bend at this point. As an alternative, it is proposed to redirect the river and form a gradual bend at this point. About 9 hectares of government forest will have to be cut down in order to form the new channel. This will regulate the flow of the river at this point and protect houses, agricultural land and the road. More than 9 hectares of land could be reclaimed. Thus again the environmental benefits far outweigh costs.

At the third site, bank protection is needed to prevent the river from taking its old course. If it did it would seriously damage the main town in the area, - Gulariya – as well as much farmland and the "Black Buck" conservation area. No environmental costs are envisaged at this site.

The fourth site is near Gulariya town. At this point the river meanders considerably and both banks are affected by erosion. It is proposed to straighten the river and protect the new banks. About 50 hectares of agricultural land and 2 hectares of forest would be lost. On the other hand about 200 hectares of land would be reclaimed. Thus again the benefits far outweigh the costs.

This environmental study has generated very useful information about population, land use, animal and plant vegetation, river water quality and likely impacts of initiatives proposed in the Flood Mitigation Master Plan. Most of the environmental benefits are positive and are significantly greater than the environmental costs.

PRINCIPAL CHANNEL CHARACTERISICS OF BABAI RIVER

Sect. No	Distance from border X (km)	River width B (m)	Section area A (m2)	Mean depth R (m)	Bank height Hm (El.m)	Channel slope I	Manning's roughness n	Channel capacity Qch (m3/s)	River segment No
NO.1	0	240.2	998.8	4.125	136.685	1/3,716	0.030	1,405	2-2
NO.2	0.77	404.7	1228.3	3.007	138.044	1/3,716	0.030	1,399	2-2
NO.3	1.60	219.1	852.3	3.804	136.726	1/3,716	0.030	1,136	2-2
NO.4	3.24	518.1	1621.4	3.113	137.097	1/3,716	0.030	1,890	2-2
NO.5	4.08	472.0	1195.4	2.519	138.531	1/3,716	0.030	1,210	2-2
NO.6	4.80	627.7	1533.3	2.427	138.573	1/3,716	0.030	1,514	2-2
NO.7	5.57	633.7	2247.7	3.529	137.401	1/3,716	0.030	2,849	2-2
NO.8	6.90	459.4	969.3	2.098	138.852	1/3,716	0.030	869	2-2
NO.9	8.03	249.5	883.8	3.482	137.928	1/3,716	0.030	1,110	2-2
NO.10	9.39	447.7	1823.4	4.034	138.046	1/3,716	0.030	2,527	2-2
NO.11	10.00	410.3	760.1	1.845	139.305	1/3,716	0.030	625	2-2
NO.12	10.87	230.3	1034.5	4.465	138.355	1/3,716	0.030	1,534	2-2
NO.13	12.01	382.6	1286.4	3.340	140.030	1/3,716	0.030	1,572	2-2
NO.14	12.78	533.9	786.6	1.466	140.124	1/1,820	0.030	793	2-2
NO.15	14.06	656.6	1089.1	1.654	140.456	1/1,820	0.030	1,190	2-2
NO.16	14.98	761.7	2515.2	3.292	140.708	1/1,820	0.030	4,348	2-2
NO.17	16.08	877.7	1008.0	1.146	141.884	1/1,820	0.030	862	2-2
NO.18	17.42	207.8	415.8	1.998	141.602	1/1,820	0.030	515	2-2
NO.19	18.57	404.1	950.8	2.322	142.468	1/1,820	0.030	1,303	2-2
NO.20	20.11	576.4	946.7	1.637	144.103	1/1,820	0.030	1,027	2-2
NO.21	21.10	326.9	488.6	1.493	143.808	1/1,820	0.030	499	2-2
NO.22	21.94	474.9	893.1	1.880	144.690	1/1,820	0.030	1,063	2-2
NO.23	22.36	390.6	1110.5	2.822	144.278	1/1,820	0.030	1,733	2-2
NO.24	24.30	674.1	2067.6	3.055	145.575	1/1,820	0.030	3,401	2-2
NO.25	25.45	271.9	1011.7	3.696	145.724	1/1,820	0.030	1,890	2-2
NO.26	27.39	500.6	1214.0	2.415	147.635	1/1,820	0.030	1,707	2-2
NO.27	28.52	323.6	1031.4	3.155	147.245	1/1,820	0.030	1,733	2-2
NO.28	29.51	386.4	765.3	1.970	147.950	1/1,820	0.030	940	2-2
NO.29	30.35	309.9	1159.2	3.723	148.197	1/1,820	0.030	2,176	2-2
NO.30	30.96	328.9	1135.9	3.437	148.923	1/1,820	0.030	2,021	2-2
NO.31	32.29	951.5	1866.9	1.958	150.842	1/1,000	0.035	2,640	2-1
NO.32	33.48	382.8	1371.4	3.578	151.672	1/1,000	0.035	2,899	2-1
NO.33	34.50	635.0	2062.3	3.230	153.240	1/1,000	0.035	4,071	2-1
NO.34	36.01	515.9	1111.1	2.139	154.451	1/1,000	0.035	1,667	2-1
NO.35	37.42	583.1	954.2	1.634	157.636	1/1,000	0.035	1,196	2-1
NO.36	38.42	646.8	1522.5	2.349	158.621	1/1,000	0.035	2,430	2-1
NO.37	39.80	647.1	1851.5	2.852	160.638	1/1,000	0.035	3,364	2-1
NO.38	40.81	832.1	1342.0	1.608	162.782	1/436	0.040	2,204	1
NO.39	42.04	1401.8	3558.4	2.533	166.417	1/436	0.040	7,915	1
NO.40	43.44	626.4	1401.2	2.226	169.114	1/436	0.040	2,859	1
NO.41	44.59	793.5	2193.2	2.720	171.770	1/436	0.040	5,115	1
NO.42	45.50	1075.3	1936.8	1.789	173.531	1/383	0.040	3,646	1
NO.43	46.45	1287.3	2539.1	1.972	176.528	1/383	0.040	5,101	1
NO.44	47.71	500.4	740.0	1.473	179.117	1/383	0.040	1,224	1
NO.45	48.90	415.3	1113.0	2.677	182.573	1/383	0.040	2,742	1
NO.46	49.84	304.8	1338.4	4.383	184.867	1/383	0.040	4,580	1

BASIN AREA AND RUNOFF HYDROGRAPHS: BABAI RIVER

Creager's C = 11.1 for 2-year flood

Section	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Location	No.46 +150m	No.44 +850m	No.36 +700m	No.28 +0m	No.25 +800m	No.23 +900m	No.18 +700m	No.15 +1050m	No.8 +400m	No.3 +400m
dA(km^2)	3002	6	12	36	15	38	83	132	92	9
A(km^2)	3002	3008	3020	3056	3071	3109	3192	3324	3416	3425
C	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Q(m^3/s)	2374	2376	2380	2391	2396	2408	2433	2473	2499	2502
Q_b(m^3/s)	390	391	392	397	399	404	415	432	444	445

DISCHARGE HYDROGRAPHS

Time	Q#1	dQ	Q#2	dQ	Q#3	dQ	Q#4	dQ	Q#5	dQ	Q#6	dQ	Q#7	dQ	Q#8	dQ	Q#9	dQ	Q#10
(hr)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
0	390	1	391	2	392	5	397	2	399	5	404	11	415	17	432	12	444	1	445
1	555	1	556	2	558	5	563	2	565	6	571	12	583	19	602	13	615	1	616
2	721	1	722	2	724	6	729	2	732	6	738	13	751	21	772	14	786	1	788
3	886	1	887	2	889	6	896	3	898	7	905	14	919	23	942	16	958	2	959
4	1051	1	1052	2	1055	7	1062	3	1065	7	1072	16	1087	25	1112	17	1129	2	1131
5	1217	1	1218	2	1220	7	1228	3	1231	8	1239	17	1256	26	1282	18	1300	2	1302
6	1382	1	1383	3	1386	8	1394	3	1397	8	1406	18	1424	28	1452	19	1472	2	1473
7	1547	1	1549	3	1552	9	1560	4	1564	9	1573	19	1592	30	1622	21	1643	2	1645
8	1713	2	1714	3	1717	9	1726	4	1730	10	1740	21	1760	32	1792	22	1814	2	1816
9	1878	2	1880	3	1883	10	1893	4	1897	10	1907	22	1928	34	1962	23	1985	2	1988
10	2043	2	2045	3	2048	10	2059	4	2063	11	2074	23	2097	36	2132	24	2157	2	2159
11	2209	2	2210	4	2214	11	2225	4	2229	11	2241	24	2265	38	2302	26	2328	2	2331
12	2374	2	2376	4	2380	11	2391	5	2396	12	2408	25	2433	40	2473	27	2499	3	2502
13	2291	2	2293	4	2297	11	2308	5	2313	12	2324	25	2349	39	2387	26	2414	3	2416
14	2209	2	2210	4	2214	11	2225	4	2229	11	2241	24	2265	38	2302	26	2328	2	2331
15	2126	2	2128	4	2131	11	2142	4	2146	11	2157	24	2181	37	2217	25	2242	2	2245
16	2043	2	2045	3	2048	10	2059	4	2063	11	2074	23	2097	36	2132	24	2157	2	2159
17	1961	2	1962	3	1966	10	1976	4	1980	10	1990	22	2013	35	2047	24	2071	2	2073
18	1878	2	1880	3	1883	10	1893	4	1897	10	1907	22	1928	34	1962	23	1985	2	1988
19	1795	2	1797	3	1800	9	1809	4	1813	10	1823	21	1844	33	1877	23	1900	2	1902
20	1713	2	1714	3	1717	9	1726	4	1730	10	1740	21	1760	32	1792	22	1814	2	1816
21	1630	1	1631	3	1634	9	1643	4	1647	9	1656	20	1676	31	1707	21	1729	2	1731
22	1547	1	1549	3	1552	9	1560	4	1564	9	1573	19	1592	30	1622	21	1643	2	1645
23	1465	1	1466	3	1469	8	1477	3	1481	9	1489	19	1508	29	1537	20	1557	2	1559
24	1382	1	1383	3	1386	8	1394	3	1397	8	1406	18	1424	28	1452	19	1472	2	1473
25	1299	1	1301	3	1303	8	1311	3	1314	8	1322	18	1340	27	1367	19	1386	2	1388
26	1217	1	1218	2	1220	7	1228	3	1231	8	1239	17	1256	26	1282	18	1300	2	1302
27	1134	1	1135	2	1138	7	1145	3	1148	8	1155	16	1172	26	1197	18	1215	2	1216
28	1051	1	1052	2	1055	7	1062	3	1065	7	1072	16	1087	25	1112	17	1129	2	1131
29	969	1	970	2	972	7	979	3	981	7	988	15	1003	24	1027	16	1043	2	1045
30	886	1	887	2	889	6	896	3	898	7	905	14	919	23	942	16	958	2	959
31	803	1	804	2	806	6	812	3	815	6	821	14	835	22	857	15	872	1	874
32	721	1	722	2	724	6	729	2	732	6	738	13	751	21	772	14	786	1	788
33	638	1	639	2	641	6	646	2	649	6	654	13	667	20	687	14	701	1	702
34	555	1	556	2	558	5	563	2	565	6	571	12	583	19	602	13	615	1	616
35	473	1	473	2	475	5	480	2	482	5	487	11	499	18	517	13	529	1	531
36	390	1	391	2	392	5	397	2	399	5	404	11	415	17	432	12	444	1	445

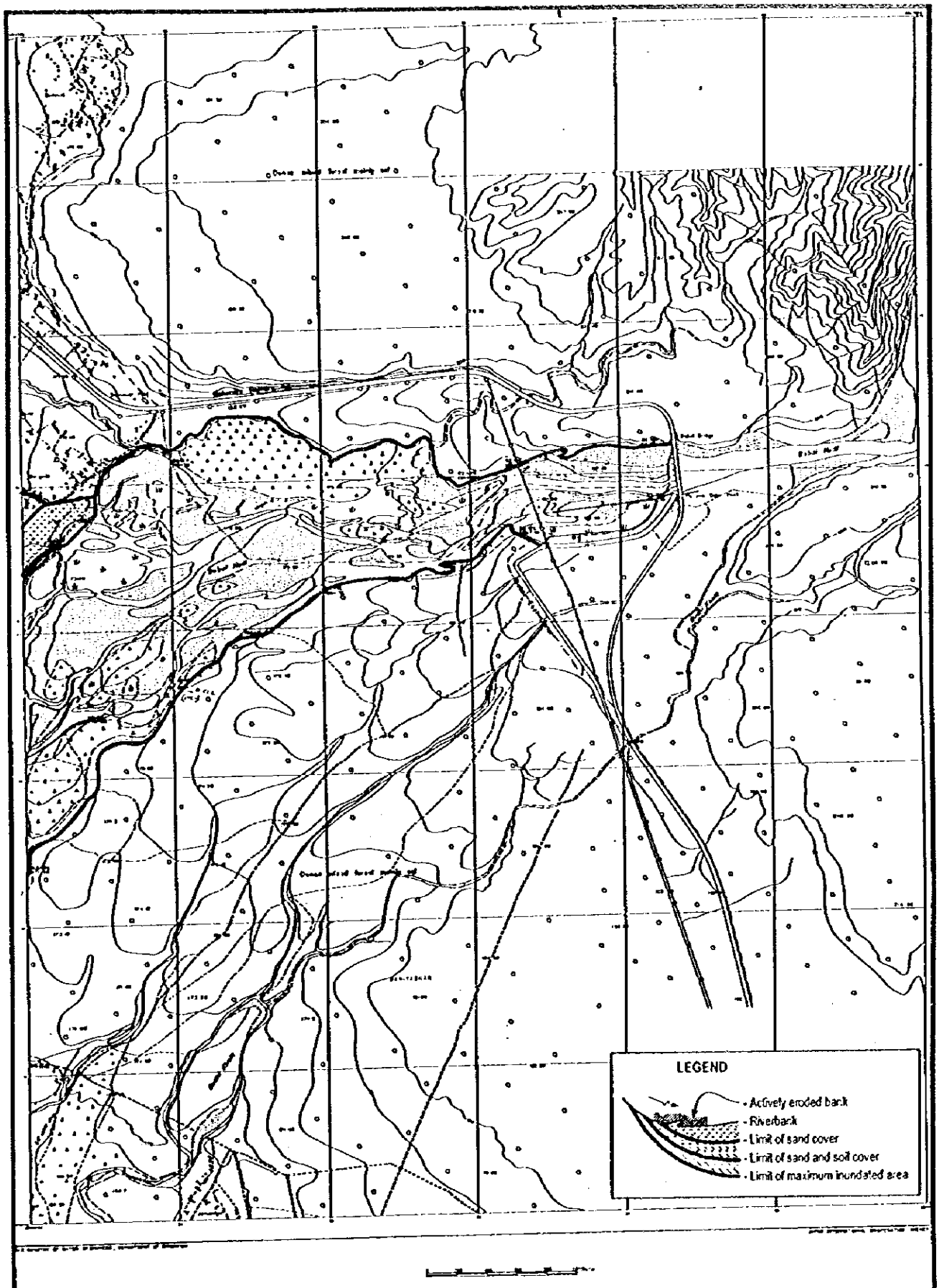
RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITHOUT PROJECT)

No.	Section	Distance (m)	2 - year		5 - year		10 - year		20 - year		50 - year		100 - year	
			H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)
1	NO.1	0	141.266	1681	141.814	2028	142.042	2175	142.221	2292	142.414	2417	142.531	2493
2	NO.2	690	141.496	1740	142.029	2342	142.244	2663	142.410	2945	142.585	3274	142.690	3489
3	NO.3	1,461	141.655	2059	142.130	3203	142.301	3822	142.415	4390	142.522	5020	142.574	5440
4	Bnd	1,891	141.835	2059	142.464	3203	142.737	3822	142.961	4390	143.205	5020	143.360	5440
5	NO.4	3,001	142.166	1576	143.030	2517	143.433	3300	143.777	4124	144.147	5165	144.384	5924
6	NO.6	4,548	142.247	1629	143.144	2288	143.587	2822	143.973	3367	144.397	4032	144.673	4504
7	NO.8	6,688	142.477	2041	143.354	2956	143.819	3415	144.229	3958	144.681	4597	144.977	5053
8	NO.9	7,708	142.755	1969	143.613	2630	144.083	2941	144.503	3244	144.970	3524	145.277	3700
9	NO.12	10,204	143.518	2076	144.415	2739	144.882	2876	145.284	3184	145.701	3573	145.971	3869
10	NO.13	11,344	143.942	2078	144.774	3264	145.209	3654	145.596	4258	146.009	4989	146.282	5519
11	NO.14	11,924	144.111	2081	144.994	3397	145.423	3963	145.826	4690	146.257	5559	146.542	6193
12	NO.15	12,836	144.254	2085	145.192	3302	145.627	3945	146.048	4729	146.503	5597	146.806	6224
13	NO.16	13,577	144.364	2043	145.336	3317	145.787	4064	146.232	4923	146.710	5862	147.029	6559
14	NO.17	14,457	144.474	1722	145.460	2789	145.917	3629	146.369	4642	146.852	5655	147.176	6418
15	NO.18	15,729	145.027	1730	145.879	2743	146.355	3289	146.847	3788	147.321	4399	147.653	4866
16	NO.19	16,809	145.749	2069	146.630	3177	147.027	3636	147.405	4290	147.846	5027	148.146	5581
17	NO.20	18,147	146.513	1817	147.375	3154	147.743	3734	148.156	4199	148.620	4768	148.942	5174
18	NO.21	19,059	146.950	1822	147.917	2715	148.308	3147	148.689	3392	149.119	3697	149.421	4003
19	NO.22	19,871	147.450	2034	148.338	3459	148.668	4196	148.986	4685	149.376	5465	149.651	6061
20	NO.23	20,291	147.683	2084	148.600	3505	148.946	4184	149.254	4716	149.657	5320	149.944	5779
21	NO.24	22,043	148.417	2076	149.500	3492	149.927	4189	150.242	4817	150.646	5467	150.936	5880
22	NO.25	23,043	148.845	2078	149.902	3503	150.356	4014	150.722	4408	151.116	4920	151.354	5392
23	NO.27	25,913	150.953	1862	152.350	2469	152.799	2860	153.125	3262	153.540	3577	153.880	3877
24	NO.28	26,865	151.293	2314	152.529	3390	152.961	4041	153.284	4666	153.667	5356	153.986	5928
25	NO.29	27,665	151.712	2303	152.869	3516	153.302	4276	153.635	5020	154.068	6001	154.398	6609
26	NO.30	28,225	152.141	2304	153.260	3520	153.724	4338	154.101	5144	154.487	6177	154.795	6884
27	NO.31	29,443	153.082	2333	154.098	3885	154.625	4828	155.085	5647	155.605	6533	155.971	7045
28	NO.32	30,593	154.393	2338	155.293	3896	155.763	4860	156.141	5783	156.531	6883	156.766	7619
29	NO.33	31,525	155.668	2339	156.652	3799	157.183	4693	157.641	5549	158.135	6676	158.439	7516
30	NO.34	32,695	157.018	2342	157.878	3949	158.355	4826	158.787	5577	159.299	6526	159.643	7213
31	NO.35	33,907	159.265	2343	160.236	3910	160.617	4712	160.936	5281	161.339	5907	161.625	6334
32	NO.36	34,759	160.824	2345	161.724	3976	162.096	4949	162.353	5712	162.635	6631	162.843	7124
33	NO.37	35,939	162.574	2349	163.427	3991	163.858	5010	164.156	5939	164.496	6978	164.664	7698
34	NO.38	36,819	164.448	2343	165.196	4003	165.608	5080	165.946	6060	166.287	7285	166.504	8197
35	NO.39	38,003	167.458	2341	168.089	3968	168.442	4988	168.744	5938	169.101	7060	169.358	7892
36	NO.40	39,267	170.889	2340	171.614	3967	171.973	4982	172.278	5950	172.604	7058	172.842	7788
37	NO.41	40,337	173.335	2332	174.168	3958	174.556	4976	174.897	6031	175.258	7267	175.480	8185
38	NO.42	40,962	174.901	2382	175.537	3927	175.881	4975	176.217	6142	176.554	7300	176.804	8252
39	NO.43	41,762	177.618	2299	178.165	3879	178.472	4917	178.904	6082	179.108	7087	179.351	7887
40	NO.44	42,791	181.925	2368	182.838	4075	183.194	5212	183.452	6302	183.682	7706	183.764	8615
41	NO.45	43,890	185.167	2370	186.278	4077	186.915	5215	187.477	6305	188.156	7728	188.567	8774
42	NO.46	44,790	187.661	2374	188.700	4083	189.263	5223	189.756	6315	190.353	7739	190.757	8784

RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITH PROJECT)

No.	Section	Distance (m)	2 - year		5 - year		10 - year		20 - year		50 - year		100 - year	
			H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)	H (m, MSL)	Q (m^3/s)
1	NO.1	0	141.297	1699	141.790	2012	141.991	2143	142.184	2267	142.403	2410	142.540	2499
2	NO.2	690	141.527	1766	142.006	2309	142.197	2589	142.375	2883	142.575	3256	142.698	3506
3	NO.3	1,461	141.683	2108	142.110	3141	142.265	3679	142.391	4270	142.517	4982	142.582	5458
4	Brid	1,891	141.869	2108	142.434	3141	142.676	3679	142.914	4270	143.191	4982	143.370	5458
5	NO.4	3,001	142.201	2107	142.979	3007	143.335	3527	143.701	4132	144.126	5070	144.399	5823
6	NO.6	4,548	142.342	2111	143.141	2938	143.513	3333	143.896	3818	144.357	4460	144.663	4973
7	NO.8	6,688	142.705	2051	143.503	2939	143.870	3349	144.258	3852	144.730	4450	145.053	4833
8	NO.9	7,708	142.935	1968	143.744	2665	144.110	2948	144.499	3281	144.972	3622	145.299	3817
9	NO.12	10,204	143.623	2107	144.510	2845	144.889	3064	145.290	3385	145.727	3767	146.013	4045
10	NO.13	11,344	144.033	2109	144.913	3307	145.267	3759	145.648	4413	146.065	5195	146.344	5743
11	NO.14	11,924	144.195	2112	145.131	3357	145.491	3940	145.892	4723	146.332	5614	146.623	6261
12	NO.15	12,836	144.332	2118	145.310	3284	145.685	3937	146.109	4784	146.572	5677	146.880	6329
13	NO.16	13,577	144.438	2123	145.445	3292	145.843	3944	146.296	4853	146.782	5805	147.107	6514
14	NO.17	14,457	144.543	2098	145.548	3267	145.955	3821	146.420	4734	146.913	5688	147.244	6428
15	NO.18	15,729	145.234	2106	146.048	3258	146.398	3681	146.881	4121	147.354	4632	147.689	5049
16	NO.19	16,809	146.097	2086	146.907	3403	147.176	4032	147.513	4673	147.904	5371	148.193	5872
17	NO.20	18,147	146.687	1802	147.631	3016	147.980	3675	148.350	4161	148.756	4831	149.053	5236
18	NO.21	19,059	147.047	1802	148.038	2649	148.418	3155	148.798	3549	149.216	3944	149.500	4182
19	NO.22	19,871	147.497	2041	148.410	3310	148.796	4062	149.126	4706	149.511	5430	149.771	5898
20	NO.23	20,291	147.718	2107	148.625	3476	149.027	4165	149.347	4813	149.729	5576	149.994	5971
21	NO.24	22,043	148.446	2099	149.492	3533	149.954	4257	150.332	4964	150.756	5728	150.997	6132
22	NO.25	23,043	148.871	2101	149.896	3568	150.352	4227	150.741	4832	151.145	5549	151.363	5922
23	NO.27	25,913	150.980	1869	152.410	2401	152.965	2730	153.443	3045	153.967	3357	154.234	3617
24	NO.28	26,865	151.315	2329	152.569	3317	153.091	3937	153.545	4509	154.040	5132	154.288	5685
25	NO.29	27,665	151.733	2317	152.879	3485	153.379	4204	153.804	4908	154.286	5683	154.548	6341
26	NO.30	28,225	152.152	2317	153.260	3488	153.759	4298	154.185	5104	154.650	6052	154.929	6804
27	NO.31	29,443	153.094	2348	154.092	3819	154.625	4789	155.110	5676	155.652	6507	156.015	7015
28	NO.32	30,593	154.403	2353	155.267	3823	155.750	4821	156.148	5785	156.542	6866	156.781	7600
29	NO.33	31,525	155.679	2354	156.612	3785	157.164	4645	157.647	5500	158.139	6560	158.445	7369
30	NO.34	32,695	157.028	2357	157.861	3938	158.328	4856	158.763	5702	159.252	6682	159.586	7426
31	NO.35	33,907	159.278	2359	160.230	3899	160.631	4691	160.992	5276	161.401	5884	161.702	6344
32	NO.36	34,759	160.835	2360	161.719	3964	162.092	4927	162.361	5724	162.645	6609	162.873	7131
33	NO.37	35,939	162.582	2363	163.421	3976	163.849	4979	164.161	5964	164.486	7003	164.673	7769
34	NO.38	36,819	164.454	2360	165.191	4016	165.597	5034	165.960	6057	166.298	7253	166.529	8156
35	NO.39	38,003	167.459	2362	168.094	4011	168.425	4991	168.738	5905	169.093	7063	169.346	7902
36	NO.40	39,267	170.903	2363	171.634	4021	171.973	4983	172.268	5917	172.607	7045	172.846	7781
37	NO.41	40,337	173.334	2364	174.201	4019	174.560	4979	174.886	6001	175.256	7210	175.481	8111
38	NO.42	40,962	174.837	2367	175.588	4093	175.892	5008	176.188	6058	176.538	7276	176.791	8151
39	NO.43	41,762	177.645	2368	178.201	3995	178.543	4969	178.893	6065	179.098	7125	179.322	7882
40	NO.44	42,791	181.997	2388	182.937	4113	183.259	5257	183.480	6358	183.748	7781	183.816	8698
41	NO.45	43,890	185.167	2370	186.279	4077	186.915	5215	187.479	6307	188.159	7736	188.571	8781
42	NO.46	44,790	187.661	2374	188.700	4083	189.263	5223	189.756	6315	190.353	7739	190.757	8784

Table A5.4 (2/2)

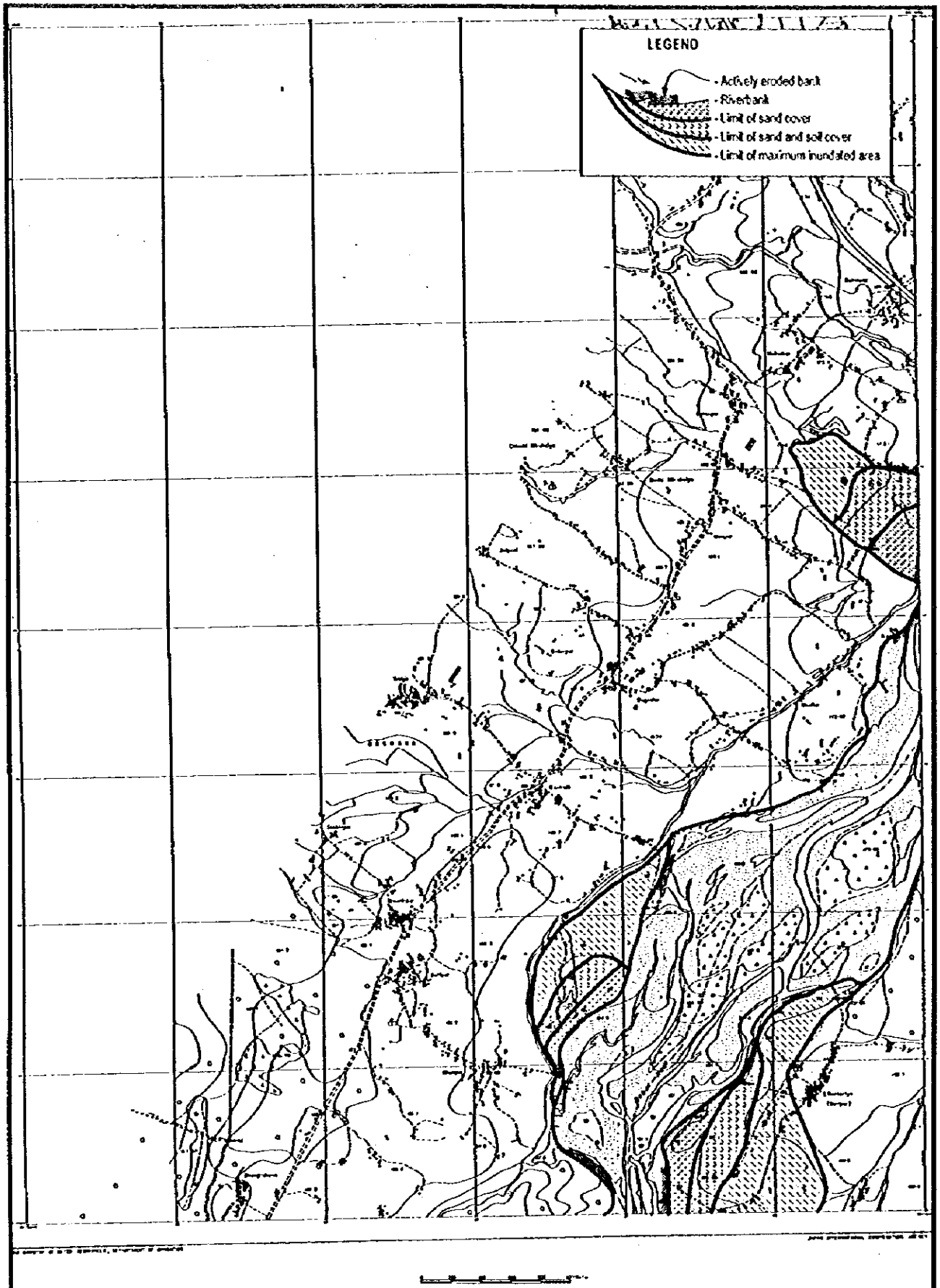


HAZARD MAP
Babai River 1995 Flood (1/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

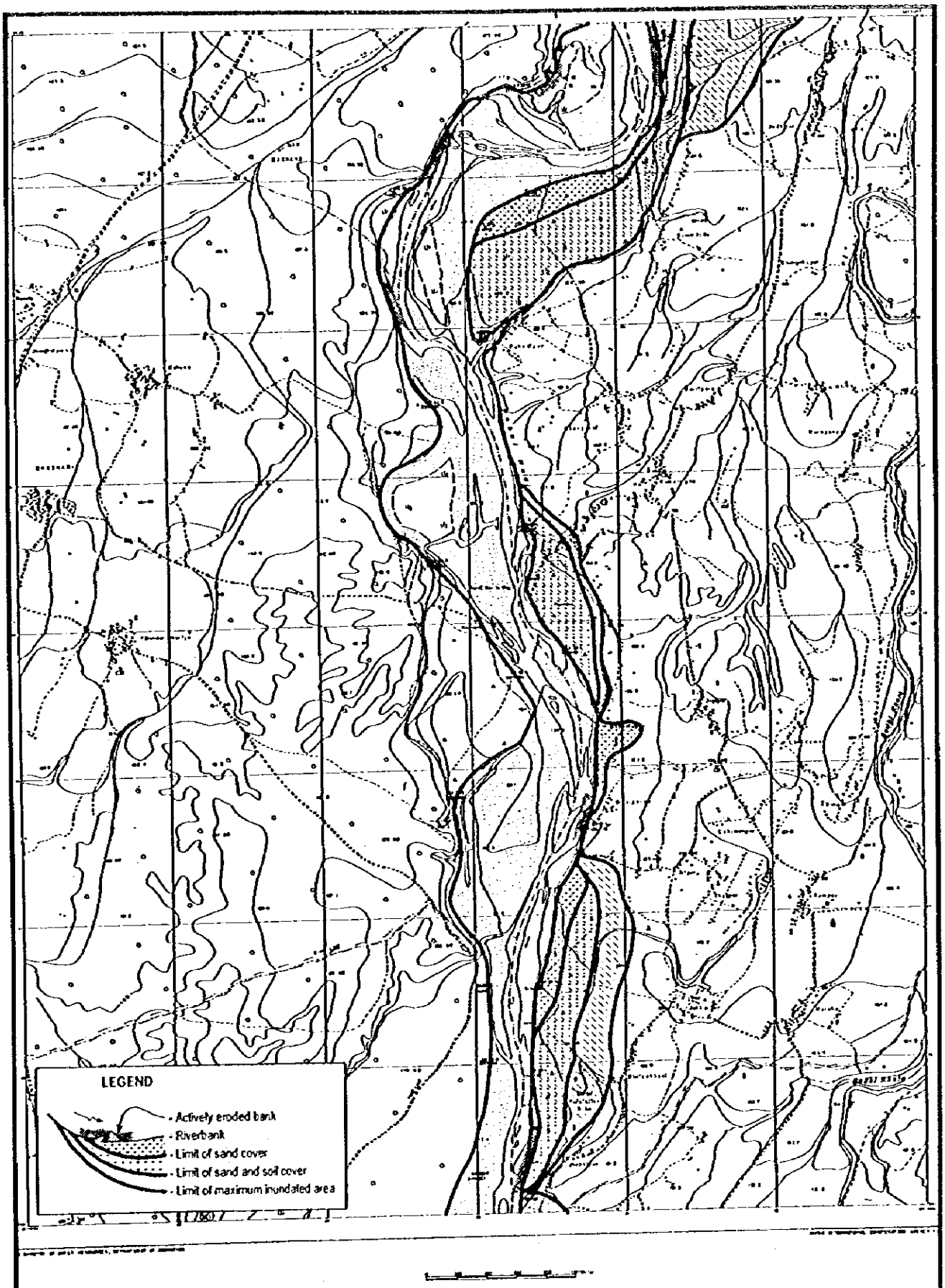


HAZARD MAP
Babai River 1995 Flood (2/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

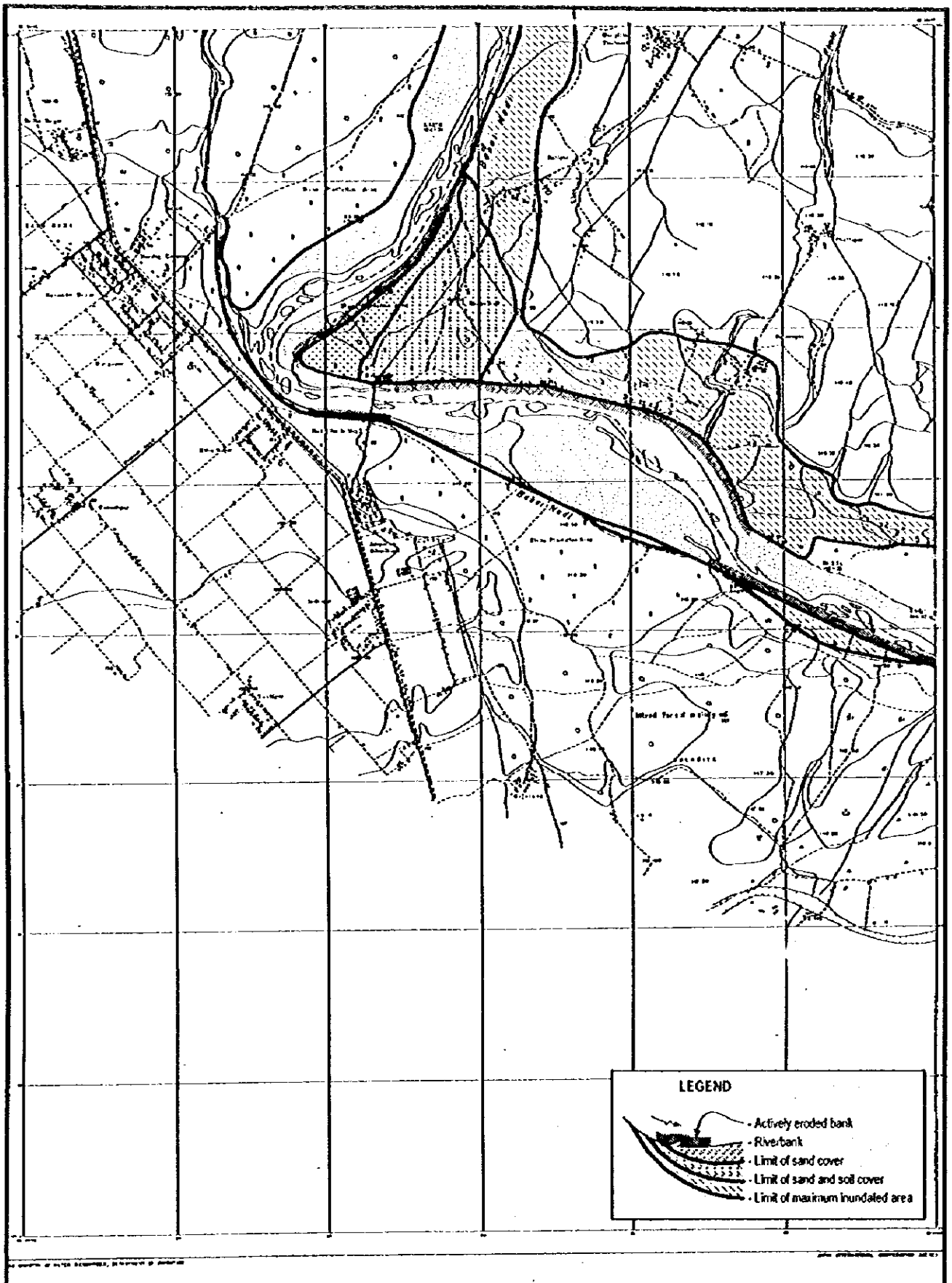


HAZARD MAP
Babai River 1995 Flood (3/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

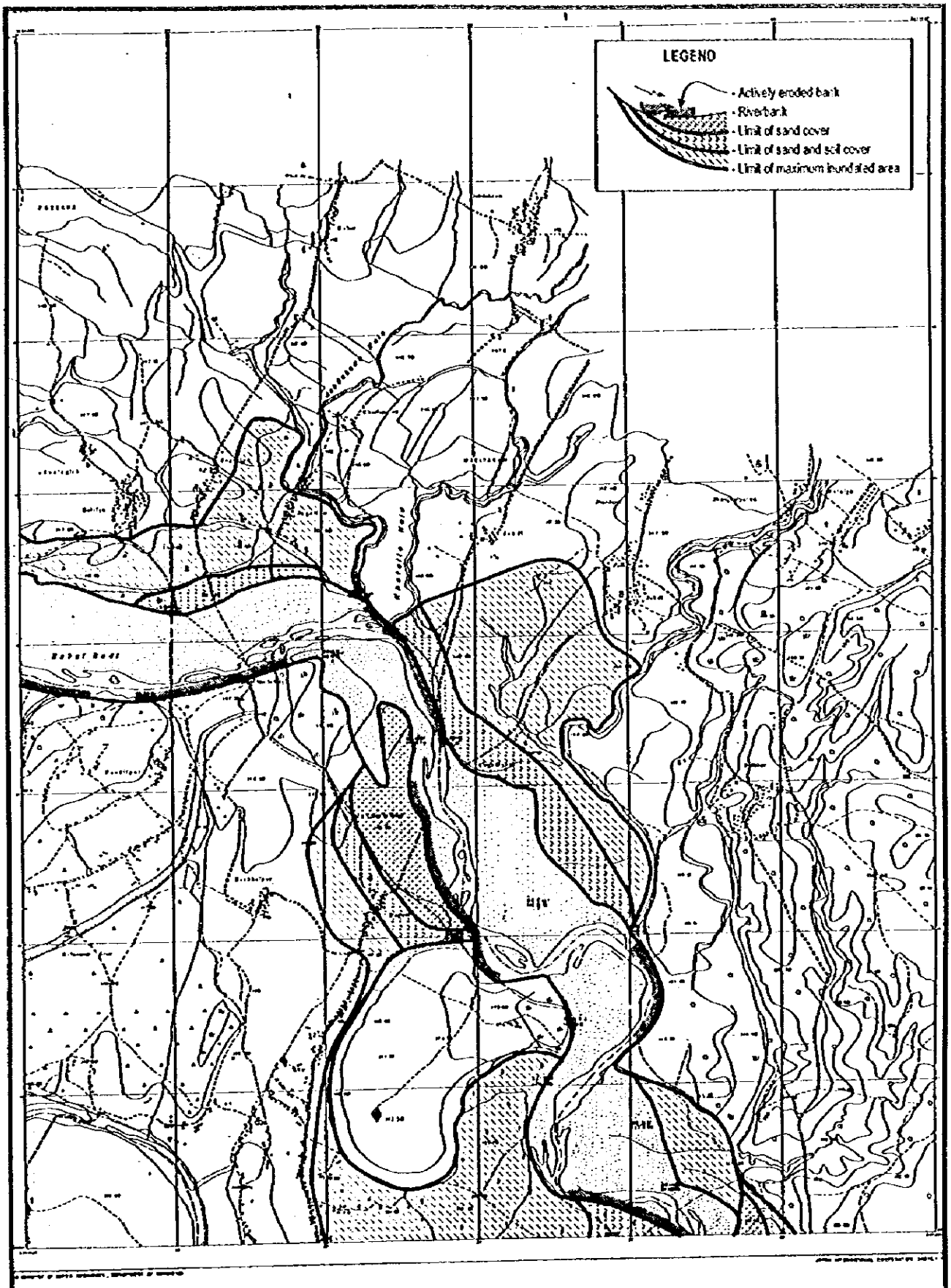


HAZARD MAP
Babai River 1995 Flood (4/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

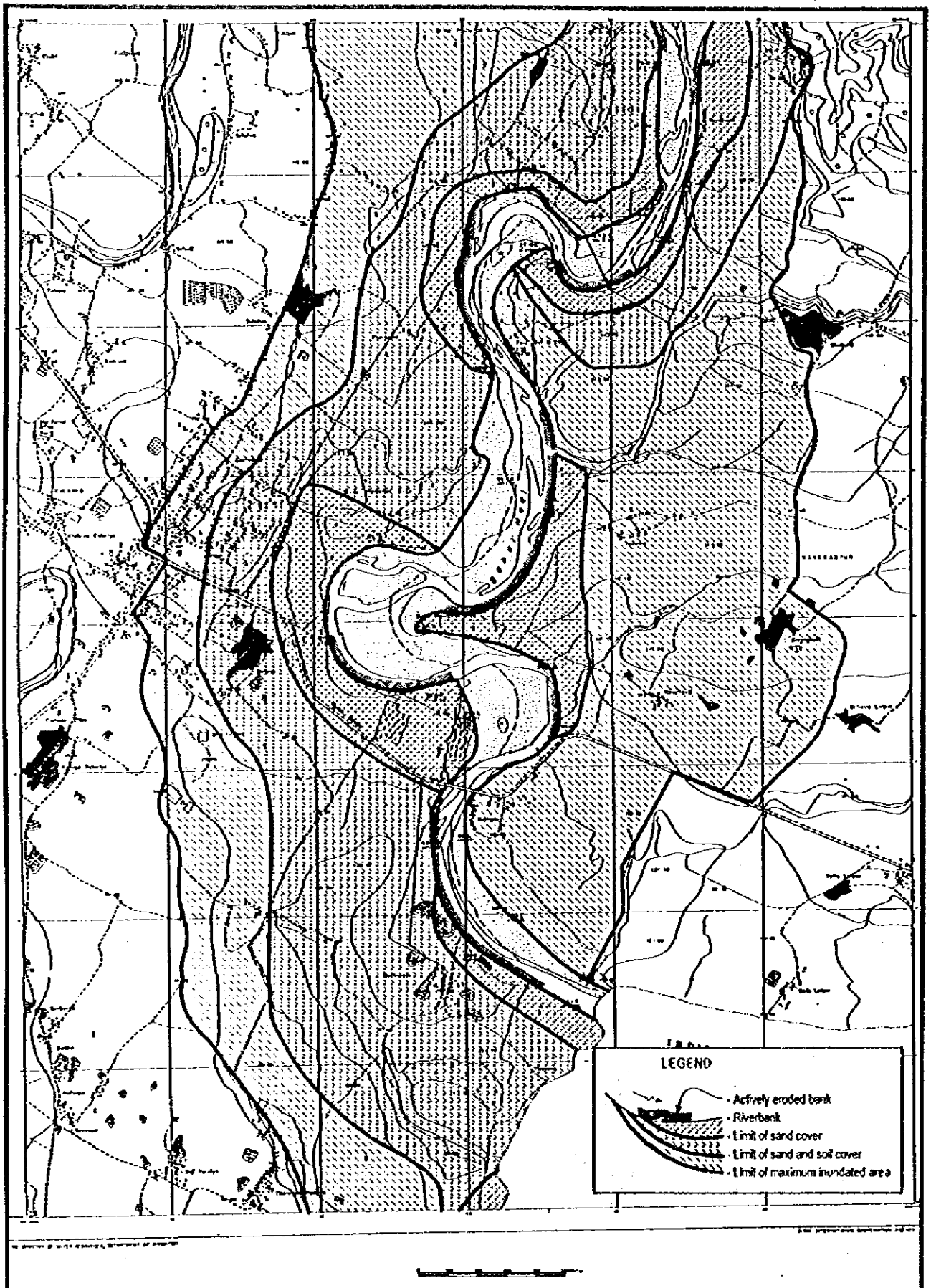


HAZARD MAP
Babai River 1995 Flood (5/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

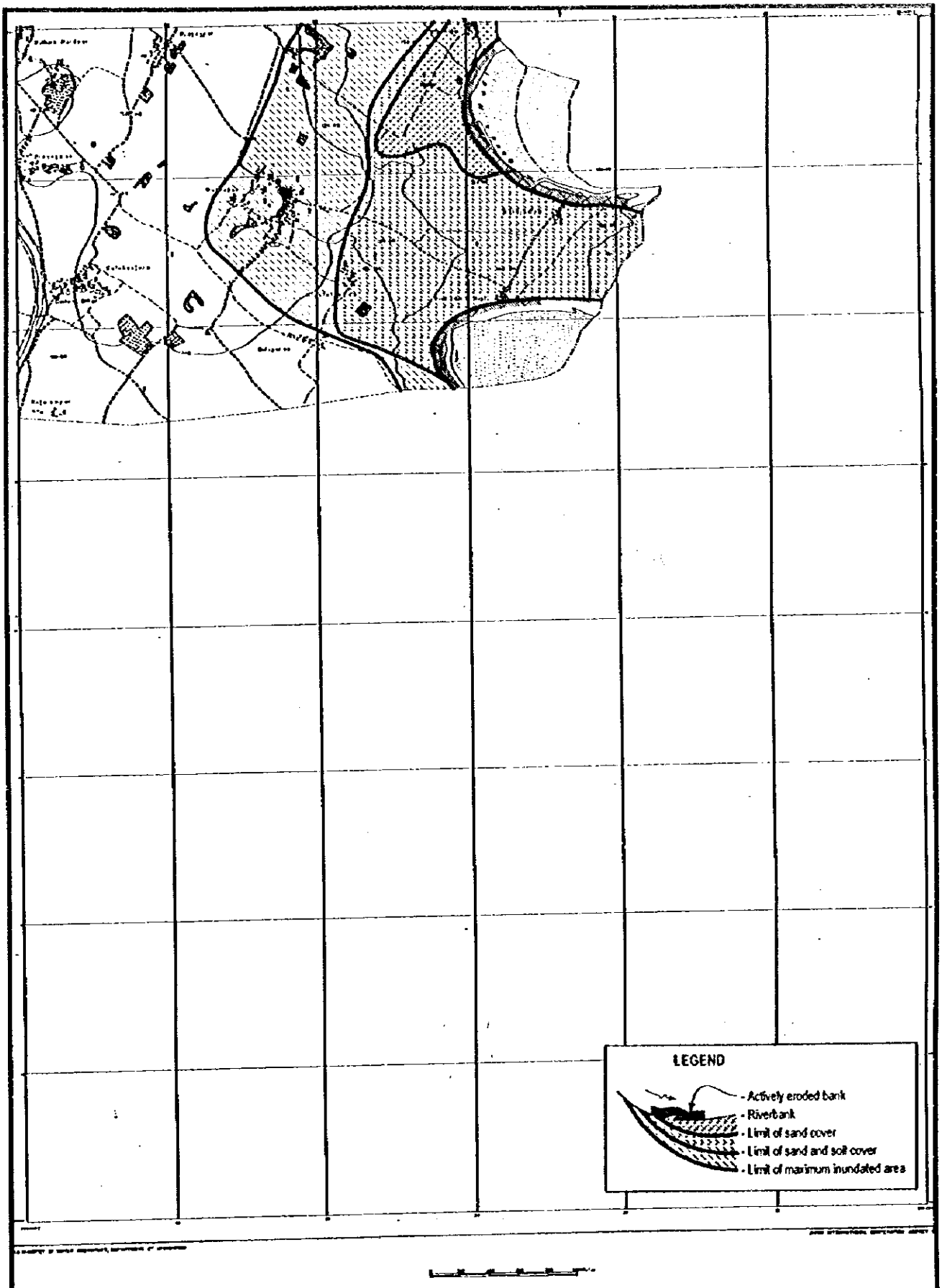


HAZARD MAP
Babai River 1995 Flood (6/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY

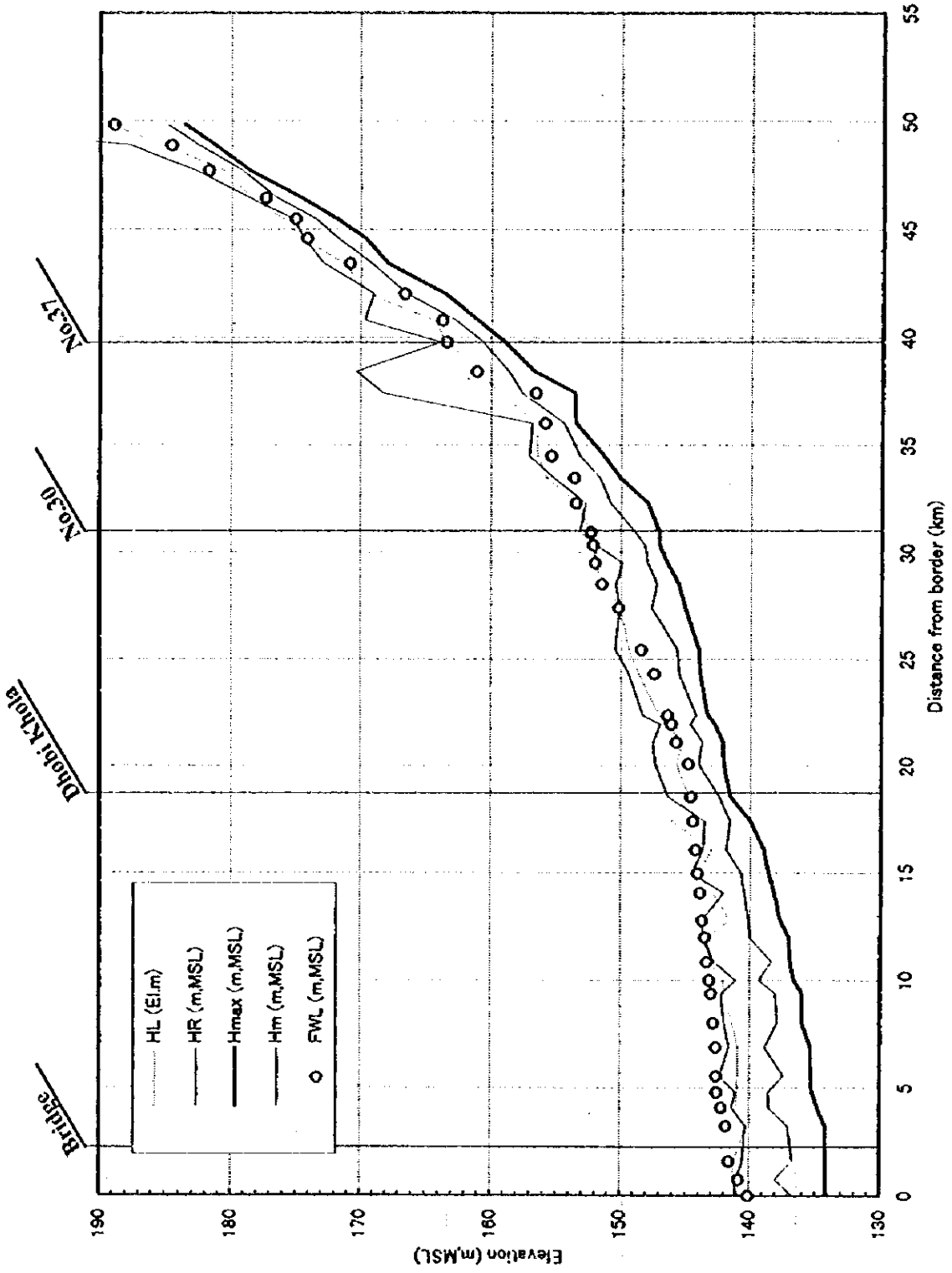


HAZARD MAP
Babai River 1995 Flood (7/7)

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources

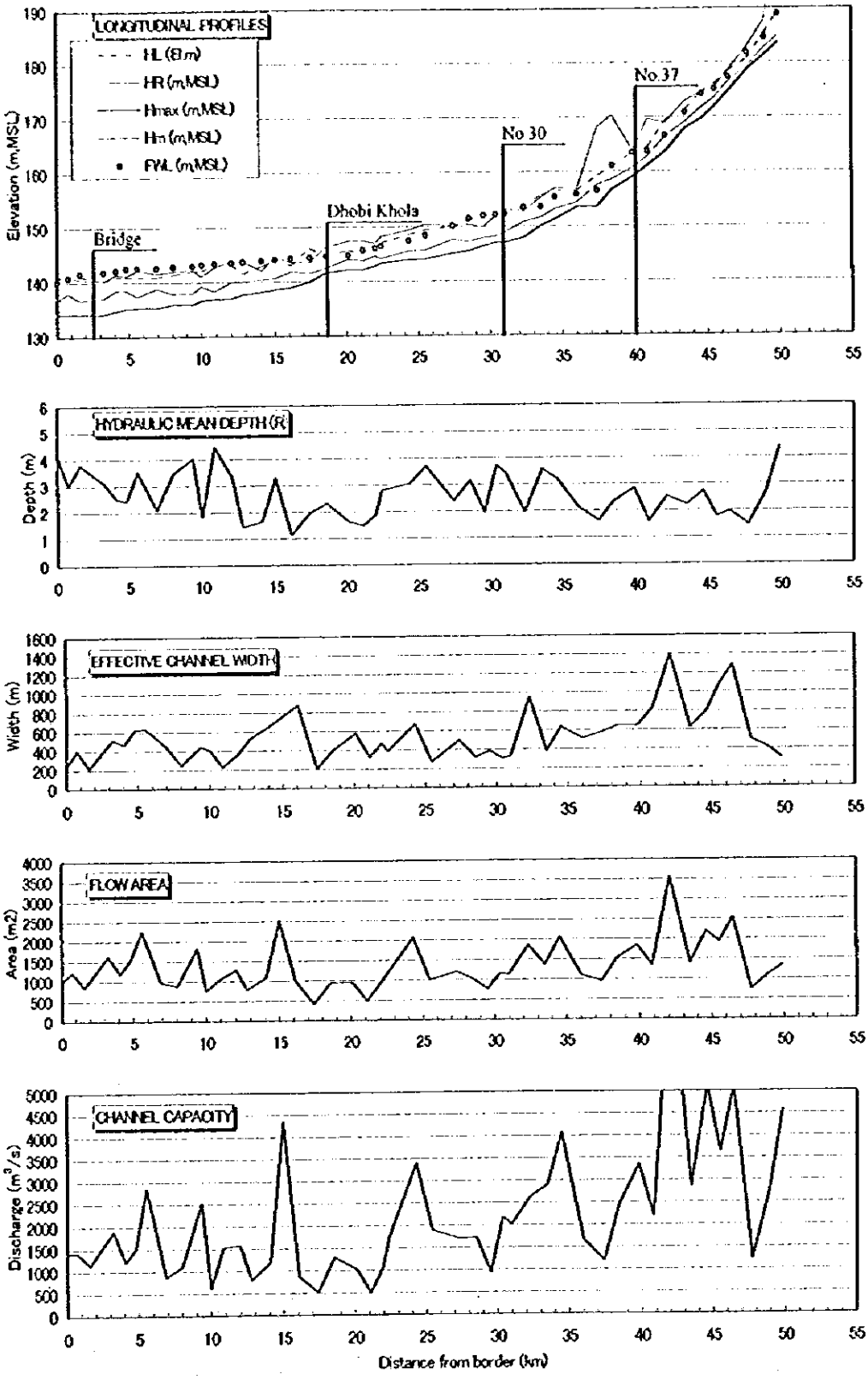
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY



LONGITUDINAL PROFILE OF BABAI RIVER

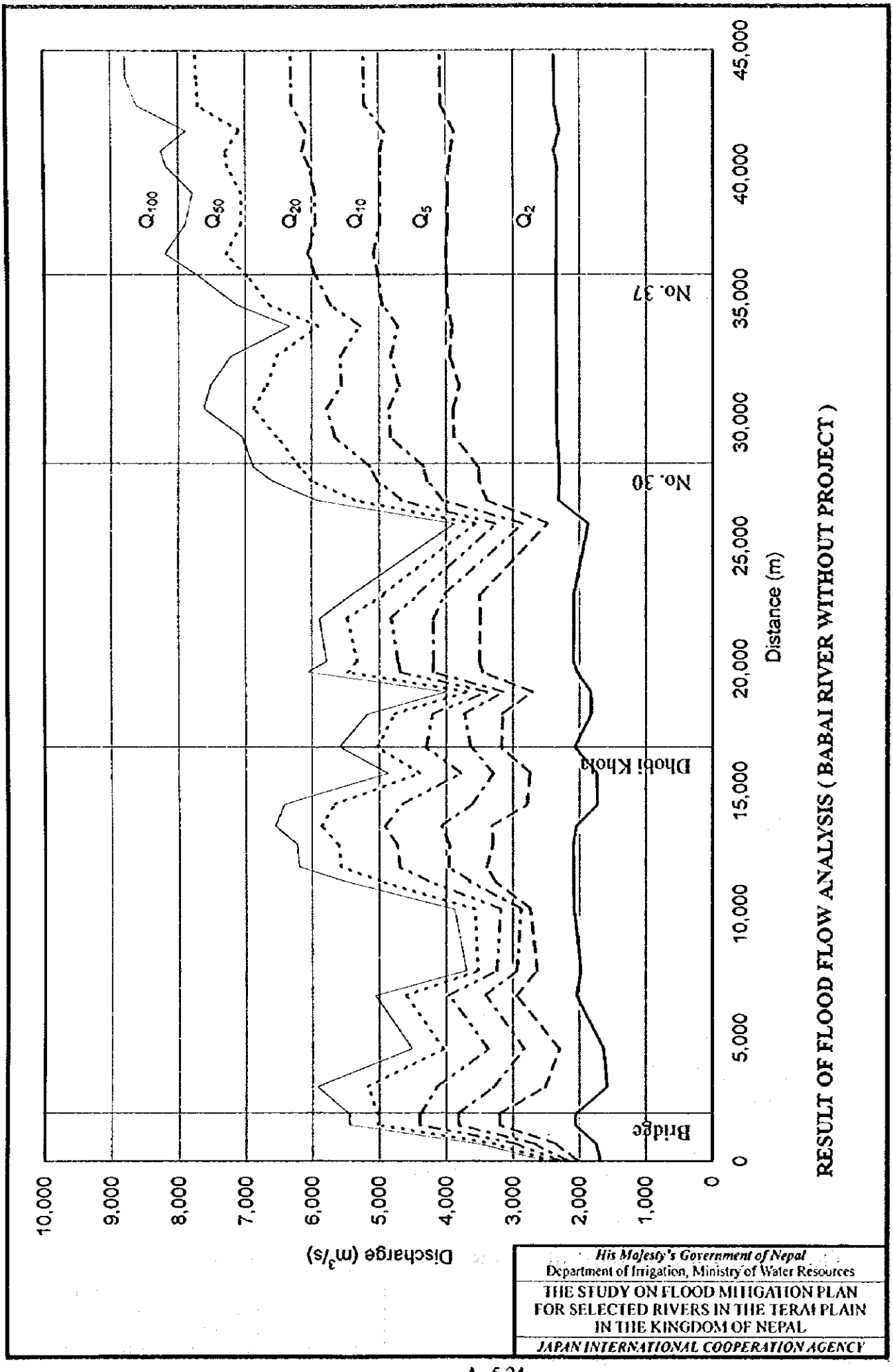
His Majesty's Government of Nepal Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY

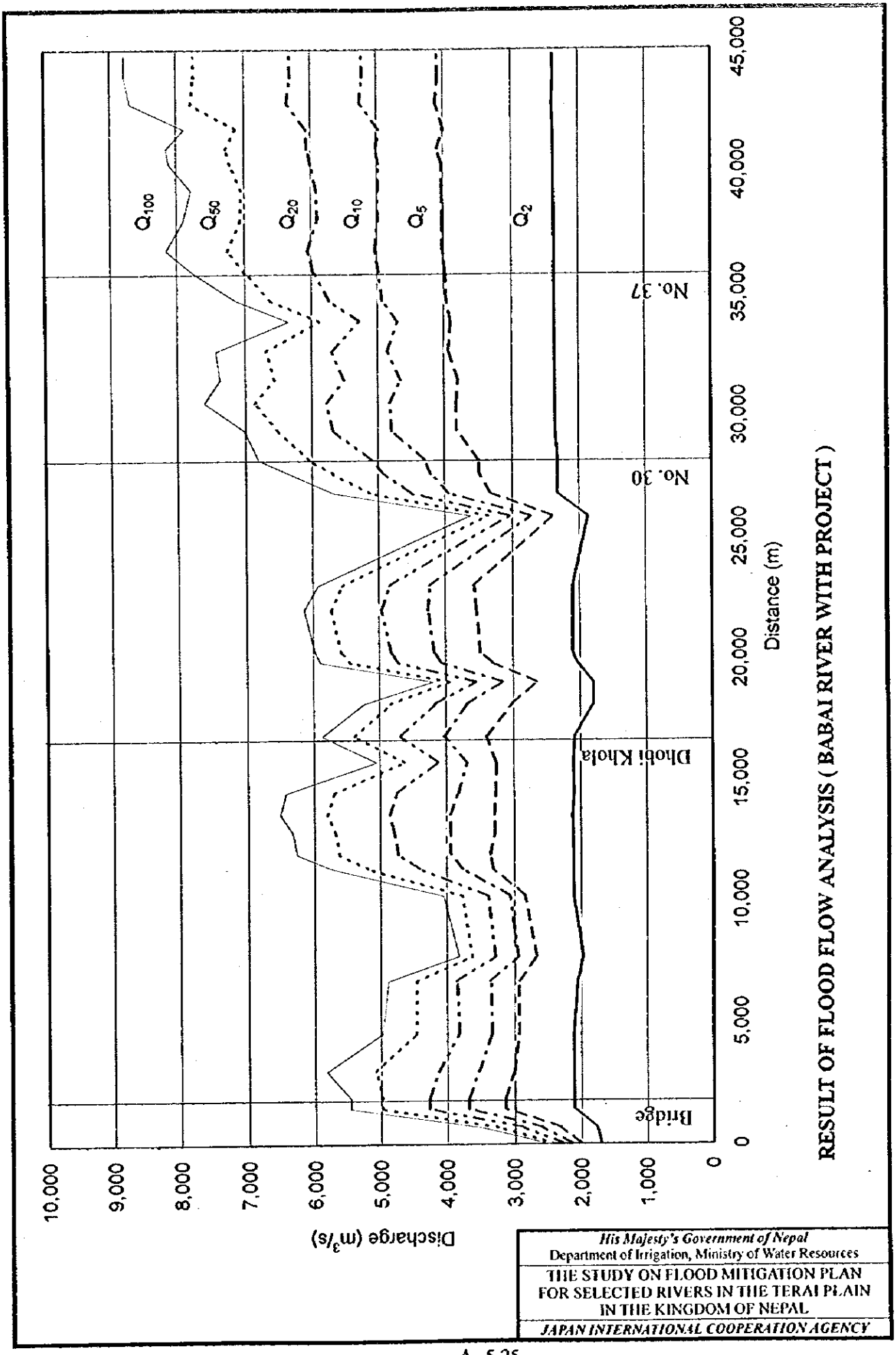


PRINCIPAL CHANNEL CHARACTERISTICS OF BABAI RIVER

His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. A5.4(1/2)


RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITHOUT PROJECT)
Discharge (m³/s)
Distance (m)
Bridge
Dhobi Khola
No. 30
No. 37
Q100
Q50
Q20
Q10
Q5
Q2
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN FOR SELECTED RIVERS IN THE TERAI PLAIN IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY


RESULT OF FLOOD FLOW ANALYSIS (BABAI RIVER WITH PROJECT)
Discharge (m³/s)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Distance (m)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Bridge
Dhobi Khola
No. 30
No. 37
Q100
Q50
Q20
Q10
Q5
Q2
His Majesty's Government of Nepal
Department of Irrigation, Ministry of Water Resources
THE STUDY ON FLOOD MITIGATION PLAN
FOR SELECTED RIVERS IN THE TERAI PLAIN
IN THE KINGDOM OF NEPAL
JAPAN INTERNATIONAL COOPERATION AGENCY