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VOLUME V

Flood and Drainage Problems of Bihar and Their Remedial Measures

(Part II)

सत्यमेव जयते

GOVT OF BIHAR

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ABBREVIATIONS

AE	Assistant Engineer
A/E	Anti Erosion
AIR	All India Radio
Av	Average
CADA	Command Area Development Agency
CD	Community Development
CE	Chief Engineer
cm	Centimetre
Cusec	Cubic feet per second
Cumec	Cubic metre per second
CWC	Central Water Commission
CWPRS	Central Water and Power Research Station
DCH	District Census Handbook
DL	Danger Level
Drg	Drawing
D/S	Downstream
DVC	Damodar Valley Corporation
EE	Executive Engineer
Fig	Figure
G	Gauge
GD	Gauge and Discharge
GDS	Gauge Discharge and Silt
GFCC	Ganga Flood Control Commission
GOB	Government of Bihar
GOI	Government of India

GW	Ground Water
GWP	Ground Water Potential
ha	Hectare
ham	Hectare metre
HFL	Highest Flood Level
HMG	His Majesty's Government
IMD	India Meteorological Department.
IRI	Irrigation Research Institute
ISI	Indian Standard Institution
JE	Junior Engineer
Jt secy	Joint Secretary
Km	Kilometre
KMPH	Kilometre per hour
L	Left
Lat	Latitude
Lt	Litre
Lha	Lakh Hectare
Long	Longitude
m	Metre
Max	Maximum
MCM	Million Cubic Metre
Misc	Miscellaneous
Min	Minimum
mm	Milli metre
MP	Madhya Pradesh
NA	Not Available
NE	North East

No	Number
NPK	Nitrogen Phosphate Potash
OMR	Operation Maintenance and Repair
PWD	Public Works Department
R/M	Repair and Maintenance
RM	River Management
Rs	Rupees
Res	Reservoir
R/S	Raising and Strengthening
RT & FC	River Training & Flood Control
R	Right
RBA	Rashtriya Barh Ayog
SDO	Sub Divisional Officer
SC	Scheduled Caste
Sch	Scheme
SE	Superintending Engineer
Sl	Serial
Sq Km	Square Kilometre
SRRG	Self Recording Rain Gauge
ST	Scheduled Tribe
SW	Surface Water
TOR	Term of Reference
Temp	Temperature
TAC	Technical Advisory Committee
TV	Television
U/S	Upstream
UK	United Kingdom

UP	Uttar Predesh
USA	United States of America
Vel	Velocity
WQ	Water Quality
WRD	Water Resources Department
WT	Wireless Transmission
WB	West Bengal
WALMI	Water and Land Management Institute
WMO	World Meteorological Organisation

AN APPROACH TO PROBLEMS OF FLOOD AND DRAINAGE CONGESTION AND REMEDIAL MEASURES IN BIHAR

(APPENDICES 6 TO 11)

APPENDIX 6

KOSI BASIN

AT A GLANCE

PLAN FOR FLOOD MANAGEMENT IN THE KOSI RIVER BASIN (IN BIHAR)

I	**Salient Features of the Basin**				
	1	Total Drainage Area		74,030	Sq Km
	2	Drainage Area in Bihar		11,410	Sq Km
	3	Population in Bihar		66.55	Lakh
	4	Water Resources - (Surface water)			
		Nepal	47065	52219	MCM
		Bihar	5154		
	5	Average Annual Rainfall (in Bihar)		1456	mm
	6	Total Length of Main River (in Bihar)		260	Km
	7	Cropped Area In Bihar		8,694	Sq Km
II	**Flood Damage (Average for 25 Years 1968 - 92)**				
	1	Total Area Affected		2.98	Lha
	2	Cropped Area Affected		1.11	Lha
	3	Damage to Crops		Rs 3188	Lakh
	4	Total Damage		Rs 4430	Lakh
	5	Human Lives Lost		19	Nos
	6	Cattle Heads Lost		332	Nos
	7	Average population Affected (Average of 1980-92)		13.454	Lakh
III	**Progress of Flood Protection Measures (1954-92)**				
	1	Length of Embankments		467.60	Km
	2	Area Protected		8.20	Lha
IV	**Eighth Plan Proposal (1992-97)**				
	1	Length of Embankment	Total	98	km in the State
	2	Additional Area to be benefited by Flood Control, Drainage and Anti Waterlogging Measures	Total	1.00	Lha in the State
	3	Total Outlay for Flood Control Measures in the State (1992-97)		Rs 35230	Lakh

AN APPROACH TO THE PROBLEMS OF FLOOD AND DRAINAGE CONGESTION & REMEDIAL MEASURES IN THE KOSI RIVER BASIN (IN BIHAR)

1 INTRODUCTION

1.1 The Ganga sub basin is an important portion of the main Brahmputra-Meghna-Ganga river basin and is the largest river system extending over an area of 8.614 Lakh Sq Km - within India. Due to high intensity of rainfall and poor drainage conditions in a large part of the sub-basin as well as flat terrain in the lower portion, there is a recurrent flooding and drainage congestion problem almost every year. The flood damage in this sub-basin accounts for a major part (about 53 per cent) of the total flood damage of the country.

1.2 Bihar is situated in the central part of the Ganga sub-basin. The portion lying on the northern side of the left bank is known as North Bihar and that lying on the southern side of the right bank is known as South Bihar. The lower part of northern region of this State is affected by serious flooding almost every year. A number of major rivers of the Ganga on its left bank like the Mahananda, the Kosi, the Kamla Balan, the Bagmati, the Gandak, the Ghaghra etc which originate from the Himalayas join the river Ganga in this region.

1.3 These rivers flow through a considerable length in Nepal and a large part of their catchment falls in the glacial regions of the great Himalayas. These rivers are snowfed and hence perennial. The river Kosi, originating from Tibet and crossing Nepal, joins the river Ganga near Kursela in Katihar district,and has a total catchment area of 74,030 sq km of which 85 per cent lies outside Bihar and only 15 per cent lies within it, excluding catchment areas of its two major right bank tributaries namely, the Bagmati river and the Kamla-Balan river.

1.4 Floods and droughts are regular features in the state of Bihar due to the vagaries of climate and rainfall. While one part of the state is under the grip of severe floods due to excessive rainfall, the other part suffers from drought due to poor rainfall.

1.5 Floods have caused devastation and acute human suffering too frequently since the dawn of civilization and man has had to live with floods since his existence. The impact of floods was not perhaps felt to the same extent in the past as is felt now. This was due to the fact that a much smaller number of people were living then and pressure of industrial activities and other development works in the flood plains was far less compared to the present-day activities. The flood problem has been accentuated due to ever-increasing encroachments on the flood plains by the growing population to meet its requirements of food and fibre. The destruction of forests for reclaiming land for occupation and for obtaining fuel for domestic consumption have also caused changes in the river regime. All these have resulted in an anomalous situation where, inspite of protection measures carried out so far in the State with an investment of Rs 611 crores (approx) and Rs 28.34 Lakh ha having been afforded reasonable degree of protection, the flood damages have gone on increasing instead of decreasing.

2 THE KOSI RIVER SYSTEM

2.1 The river Kosi originates at an altitude of over 7,000 m above MSL in the Himalayas and the river system lies between 85° and 89° E Longitude and 25° 20' & 29° N Latitude. The upper catchment of the river system lies in Nepal and Tibet in the hilly reaches of great heights of the Himalayan range. The highest peak in the world, the Mount Everest and the Kanchenjunga are in the Kosi catchment. The Kosi, after it debouches into the plains, is the third biggest Himalayan river, being next only to the Indus and the Brahmaputra. It is one of the ancient rivers of India and has its mention in the old literature as 'Kaushika'. It is known as 'Sapta Kosi' in Nepal because its seven tributaries the Sun Kosi, the Bhotia Kosi, the Tamba Kosi, the Budh Kosi, the Barun Kosi, the Arun Kosi, and the Tamur Kosi meet above Tribeni (about 10 Km upstream of Chatra). But for all practical purposes, the confluence at Tribeni in Nepal is considered to be formed by the three major tributaries out of the seven, the Arun from north, the Sun Kosi from West, and the Tamur Kosi from east. The Arun, the longest of these tributaries passes through Tibet, named there as Phung Chu, drains the highest peak of the world, ie Mount Everest. The Tamur drains the second highest peak, the Kanchanjunga and the Sun Kosi drains the eastern Kathmandu valley in Nepal. Below the confluence at Tribeni, the river Kosi flows in a narrow gorge for a length of about 10 Km till it debouches into the plains near Chatra in Nepal. From here the river runs in relatively flat plains of the terai region of Nepal consisting of sandy soil. After flowing through the Nepal territory for 50 Km below Chatra, the Kosi river enters the Indian territory near Hanuman Nagar in Nepal. Below Chatra, the river divides itself into several channels spread over a width of 6 to 16 Km east to west and flows in south-west direction upto Galpaharia in Nepal. Below this point the river flows almost straight in south-west direction upto Mahesi near Supaul to a distance of 100 Km after entering into India near Bhimnagar. Here it is worth mentioning that Kosi has been notorious for its meandering behaviour, having its movements from east to west. It is Known to have changed its course across a width of about 112 Km in its lower portion in India in a period of about 250 years. This meandering behaviour of the Kosi has rendered, about 1,295 Sq Km of land in Nepal and about 7,770 Sq Km in Bihar useless as a result of sand deposition. In the course of shifting it has wiped-out many towns and villages inflicting heavy losses of human, cattle life and property. Below Mahesi the river starts taking turn to south and south-east direction passing through Dhemraghat in a single defined channel. Subsequently it flows in the easterly direction and joins the Ganga finally near Kursela in Katihar district.

2.2 The river Kosi drains a total catchment area of 74,030 Sq Km in India and other countries, excluding catchment areas of its two major tributaries on right bank, namely, the Bagmati river having catchment area of 14,384 Sq Km and the Kamla-Balan with 7,232 Sq Km. Out of the total catchment area of the Kosi only 11,410 Sq Km lies in India and the rest 62,620 Sq Km lies in Tibet and Nepal. At the confluence of its three main tributaries the Sun Kosi, the Arun Kosi and the Tamur in Nepal at Tribeni, the areas drained by them are 19,000 Sq Km, 34,650 Sq Km and 5,900 Sq Km respectively giving a total area of 59,550 Sq Km. About 5,700 Sq Km portion of the catchment in Nepal and Tibet lies in the glacial region of the Himalayas. It is a snowfed river and hence perennial. The catchment area upto Bhimnagar (in Saharsa district of Bihar) is hilly and the rest in India forms part of the Gangetic plains.

2.3 The Kosi river system is bounded by the ridge of the Himalayas in the north separating it from the Brahmputra river system, the Mahananda in the east, the Gandak/Burhi Gandak in the west and the main Ganga stem in the south. The area within India is almost flat and lies in the Gangetic plains. The vast plain, on which the Kosi delta has been formed, has a general slope from north to south and west to east, being steeper in the north and flatter in the south. In the north, the slope is 56-75 cm per Km but it is 6 cm per Km beyond Bhaluahi in India. Thus, the entire lower catchment is nearly a level country which is split into numerous 'Dhars' in the old beds of the Kosi river. There are undulations and innumerable depressions called "Chaurs", where water remains accumulated for most part of the year. The average bed slope of the river in different reaches is indicated below:

Table No 1

Average Bed Slope of the River Kosi in Different Reaches

Sl No	Reach	Average bed slope
1	0 Km to 42 Km	1.4 m/Km
2	42 Km to 68 Km	0.716 m/Km
3	68 Km to 134 Km	0.45 m/Km
4	134 Km to 310 Km	0.11 m/Km

Geographically, the entire Indian portion of the Kosi river system falls in the state of Bihar only.

2.4 The main Kosi river catchment falling within the Indian territory is distributed under several districts of Bihar, namely, Madhubani, Darbhanga, Saharsha,Supaul, Madhepura, Araria, Purnia, Katihar, Bhagalpur and Khagaria. The important places of Bihar falling in the drainage area of the river Kosi are Birpur, Supaul, Nirmali, Saharsa, Madhepura, Purnia, Murliganj, Kursela etc. On the left bank of the river Kosi the districts of Saharsa, Madhepura and Purnia and on the right bank Katihar, Madhubani, Darbhanga, and Khagaria are flood prone areas. The important commercial centres are Nirmali, Saharsa, Supaul, Madhepura, Gulab bag (Purnia), Forbesganj, etc.

2.5 Details of different rivers of the Kosi drainage basin in India are given below -

Table No 2

Sl No	River or Dhar	Bank Left (L) or Right (R)	Origin	Outfall	River condition
1	Bagmati	R	Shivpuri range of hills in Nepal at elevation 1500 m	Near Bang village on the border of Samastipur and Saharsa district in Bihar.	
2	Kamla-Balan	R	Mahabharat range of hills	River Bagmati near Badlaghat village in Khagaria district.	
3	Bhutahi Balan	R			
4	Trijuga	R	Foot hills of Himalayas	Below village Galpaharia in Nepal.	
5	Fariani dhar	L		Between Koparia and Kursela.	Drainage channel silted up
6	Dhemra dhar	L		,,	These are the old and abandoned courses of the river Kosi now serving as drainage channels
7	Pakilpar	L		,,	
8	Hareli dhar	L		,,	
9	Basanwara dhar	L		,,	
10	Kashnagar dhar	L		,,	
11	Sapni dhar	L		,,	
12	Beldaur dhar	L		,,	
13	Chausa dhar	L		,,	
14	Gaidhar	L		,,	

This report has been limited to the main Kosi river system only. The other two river systems, ie the Kamla-Balan and the Bagmati are being dealt with separately as individual river system because of their distinct identity, individual problems and the considerable expanse of the catchment of these rivers.

2.6 The Kosi river basin in India lies in the Gangetic plains which has been built up in the process of land formation. The rivers originating from the Himalayas and falling into Ganga have played a major role in such a land formation process. The sediment brought by them formed inland deltas where the steep slope of the terai converged into the flat slope of the plains. This resulted in the meandering and braiding tendencies in the rivers leading to shifting of their courses. Such changes in the river course and avulsions/cut-offs of the meander loops formed local depressions known as 'Mauns'. The Kosi river basin has numerous gullies and ridges and also saucer type natural depressions locally known as 'Chaurs'. The outfall conditions of the leading trunk drains have degraded due to non-functioning of sluices in the Kosi embankments as also the rise in the river bed near the embankments substantially (more than 1 m above the country side G L) due to heavy deposition of silt. The southern portion of the basin, however, is fairly level and without much undulation.

2.7 SOCIO-ECONOMIC ASPECTS

2.7.1 The total population in the Kosi river system within India as per 1991 census is about 66.55 Lakh which is likely to cross 83 Lakh by the end of 2000 AD. The density of population in the basin in India, ie in Bihar is nearly 583 persons per Sq Km. About 90 per cent of the population live in rural areas and only 10 per cent in the urban areas. Nearly 85 per cent of the population constitute the work force engaged in agriculture.

(Computed on the basis of the data obtained from Directorate of Statistics & Evaluation, Government of Bihar.)

2.7.2 There are a good number of small-scale industries located in this river system. Two jute mills and a flour mill at Katihar and few rice mills in Darbhanga district can be counted as the few medium scale industries in the basin. However, outside India, Biratnagar in Nepal is developing into a major industrial complex. There is ample scope for developing agro-based industries in the basin in Bihar.

2.7.3 The important highways, railways and aerodromes in the river system are indicated below -

<u>Highways</u>

1 Birpur - Bihpur road
2 Purnea - Murliganj - Madhepura - Saharsa - Mahesi road
3 Purnea - Dhamdaha - Rupauli - Bijayghat road
4 Purnea - Korha - Kursela road (NH 31)
5 Katihar - Korha - Falka road
6 Pratapganj - Narpatganj - Forbesganj road
7 Supaul - Pipra - Tribeniganj - Jadia road
8 Jogbani - Forbesganj - Araria - Purnia road
9 Kursela - Mirganj - Sarsi - Raniganj - road.

<u>Railway - (North -Eastern Railways)</u>

1 Purnea - Murliganj - Mahhepura - Saharsa section
2 Supaul - Saharsa - Mansi section
3 Supaul - Narpatganj - Forbesganj section
4 Banmankhi - Bihariganj section
5 Katihar - Barauni section
6 Katihar - Purnia - Jogbani section (North East Frontier Railway)

Aerodromes

1 Saharsa

2 Birpur

3 Purnea

2.7.4 Irrigation canals taking off from both sides of the Kosi barrage at Bhimnagar namely the Eastern Kosi Canal and the Western Kosi Canal and the Chatra Canal taking off from Chatra in Nepal are spread over in the terai and plain areas of this basin both in India and Nepal. These canals provide irrigation facilities in both Nepal and India, except below unconstructed portion (29.69 Km out of total 208.7 Km) of the Western Kosi canal system, which is still under construction. The CCA of Eastern and Western Main canals are 4,94,948 ha and 1,62,689 ha respectively. The salient features of the Kosi Irrigation project is enclosed at Annex - 10. There is a hydel power station at the 5th Km (14 RD) of the Eastern Kosi Main Canal in India with an installed capacity of 20 MW. People of the basin are benefited from this.

2.7.5 Almost all the cities and towns located in the Kosi river basin in India,namely, Birpur, Nirmali, Saharsa, Supaul, Madhepura, Forbesganj, Banmankhi, Jogbani, etc, get their domestic water supply from the ground water potential of the basin.

2.8 The land use pattern in the Kosi river basin in India is reported to be as follows -

Sl No	Category		Area in Sq Km	Per cent of total area
1	Forest land		32.97	0.30
2	Land under miscellaneous trees & groves		343.32	3.01
3	Current fallow Other fallow Culturable waste	900.52 317.53 70.86	1288.91	11.30
4	Net area under cultivation		7092.09	62.15
5	Barren land and permanent pastures		792.57	6.94
6	Area under non-agricultural use		1860.33	16.30
	Total		11410.19	100.00

	Area under cultivation	Existing	Proposed in the project
a	Bhadai	14.09 % of CCA	12 %
b	Jute	57.66 % of CCA	15 %
c	Sugarcane	21.54 % of CCA	3 %
d	Agahni paddy	0.09 % of CCA	65 %
e	Rabi	9.46 % of CCA	20 %
	Total	102.84	115

The principal crops are, Paddy, Maize, Jute, Sugarcane, Wheat, Gram and other Rabi crops.

[Note : A map showing the Kosi River Basin is enclosed as Drawing No 6/01]

3.0 GEOLOGY

3.1 As already stated earlier, the catchment of the Kosi river system is a part of the Indo-Gangetic plains, the large part of which falls in the Nepal and Tibet Sub-Himalayan hill range. The geology of the Mount Everest and Kanchenjanga regions in Tibet and Nepal represents the geology of the upper catchment of the Kosi, whereas thick alluvial deposits of the Gangetic alluvial plains in India represents the geology of the lower catchment.

In Mount Everest region a broad zone of folded Jurassic strata composed of black shales and argillaceous sand stones lie which enclose a well- preserved ammonite shell or some other fossil as nucleus. The whole group of rocks is soft and fragile and has received a great amount of crushing and compression. Immediately underlying there is a layer of dark grey limestone, dipping northwards, about 300 m thick, followed by an yellow slabby schistose limestone 300 m thick, which together form the actual summit of the Mount Everest. The thick zone of rocks below the Mount Everest limestone consist of slaty rocks with limestone bunds carboniferous, 1220 m thick, underlain by metamorphosed foliated slates and schists. The composition of the Siwalik deposits shows that they are nothing else than the alluvial detritus derived from the subacrial waste of the mountains swept down by their numerous rivers and streams and deposited at their foot. The weathering of the Siwalik rocks has been proceeding at an extra-ordinary rapid rate since their deposition, and abrupt forms of topography have been evolved in the course of time.

The terraces below Chatra comprise clay, sand and gravels. The hills at the flank comprise conglomerates and thick beds of sand, rock and shales. Lower down in the Kosi flood plain, there is thick alluvial deposit, being a part of the Gangetic alluvial plain.

The geology of the Kosi catchment, by and large, is unstable in nature and susceptible to heavy wear and tear which ultimately increases sediment load in the flow of the river.

3.2 The drainage basin of the Kosi on the basis of soil characteristics, can be divided into three zones:

i Upper catchment zone

ii Mid area zone

iii Lower reach zone

i Upper Catchment Zone- The upper catchment of the Kosi basin lies totally in mountainous region. The soils of this region are usually of three types, namely, (a) Mountain Meadow Soil, (b) Sub Mountain Soil and (c) Brown Hill Soil.

a Mountain Meadow Soil - These are found at the elevation of 3700 m in Himalayan region having different texture and structure with grass vegetation cover acting as binding material. Wherever such soil thickness is limited to 7 to 15 m, they are so much erosive in nature that even the wind can remove the soil and expose the rock surface.

b Sub Mountain Soil - These types of soils are found in the Sub- Himalayan region under forest vegetation of the coniferous type. These soils are generally siliceious in nature having pH value on the acidic side.

c Brown Hill Soil - These types of soil are found in hilly region and under moderately heavy vegetation. They are composed of compact grey and dark drown clay loam having p_H value between 6 to 6.5 on slightly acidic side.

ii Mid area Zone - The Mid area zone comprises the area between the mountaineous and plain portions of the catchment at the foothills of the Himalaya, also known as terai region, which basically lies in Nepal. These terai regions have excessive growth of vegetation and weeds on account of excessive moisture content.

iii Lower reach zone - Lower reach zone of the Kosi basin in the plains comprises large inland delta formed by the huge sandy deposit of the Kosi river. On account of heavy siltation of the order of 25 million cubic metre of sand/silt per year and thereby in the process of building up the delta as already stated the river Kosi has shifted over 112 Kms from east to west in a span of 250 years prior to the construction of flood embankments. A short description of soil characteristics in the different districts of the Kosi river system is given below :-

Darbhanga, Madhubani :- The soils of these districts falling within Kosi basin consist of sandy loam and clay. Some area to the west and east of Madhubani district consists of heavy clay and clayey soil, while to the extreme north-east and north west there are patches of sandy clay with saltpetre etc. All over the area in these district patches of 'Usar' land, which are unproductive due to salt effervescene, are found.

Saharsa :- In this district mainly sandy soil is found, except a few places in south of this district where sandy loam soil is found on account of recurrent flooding by the river Ghughri carrying combined discharges of the Kamla Balan, the Bagmati and the Kosi.

Khagaria :- The areas of this district which are flooded by the Ganga comprise loamy soil and those areas flooded by the river Ghughri comprise marshy swamp of clay and loam.

Purnia :- The central and western portion of this district comprises sandy soil whereas the eastern part falling within Mahananda has loamy soil.

4.0 HYDROLOGY

The Kosi drainage basin in India forms part of the Gangetic plains and is situated in the direct path of the tropical depressions which form in the Bay of Bengal during the monsoon season and travel in a north - westerly direction. As such, 85 per cent of the annual rainfall occurs in the monsoon period of June to October. The intensity decreases from east to west and from north to south. It is, therefore, the catchment in Nepal which contributes a major portion of the runoff in the Kosi river.

4.2 According to the norms laid down by the Bureau of Indian standards (IS 4987), one raingauge for drainage area upto 520 Sq Km in plains is sufficient. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser, particularly in the upstream. In not-too-elevated a region, ie, with average elevation one kilometre above sea level, the required network density is one raingauge station for every 260 to 390 Sq Km area. The IMD has, however, prescribed at least one raingauge station for every 500 Sq Km of the drainage area. It also specifies that at least 10 per cent of such raingauge stations should be self-recording. This has to be increased to 20 per cent, as recommended by the Rastriya Barh Ayog (RBA).

4.3 According to the norms laid down by the World Meteorological Organisation (WMO) the following densities are required :

Table No 3

Sl No	Type of terrain	Density required (one station for)	
		Ideal	Acceptable
1	Flat regions of temperate Mediterranean and tropical zones	600 - 900 Sq Km	900 - 3000 Sq Km
2	Mountainous regions of temperate, Mediterranean and tropical zones	100 - 250 Sq Km	250 - 1000 Sq Km
3	Arid and Polar zones	1500 -10,000 Sq Km	depending on the feasibility

10 per cent of the raingauge stations are required to be self recording to know the spatial and temporal distribution of rainfall in the area, which, however, has to be increased to 20 per cent as per the recommendations of the RBA.

4.4 According to the norms of the IMD, a total of 145 raingauge stations is considered necessary in the drainage area of the river Kosi, of which 25 such stations are required in the lower catchment in India. Against this requirement, there are 35 raingauge stations in India for which data for reasonable period are available. The number of raingauge stations maintained in the portion of the catchment in Nepal and Tibet is only 48 as against the requirement of 120. It indicates that while the number of raingauge stations in the plains is more than adequate, the hilly catchment is not satisfactorily covered.

4.5 The above facts clearly establish the necessity of installing more raingauge stations in the catchment of the river Kosi in Nepal and Tibet with adequate numbers of self recording raingauges amongst them in the light of recommendation of the RBA so that reliable rainfall data are available for a sufficiently longer period for detailed hydrological studies of the Kosi river. This also necessitates an understanding of the HMG, Nepal and Government of People's Republic of China with the Government of India for regular exchange of such available data/information.

4.6 RAINFALL

4.6.1 Rainfall data of 41 raingauge stations in the upper catchment (Nepal portion) for the period 1948 to 1960 and 26 raingauge stations in the lower catchment (India portion) for the period 1951 to 1970 maintained by IMD had been collected and analysed by the GFCC while preparing a comprehensive plan of flood management of the Kosi river system in 1986. The GFCC was not able to get any rainfall data beyond 1970 from the IMD. However, rainfall data for 26 raingauge stations in the lower catchment (India portion) for the period 1974 to 1987 from the Hydrology Cell of the Water Resources Department, Government of Bihar and Districtwise annual rainfall data for the period 1979 to 1985 from Directorate of Statistics, GOB have been made available to this commission.The rainfall data made available are enclosed at Annex 1B. In spite of the serious efforts made the data for the missing year 1971 to 1973 could not be obtained.

4.6.2 The mean annual rainfall in the whole catchment varies from 1589 mm in the upper portion of the river system to 1323 mm in the lower part. The maximum value of 24 hours rainfall in the lower catchment during 1951 to 1970 and again during 1974 to 1987 is in the range of 118 mm to 406 mm in the Indian side and 180 mm on the Nepal side at Barahkshetra.

The rainfall data made available are enclosed at Annex 1A.

4.7 GAUGE AND DISCHARGE

4.7.1 According to the norms prescribed by the WMO, one gauge-discharge site is required for every 300 Sq Km of the drainage area in the hilly portion and for every 1000-2500 Sq Km in the plains. Accordingly, 224 gauge discharge sites are necessary in the basin, 213 in the upper catchment area in Nepal and Tibet and 11 in the lower part in India. Against this, 22 gauge-discharge sites and 3 gauge sites, ie, altogether 25 observation sites are located in the Indian portion of the Kosi basin as listed below :

Table No 4

List of G-D Sites Located in India Portion

Sl No	Name of site	Name of stream	Maintained by	Observation Site for
1	Trimohan	Kosi	WRD	Gauge only
2	Chausa	Sapandhar	,,	Gauge-Discharge
3	Chandpur	Fariyani	,,	,,
4	Koskipur	,,	,,	,,
5	Dumar	Barandi	,,	,,
6	Koparia	Kosi	,,	,,
7	Dumariaghat	,,	,,	,,
8	Kurselaghat	,,	,,	,,
9	Banmankhi (1)	Fariyani	,,	,,
10	Raniganj	,,	,,	,,
11	Madhepura East Gumti	,,	,,	
12	Madhepura West Bhirkidhar	,,	,,	
13	Sonbarsa	Maindhar	,,	,,
14	Durgapur	Kari Kosi	,,	,,
15	Harda	,,	,,	,,
16	Mushahari	Boro	,,	,,
17	Jarlahi	Barandi	,,	,,
18	Baghmara	Kosi	,,	,,
19	Birpur (1)	,,	,,	,,
20	Birpur (2)	,,	CWC	Gauge only
21	Basua	,,	,,	Gauge Discharge (seasonal site)
22	Baltara	,,	,,	Gauge-Discharge & Silt
23	Kursela	,,	,,	Gauge only
24	Pipra	old Kosi	,,	Gauge-Discharge-silt
25	Banmankhi (2)	Fariyani	,,	,,

Source: Water Year Book - 1990 by State Hydrology Cell of the Water Resources Department, Government of Bihar, Sept 1992.

The information given in the above table indicates that out of 25 sites only three sites namely at Baltara, Pipra and Banmankhi, maintained by the CWC have facility for silt load observation. The list of stations, as mentioned in the Water Year Book : 1990 does not indicate as to how many stations are actually in operation and data for the same are being collected.

However, in the upper catchment of the river on the Nepal side altogether six observation sites have been installed by the CWC, of which excluding the Barahkshetra site, the rest of the five sites have been installed recently in 1991 and are to be maintained by the Nepal Government under an agreement reached between Government of India and HMG, Nepal. The status of all observation sites in Nepal is as indicated below:-

Table No 4 B

List of G-D Sites Located in Nepal Portion

Sl No	Name of site	Name of stream	Maintained by	Observation site for	Additional to be made for
1	Barahkshetra	Kosi	CWC	Gauge-discharge	
2	Pachuwar Ghat	Sun-Kosi	HMG Nepal	,,	
3	Toksel Ghat	,,	,,	Gauge-only	Discharge
4	Balua Bazar	Dudh Kosi	,,	Gauge-discharge	
5	Turki Ghat	Arun	,,	,,	
6	Majhitar	Tamur	,,	,,	

Source : CWC, Patna Division No 4, Rajendera Nagar, Patna.

It is reported that one more G-D site at Angba Ghat on the river Tamur is likely to be installed by the CWC very soon.

4.7.2 The maximum and minimum discharges observed at the Barahkshetra and Baltara sites on the river Kosi for the period mentioned are as follows :

Table No 5

Sl No	Location	Period of Data	Peak Discharges in cumecs				
			Maximum	Year	Minm.	Year	Average
1	Barahkshetra	1947-1992	25,856	1968	5,420	1953	12,239
2	Baltara	1957-1982	12,043	1974	4,368	1957	7,483

Source : As per comprehensive plan of Kosi prepared by GFCC, 1986 and Report by CE Birpur 1993.

4.7.3 From the data/information contained in Para 4.7.1, it is apparent that the number of gauge-discharge sites in the upper catchment of the river Kosi on the Nepal side is much less than the actual requirement. For a fairly reliable hydrological analysis for assessment of water resources, data for a reasonably longer period and for required number of locations are essential. Although the number of gauge-discharge sites in the lower catchment on India side is more than the minimum requirement, data for most of the stations could not be obtained, except for a few stations for a limited period, in spite of efforts made by this Commission.

It has been reported that five more sites at suitable locations in Nepal have been installed by the CWC, which, of course is likely to improve the situation to some extent.

4.8 RUNOFF FACTOR

4.8.1 Finding out the run-off factor of the catchment is essential to know the runoff likely to result from short duration heavy rains. In order to find out the total run-off during the monsoon period for planning schemes for drainage of accumulated water, it is necessary to determine the runoff factor applicable for the monsoon period as a whole. In order to conduct such a study and analysis, rainfall data for the stations spread over the entire drainage area of the basin and runoff data at suitable locations on the river for a sufficiently longer period (at least 20 years or more) are considered to be the necessary input.

4.8.2 The GFCC were able to get hold of the rainfall data of 41 raingauge stations situated in the Nepal territory for the period 1948 to 1960 and 26 raingauge stations in the lower catchment (India portion) for the period 1951 to 1970 maintained by the IMD. This Commission, in its attempt to update the aforesaid data, could be able to get rainfall data of 23 raingauge stations only in the lower catchment for the period 1974 to 1985 from the State Hydrology Cell and for the period 1979 to 1985 districtwise annual rainfall data from the Directorate of Statistics, GDB (para 4.6.1). The discharge data at Barahkshetra for the period 1947 to 1992 and at Baltara for the period 1957 to 1982 only could be available. It is for this reason that the rainfall-runoff relationship could not be precisely established. On the basis of longer duration data which would have indicated more accurate results, as compared to the analysis done by the GFCC with shorter duration figures. This Commission, therefore, suggests that the State Government should make all-out efforts to collect the rainfall and runoff data in the basin for as many years as possible and carry out further studies to establish a precise rainfall- runoff relationship at suitable locations on the river Kosi for future use.

4.9 SEDIMENT CHARACTERISTICS

4.9.1 The past history of the river Kosi indicates that the river has a meandering tendency and in the process it has shifted its course from east to west very frequently before construction of the embankment. This trend of translatory movement is still continuing in the shape of continuing attacks on both sides of the flood embankments in one or the other reach every year where huge amount is being spent regularly to prevent any possible breach in the embankment. The perusal of river cross-sections broadly indicates signs of bank erosion and silt deposition.

4.9.2 One of the main reasons for such a shifting and erosive tendency appears to be the excessive silt charge in the river flow which might be due to landslides and erosion which occurs as a result of removal of forest trees and undergrowth from the steep hill sides in the Nepal portion. The seriousness of the silt problem in the basin leading to aggravation of flood problems in India deserves urgent attention. Suitable measures for afforestation and catchment area treatment for soil conservation in the hilly catchment in Nepal are required to be undertaken on a priority basis. The State Government may take up this issue with the Government of India for appropriate action in consultation/co-operation with the HMG Nepal.

4.9.3 The location of sites in the Kosi river basin for observation of sediment data along with discharge (India and Nepal) are indicated below -

Table No 6

Location of Sediment Data Observation Sites in the Kosi Basin.

Sl No	Location	River	Distance from Chatra	Remarks
1	Tribeni	Sun Kosi	18 Km u/s	Nepal
2	Tribeni	Arun	12 Km u/s	,,
3	Tribeni	Tamur	11 Km u/s	,,
4	Site No 13 (Barahkshetra)	Sapt Kosi	6.5 Km u/s	,,
5	Baltara	Kosi		India
6	Pipra	Old Kosi		,,
7	Banmankhi	Fariyani		,,

Source : Comprehensive Plan of Kosi prepared by GFCC,1986

The available silt data for site No 13 on Sapt Kosi and Baltara on Kosi are enclosed at Annex 3.

The average annual sediment load analysis of the above data reveals the following position -

Table No 7

Average Annual Sediment Load Composition at Barahkshetra & Baltara

Site	Based on data for the period	Composition in % of total load		
		Coarse	Medium	Fine
Barahkshetra	1948-81 & 1985-89	19.82	24.79	55.39
Baltara	1973-81	8.19	19.81	72.00

It is further observed that, on an average, about 95 per cent of the silt load comes down the river during the monsoon months of June to October and the balance 5 per cent in the remaining period of seven months of the year. The silt charge is not uniform even during monsoon months. It is maximum in the months of July and August and minimum in the months of January/ February.

5.0 FLOOD FREQUENCY ANALYSIS

5.1 Frequency analysis is carried out to interpret the past records of the hydrologic events like the precipitation, run-off, flood levels, etc, to predict the probabilities of such occurrences in future. For quantitative assessment of the magnitude of flood problem, it is essential to evaluate or estimate the frequencies of rainfall, flood, etc. Such studies are necessary inputs for proper design and location of hydraulic structures as well as other related studies.

5.2 CRITERIA OF DESIGN FLOOD

5.2.1 The Ministers' Committee on Floods and Flood Relief Constituted by the Government of India in 1970 had recommended that,

"As most of the embankments have been constructed on inadequate and meagre hydrological data available, it is necessary that the existing embankments are reviewed to see that these are safe for a flood of 50 years frequency for major rivers and at least 25 years frequency for small tributaries. Similarly, all the future proposals of embankment should also be based on the above criteria".

5.2.2 The recommendations of the RBA constituted by the Government of India in 1976 (which submitted its report in March, 1980) regarding the degree of protection by the embankments are as follows :

"The use of the benefits - cost criterion would require (i) damage data with respect to different flood frequencies, (ii) data on damages due to probable failure of embankments, and (iii) expertise to carry out alternative benefit - cost and trade - off exercises. These are not available at present. Hence, for the time being, the Commission recommends, as a general guide, adoption of the following criteria based on flood frequencies :

i For predominantly agricultural areas: 25 years flood frequency, (in special cases where the damage potential justifies, a higher design flood/maximum observed flood, may be adopted).

ii For town protection works, important industrial complexes, etc : 100 years flood frequency, (for larger cities like Delhi, the maximum observed flood, or even the maximum probable flood should be considered for adoption).

Meanwhile, studies should be undertaken to review the basis of these flood frequencies and attempts made to collect the data and appoint the necessary personnel, so as to enable the application of the benefit-cost criterion in due course" (Para 13.5 of RBA report).

5.2.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guide lines and instructions for implementation of the recommendations, of the RBA are reproduced below :

"In the case of embankments, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile, necessary steps may be taken for the eventual application of the benefit-cost criterion for fixing the design."

The summary of recommendations as accepted is as follows-

"In the case of embankment schemes, the height of the embankment and the corresponding cost be worked out for various flood frequencies and also the benefit- cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available, the embankment schemes might be prepared for flood of 25 years frequency in the case of the predominantly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of industrial and other vital organisations".

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of vital industrial establishments.

5.3 ANALYSIS OF AVAILABLE DATA

5.3.1 At present gauge-discharges are being observed by the CWC at Barahkshetra, Basua, Baltara, Pipra and Banmankhi and gauge observation at Birpur and Kursela. The gauge and discharge data on the old Kosi dhars, namely, the Parwane dhar and the Fariani dhar at Pipra and Banmankhi respectively are being observed since 1977. In order to obtain a reasonably good estimate of future probability of occurrence of the event, atleast 20 to 25 years of yearly peak value of gauge and discharge are required for frequency studies. The gauge discharge data for Baltara and Barahkshetra sites available for 25 years and more have been used in the study. The yearly peak gauge for Barahkshetra, Birpur, Basua,Baltara and Kursela and gauge discharge data for Barahkshetra and Baltara are enclosed at Annex 4.

5.3.2 The frequency analysis of the above available data using Gumbel method gave the following results:-

Table No 8

A Flood Discharge in the River Kosi.

(By Gumbel method)

Site	Year of data available	Flood discharge in Cumec corresponding to				
		5 yrs	10 yrs	25 yrs	50 yrs	100 yrs
Barahkshetra	1947-92	13524	16120	19395	21826	24239
Baltara	1957-82	9107	10366	11955	13134	14304

Table No 9

B Flood Levels in the River Kosi (By Gumbel method)

Site	Year of data available	Flood levels in metres corresponding to				
		5 yrs	10 yrs	25 yrs	50 yrs	100 yrs
Barahkshetra	1948-92	125.120	126.551	128.360	129.700	131.030
Birpur	1975-92	75.090	75.420	75.840	76.150	76.450
Basua	1971.92	48.423	48.675	48.984	49.213	49.442
Baltara	1957-92	35.213	35.589	36.062	36.414	36.763
Kursela	1967-92	31.890	32.490	33.260	33.830	34.400

5.3.3 It is observed from the peak discharge data available for Baltara and Barahkshetra sites (Annex-4) that the maximum recorded discharges of the two sites were not in the same year, (in 1974 at Baltara and 1968 at Barahkshetra). Sometimes higher discharges have been observed at lower stages. The rise in river stage corresponding to a flood of 25 years and that for 100 years are 2.22 per cent, 0.83 per cent, 1.76 per cent and 3.26 per cent for Barahkshetra, Basua, Baltara and Kursela sites respectively. Similarly, the increase in flood discharges, for a flood corresponding to 25 years to a flood of 100 years for Baltara and Barahkshetra sites are 19.68 per cent and 24.20 per sent respectively.

5.3.4 It is further noticed from the recorded peak discharge data contained in Annex 4 that the discharge at the Barahkhetra site is higher than at Baltara in most of the years although the latter is a downstream site. This might be, besides others, due to the fact that extensive flooding might have taken place in the flood plains within the basin by the creation of valley storage between the two sites leading to considerable flood moderation. The other reason could be that at the time of floods the river spilled between the two discharge sites leading to diversion of some of its flood flows in the adjacent basins. The overbank spilling has since been contained by embanking the river in its entire spilling zone.

5.3.5 Further studies may be carried out to ascertain the real reasons for the aforesaid anomalies so that assumptions/ presumptions are not the only alternative to be relied upon in future decisions.

5.4 UTILITY OF FLOOO FREQUENCY STUDIES

5.4.1 The results of flood frequency studies are useful in delineating the floodprone area on the contour map in order to be aware of the situation in the unprotected area at different stages of the river during flood. To make this study useful it is essential to have the contour map (with contour at a suitable interval) of the area prone to flood preferably in a scale of 1:15000. The next utility of these studies will be in formulation and planning of the flood control projects in the basin.

5.5 AGGRAOATION ANO DEGRAOATION OF THE RIVER BEO

5.5.1 In order to keep a watch over the aggradation and degradation tendency of the river Kosi, its 167 Km length from Chatra to Koparia has been divided into six different reaches with a number of fixed points on both sides of the bank within each reach for taking cross sections of the river every year since 1955, as given below :

Table No 10

Reach-Wise Distribution of Cross Sections

No of reach	From	To	Cross Section No	Length of the reach in Km
i	Chatra	Jalpapur	1-19	27
ii	Jalpapur	Bhimnagar	19-32	15
iii	Bhimnagar	Dagmara	33-49	26
iv	Dagmara	Supaul	49-70	34
v	Supaul	Mahesi	70-90	40
vi	Mahesi	Koparia	91-98	25

Source : Comprehensive Plan of Kosi prepared by GFCC, 1986

The Indian Institute of Technology, Delhi, on the advice of the Kosi Board of Consultants headed by Sri Kanwar Sain, undertook Cubature analysis in 1974 based on data from 1955 to 1974 for assessing the change in the Kosi river bed in various reaches. The findings of the above study indicated the reachwise tendency of aggradation/degradation of the river bed as shown in the following table.

Table No 11

Summary of Cubature Study, 1955-74

Siltation (+)		Scouring (–)	Rise (+)	Fall (–)
Reach	Bed variation during 1952-62 in mm/year	Bed variation during 1963-74 in mm/year	Volume change in river bed in MCM/year	
			1955-62	1963-74
I	(–) 17.6	(+) 123.4	(–) 4.046	(+) 28.304
II	(–) 165.6	(+) 107.0	(–) 16.058	(+) 10.436
III	(–) 35.6	(–) 08.3	(–) 5.082	(–) 1.181
IV	(–) 03.8	(+) 18.6	(–) 2.081	(+) 10.228
V	(+) 95.6	(+) 63.5	(+) 42.900	(+) 20.949
VI	NA	(+) 120.3	NA	(+) 15.730
		Total	(+) 15.633	(+) 84.466

Source : Comprehensive Plan of Kosi prepared by GFCC, 1986

The analysis of the above cubature study as mentioned in the comprehensive plan for Kosi prepared by the GFCC in 1986 in being reproduced as below -

"We have already indicated that the average annual silt load of the river Kosi was of the order of 95 million MCM as observed at Barahkshetra. Despite the above silt load the reaches I to IV, ie, from the Chatra gorge to about 102 Km downstream at Supaul, the cross-sections did not indicate any silting during the period 1955-62. As a matter of fact, in this reach, there was about 27 MCM of bed material scoured away by the river. Thus, this length of 102 Km from Chatra to Supaul was a degrading reach, the average rate of degradation being between 165.6 mm to 3.8 mm in the different reaches as shown in column 2 of Table 11. The silt deposit that was occurring during 1955-62 was only in the Vth reach, which was of the order of 43 MCM during the above period, the annual average rate of silting up of the bed being 95.6 mm. Data for the next reach, ie reach VI is not available for period 1955-62. This period of 1955-62 approximately corresponds with the commencement and completion of the embankments. The average annual silt load of the river and the overall deposit of the same in the river up to the Vth reach during the period 1955-62 are widely different,against a total annual silt load of about 80 MCM. The two possible reasons for this phenomenon are either (a) they got deposited in the flood plains at the upper reaches during the pre-embankment or partly embanked periods, or,(b) bulk of silt deposits occured in the reaches below the reach V.

During the period 1963-74, all the reaches I to VI became aggrading, except reach III , where also, the rate of degradation reduced considerably from the period prior to that,as can be seen from Table 11. The rate of rise of the bed level per year during this period varied from 123.4 mm to 18.6 mm in the different aggrading reaches as shown in column No 3 of Table 11. The reach III, downstream of the barrage was degrading in a nominal rate of 8.3 mm per year. The overall silt deposit per year during this period was about 84 MCM per year, which approximately corresponds to the annual average silt charge of the river at Barahkshetra.

The fact, that after the embankment, when the spills of river Kosi could be checked, corresponding to the period 1963 to 1974, the silt charge and the silt deposit as per cross-sections could be correlated and that it could not be correlated prior to the embankment during the period 1955 to 1962, as considerable silt used to spread over the flood plains along with uncontrolled spills.

The ponding effect of the barrage has obviously played an important role in the intense deposition of silt in the various reaches. The rate of rise in the bed level in reach II, immediately upstream of the barrage is, however, not the highest of all the reaches as could be expected normally. This reach had, however, the maximum annual degrading rate of 165.6 mm prior to the barrage, which, after the barrage came under operation, changed to aggradation at a rate of 107.0 mm, thereby indicating the overall impact of the barrage on this reach".

In the year 1984 the Department of Civil Engineering of the University of Roorkee was requested by the GFCC to examine the problem of aggradation of the river Kosi and indicate, with the help of a mathematical model, the response of the river to the construction of forward embankments. The report submitted in 1990 concluded that aggradation (with respect to the levels of 1984) of the order of 2.44 m (8ft) may occur within the existing embankments by 2005 AD and uniform reduction of the river width in the entire leveed reach is not a feasible solution to the large aggradation noticed in the river. However, the proposed forward embankments between cross sections 67 and 75 (Table-10) provide a feasible solution to the control of aggradation (map enclosed at Drg No 6/02). So, on the basis of this study it has been recommended that in view of the expected aggradation by 2005 AD raising of the existing embankment in some reaches is desirable and a forward embankment between cross-sections 67 and 75 may be constructed for reducing aggradation tendency after due verification of a physical model.

5.6 MORPHOLOGY OF THE RIVER KOSI

5.6.1 Morphology of any river channel, when considered for its detailed study, is associated primarily with the study of the size (ie bed width and depth), shape and pattern of river to be supplemented by study of structure of the basin and the texture of its drainage area. The study of morphology of a particular river requires association of geologists, meteorologists, hydrologists and biologists. This is particularly important because any river or stream flowing in a particular size, shape and pattern today is a result of short time and long time changes of various factors influencing its morphology over different spans of time, which may be designated as geological time, graded time and steady time for proper appreciation of the whole process of metamorphosis of a particular drainage channel. Variables influencing river morphology by a varying degree of inter-dependence for the three different spans of time can be considered as below:

1 Time (stage)

2 Initial relief

3 Geology (lithology, structure)

4 Paleoclimate

5 Paleohydrology

6 Relief on volume of system above base level

7 Valley dimensions (width, depth, slope)

8 Climate (mean ppt, temp, seasonality)

9 Vegetation (type and density)

10 Hydrology (mean discharge of water and sediment)

11 Channel morphology

12 Observed mean annual flood and peak annual flow (reflecting meteorological events)

13 Hydraulics of flow

The significance of these variables is different in different time spans and for some consideration, some of them may appear irrelevant even for broad study of the subject but at times they are relevant in some specific spot or location. As for example, time, initial relief, may not appear to be of any significance for the study of a drainage channel in the graded time span, arbitrarily defined as a period of last few hundred years, because it is the present relief of the remaining mass of the landscape through which the river flows today which is of instant significance. Study of geology, forming the river basins may not be of significance today but still it is of prime importance because it determines, to a large extent, the quantity and type of sediment, fed into the stream. Similarly, paleoclimate and paleohydrology could be considered to be not relevant to modern channel morphology but if the same have determined the dimensions and slope of the valley in which the river flows, then their study becomes relevant.

5.6.2 Introduction to Morphologic Study of Kosi

For an understanding of the characteristics and behaviour of a river it is necessary, in the first instance, to view the entire aluvial landscape in a historical perspective. The factors influencing the river channels and river systems can be broadly categorised as : (a) Structure, (b) Stage and (c) Process. The term structure, as used in geomorphology, implies not only the effect of various kinds of rocks but also the differential erosional character of the rocks, the influence of fractures, joints and faults and their distribution in a drainage basin. The passage of time and the change of land form character with time is referred to as stage of development of a land form which takes place through the processes of erosion and deposition. This phenomenon is also referred to as avulsion. The example of the avulsion of the Kamla river into the Balan river can be cited for such a phenomenon. So, study of this factor is of particular importance in case of the Kosi river because it is reported that in the past the Kosi river used to fall into the Brahmputra and more recently was the tributary of the Mahananda before sporadically shifting westward to join the Tiljuga in 1940. The third factor process, which is influenced by the erosional forces acting at the bed of the river due to magnitude of the flowing water and internal forces acting below the earth surface causing displacement of earth (very slowly at the rate of 0.76 cm per year) and thereby changing topographic features and drainage pattern, need an in depth study.

The morphological study for the Kosi river is of particular importance in view of the uniqueness of its problem and its notorious shifting tendency. A map showing the shift in courses of the river between 1731 to 1954 is given in figure 6/03.

The approximate rate of movement of the Kosi between 1731 and 1954 measured on a line passing through Belhi and Purnia can be seen in the following table :

Table No 12

Approximate rate of movement of the Kosi between 1731 and 1954

Year	Name of the main river course	Shift in Km	Period of shift in year	Average rate of shift Km/year	Remarks
1731-70	Kali Kosi Livari	11.0	39	0.28	Period of shift has been taken as mid point to span of years of live existance of two successive courses
1807-39	Dhamdaha Kosi	8.0	33	0.15	
1840-73	Kiran Dhar	6.5	34	0.19	
1875-92	Sursar Dhar	11.0	18	0.40	
1892-1922	Mirchai Dhar	16.0	31	0.66	
1922-36	Parwane Dhar Belhi Dhar and Dhusar Dhar	16.0	15	0.72	
1936-46	Tilawe Dhar	11.0	11	1.57	Period of rapid shift.
1946-54	Flowing Kosi	27.0	9	1.80	

Source : Comprehensive plan of Flood Control for the Kosi River prepared by GFCC in 1986.

The above table indicates that during 1807 to 1873, when the river Kosi was flowing direct into the Ganga, the rate of the lateral movement was relatively slow, but since the Kosi began to flow into Ghughri to the West of where that river joins the Ganga, the rate of translation increased markedly.

5.6.3 Past History of the River Kosi

The past history of the Kosi is the history of the different courses which it adopted in successive decades below Chatra. The oscillation of the Kosi bed below Chatra can well be compared with that of a pendulum of a clock having its fixed point at Chatra and oscillating between the district of Purnia on the east and the district of Darbhanga on the west. More than 150 years ago Dr B Hamilton formed an impression that the Kosi during the remote past, possibly flowed more towards the south east than towards the east and joined the Brahmputra. That means that the Kosi had no connection with the Ganga at that time. In his opinion, the Kosi probably afterwards, when it joined with the Ganga, the great chains of lake and marshes north and east of Malda (WB) were the remnants of a great river bed formed by the united Kosi and the Mahananda and the united river opened up the wide channel now known as the Padma at Jangipur in west Bengal through which the Ganga is still flowing. However, this theory advocated by Dr B Hamilton has insufficient evidence in support of the suggestion that the Kosi used to join the Brahmputra.Hence a second theory was put forward by Mr O'Donnell in the Bengal Census Report of 1891 that the original course of the Kosi was the one then occupied by a river in Bengal Known as the Karatoya. In his opinion the Karatoya in the days of its real greatness was the bed not only of the Teesta but of the Kosi and of the numerous hill-streams which now unite to form the Mahananda.

Although no historical records regarding the Kosi joining to Mahananda are available, the local belief is that in some bygone days the Kosi used to flow along the course of the river Parman near Araria (Purnea Division) and, finally, joined Mahananda. This fact has been corroborated by Mr Shillingford who wrote "The Kosi in remote times broke away eastward, in part, along the present bed of the Parman or Panar", and this statement is in conflict with the theory advocated by Dr Hamilton.

5.6.4 Different Ancient Beds of the Kosi

The different past courses of the Kosi for which records are available are given below :

1 The Kali or Kari Kosi : It was known in its upper reaches as the Kamla and in Nepal as the Kajri. It flowed about 1.5 Km west of the civil station of Purnia. The name 'Kali',as given to this river is from the curious fact that this is the only abandoned channel of the Kosi, which carried dark limpid water. This was the main Kosi in 1731, forming at that time the western boundary of the Purnia district.

2 The Dhamdaha Kosi : It is known in the higher reaches as the Fariyani. Dr B Hamilton showed this to be the main Kosi during 1807-1811. Between the Kali and the Dhamdaha Kosi, there is another silted up bed, called in upper reaches the Livari and in lower reaches the Burhandi, which must have been occupied by the main Kosi between the year 1731-1807, but no record in this regard is available. This channel crosses the North-Eastern Railway line between Karhagola Road and Kursela Railway station and joins the Ganga near Karhagola.

3 The Hiram : It was the main Kosi as per the Revenue Survey maps of 1840-47, flowed to the west of the Dhamdaha Thana and about the year 1870 began to throw off branches into the Daus Swamps, which became the main Kosi in 1873 and flowed into the Ganga opposite Patharghata.

4 The Daus : It was the main Kosi from 1873 to 1893 which marked the further westward swing of the Kosi. The Daus flowed into the Ghugri (coming from west) and they cojointly fell into the Ganga below Kursela.

5 The Loran : It became the main Kosi channel in 1893 though the Kosi began to throw off shoots into it since 1891. The Daus and the Loran in their upper reaches used to be fed by the Sursar Dhar which is still existing. The main Kosi stream remained confined within the Sursar (Daus) for a pretty long time and was quite vigorous up to the year 1909. Up to the year 1921 the main Kosi followed the course of the Mirchaia dhar which flowed about 13 Km to the east of Madhepura town. During 1917, the straight Kosi channel got completely silted up.

The Kosi flowed during 1922 to 1936 through a number of channels, such as the Belhi dhar, the Parwane dhar, the Tilawe dhar, etc. During this period the town of Madhepura suffered a good deal due to the Kosi flood havoc and the headquarters of the then Madhepura subdivision (now district) had to be shifted to Supaul.

While discussing the shifting of river Kosi and flowing through various channels, the Bir bund constructed nearly 700 years ago from a point about 5 Km south west of Bhimnagar and terminating quite close to the Soranga Range, deserves special mention.The old line of borrow pits which were made west of the bund had become one of the main feeders of the Dhemra channel. The flood waters of the river Kosi used to spill into this feeder of the Dhemra channel whenever the Bir bund breached from time to time. The Tilawe depression also started from the line of borrow pits on the west side of the Bir bund. There were many places between Bhimnagar and Saharsa where Kosi used to spill into the Tilawe. In 1925 the Bir bund in the Indian territory was repaired. Nothing was, however, done in the major portion of the bund lying in Nepal territory. As a result the Kosi waters used to spill into the Dhemra and Tilawe channels on the west.

During the years 1924-26 a small channel was formed, about 3 Km south east of Bhaptiahi. This was an off-shoot from Dhemra and became known as the Udha channel. This channel in the following years opened up and from 1928 to 1932 it got further enlarged. The earth quake of 1934 in Bihar had its epicentre in the Kosi catchment which caused disastrous land slides and enormous local subsidences in the catchment. In the following year, ie in 1935 there were heavy floods in the Kosi river causing extensive flooding. There was about 18 Kms of westward movement of the Kosi between 1930 and 1932 and a further movement of nearly 38.5 Kms between 1936 and 1938. The udha channel mentioned above became the main channel of the Kosi river. Thus it can be said that due to quick silting of the old channel on account of the heavy silt brought down by the river as a result of the disintegration of rocks in the catchment due to the 1934 earth quake, there was apparent shifting of the main course of the river Kosi.

Nirmali, then a block in the Madhubani district, was considered to be free from the Kosi floods upto 1938 but was affected by floods in subsequent years. This place for many years had been protected from flood by various bunds and consequently, had received no silt from the Bhutahi Balan river which had built up the surrounding country by as much as 2.7 m. Nirmali, therefore, became a natural depression with the result that the Kosi rushed to the low lying area and became active there. After 1939 the westward movement of the river Kosi was very slow.

In the year 1936 the river Mahuli became one of the Kosi channels. It received a fair quantity of the Kosi flood discharge through a gap in the Bir bund, in the Nepal territory and carried the same down to the Beti below Raharia railway station. By this time the Dhemra was also carrying down a percentage of the Kosi right bank spill through the gaps in the Bir bund. Bhaptiahi also came under threat by the flood of a branch of the Dhemra, locally called the Udha dhar.

In the flood of 1936 the gap in the Bir bund near Badia ghat (just to the north of Bhimnagar in the then Bhagalpur district) was widened and in 1937 practically the whole of the Kosi discharge was thrown into the Dhemra basin. All the culverts and the bridges of the railway line between Nirmali, Bhaptiahi and Supaul were severely affected and most of them completely damaged during the flood of 1937. Since 1936 till the river was confined between the eastern and western flood embankments, the Kosi flood discharge used to be carried down by the Dhemra, the Beti, the Tiljuga and innumerable right bank spills of the Dhemra between Bhaptiahi and Parsarma railway station.

The abandoned beds of the Kosi from east to west are respectively the Panar, the Kali Kosi, the Sursar, the Rohua, the Khunia, the Maria, the Jamua, the Bochaha and the old beds of the Kosi at east of Bhimnagar, etc. The Sursar, the Rohua, the Maria, the Jamua, the Bochaha, etc, ultimately unite together and form the three principal channels, ie the Sursar dhar, the Bochaha dhar and the Haiyaha dhar. The Kali Kosi has already been discussed in para 5.6.4 while discussing the ancient beds of the Kosi. The principal dhars as mentioned above is being described in brief as given below:-

1 The Panar - It was also called the Parman dhar and formed the eastern most channel. It used to be fed by the Sursar dhar branch of the Kosi through local diversions in the Nepal territory. In the ancient past this river invigorated the Mahananda river through a number of channels taking off from Panar near Agaganj and Sonapur, south of Malharia in Araria district. At present the Panar gets water from its own catchment and flows to join Mahananda after breaking into two channels nearly 54.5 Km below L R P road (Lateral Road Project road) near Araria. The left channel which carries much more discharge in comparison to the right channel, is called as the Parman and joins the river Mahananda downstream of Bagdob. The right branch of the river known as Panar or Riga meets the river Mahananda upstream of Jhaua railway bridge.

2 The Sursar Dhar - It takes off from the main Kosi at Chatra and is locally known as the Khunia or the Babhani dhar. This river is fed by the Kosi during flood season only because during the non-monsoon period it becomes unable to draft discharge from the Kosi due to its offtake filled up with boulder and sand in the 3 Km stretch. From enquiry it appears that about 100 years back, the Sursar was the main Kosi channel but in course of time its bed became silted up. The Sursar dhar carries

some high flood spills of the Kosi along with the local drainage of the area through which it passes, but practically the supply for Kosi spill into Sursar has stopped since the execution of the Kosi Project. It crosses the Nepal border just North of Ghurna village in Araria district, and then flows directly southwards upto village Chuni where it divides into three channels,viz,the Sepaha dhar,the Gordhwa dhar and the Gorawa dhar, which ultimately fall into the Ghughri under the name of the Kathantia dhar to the north of the Katareha railway station.

3 The Bochaha Dhar - It is an abandoned bed of the river Kosi which nearly 87 years back used to receive Kosi spills during high floods. Its offtake is now silted up and therefore, it is now completely separated from the Kosi main channel and working as a drainage channel. The river flows in a southerly direction and enters the Purnia district near village Bela. Further down it joins the Haihaha dhar to the south of village Bhawanipur.

4 The Haiyaha Dhar - The river is called as the Jamua dhar in Nepal territory and enters India on the east of Birpur. It is said that Haiyaha was very vigorous some 72 years back. It meets Thalaba dhar, a small stream and a branch of the Bochaha dhar, at nearly 6.5 Km south of Nepal - India Border. Further down it bifurcates into two branches, one meeting the Bochaha dhar to the west of village Bahuan and the other flowing directly south to meet the Garah dhar which is in continuation of the Bochaha dhar. Up to 1940 it was active during floods only but later on after the floods of 1941, the eastern main channel of the Kosi in the vicinity of Bisaria had greatly developed and the left bank erosion had been going on so vigourously that the Kosi had encroached upon the silted course of the Haiyaha, the result of which was that the Haiyaha had a direct connection with the Kosi.

5.6.5 Opinions of Various Experts on Problems of River Kosi

Many prominent engineers and scientists have studied and analysed the complex behaviour of the Kosi river, such as its shifting tendency, excessive sediment load etc. Some of their relevant observations have been quoted in this report at Para 5.6.3,however,in the present context, some more observations are brought out here. Mr J Inglis (Maori) described the general characteristics of the Kosi as follows -

"The main stream flows with a swift milky flood, dividing the two great indigo and rice districts of Bhagalpur and Purnia. When swollen by the melting of the snows or by the annual rains, the river overflows its banks, and at such time presents the appearance of a broad swiftly flowing sea, for its breadth from bank to bank is often ten and in some places even twenty miles across. In the dry season, the waters, always of the same milky hue, are confined to innumerable channels, some so shallow that the stilted ployer can wade across, the other running deep and strong, with a ceaseless gurgling swish that would sweep the stateliest elephant off its feet and carry its ponderous bulk far down the stream. These streams seem to run at random over this deltaic plain diverging here, reuniting there, forming a wide bend at one place, and cutting direct through the sandy soil in another. The face of the country is split up into an infinitude of islands, and recticulated every where by a network of dry channels and shifting sand banks, and overall wherever there is inch of soil the stately elephant grass spreads its feathery mantle".

Mr F A Shllingford in 1893 made his conclusions after 25 years of observation of the river. These are:-

"a The bed of the Kosi oscillates over a vast tract of country from the Bramhaputra to near the mouth of the Gandak, the oscillation being repeated at long intervals of time.

b The westward movement in each oscillation is slow and in a series of steps each of which is attended with damage to property but of a temporary nature.

c The eastward movement of the oscillation will probably, be accomplished in one great swing and will be accompanied with great loss of life and property with a remoter danger of serious nature".

In support of the facts described in (a) above, it would be quite interesting to note that description of Mithila territory by a famous court poet Vidyapati during the reign of Raja Shiva Singh in about 1402 reveal that the limit of land bounded on the south by the Ganga, on the east by Kosi, on the west by the Gandak, and on the north by the Himalayas and being traversed by the Kamla, the Tiljuga, the Amrita (Jiwachh), the Dhemra, the Bagmati, the Lakhna, etc is called Mithila, the fountain of learning.

Regarding the translatory motion of the river, the contention of Mr C C Inglis is reproduced below in his own words "Translation of the Kosi is normally started by spill from the outside of a bandh entering a small natural drainage. Such drains tend to form wherever surface drainage is concentrated, which occurs wherever surface flow is interfered with by road or embankment or where the waste water from rice fields concentrates to form a drain. The Khata nala, which used to flow into the Dhemra, is a good example, while the Sakardyi nadi, which was hitherto protected from spill by the Hanumannagar-Kanauli Road, is another case.

Early spills contain little sand. As the slope of a small drain generally far exceeds that required to carry the increased supply, scour is rapid. So, in a very short time, what was previously a small surface drain becomes an angry, turbulent flood flowing with 'ceaseless gurgling swish' as typical of the Kosi, where scour is occurring. The almost universally assumed cause of silting or scour is the magnitude of discharge relative to slope, whereas the major factor in the case of the Kosi is the distribution of sand charge.

Where there is an excess sand charge, the main channels are curved and at the outside of each curve the water banked up by as much as two feet (0.6 m) and at this point, the channel carries little sand, whereas at the inside of each curve, the reverse is the case. It follows that channels which take off from the outside of a curve (in its middle portion) carry water which is relatively free from bed sand, whereas channel taking off from the inside of a curve carry excess bed sand and consequently silt rapidly. In general, bank scour is continuous at the outsides of bunds and a channel which at first draws water from the outside of a curve will at a later stage, draw water from a point where a heavy charge of sand will be drawn.

In the former case, owing to the small sand charge and high water level, the new channel will scour rapidly, even though the slope be small, whereas with a heavy charge of sand and a relatively lower water level, the head of the off taking channel will silt rapidly, even though the channel be steep.

Where, however, the slope is steep and the sand charge is small, all factors are then favourable, and a very rapid scour occurs.

Under these overchanging conditions, new channels are being continuously formed and other channels are being continuously closed up, while this is in progress, accretion is simultaneously taking place on the shoals and islands, especially where the velocity of flow is retarded by grass. The annual depth of accretion on the latitude of Hanumannagar was so far as Inglis could judge, about 0.6 m but in some cases around Supaul a much greater depth had been deposited and in depression up to 3.6 m had been observed.

An embankment like the Bir bandh, if built on land sloping up gradually towards it, will effectively prevent translation as long as it is carefully maintained and its lower end strongly held, but an embankment built on land sloping down towards the west would lead to a drain forming along its face. This would later become a channel along the toe of the embankment, with consequent severe attack so that, unless its toes were very strongly protected, it would fail".

Mr C C Inglis, the then Director of the erstwhile Central Irrigation and Hydro-Dyanamic Research Station, Pune further expressed the following views in regard to the problems of the Kosi river -

a. The river is now held firmly along the Right Bank and will continue to fill up the trough of low land which is now occupied by the Tiljuga and Balan rivers, until its westward translation is stopped by the somewhat higher land running south from Tamuria, along which an embankment will probably be required to prevent still further westward movement.

b The cause of the movement is building of the submontane delta due to an excess charge of sand. This sand is stated to be due to a considerable extent, to land slides and erosion which occur as a result of removal of forest trees and undergrowth from the sweeply sloping hillsides in order to do short term cultivation.

Though such erosion must, in the course of time cause great loss to the State, I was told that there was little likelihood of this being brought under control in the near future. If this be so, the cause of the trouble cannot, for the present, be removed. The alternatives, therefore, appear to be to allow the river to fill up the trough of the Balan and Tiljuga as far as Tamuria or to train the river for some 20 miles below the Gorge to cause it to return to the neighbourhood of Purnia. The data available is inadequate to make it possible to say whether such training is practicable. All that can be said is that should the river be brought into this course, its slope would be much more favourable for permanent control than at present but much more data would be required before the cost of such a scheme could be estimated. This data must include information regarding sand charge and bed movement".

Mr M Mathrani, I S E (Retd) Chief Engineer, Irrigation Bihar was of the view that the topography of the Kosi basin had not fully developed and the bedslope of the river in the upper reaches was too steep for carrying a discharge varying between 8,490 cumecs and 19,810 cumecs in a channel made up of weak sandy material. He did not consider the silt charge of the Kosi river to be excessive as compared to that of the other Himalayan rivers.

M/s Leopold and Maddocks, Experts from The United States, were of the view that the braided channel of the Kosi would continue to shift laterally at a rate dependent on the rate of deposition of silt. As one course of the river became higher, the river would shift to the adjoining lower channel.

M/s C V Gole and S V Chitale of the CW & PRS expressed the view that the Kosi formed a conical delta with its apex at Chatra and the base plane passing just north of Mansi and Kursela. On the east, the delta extended a little to the east of Katihar-Jogbani railway line and on the west up to Belhi. Any one course of the river occupied a part of the cone with an appex angle of about 10°. After deposits were formed where the river slope was deficient for carrying the material further down, the adjoining part of the cone remained low, inviting the river to shift towards the low ground. This shifting was neither systematic nor regular. However, the general pattern was the same. Out of the several flowing channels only a few channels at a time carried major discharge. When these channels got silted up and their beds were raised the adjoining channels carried more discharge and gradually became the major channels.

Mr Gole and Mr Chitale were of the opinion that in conical delta building, as in case of Kosi, sediment deposition, rise of bed levels and consequent shifting of the river course occured progressively from one edge of the cone to the other. After reaching the other edge, the process of deposition and rise of river bed with consequent shifting of the course, would continue in the opposite direction.

Dr K L Rao of the CW & PC was of the view that the lateral movement of a river occured due to the five basic factors such as valley slopes, bed load and coarse silt, discharge, bed resistance and transverse slopes and these.variables occured in conjunction and should not be studied in isolation . Hydraulic model studies are necessary to observe the effect of these factors individually. According to him all the basic factors favourable for violent shifting of the course are present in the case of the Kosi river. The gradient is steep, having on an average 0.763 per 1000 for the reach of 48 km below Chatra. There is an appreciable amount of coarse silt in the river and bed resistance is low, there being no boulders in this steep reaches. At times, the discharge are also appreciably large, against the normal flood of 7,080 M^3/sec. The most important contributory factor for side way of the river, as appeared to him, is due to excessive coarse sediment in the river. He felt, it was necessary to flatten the gradient, to reduce or trap the coarse silt and if possible, to reduce the intensity of peak flood flow.

5.6.6 Study of River Morphology of Kosi by Different Experts

It has already been stated in the introductory para that no systematic study of river Kosi and its behaviour has been done uptill now. But in connection with the finalisation of the 1953 Kosi Project, the Government of India and the State of Bihar had obtained the views of a number of foreign experts. Among those, M/S Leopold and Maddocks Jr. of the United States Technical Co-operation Mission to India, New Delhi submitted a report on reconnaissance of flood control problems in North Bihar on April 9, 1955 which contained a broad analysis of the Morphology of the Kosi river, its different patterns and the analysis of the situation existing then. Relevant extracts of the above report are enclosed at Annex 11.

The description related to the study of morphology of the river Kosi made in the above report, though not in detail, contains for during pre-barrage and pre-embankment period. After the construction of the barrage and flood embankment on Kosi were completed, the State of Bihar appointed a Technical Committee in the year 1971 under the Chairmanship of Shri Kanwar Sain a former Chairman of the earst while Central Water and Power Commission. One of the terms of reference to the Committee was to review the functioning of the existing barrage and to suggest further measures that may be necessary to ensure optimum flood protection in the Kosi basin. While analysing the effect of the Bhimnagar barrage and flood embankment on the Kosi River Regime in chapter IV of its report, the Committee had outlined the causes of shifting courses of Kosi river, as under :

"In order to understand the process of the shifting courses of the river and the delta building activity a topographic plan of 1926-1938 was prepared for the Kosi basin, bounded by Mahananda river on the east and Balan river on the west. The base plane on which the Kosi delta is being built has a slope from north to south and west to east. On this plane the Kosi is building a conical delta with contours running almost circumferentially with the centre situated in the vicinity of Belka Hill. The toe line of the Kosi delta could easily be demarcated comparing the contours of the base plan with those of the Kosi delta which rest on it. On the east, the delta appears to extend a little east of Katihar-Jogbani railway line beyond which the area is occupied by the Mahananda valley. On the west, western most Kosi channel of the present river course is running almost along the other edge of the cone.

In the process of building up of the land, the Kosi river moved westward to Madhepura by 1938 and the cone between the eastern most limit and the Mansi-Saharsa railway line was fully developed by then. Further west, the contours show a sudden depression ting the part of the cone to be built next, ie, after 1938. This remaining part of the cone was occupied by the Kosi by 1957 and the land was partly raised by sediment deposition resulting in partial smoothening of the 1938 contour lines. That the thickness of sand deposition after the Kosi has passed over a part of the cone could be gauged from the pattern of the contours. The maximum thickness appears to be of the order of 6 feet (1.8 m) in the middle reach in between the contours of the 150 and 175 knowing the thickness of sediment deposition and the part of the cone over which deposition has occurred during the period 1938 to 1957 the total quantity of sediment deposit works out to 1.6 million acre-ft (1973.6 MCM) in 19 years, ie, 0.083 million acre-ft (102.4 MCM) per year.

After deposits were formed where the river slope was deficient for carrying material further down, the adjoining part of the cone remained low inviting the river to shift towards the low ground. This shifting was neither very systematic nor regular. However, the general pattern was the same. Out of the several flowing channels, only a few channels at a time carry major discharge. When these channels get silted up and their beds are raised,the adjoining channels carry more discharge and in turn, become the major channels. Thus, in the progressive shift of the river from east to west the major channels existing at any one time slowly went on dying, while the channels further west progressively opened out.

The study of the contour plan of the Kosi delta from 1947 to 1963, although not covering the whole area of the delta, is helpful in indicating the river reaches that are prone to silting and scouring. From the contours that again run circumferentially south of Hanumannagar, the tendency of cone formation is evident. It may, therefore, be inferred that the river is aggrading in this reach. North of Hanumannagar, the contours run mostly straight while near Belka hill the contours are curved in a fashion opposite to those indicated downstream of Hanumanagar and further upstream and tendency for bed scour is indicated till near about Belka Hill.

From the above findings, the shifting of the courses of the Kosi river appears to be caused by the deficient river slope in the lower reaches, which is not able to carry the excessive load brought down by the river. The river in the natural course would have continued building the delta for many years causing heavy devastation in North Bihar during these years and ultimately achieved such a stable slope, probably along the line running straight south from Chatra, so that all the sediment could be carried down the river, with progressive changes in the bed materials load caused by attrition and sorting. The 1953 Kosi Project was designed to hold the river to one course, occupied by the river at that time .This naturally hindered the processes involved in the delta activities of the river giving relief to vast areas formerly effected in such process".

Dr S V Chitale of the Central Water and Power Research Station, Pune has held that the river slope immediately down stream of the barrage which is 0.44 metre per 1 km is the most stable.

He has advocated an idea that if the river bed is regraded in accordance with this stable slope, the shifting tendency of the river and its erosive nature would disappear. On this consideration he has suggested the following measures to be adopted -

i The length of the river Kosi should be shortened by joining it with the Ganges near Mansi, according to the above mentioned stable slope of 0.44 m/Km or alternatively.

ii An altogether new channel from the Chatra to Kursela be developed according to this stable slope.

The ideas formulated by Dr Chitale are based on sound logic. Leopold Maddocks of the United states Technical Co-operation Mission to India expressed a similar view as early as the year 1954 which was also reiterated by Dr Kanwar Sain as it has been pointed out in the comprehensive plan of the GFCC that the two alternatives suggested by Dr Chitale suffer from serious limitation as would appear from following -

(a) Both the proposals would involve developing of artificial channels of gigantic size which obviously would pass through developed and populated areas. This would naturally invite serious public objections.

(b) Prior to construction of the barrage, only part of silt of Kosi and that too only suspended silt used to be transported to the Ganga. This trend continues even after construction of the barrage and the flood embankments. But, after regrading of the river bed as suggested above the silt carrying capacity of the Kosi river will considerably improve, thus increasing the contribution of silt to the Ganga. Consequently, the river Ganga itself is likely to aggrade. In effect, this would mean transferring the problem of the Kosi to the Ganga. The possible repercussions of this excess silt contribution to the Ganga will therefore need a detailed study.

(c) The slope which has been considered to be stable by Dr Chitale is showing this apparent stability only because the upper reaches to this is having large scale deposits of coarser variety of sediment. This is borne out from the fact that even with a steeper slope in the reaches upstream of this so called stable slope reach, the river is aggrading. Hence, a stable slope, which shall give a sediment transport capacity, for all the sediment that emerges at Chatra gorge shall be much steeper than that considered by Dr Chitale.

(d) The Kosi is joined by other rivers like the Kamla, Bagmati etc. These, and the numerous drainage channels shall need a separate system of rivers for draining their catchment with independent outlets to the Ganga, at least one on the east and another on the west, creating more of the problems of getting land in developed areas, already discussed. In this case, this Commission is of the view that the idea propounded by Mr. S V Chitale of the CWPRS, Pune, and the comments offered by GFCC in the above para may be investigated thoroughly as well as hydraulic model studies should be carried out and final decision may be taken on the basis of such detailed studies.

The study of Morphology and Mechanics of the Kosi river has been attempted by the River Morphology and River Mechanics wing of the Central Water Commission. The important contents of their reports are as under -

1 The Kosi river can be divided into the following broad reaches from its origin in Nepal to its point of outfall near Kursela on the Ganga in Bihar. There is difference of elevation between the point of origin and the point of confluence to the extent of 80 metres. The length of the valley between these two points is 160 kms, indicating a broad valley gradient of 1 in 2000. Against this, the bed gradients of the river along its different reaches are as follows -

Sl No	Extent of the reach	Existing bed gradient	
1	0-42 km	1.4 m/km	(1 in 714)
2	42-68 km	0.716 m/km	(1 in 1396)
3	68-134 km	0.45 m/km	(1 in 2222)
4	134-310 km	0.11 m/km	(1 in 9090)

The above details will indicate that there is considerable difference between the valley gradient and the bed gradient of Kosi. Probably because of this, the river is showing the tendency of changing its course with a view to maximising the length to be as near the valley gradient as possible. Detailed model experiments are necessary to determine a stable channel length so that the valley gradient of the river equalises.

2 Long term data should be collected in a phased manner and studies on various aspects, such as aggrading and degrading tendency of the river along with the process of shifting of course due to change in slope or otherwise should be conducted. The data required and studies to be conducted have been indicated.

3 Prior to the construction of the Kosi Project, the river changed its course in westward direction moving about 112 kms between 1736 and 1953. It appears that there were three major directions in the river course and all the three took place in a very short reach between Chatra and Hanumanagar. It was from these three primary spill channels that the other secondary channels took off in the lower reaches and most of them took off between Hanumannagar and Bhaptiahi. Lower down the channels usually did not spill as frequently. Except for a few exceptions all the spills took place from the western bank. The long time gap between the major duration suggests that the silt deposition and the erosional processes responsible for the development of the new channels were rather slow. These processes lower down were quicker. It is also clear that the bank material in the upper reaches was more resistant to erosions than that in the lower reaches.

4 The above observations will help in identifying the relatively stable and unstable reaches of the river. A number of basic studies have been recommended for identification of the stable and unstable reaches, besides studies on the channels geometry also. These are listed under the next paragraph.

5 Study of morphology of the river should include the study of deep channel of the river and the prevailing water levels in the river from season to season.

6 It is desirable that the details of river training works of different types are collected and studies on their effectiveness be made. Whether any improvement in the case is necessary has to be studied in detail.

7 The solution for stabilising the Kosi appears to be in reducing the extra-ordinary high charge of silt brought by it from its unstable catchment. The reduction of this high charge of silt by appropriate methods has to be considered for any permanent solution of the Kosi.

8 One of the solution to achieve the objective of reductions of silt has been to construct a high dam in the higher reaches. The after effects of a dam have to be analysed and studied in detail.

5.6.7 In the study of morphology of the Kosi river in the Central Water Commission as described above a programme for collection of data in four phases has been suggested as a first prerequisite of the long lasting solution of the problem of the Kosi river. These are reproduced below -

Phase-I

i The river configuration plans should be prepared every year. These should show the bank lines, shoal formation and current direction. This may be supplemented by aerial mapping (This work except aerial mapping is done every year).

ii The stable and unstable reaches should be identified.

iii The river cross sections and L-sections should be taken every year and contour plans should be prepared after every five years or so to ascertained any appreciable change in the topography of the flood plain between the embankments (this work is done every year).

iv The most obvious causes of river attack should be accurately recorded for different reaches eg deflection of the current towards the bank due to the formation of sand bars or development of a deep channel near the embankment or sloughing of steep banks under saturated conditions. The distribution of the flow in various channels and the current direction should be recorded both for the low and high stages of the river.

v A detailed geological report should be prepared for the entire river basin highlighting -

a Various potential erosion spots contributing sediments.

b The past history of the river giving major geological and hydrological events that may have caused major changes in the river course and flow patterns.

c The mineral composition of the entire range of sediment particles.

This will help in understanding the process of reduction of sediment size in the downstream direction.

vi Additional GD and silt observation stations should be set up at the following places :

a Half-way between Barahkshetra and the barrage.

b At four places between Hanumannagar and Koparia to have five study ranges of equal length. The discharge should be measured by modern sophisticated equipment at all stages. In addition to the above stations, gauges should be observed at a number of intermediate points, preferably at the existing spurs so as to get accurate energy slope for different reaches.

c Representative river bed samples should be collected from each of the above study ranges to study the processes of deposition, erosion.

vii All visible effects of various spurs on the river flow, erosion of sand bars or deposition, etc, should be accurately recorded in detail. General performance of each spur during flood should be recorded in a history sheet.

Phase-II

The next phase will comprise the following basic studies for stable and unstable reaches -

i Analysis of hydraulic parameters establishing relationship between discharge, on one hand and depth, width, bed slope, velocity and Mannings 'n' on the other.

ii Relationship between various parameters of channel geometry, eg meander length, meander width, river width, depth. How these relationships get affected by major changes in discharge and velocities.

iii Aggradation/degradation of the river bed should be ascertained by a study of the G-D rating curve for each study range.

Phase-III

This phase will comprise the following -

i Finalising the empirical formula for use in mathematical models for the river.

ii Work out the maximum and minimum safe discharges for a stable meandering river.

iii Work out the meander length, width and other channel parameters for the river and the river alignment.

iv Work out the critical design hydrograph for the river.

v Work out the appropriate silt charge that can be safely routed.

Phase-IV

This phase will comprise :

a Planning structures like spurs, revetments to bring the river to the desired alignment with proper curves, bends and meanders.

b Planning control structures for routing the design hydrograph and silt cnarge. Data collected in each phase shall have to be analysed to establish relationship between various hydrologic parameters of flow and some characteristic of the flow of river Kosi will have to be enclosed which can be then projected for working out a pattern of stable river regime, which is the end-result of all data collection.

As a second line of future action, study on the following specific points has been suggested:

1 To evolve measures to be taken for the shifting of the river towards the centre from the present trend of shifting eastward.

2 To examine and work out a programme to make the river straight downstream of the barrage from its present trend of immediately turning on the eastern side.

3 To check up whether the original course of river Dhemra dhar is just hugging the line on which the eastern embankment is constructed at present.

4 To examine the possibility of construction of cheaper permeable spurs instead of the present costly impermeable spurs.

5 To explore the possibility of constructing sloping spurs to remove unwanted shoal, sand, bars, etc.

6 Study of aggradation, degradation, pattern of natural meandering and other characteristics for this river.

7 To decide the necessity of raising the flood embankments.

5.6.8 Comments of the Ganga Flood Control Commission on the aforesaid study of the Kosi river morphology and its mechanics by the CWC is given below :

1 The study of the morphology of the river Kosi should aim at not only achieving the stable course of the river, but also ensure that the regime thus achieved is capable of safely carrying the flood discharge from the gorge to the Ganga as well as permit the entry of drainage channel from the countryside into the river so as to effect satisfactory drainage in the nonflood periods. It is, therefore, suggested that the study of the morphology of the river should include the study of the deep channel of the river and the prevailing water levels in the river from season to season. The entire process of drainage is still going on and a long term solution has to be found out with regard to the trend of development during recent years.

2 The history of the Kosi is that it has been shifting its course from time to time. Even after the construction of the barrage and embankments, the river has been maintaining its shifting tendency

but it has been kept confined within the embankments. The study of the effect of the Kosi project on the river Kosi has therefore, to take into account the change of the river prior to the construction of the Project vis-a-vis the trends in the post-project condition.

The physical phenomenon of prevention of the change of the course of the river beyond the limit set by the two marginal embankments is self evident.But it has to be remembered that in the Post project condition, the river is carrying depositing silt in a limited space between the embankments the implications of which have to be assessed in the study of the morphology of the Kosi.

3 The river Kosi has a much more stable reach lower down where the country slope becomes flat and the silt charge becomes manageable. On account of the steep slope in the upper reaches, it may be extremely difficult to attain a slope as flat in the upper reaches as is prevailing in the lower reaches. Even if a flat slope is achieved in the upper reaches due to the barrage the problem of silt in the upper reaches with an artificially created slope may become enormous. It becomes, therefore, clear that a mere identification of the relatively stable reach of the river and trying to induce the geometrical parameters of these stable reaches in the unstable reaches may not bring about the desired result of stabilisation.

4 Keeping in view the observations in para 3 the solution for stabilisation of the Kosi appears to lie in reducing the extra ordinary high charge of silt brought by it from its unstable catchment. Thus a mere study of the data relating to the river in the reaches down the gorge may not provide the desired solution. The reduction of the high charges of the silt by appropriate methods has to be considered for any permanent solution of the Kosi.

5 One of the solutions suggested to achieve the objective of reductions of silt has been to construct a high dam in the higher reaches. One consequence of the dam may be degradation below the dam which may be limited by the coarse material of the bed forming an armour. But the size of bed material decreases with distance from Chatra, hence a larger and larger volume of sediment may be removed to secure adequate amount of material large enough to resist in flowing water. This section may result in steepening of the slopes for some distance and at some point further down a deep channel might be excavated. The ultimate result in the lower reaches may be a larger and still a larger amount of material by side-ward movement of the river and, finally, resulting into development of a meandering river. Such a situation has been reported to have taken place in the USA on the Colorado river below the Hoover dam. The after-effects of a dam have also therefore, to be analysed and studied in the morphological study of the Kosi.

6 The main thesis of the report appears to be the observation given at page 138, that the river would be stable when the channel gradient and valley gradient are the same. The author advocates experience to determine this channel length of orientation by model study and adopting river training works for ensuring this. The Mississippi river is quoted as an example. The detailed justification for this theory should be given in the report before suggesting its adoption.

7 Lots of silt data are available in respect of the Kosi. Any morphological study of the Kosi is, therefore, incomplete if these data are not incorporated in the study and discussed to identify the problems and remedial measures.

8 Training works of different types have been used with a view to taming the Kosi. It is desirable that the details of these training works are collected and included in the report. How far they have been effective and whether they need any improvement to achieve the objectives are some of the questions which need to be discussed and answered in a report of this type. The cubature study of the Kosi was made about 14 years back.

9 The last 14 years data can be utilised to find out the present status of the behaviour of the trend of the river.

5.6.9 Changes in the Regime Characteristics of the Kosi River.

Considering from the general appearance, the formation of the river Kosi is rather peculiar and distinct from that of other rivers. Normally, a river has three distinct reaches first in the hills where the stream very rapidly flows generally in a deep gorge with steep sides followed by the second one called up-land region. In the second reach the river is comparatively much broader and still flows in a deep valley with high margins on both sides. The next stage, ie, the third one is a deltaic formation. In case of the Kosi the middle reach which is called the upland region is practically absent. The river begins to exhibit the deltaic characteristics immediately after it enters into the plains at Chatra.

The first and second reaches, as mentioned above, usually provide a favourable location for construction of control structures. Prior to construction of the Kosi barrage a lot of deliberations and apprehensions were made regarding technical feasibility of the project, its location, post-effects, etc. Finally, the barrage site was fixed at the end of a steep reach of the river about 5 Km upstream of Hanumannagar. From all considerations, this location is found to be most stable excepting the absence of a high margin, particularly in the eastern side to tie up the structure. So a fairly high and rather long afflux bund was considered to be a solution to this problem. This naturally made the weakest link in the scheme.

Some of the apprehensions made at that time in this regard by eminent experts in the field are brought out as follows:

i That the inter position of a barrage would greatly alter the river condition by flattening the gradient upstream of the barrage which would cause considerable deposition of the coarse sediment at further end of the pond. In the initial years, due to canalisation and centralisation, heavy deposition of silt would be likely to take place at the flanks which would, in effect, strengthen the earth dam, eastern and western embankments and a small reach of the afflux bunds up stream of the barrage. In the long run flattening of the gradient would cause aggradation at the upper end of the pond and intensify the braiding action there.

ii The new spill channels might appear in the upstream which would attack the eastern afflux bund as the country slope is from west to east there and the river runs at a higher level than the adjoining country on the east.

iii To the brighter side, it was observed that it would improve the regime of the river below, as the sediment load below the barrage would be less because of trapping of a part of the sediment load in the pond area. Since the sediment load in the Kosi flood water is excessive, such action is likely to introduce an altered condition in the river section in regard to width, velocity and slope, which might lead towards the establishment of stable condition in the downstream.

iv It was felt that the life of the barrage would be the life of the afflux bund looking at the problem from the element of the risk involved in the pond. Next came the question about the period of usefulness of the barrage assuming the eastern afflux bund would be held on to. In this context, Messrs Maddock and Leopold observed that gradually a stable gradient would be established in the upstream of the barrage and subsequently the full load of coarse material would pass down the barrage. However, they were unable to estimate the length of the period by which time such position would be reached.

v Sir C C Inglis rather made a very alarming statement that the barrage capacity for the suggested pond level would be filled up in some seven and half years if all the coarse material were trapped and in 2 years if both coarse and medium sediment were collected. However, this observation of Sir C C Inglis evoked much adverse criticism and such statements were disregarded as lacking in a realistic basis. After about thirty years of operation of the barrage, this apprehension has proved to be baseless.

Since commissioning of the Kosi barrage, nearly thirty years have passed by. If those apprehensions are reviewed in the light of the present position, it would be seen at the first instance that all the components of the Kosi project still stand effectively performing the functions for which they were meant. However, aggradation is found to be taking place extensively both upstream and downstream of the barrage. There are also instances of bank erosion in some reach or other of the river both upstream and downstream. The flattening of the steep slope in the upstream of the barrage has taken place which was one of the objectives of

As already stated earlier, the river Kosi from Chatra to Supaul is braiding in nature, consisting of a number of interlacing channels. Sometimes, the main river is concentrated in one of the channel which may get transferred to another one during the next year. Such changes in one single flood season are also not very uncommon in the Kosi. This causes shift in position of attack on river banks and the flood embankments from year to year and even from season to season. It has also been explained already as to how expensive the anti-erosion measures in the Kosi belt are proving to be. It is, therefore, of paramount importance to analyse the river behaviour in order to find out the channel pattern and its tendency, whether the braided reaches in the pre-barrage conditions have changed to the meander pattern or if not, whether at least the braiding pattern has minimised.

The attempt so far in the study of the morphology of the Kosi has been just to introduce the morphological aspect of Kosi river in a very preliminary form. This Commission, however, hopes that with further strengthening of the concerned organisations and collection of the basic data, further analysis covering more details about the Kosi and its morphology will be done so as to utilise the same for working out a better and quicker solution and at the same time at a lower cost which will serve for decades.

6.0 FLOOD AND DRAINAGE PROBLEM

6.1 Flood Problem

6.1.1 The records are available in the District Gazetteers of Saharsa and Purnia as well as in the Water Resources and Revenue Departments of the State Government for the floods that occurred in the Kosi river basin since 1866. During floods the river used to spill over its banks and flood a large tract of land in the Districts of Madhepura, Saharsa and Purnia and the high velocity generated during flood caused a huge loss to both human and cattle life and property. From 1922 to 1936 the Kosi flowed through a number of channels, such as the Belhi dhar, the Parwane dhar, the Tilawe dhar, etc. During this period the town of Madhepura suffered a great deal due to the Kosi flood havoc and the sub-divisional offices had to be shifted to Supaul.

The severity of flood problem in the Kosi river system has been mitigated, to a great extent, after implementation of the Kosi project partly in 1959, when embankments on both sides of the river of full length were completed. The eastern embankment having 144 Km length extends from Nepal to Koparia in India and the western embankments having 123.2 Km length extends in two parts from Jalpapur in Nepal to Nirmali in India and Ghoghardiha in India to Ghoghepur opposite Mahesi. In 1968 the highest flood discharge ever recorded in the Kosi was observed, but damages were comparatively low and that too, because of the four breaches in the lower reaches of the embankment. In other portions, the embankment stood well and prevented the recurrence of 1954 flood disaster. The flood prone area in this river system is about 1.015 million ha in Bihar.

6.1.2 Unlike many rivers in India, the river Kosi does not have any defined flood plains. It is rather extensive and changing alongwith the shift in the course of the river towards the west. The flood problem gets aggravated when the Ganga is also in flood simultaneously and the outfall of the river Kosi is choked resulting in back flow of the Ganga in to the Kosi. Any breach in the embankment in such a situation, therefore, results in a catastrophe in the area.

6.1.3 The river Kosi brings an enormous amount of silt from the Himalayas. The silt load is deposited in the bed as the river travels in the plains and causes the river to spill its banks and shift its course. Such excessive deposition of silt is reducing the capacity of the river channel gradually and lots of shoals and islands have been formed in the bed of the river. The average annual silt load carried by the river is about 95 MCM as observed of at the Barahkshetra site. The braiding and shifting nature of the river along with aggradation of its bed is considered to be the direct consequence of the excessive quantity of silt load brought down by it during the monsoon period. The river Kosi is known to have shifted by a distance of about 112 Km to the west in the last 250 years and this trend of transitory movement is still continuing in the shape of continuing attacks on the two marginal embankments. The everchanging river course is threatening the flood embankments in one or another reach every year. The Belka nose, where the slope flattens from 95 cm to 61 cm per km is obviously the place where most of the bed load is dropped. The consequent aggradation of the river bed then results in a braided pattern for the river nearly up to Hanumannagar. Below Hanumannagar, there is a further flattening of the slope to about 38 cm per km which continues up to Sikrahata and Bhaptiahi. Beyond, there is a further flattening of the slope to about 19 cm per km. It is in this reach where the slope changes and most of the coarse sediment gets deposited. Only medium and finer materials are found below Kharhara about 64 Km downstream of Hanumannagar. Below Jamalpur which is about 86 Km downstream of Hanumannagar the medium grade materials also practically disappear.

6.1.4 The Kosi project was taken up in 1955 and the embankments were completed in 1959 and the barrage by 1963. After commissioning of the Kosi project, flood damage in this basin takes place, mainly due to spilling and drainage congestion. The protective measures in the Kosi project flood embankments are being taken up every year to ensure the safety of the embankments. Before taking these measures, it has been the normal practice every year to prepare a survey plan and cross-sections of the river after the flood season in order to send the data to the CW & PRS, Poona for conducting model studies. The result of model studies used to be available to the project authorities sometime by the end of March or April.Thus the project authorities were left with very little time before the next monsoon for executing the works recommended by the CW and PRS, Poona. To obviate this deficiency a standing highlevel experts committee has been constituted by the Government of Bihar to advise on the immediate works to be undertaken every year well before the next flood season in Eastern and Western Kosi afflux bunds, eastern and western Kosi flood embankments and Jalpapur protection works. The proposals given by this highlevel experts committee relates to strengthening, rebuilding of the existing spurs, extension of existing spurs, constructions of new spurs at locations indicated by previous model studies and/or experience in the past flood seasons, alongwith construction of flush bunds and channelisation of dhars at some places.

6.1.5 The History of past floods as available from the records of the district gazetteers of Saharsa and Purnia as well as Irrigation and Revenue Departments of the State Government have been summarised in the statement at Annex 5.

6.2 Drainage Problem

6.2.1 The Kosi river basin suffers from acute drainage congestion due to the existence of numerous depressions known as 'Mauns' and 'Chaurs' and the old, abandoned courses of the river. The topography of North Bihar had been thoroughly disturbed during the major earth quake of 1934, causing upheaval and depressions which disturbed the gradient of the rivers and aggravated the problem of flooding and drainage congestion. The abandoned courses of the river Kosi, commonly known as "Dhars", are meandering, mostly overgrown with weeds, partly silted and are not able to drain the area properly. The capacity of most of the right bank tributaries of the river Kosi has declined considerably due to the siltation of the bed, weed growth and flattening of the hydraulic gradient. Their water ways have mostly been encroached upon for cultivation and are blocked at some locations by means of artificial barriers for fishing. All these factors lead to drainage congestion in the basin particularly during the non-monsoon months. A wide strip of area along the countryside of the embankments shows waterlogging conditions throughout the year. This is so due to the non-functioning of the sluices in the embankments on the Kosi due to a substantial rise in the river bed (1.5 m to 2 m higher than the countryside G.L.)near the embankment as well as the non-existence of favourable conditions of the outfall of the Kosi due to the high level in the Ganga. These are the main impediments in the drainage of the area during the monsoon. Heavy precipitation coupled with high stages in the outfall channels further aggravates the drainage problem during the monsoon months. Inadequate waterways in many rail and road bridges and cross drainage works in the canal system and non-provision of such structures at certain locations where water accumulates for want of proper drainage arrangement are also factors contributing to drainage congestion in the basin. The total area reported to be suffering from the drainage congestion and waterlogging is estimated to be about 1.82 Lakh hectares. Apart from the problems of congestion in the trunk drains, the absence of subsidiary trunk drains connecting the depressions with the trunk drains and drainage congestions in the subsidiary trunk drains also accentuate the problem.

6.2.2 It appears that the area suffering from surface drainage congestion in the basin is not being systematically surveyed and recorded every year in order to know the magnitude of the problem. It has also not been possible to separate the areas affected by flood spills from those affected by the drainage congestion because such details have not been observed. Efforts should be made to observe and keep separate records for the two aforesaid categories without any further delay. In the absence of such information, it is not possible at this stage to make an analysis and relate the extent of drainage congestion or flooding with the magnitude and duration of floods experienced in the river in the different years.

6.2.3 A sub-surface drainage condition in the basin is also a likely factor which contributes to the problem of drainage congestion. The introduction of canal irrigation which adds to the rainfall contribution charging the sub-soil may, therefore, cause local rise of the sub-soil water level. This effect has not as yet been identified due to the prevailing surface drainage congestion. After the surface drainage congestion is removed the studies of the variations in the sub-soil water level may eventually indicate the necessity of relieving related sub surface drainage congestion. The problem of drainage congestion and waterlogging of the Eastern Kosi canal command area has been surveyed by the project authorities and it has been found that for improving surface drainage and removing waterlogging resectioning and regrading of about 694 km of trunk drains, 1411 km of subsidiary drains and excavation of 1080 km of Chaur link drains will have to be carried out for effective drainage and reclamation of about 1.092 Lakh ha of water logged area in the Eastern Kosi Canal command. Well observation in the Kosi canal command is being done in the monsoon and non-monsoon periods after introduction of irrigation. The observations made so far indicate that since 1965 to 1970 there is a tendency of rise of 0.6 m to 0.9 m in the sub-soil water level in the Kosi basin. The available records indicate that the ground water level varies between depths of 1.5 m to 6 m depending upon the zone and the season. Thus it is clear that with the advent of irrigation from the Kosi canal there are indications that the sub-soil water level has risen. The Kosi Technical Committee, 1971, in its report had said that in certain areas where the water table is already high and within 1.50 metres of the ground surface it is apprehended that such rise will lead to waterlogging conditions resulting in damage to crops. It is, therefore, necessary to carry out systematic field investigations regularly so as to pin-point such water logged zones which are due to lack of proper sub-surface drainage.

6.2.4 It appears that a post-facto evaluation study of any of the completed drainage schemes either in this basin or any other basin in North Bihar has not been undertaken so far. Such evaluation studies for a few completed drainage schemes in the basin need to be undertaken quickly so that future planning for removal of drainage congestion in the basin is executed after knowing their usefulness and efficiency.

6.2.5 A number of sluices have been provided in the embankments at suitable locations in order to provide drainage of the area lying on the countryside of the embankment when the river stage is low after floods. It is necessary to conduct a review of the overall functioning at present as well as the adequacy of such sluices in the embankments in the basin and to take further necessary action on the basis of such a review. It is, however, observed that even where sluices have been provided, they have become inoperative due to one or more of the following reasons-

a Substantial rise in the river bed near the sluices, as compared to the natural surface level on the countryside.

b High stages prevailing in the river,

c Choking of the leading channel of the sluices due to siltation or encroachment,

d Non-operation of the gates due to mechanical faults and

e Shifting of the river channel away from the sluices and heavy siltation near the sluice on the river side.

6.2.6 It is a common saying that the problem of drainage congestion and waterlogging increases with the introduction of irrigation. While this may be true in some cases, it cannot be applicable universally.

Some of the waterlogged areas in the basin existed even before introduction of irrigation in the river system and virtually, there has been no change in their extent. It is, there-fore, necessary that groundwater structures in the basin are systematically and regularly observed to ascertain the fluctuations in the sub-soil water table and records maintained for future planning of remedial measures. It appears that such studies are not being carried out regularly in a systematic manner.

6.3 Flood Damages

6.3.1 The damages caused by flood and drainage congestion are classified broadly into the following two categories -

a Direct damages and

b Indirect damages.

6.3.2 The direct damages are those which are caused due to the direct physical contact with flood water. These include losses to (a) growing and pre-harvest crops, (b) houses and household assets, (c) public utility works, (d) public buildings and (e) loss of human lives and livestock.

6.3.3 The indirect damages are not susceptible to quantification. Therefore, approximate monetary evaluation can only be done for such damages. These generally include :

a Loss of earning in agro based industry and trade,

b Loss of revenue to the road and rail transport system due to disruption of services,

c Loss of earnings to small shopkeepers and other daily wages earners and

d Loss of employment to the daily wage earners in the public and private sector.

6.3.4 The flood damage data are collected by the Revenue (Relief and Rehabilitation) Department of the State Government and passed on to the various concerned organisations of the State & Central Governments. The CWC is collecting and compiling such damage data of all flood-prone States at the national level.It is observed that the flood damage statistics,which is essentially required for the benefit-cost studies for any proposed flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed.The commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river basin wise be carried out every year under the following three separately identified categories:-

i Unprotected areas;

ii Protected areas due to failure of protection works;

iii Areas between the embankments and the river.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned Departments at the end of each year.Such reconciled long-term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area. The Central Flood Control Board had decided that the Flood Control Departments of the States should compile basin wise flood damage data with effect from 1960.

This is not being followed in Bihar and the flood damage data still continue to be collected districtwise (not basin wise) by the Revenue (Relief and Rehabilitation) Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of relief operations that become necessary on account of the immediate requirements of current damage caused by the flood. As such, the need for compiling the annual flood damage data, according to the administrative jurisdiction in district and blockwise category in the State, cannot be denied. On the other hand, planning of the flood management measures are to be done on a basin and sub-basin basis. It is, therefore, necessary that such data are collected by the revenue authorities with active co-operation of the staff of Water Resources, Agriculture and Roads and Building Construction Departments and the data are processed and compiled both districtwise and basin/sub-basin wise by the statistical organisations at the district and the state level for future use for planning of relief measures and flood management works respectively.

The flood damage data for the Kosi river basin converted from the available districtwise figures are enclosed at Annex 6. Proportionate damage in accordance with area has been accounted for in the case of the districts which partially lie in the Kosi river basin.

6.3.6 From the perusal of the data processed by the Revenue Department, it is noticed that damages to property of the Central Government, such as Railways, Posts and Telegraphs, etc, are not properly accounted for. On the other hand, the cost of relief and rehabilitation measures, grant of loan, remission of land revenues, etc, is added to flood damage. This does not appear to be in order.

6.3.7 It would be evident from the available flood damage data of the basin (Annex 6) that average annual area effected by flood is 3.10 Lakh ha. The average annual damages to the crops, houses and public utilities at the 1991 prices work out to Rs.3188.20 Lakh, Rs.548.88 Lakh and Rs. 693.52 Lakh respectively, totalling to Rs. 4430.60 Lakh. During the period (1968 to 1992) for which the data are available, the maximum damage amounting to Rs 38,917.38Lakh occurred during the year 1987 and the minimum damage of Rs 176.31 Lakh in the year 1990 at the 1991 price level.

7.0 PAST APPROACH AND ACHIEVEMENTS

7.1 In the early days embankments were constructed to prevent the spill of river from causing damage to the agricultural lands, properties and inhabitated area. It is also observed that such embankments were not constructed in continuous lengths in a systematic manner but in scattered reaches. The construction of Eastern and Western Flood Embankments were taken up in January 1955 and were completed by 1958-59. Prior to the construction of these embankments, there is no available record regarding zamindari or unauthorised embankments in the Kosi basin. However, in 1896-97 on the basis of findings at a conference at Calcutta presided over by the Secretary to Government of India, PWD, several short lengths of embankments of varying dimension were put up to protect individual properties or areas by interested parties all over the region without any standard selection and without ascertaining the effect of such bunds on the course of the river lower down.

7.2 No clear cut flood control policy was laid down in earlier years but committees of Experts were appointed to examine the problem and suggest remedial measures whenever flood of severe intensity causing large-scale damage occurred. Most of the suggestions made by such committees could not be implemented either for want of funds or for other reasons. One of the worst and devastating floods occurred in the country in the year 1954 and Bihar was no exception. The Government of India announced a national policy on flood control and launched a national programme of flood control in the year 1954. This policy stressed the need for collection of data and formulation of plans, implementation of short-term measures like embankments and channel improvements and long-term measures like construction of storage reservoirs on tributaries in conjunction with embankment,all under an outline of time-bound programmes. No long range plan could, however,be immediately formulated for want of survey and investigation as well as historical data but emergent schemes were prepared and executed to provide a reasonable degree of protection from the ravages of floods to the areas concerned. These schemes have served their desired purpose.

7.3 The river Kosi was embanked on its both banks. The details of these embankments are enclosed at Annex 7.

7.4 The Central and State Governments appointed several committees to go into the problems of flood and suggest remedial measures. The recommendations of such committees relating to the Kosi river basin are described in the following paragraphs.

7.4.1 In November 1937, a conference of officials and non-officials was called by Government of Bihar to discuss the very difficult and pressing problem of floods in North Bihar. At this conference the controversy centered mainly round 'Embankments' or No Embankments. Captain G F Hall, Chief Engineer, Bihar was for an all-out policy of removing all embankments, public or private on the ground that embankments did more harm than good, that they merely transferred the trouble from one area to another and that they gave a false sense of security. He contended that embankments interfered with the natural process of land-building and delta formation of the river. The deliberation of this conference, however, did not lead to any constructive approach towards the solution of the flood problem in North Bihar.

7.4.2 Sir Clande Inglis submitted a report after visiting the areas in the Kosi basin in January 1941. He suggested for possible check in soil erosion in Nepal through a comprehensive scheme preferably based on model experiments after investigating river discharge, silt charge, ground levels and sub-soil water level. But as no satisfactory scheme for the control of the Kosi and flood damage could be prepared on suggestions made by Lord Wavell, the then Viceroy of India in December 1945, the problem of the Kosi was referred to the then newly constituted Central Waterways, Irrigation and Navigation Commission for advice.The Central Waterways, Irrigation and Navigation Commission in June, 1950, after considerable field surveys and geological investigations of the site, submitted a project report for a multipurpose scheme which comprised the following :-

a Construction of 238.72 m (783 ft) high dam at Barahkshetra to impound 0.85 million ha m(6.9 million acre ft) of which 0.38 million ha m(3.1 million acre ft) was to provide silt reserve, the remaining 0.47 million ha m (3.8 million acre ft) was intended to moderate floods to a safe maximum of 5664 cumecs (2 Lakh cusecs).

b Generation of hydroelectric power to the extent of 1800 MW.

c Provision of navigation facilities in the reservoir and the river below and

d Construction of a barrage and canal system for irrigation of 15.54 Lakh ha (38.4 Lakh acres) in Nepal and Bihar, annually flushing drainage channels and siltation of low lying areas and for generating 90,000 KW hydroelectric power on the Eastern canal.

On the basis of the Advisory Committee (1951) recommendations, investigations at the Belka dam site lower down in Nepal were conducted and detailed estimates were prepared for the Belka dam. But these estimates were far in excess of the figures assumed by the Advisory Committee. The CW & PC, therefore, made alternative studies for a low detention dam at Belka. When these proposals were under discussion with some of the members of the Advisory Committee and Planning Commission, Shri Kanwar Sain, Chairman of CW & PC inspected the Kosi area with Bihar engineers during the flood season and discussed the problem of prevention of flood damage in Bihar in great detail. The outcome of the discussion indicated that even a flood of 5664 cumecs (2 Lakh cusecs) obtained after moderation through the Barahkshetra Dam would inundate large areas on both the banks, Thus, the embankments appeared in-escapable on account of the fact that there is a difference of a few feet of inundation between 5664 cumecs (2 Lakh cusecs) and 25488 cumecs (9 Lakh cusecs) of discharge values. Therefore, as regards the construction of a high dam at Barahkshetra, it appeared then that the investment of large fund was not justified owing to the insignificant flood moderation effect and low demand of power generated at the dam site. On these considerations, the comprehensive project prepared by the CW & PC in 1950 did not appear to be economically viable. The flood problem of the Kosi was recurrent and had to be lacked without further loss of time. Fresh studies and deliberations in the CW & PC culminated into the revision of the former proposals and formulation of what is known as the Kosi project, 1953. The 1953 project proposed construction of a barrage at Hanumannagar at a distance of 48 Km below Chatra with pond level at 74.69 m (245 ft). Embankments were proposed to be constructed on either bank of the river, the right embankment extending from Jalpapur to Jhamta and the left embankment from opposite Belka to Bangaon. These embankments were to confine the river in the middle reach, where the effect of its lateral movement was mostly felt. A regulating structure was also proposed in the barrage to enable 50,000 cusecs (1408.5 cumecs) to be diverted away from the main river into the old dhars on the left bank.

The CW & PC invited several experts from inside as well as outside of the country to review 'the 1953 project' in the light of the fact that the Kosi river carries a large quantity of coarse silt. Most of the experts agreed that the problem of flood control in the Kosi was a long drawn affair posing difficult issues and would require constant attention for the protection of a vast region of thickly populated area. Some useful suggestions were received and taken note of. In continuation of these studies, Shri Kanwar Sain and Dr K L Rao, eminent engineers, were deputed to china by the GOI to study the flood control works there on the yellow river and other similar rivers. On return, they recommended that the free board of the Kosi embankments should be increased from 1.22(4 ft) to 1.83 (6 ft) to provide ample margin in case any silting in the bed of the river between embankments took place. Another recommendation of this team was that the embankments be constructed with public cooperation.

7.4.3 The Ministers' Committee on Flood constituted in 1964 by the Ministry of Irrigation and Power GOI had observed that a programme should be drawn up for the utilisation of 'chaurs' as detention basins. Widening of waterways in railway and road bridges should be taken up more vigorously.

7.4.4 The North Bihar Drainage Committee was set up in 1965 by the Ministry of Irrigation and Power, GOI to make a detailed study of the drainage requirements in North Bihar. The committee made the following recommendations :

a Augmentation of the existing network of rain-gauges, gauge and discharge stations and collection of data on a systematic basis,

b Provision of adequate drainage systems in irrigated areas and the criteria which are to be followed in their design and

c Provision of additional waterways for road and railway bridges and adequate drainage sluices in the embanked portions.

7.4.5 At the instance of the National Flood Commission appointed by the Government of India in 1976 the programme evaluation organisation of the Planning Commission undertook evaluation of the Kosi embankment project with a view to assessing the economic benefits of the projects. The abstract of the relevant assessment made by the Programme Evaluation Organisation is given below :

i According to an estimate, the annual loss in pre-embankment period was of the order of Rs. 6 to 10 crores depending on the intensity of flooding which on the basis of the present price structure would be very high. The same could be prevented with the construction of embankments. The duration of floods generally lasted for 2 to 3 months, thereby disrupting the communication system.

ii Long embankments on both sides of the river and a barrage upstream at Hanumannagar helped to hold the river and the people of the area developed a sense of security. A vast area of 1.6 Lakh hectares in the district of Saharsa could be protected from the ravages of flood. The barrage helped in creating the irrigation potential through the networks of canals.

iii More than Rs 1 crore were being spent on the maintenance of embankments every year. Since attack on embankments has been shifting from year to year, it necessitates construction of new aggradation spurs. In the absence of proper maintenance of embankments, serious flood hazards are likely to be witnessed by the protected areas.

iv Though embankments by stemming the floods had benefitted the area and the people, it created some potential dangers to the zone inside embankments which is liable to experience greater threats of floods than before. The annual sediment load of the river which is not reduced by way of construction of barrage tends to concentrate in the central basin raising its level and creating the problems of seepage and drainage congestion due to choking up of the sluices. It may also result in overtopping of the embankments thus defeating the very purpose of embankment. Moreover, the heavy sedimentation may obstruct the flow of the Kosi further downstream and lead to overtopping of the ridge north of the Ganga.

v As a result of embankment, a vast area lying within 5 Km of left embankment is submerged under water. Besides a vast area on eastern embankment is obsessed with the menace of water logging and even in a period of two decades since embankment nothing could be done to mitigate the worsening situation of the people there.

vi The water table of the Kosi area, because of constant inundation and heavy rains has risen high to the extent that it is detrimental to the agricultural productivity.

vii The embankments were constructed with a view to protect the area from the ravages of floods and bring about speedy economic regeneration. Since the whole gamut of developmental activities were not taken up simultaneously, tangible effects were not realised in most of the area.

7.4.6 Rastriya Barh Ayog (RBA) in March 1980 has given its view on the assessment made by Programme Evaluation Organisation of the Planning Commission. It reads 'As some of the members raised points which go to the very root of some of the findings of the case study and as for want of time the Commission could not discuss these points with the Planning Commission and representative of the Bihar Government, it has not been possible for the commission, however, agrees with the following findings of the case study-

"The annual loss of pre-embankment period was of the order of Rs 6 to 10 crores depending on the intensity of flooding, which on the basis of present price structure would be still higher. The same has been prevented with the construction of embankment which was completed in 1959. The total expenditure on the embankment to derive the above benefit was about Rs 40 crores, including cost of special repairs and of impermeable spurs etc constructed up to March 1978. The people of the area have developed a sense of security after the flood protection and holding of the river which was of a shifting nature in its present course between the embankments.

The cost of protection of the embankments against river attacks has been more than Rs 1 crore per year. In the absence of proper maintenance the protected areas are likely to be exposed to serious flood hazards.

On the negative side, the embankments have enhanced flood problems in the unprotected area between the two embankments. The continued rise of river bed has created problems of seepage and drainage congestion, aggravating the water logging problem of the protected area particularly in a strip along the eastern flood embankments.

The case study has also highlighted the interaction of irrigation introduced in the protected area and how in the absence of the whole gamut of developmental activities, tangible effect of speedy economic regeneration were not realised in most of the areas.

This single case study represents the problem of embankment along a specific aggrading river with high silt charge".

In the same report given by RBA, it has indicated the method of evaluation of performance of flood embankments, wherein, it has emphasised on the collection of the required data for dependable evaluation of the performance of the existing and future flood control works. The report says "Some of the required data would be with regard to the pre-project status -

a The proposed protected area, and perhaps some neighbouring protected area, and

b The river regime and its hydrology"

The Commission had asked for the following informations with regard to each embankments scheme costing more than Rs 25 Lakhs in the Kosi river basin vide its questionnaire sent to the Engineer-in-Chief and the Chief Engineers Birpur and Purnia of the Water Resources Department -

a past breach or overtopping,

b past retirement due to river attack or protection work,

c estimated assets ie, building etc and extent of area cultivated before and after completion of the scheme,

d post-embankment drainage congestion with average depth, duration and extent of water accumulation over the protected area,

e benefits derived year by year in crop area and monetary value of the same,

f quantitative evaluation of the economic condition before and after construction of embankments,

g creation of additional flood problem on upstream, downstream and opposite bank after embankment construction,

h river behaviours and post monsoon river survey including river cross section, and

i actual performance compared to the same in the project report regarding evaluation of economic viability.

The replies to these questionnaires have not been received by the Commission. The Commission would suggest that such details be prepared for the past by retrieving historical records and should be continued to be compiled, analysed and properly recorded in future at different levels so as to make these easily available whenever required.

7.4.7 Other flood control measures considered in the past in the Kosi river system are as follows:

i Alternative sites for flood moderation reservoirs-

The Belka dam had been recommended by the 1952 Advisory Committee in its report submitted to GOI. The 1965 Kosi Technical Committee observed that this dam would provide silt storage of 0.8 million acre feet (0.986 Lha-m only), which would not be adequate for more than 10 years. Also observing the cost and submergence area, the committee opined that no tangible advantage would be obtained by construction of this dam.

ii Erstwhile CWPC had suggested investigation for a 155.5 m (510 ft) high dam at Kothar 6.4 Km (4 miles) downstream of Barahkshetra dam site.

But the geological conditions at this site did not suggest construction of such a high dam. Further the reservoir created by this dam would have submerged the ancient Hindu Temple at Barahkshetra which would arouse religious sentiment against this dam.

In view of this the 1965 committee was of the opinion that further investigation on Kothar dam need not be pursued.

iii Closure of bifurcating channels and development of central channel by dredging - There was a proposal to close a number of interlacing branch channels of the Kosi within the embankment in order to increase the capacity of the main channel as well as increase in the equilibrium depth of the channels as it was found that blocking of several dhars at or near the points of off-take proved successful in ordinary floods to check erosion and damage which used to occur otherwise. Although, the Kosi Technical Committee of 1965 had strongly recommended dredging as a means to maintain and improve silt carrying channels of the Kosi, it was later on found that dredging of silt from river bed from year to year was economically not viable.

iv Bundalling - Bundalling was resorted to at several places in the river and has proved to be effective specially during low discharge conditions.

7.4.8 The list of flood control works completed in the Kosi river basin is enclosed at Annex 7.

7.5 DRAINAGE SCHEME

7.5.1 The abandoned courses of the river Kosi, commonly known as 'dhars' are meandering, mostly overgrown with weeds, partly silted and are not able to drain the area properly. These Dhars run from north to south along the general slope of the country. Due to these reasons, the Kosi river system had considerable problems of drainage even before the Kosi project was taken up. After construction of the flood embankments on both banks in the year 1959 and introduction of intensive irrigation on the eastern side by eastern Kosi canal system in the year 1964 followed by irrigation by the Rajpur canal system the drainage of countryside posed serious problems. A Master Plan for drainage of Kosi Command was accordingly prepared by the State Irrigation Department which has further been updated by the Project Report (as modified by Task Force) on drainage schemes in the irrigation commands of Gandak and Kosi Projects in North Bihar prepared by PP Cell of WRD, Government of Bihar in January 1988, in order to tackle the problems of surface drainage congestion and water logging in a systematic way. A number of major trunk drainage schemes with subsidiaries and laterals were taken up for execution. Some of them are Dhemra, Tilawe, Parwane, Bhenga, Pakilpar and Libri on the left bank, and Arbisia, Tugerue Nadi and Soni Nadi on the right bank of the river Kosi.

7.5.2 These channels were once the spill channels of the river Kosi and used to provide irrigation during high flood and acted as drainage during the receding flood in the river. It is reported that their free passages have been restricted due to the construction of embankments and the network of canal system even though a number of anti-flood sluices in the embankment and cross-drainage works in the canal system have been provided. These structures are not proving effective and the problem of drainage congestion is turning out to be serious. Not only that but due to cultivation in the bed of these channels and other encroachments, progressive siltation has taken place and lots of weeds have also grown. Some of the drainage channels have become extinct. Some of these channels have been put to use as escape channels of the Kosi canals.

7.5.3 The drainage schemes either executed or under construction are meant for revival of the old drainage channels with proper cross section and bed slopes so as to make them function as trunk drains. Artificial drains have also been excavated to act as subsidiaries and laterals. These schemes are under various stages of construction and have been found to be effective, to a certain extent, in easing of the drainage congestion in the area.

7.5.4 Many drainage schemes in the basin were taken up as a part of the Kosi irrigation project and either completed or were at various stages of completion. After closure of the Kosi project estimate in

March 1985 the incomplete and left over schemes were proposed to be taken up in Kosi Phase II project. Some drainage schemes were taken up as Special Area Programme.

7.5.5 The remaining drainage works which were not included in the above two programmes in the entire Kosi command were proposed to be taken up through a new proposal for which a project report on drainage schemes in the irrigation commands of Gandak and Kosi projects in North Bihar was prepared by PP Cell of WRD Government of Bihar. This is proposed to be completed in three phases-

Phase- I It comprises of catchment area of Bhuthi Balan river. The command area of this Phase- I drainage work (which extends on the east of Bhuthi Balan river) is about 19000 ha.

Phase- II This includes drainage work in the western Kosi command comprising of the area bounded by western Kosi canal on the north, Bhuthi Balan river on the east, Kamla Balan river and Patghat on the west and the western Kosi embankment in the south. Total GCA of the command is 0.9 Lakh ha, CCA is 0.48 Lakh ha and rabi is proposed to be sown in an area of 0.145 Lakh ha.

Phase- III It comprises of the area between Kamla river on the west and Dhaut river on the east. Total GCA of this command is 2.61 Lakh ha and CCA is 1.33 Lakh ha. Rabi crop may be grown in an area of about 0.4 Lakh ha.

It is estimated that only about 60 per cent of the water logged area can be economically reclaimed for Rabi irrigation, the remaining 40 per cent water in the depressions may be allowed to remain there and utilised for pisciculture and other aquatic crops such as Makhana, Singhara etc.

7.5.6 A list of the drainage schemes either completed or under construction in Kosi river basin is enclosed at Annex 8 and list of proposed drainage schemes in Kosi River Basin are enclosed at Annex 9.

7.5.7 Flood Forecasting System in Kosi Basin -

The importance of flood forecasting system, in reducing the flood damages by giving timely warnings, is now fully realised, although it can in no way prevent the recurrence of floods. The Central Flood Forecasting Organisation of CWC has been conducting the flood forecasting work in the Kosi river system since June 1970. At present there are three forecasting sites on the river Kosi, namely, Basua, Baltara and Kursela with two base stations at Barahkshetra and Birpur Barrage. All these sites are equipped with wireless system for efficient communication purpose. The method of forecasting is practically on the basis of gauge to gauge co-relations among these stations in the network.

Basua is the first forecasting site on the river Kosi where co-relationship between change in discharge with change in gauge at Barahkshetra base station and the corresponding gauge observations at Basua is developed having time of travel ie warning time as 24 hours. However, the warning time at Basua forecasting site is reduced to 16 hours when co-relationship of discharge released and gauge observation at Birpur barrage and corresponding stages at Basua is established.

Baltara is the second forecasting station on the river Kosi having co-relations of gauge observations between Basua and Baltara. The river Bagmati along with the river Kamla-Balan meets the river Kosi at a point which is slightly upstream of Baltara. so the gauge at Hayaghat site on the river Bagmati is also co-related with the gauge at Baltara which gives another parameter for forecasting at this site. The travel time for Basua to Baltara is 18 hours and from Hayaghat to Baltara is 28 hours.

Kursela, which is the third and the last forecasting site on the river Kosi, is affected by the back water of the river Ganga. Therefore, the gauge at Kursela is co-related with the gauge at Hathidah on the river Ganga as well as with the gauge at Basua. The travel time from Basua to Kursela is 26 hours.

The overall performance of the forecastings made at all these three stations during 1976 to 1992 have been found to be quite satisfactory when compared with actual gauge levels. However, the forecasting can be further improved by increasing the warning time if more gauge-discharge sites being established by CWC in the upper reach of the river in Nepal portion start functioning.

8.0 FUTURE APPROACH

8.1 The river Kosi has already been embanked on both sides in its entire flood prone length which has prevented flooding of the basin from the spill waters of the river. There have been varying opinions and analysis on the problems of the Kosi river and their solutions, but most experts agree on one point that the high percentage of coarse silt is the root of all problems of the Kosi river. The residual flood problems in the Kosi river system as existing now are as follow:

a Excessive silt charge in the river causing aggradation of river bed and braiding pattern of flow, further causing erosion of banks and threatening the existing embankments. The average annual silt load as observed at Barahkshetra is 95 Mcm, the percentage of coarse, medium and fine silt being 19.82, 24.79 & 55.39 respectively on the basis of data for the period 1948-89. The excessive silt charge is the main reason for attack on Eastern Flood Embankment during high flood. In addition to this due to certain changes in gorge and immediately below Chatra due to possible land slide or sudden deposit of coarse silt, the major flood was pressing towards the Eastern Embankment on the down stream of the Barrage till about three years back. This situation has now changed and the river has started threatening its Western Embankment in Nepal below the barrage.

b Inundation problems on the left bank in the lower reaches, below Koparia, affecting an area of 450 Sq Km.

c Erosion of banks, particularly the Eastern bank in the lower portion and Western bank in the upper portion below the barrage. The severity of the problem can be very well imagined on consideration of the fact that annual average cost incurred on anti-erosion works is about Rs 700 to 1000 Lakhs.

d Erosion of banks on the eastern side in the portion lying on the upstream of the barrage necessitating huge protection works to protect the Eastern Afflux Bund every year.

e Water logging and drainage problems on the eastern side of the river. An area of 1.82 Lakh ha has been found to be suffering from drainage congestion and water logging. This includes the area in the bed of the old abandoned dhars.

8.2 In order to find suitable solution to the above problem the following measures could be taken up.

8.2.1 Reservoirs

According to numerous experts, properly operated flood control reservoir/reservoirs combined with efficient flood forecasting, offers the most dependable flood control. The National Policy on flood of 1954 also recommended dams on tributaries as a long term measure of flood control. Reservoir in general, even without specific flood cushion have a benificial effect on the flood problem of a basin. The effectiveness of reservoirs in moderating floods would depend upon the capacity available for absorbing flood run-off. Because of their high cost, the reservoirs are not economically viable or justified exclusively for flood control purpose but a multipurpose reservoir to provide irrigation, power, domestic water supply, recreation and other benifits alongwith flood moderation would be economically viable.

The provision of reservoirs in the main Kosi and its tributaries have been considered to be indispensible for a long term solution of the Kosi problem. With this in view, some sites on tributaries of Kosi river were also investigated alongwith the Barahkshetra high dam in the late forties. A silt control reservoir on the Tamur tributary of Kosi was proposed at the first instance due to the fact that it contributed highest intensity of sediment charge in the Kosi river. But all these proposals were kept under abeyance because the Kosi Technical Committee of 1965 and 1971 did not favour these proposals. Lateron the Board of Consultants under the chairmanship of Dr Kanwar Sain realised the need for resumption of investigation of the reservoir projects on the main river as well as on the tributaries and accordingly a feasibility report on the high dam projects across the Kosi at Barahkshetra prepared by CWC in 1981 is under consideration at various decision making levels. Proposed Kosi dam at Barahkshetra will moderate the maximum probable flood of 42475 cumecs (15 Lakh cusecs to a flood of 14000 cumecs (5 Lakh cusecs) at Barahkshetra. It will trap the bulk of coarse and medium silt carried by the river and a sizeable portion of fine silt will also get trapped in the reservoir. This will help in stabilizing the river in Nepal and India and reduce the over flows as well as the braiding tendency of the river. The project also envisages afforestation and soil conservation works on the tributaries on the basis of photo-interpreted aerial surveys and other field works which will reduce the silt inflows in the reservoir thereby increasing its useful life.

It has already been recognised that a series of dams in the main river and the tributaries will be essential steps towards an effective long term solution of the silt problem. But, so far, except for the Barahkshertra high dam, no dam site has been found feasible after detailed explorations and investigations on the main Kosi river. Another dam site across the Kosi at Kothar, about 6.5 Km downstream of Barahkshetra had already been abandoned as the same was not found suitable after detailed investigations and geological explorations. However, a number of suitable sites are available in the hilly region of the river Kosi and its tributaries where construction of a series of low height rockfill check dams can be possibly planned which could trap the coarse silt above the gorge at Chatra. But their feasibility can be reviewed only after detailed investigation at these sites are taken up and hydrology as well as silt data thereof are analysed. As these sites are located in Nepalese territory, co-operation of HMG, Nepal will be necessary for joint exploitation of these sites for mutual benefits of both the countries. These would generate hydel power which can be used by Nepal as well as sold commercially to the Government of India by the HMG, Nepal.

It is learnt that the GOI has started negotiations with HMG, Nepal for finalising Kosi high dam at Barahkshetra and schemes of reservoirs on the tributaries of the river Kosi in Nepal. It has to be ensured that possible flood control as well as sediment control benefits are taken care of besides power, irrigation and other benefits in the finalised projects prepared for execution after detailed surveys and investigations.

8.2.2 EMBANKMENTS

The right bank of the river Kosi is almost fully embanked except for a small gap near Phuhia which is left deliberately to receive the combined flow of the Bagmati and the Kamla into the Kosi. The left bank, however, is still unembanked below Koparia upto Kursela. This has been engaging serious attention since the very inception of the project. In this regard, Kosi Technical Committee of 1965 recommended that a detailed investigation was necessary to decide whether or not to construct an embankment in this reach, as large numbers of rivers join the Kosi river between Koparia and Kursela. It is apprehended that construction of the embankment from Koparia to Kursela may aggravate drainage congestion and waterlogging as a result of flood locking of spills from tributaries joining the Kosi. A synchronisation study conducted by GFCC on the basis of rainfall data obtained from IMD and Directorate of Statistics, GOB, indicate that the proposed embankment below Koparia on the left bank may aggravate the drainage problem of this area and it is also evident from the studies carried out so far that this embankment may not technically be feasible. However, detail investigation is under progress in the Master Planning wing of the WRD.

In the Kosi river, the spacing between the two embankments varies from 5 to 13 Kms which is apparently 3 times the requirement and on very high side. The result is that the river even after embanking has been left with ample space to swing, braid and shift its course, which no doubt is confined within the left and right embankments now. But the river even in the present condition is causing extensive erosion and posing great threat to some area or the other. The average cost of maintenance of flood embankment and anti-erosion works has been found to be of the order of Rs 1.42 Lakh per Km per year, which is already high. The concept of constructing forward embankments in order to bring about improvement in the hydraulic conditions of the river with the belief that a central channel may develop after the initial erosive actions for a few years, was thought of some time back. This was referred to the Department of Civil Engineering of the University of Roorkee by GFCC in Feb 1984, which submitted its report in July 1990. The report with regard to proposal of forward embankments concluded that uniform reduction of river width in the entire leveed reach is not a feasible solution to the large aggradation noticed in the river, but selective reduction in width does offer a good solution.

It is, therefore, necessary that a permanent river model of the affected reach is laid out in the Irrigation Research Institute, Khagaul and study of the river morphology and behaviour is carried out in depth to ascertain the reasons for such tendency of the river and to suggest future protection measures to make the river regime stable. Protective measures and anti-erosion works should be carried out on the basis of the model studies and effects of such works at other locations on the upstream or downstream side or the opposite banks should duly be taken care off.

Detailed studies should be undertaken to find out the effectiveness and adequacy or otherwise of the existing sluices in the embamnkments and remedial measures be taken on priority basis to make them function properly as and when necessary. If found necessary, more sluices may be provided for proper and efficient drainage of the countryside and for providing irrigation to the areas on the countryside in case of drought.

8.2.3 DRAINAGE IMPROVEMENT

Some drainage schemes have already been executed and some are under execution in the Kosi river basin. These are detailed in the list at Annex 8. All lingering schemes for drainage improvement in the basin which have remained incomplete so far should be reviewed on priority and completed as early as possible to realise the full benefits and to prevent large scale escalation in their costs due to delays. The benefits accruing from the completed schemes should be evaluated and if it is found that these schemes are providing intended benefits then other drainage schemes may be executed accordingly. If certain modifications are considered necessary in order to get the intended benefits or more benefits are likely to accrue as a result, then such modifications should be carried out immediately on priority. Future drainage schemes should be planned, designed and executed on the basis of the result of such post-facto evaluation studies carried out carefully. A list of proposed drainage schemes in the basin is enclosed at Annex 9.

A Technical Experts Committee constituted by the Government of India in 1965 had carried out studies to find out the drainage congestion caused by the inadequacy of waterways in the railway and road bridges in North Bihar. The recommendations of the Committee with respect to river Kosi are enclosed at Annex 12. Further detailed studies may be carried out by the WRD on the basis of past hydrometeorological data to confirm the reported inadequacy of waterways or otherwise in the railway and road bridges and cross drainage works in the canal system and further action of extending such inadequate waterways to the required size should be taken up and completed as quickly as possible for removal of drainage congestion caused by such structures.

There are certain low lying pockets in the deepest portions of the 'Mauns' and 'Chaurs' which can not be drained by gravity due to existing outfall conditions in the main and trunk drains, such areas may be delineated on the village maps and developed for aquaculture or pisciculture as the case may be. Draining such low pockets by pumping is not considered to be economically viable as the present and likely future availability of power may not be adequate.

8.2.4 Soil Conservation

Under an Integrated Action Plan for Flood Management in Indo-Gangatic Plain, watershed treatment and soil conservation measures were taken up in a few flood prone catchments due to limited availability of funds. These measures are still limited to pilot and experimental applications. Their effectiveness in reducing the peak flood during monsoon is yet to be established. However, soil conservation and watershed treatment measures are likely to have beneficial impact by way of reduction in the quantities of silt flowing into the river. Such measures are likely to be effective in the case of the Kosi river because of the high silt charge of the river and its meandering tendency. Soil conservation to mitigate soil movement from hills in the upper mountainous catchment in Nepal territory is of absolute necessity for holding soil erosion in hills. In early nineteen fifties a Soil Conservation wing of Government of India was stationed at Chatra to advise and assist in formulating actions to stop soil erosion in hilly catchment of the river Kosi. The Commission has come to notice that now the aforesaid soil conservqation wing of GOI is not functioning and it is not known if Nepalese authorities are doing anything to stop soil erosion in Kosi catchment. In the light of the fact that although Soil Conservation work is a long term operation, it is felt that it gives the lasting solution. Therefore, the suggested measures in this direction would be firstly, afforestation with suitable grass and trees to hold soil with moisture on hill top and slopes. This is to be taken up in whole of hilly catchment intensively and extensively. Secondly,the cultivation on hill tops and slopes should be carefully supervised and so planned that it should not cause erosion during rains. Cultivation fields should be planned in terraces with contour bunding to control the flow of rain water during precipitation down the slope of the hills. Thirdly, all tributaries of the river Kosi which contribute signigicant silt charge, should be provided with small boulder check bunds to stop the eroded soil from coming down with precipitation runoff. All these works would require constant vigil for stopping denundation of hilly catchment and wasting down of soil crust which is vital for vegetation, forest and cultivation and ultimately this would reduce the silt charge being carried with flood waters in Kosi causing immense problem in the lower basin.

In connection with the preparation of feasibility report on Kosi High Dam at Barahkshetra, CWC have dealt at length on the necessity of Kosi water shed management and have furnished a programme for ten years for execution of the required works under this programme. In the absence of any survey giving the areas requiring treatment a tentative programme for treating about 3 Lakh ha area constituting about 11 per cent of the total catchment area in Nepal has been framed. Out of this 3 Lakh ha, 2.25 Lakh ha will be in the sub-catchment of the Tamur and the rest will be in the selected watersheds of other two sub-catchments having direct bearing on sediment production into the reservoir at Barahkshetra. The break-up of different types of works are given below:

Item of works	Area in ha	Time involved
1 Agricultural land bench terracing etc	50,000	10 years
2 Development of orchard plantation crops	25,000	10 years
3 Afforestation/Pastures development	1,50,000	10 years
4 Land slides in 110 Km length (including kholas)	Covers additional area 75,000 ha	10 years
5 Gully plugs/check dams for 14 kholas only remaining to be worked out after the survey is over		
6 Survey and categorisation		2 years
Total	3,00,000 ha	

Land treatment through afforestation and grass land development should also be supplemented by structural works in the upper catchment for retarding the velocity of water and detaining silt efficiently. Such works obviously,would also increase the life of the proposed reservoirs.

The following points, however need special attention on this aspect-

a Watershed treatment works are to be carried out in the Nepalese territory,for which the co-operation of HMG, Nepal will be necessary.

b The works proposed will be small in size and scattered over a large area without suitable and proper approach to the sites. Under such conditions,the transport of materials, effective supervision and quality control are likely to be a tough proposition.

c The maintenance of these works is likely to be difficult and costly due to the reasons indicated at (b) above.

d Adequate cooperation and proper response from the local population is essential for the success of such programme. Special efforts will be necessary to secure public co-operation, in a foreign country (Nepal)

The difficulties mentioned above, however, should not overweigh the benefits expected from the watershed management programme. Major portion of the benefits like afforestation and prevention of soil erosion will accrue to Nepal. Its benefit in the Indian territory would be limited to less flow of silt into the river and consequent improvement in river behaviour leading to less expenditure on the maintenance of embankments. The cost and benefits of such works would, therefore, have to be weighed critically alongwith constraints and difficulties mentioned in the above paragraph.

8.2.5 Silt Catching Sills in the River Bed for Gradient Control

The varying steepness in bed slope of Kosi appears to be the main cause of deposit of course silt in the river bed on the one hand and tendency of meandering on the other hand. Therefore,if by constructing raised sills at suitable sites between Barrage and Bhaluahi,the varying steep slope can be flattened to some extent as uniform bed slope by deposition of coarser silt and the suspended silt may move foreward on account of the variation in velocity. In such case the coarser silt will initially be arrested by the raised sills in the bed of the rivers and in due course of time the bed gradient may be flattened. After flattening of the bed gradient the silt instead of being deposited in bed may flow partly into the river Ganga. But suitable sites,after a detailed survey and study of the river regime, will have to be judiciously selected. The sills to be constructed will have to be suitably designed such as to maintain the Kosi channel midway of the two embankments. This can be done by designing sills sloping from the two embankments towards the centre where main Kosi channel is proposed to be maintained.

8.2.5.1 Here it is worth mentioning that in 1965 Kosi Technical Advisory Committee headed by Shri Kanwar Sain, Ex-Chairman C W P C recommended construction of another barrage at Dagmara downstream of existing barrage at Bhimnagar. This was in fact conceptualised for achieving gradient control by flattening of the slope and also to act as second control point for the Kosi down stream of Bhimnagar barrage. Added advantages of this structure foreseen at that time were creation of a shorter communication between Darbhanga and Saharsa by construction of a rail cum road bridge linking the existing LRP road. In the opinion of this Commission, the above proposal still holds sound and beneficial and therefore, it is suggested that this proposal may be investigated in detail and hydraulic model studies be carried out to find out the usefulness or otherwise of the proposed barrage at Dagmara at the earliest. Proposal for canal system on both banks for irrigation during Rabi and hot weather seasons only to avoid siltation of the canal bed ,as has happened in the existing Kosi Canal System,may also be examined to improve the benefit cost ratio of the proposed scheme.

8.2.6 Flood Diversion in Low Lying Pockets

The original Kosi Project Scheme prepared in 1950 was revised in 1953 and this contained a plan for flood control by construction of a diversion barrage for diverting nearly 1400-2000 cumecs (50,000-70,000 cusecs) of flood for reviving old and abandoned dhars of Kosi on the eastern side and thereby reducing the flood intensity in the main river. Since quantity of silt increases with increase in flood discharge, diversion of flood to old dhars during high floods would have also carried silt alongwith. It appears that the experts, after examining the above proposal in September 1957, abandoned this idea due to apprehensions regarding uncertainties of the river Kosi and expected opposition from public who were cultivating the old bed of Kosi. Although it cannot be denied about risks involved in such type of proposed experiments, still the idea of flood diversion in old Kosi dhars, in the opinion of this Commission, appears to be best first hand solution for saving the suffering mass of population from vagaries of the Kosi during floods. For keeping the river in the present course, the excess silt deposit in Kosi bed is causing adverse consequences as already experienced.The breach in 1984 flood resulted in siltation of depressions and water logged areas converting them into raised plots which were lying useless being permanent depressions. This proves that flooding can be a possible method for tackling the silt problem of Kosi. The excess silt has to be transported to locations it is required ie in low waterlogged areas in the zone abandoned by old Kosi dhars.

Therefore, this Commission is of the opinion that all such low lying zone in the old Kosi dhars which can be filled with Kosi silt being carried every flood season preferably adjacent to the eastern flood embankment,should be identified through detailed survey. The purpose of this accumulation of flood will be for siltation of the low lying water logged areas as well as reducing the impact of flood along with the quantum of silt in the down stream main course of the river Kosi. A bold and firm decision to declare all the low lying pockets as detention basins during the higher flood stages in the river will have to be taken for operation of this scheme. The pockets will have to be embanked to receive the flood at HFL, linked with the river through link channels passing through low lying alignment through a regulator at its head located on the existing eastern flood embankments. The embanked low lying pockets will also have to be provided with a waste weir to pass out silt free water to the nearest drainage channel during flood season, if required, and to drain the flooded pocket completely after the flood season to make the area free for production of Rabi crop. All these pockets will get restricted to only single Rabi crop till the area gets silted up sufficiently to receive irrigation from the nearby canal system.

This scheme of diverting flood to low lying pockets for disposal of Kosi silt may meet stiff opposition from the local people who may be likely to be affected. But keeping in view the long term advantages from this scheme, there is no doubt that it would bring in much relief and prosperity in the future.

Preliminary studies of the toposheets of the area adjoining eastern embankment indicate that possibility of diversion of flood waters of Kosi might be possible through the Berda Dhar and Tilawe Nadi and other existing abandoned courses of the river nearby. Further detailed investigations would, however, be necessary to find out the techno-economic viability of such proposal and its usefulness in the long run.

8.2.7 Maintenance of Existing Works

While new structural measures as suggested above are necessary for solution to the residual flood and drainage problem in the basin, it is equally important to properly and adequately maintain the assets already created so that they can withstand the pressure exerted due to the flooding of the basin. Besides regular supervision and necessary repair of embankments well before the onset of the monsoon season, the following points deserve special attention.

During past few years the highest flood stages in the river at different locations have been noticed to have gone up resulting in encroachment in the free board of the embankments. A systematic survey and investigation of the existing embankments on both banks of the river is required to be carried out every year after the flood season and encroachment, if any, in the free board in any portion should be eliminated by raising the height of embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankments and river training works may be carried out after model studies to keep the flowing channel away from the embankment. In the portion,where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or atleast provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently during emergent situations.

8.2.8 Construction of Raised Platform

During the flood season, breaches sometimes occur in the embankments as a result of which protected areas get flooded. Submergence of the protected area is also caused due to heavy precipitation on the countryside coinciding simultaneously with high stages in the outfall channels. The affected persons take shelter on the embankments alongwith their livestock and properties in such situations. As a result, not only the embankments get damaged but the works like flood fighting and rehabilitation get hampered. Generally people do not go back to their original living places even after the flood subsides and continue to live on the embankments endangering its safety and hampering regular maintenance. It is, therefore, suggested that :

i Occupation of embankments and the lands acquired should be got vacated effectively to avert any danger or risk to the flood management embankments and to the people living in the protected areas.

ii Raised platforms above the highest flood level may be constructed in areas liable to inundation near villages on Government of acquired lands. These could be also constructed on the countryside of the embankments abutting the same. Such platforms should preferably be connected with all weather roads and should also be provided with necessary facilities for warehousing, community living, sanitary and potable water supply installations, space for keeping cattles and storing fodder, telecommunication facilities etc in order to obviate likely inconveniences to the people residing on such platforms during floods. These should be handed over to local bodies panchayats for being utilised as community property and kept free from encroachment.

8.2.9 Non-Structural Measures

a Flood Plain Zoning

The question of introducing flood plain zoning measures has been under consideration for a long time. In view of the increasing pressure of population and consequential greater encroachment of flood plain, zoning has assumed added significance. The continuing trend of rise in flood damage figures in recent years is primarily due to greater encroachment into flood plains. The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As a major portion of flood prone area in the Kosi basin is protected from flood since 1959 after construction of flood embankments, such zoning regulations should be introduced in the first instance in the unprotected areas and for future developments in the protected areas.

It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour intervals of 0.3 metre for implementation of this measure. Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of flood such as 5 years, 10 years 25 years, 50 years and 100 years. Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain corresponding to a 50 years and 25 years rainfall will also have to be prepared.

b Flood Forecasting and Flood Warning

Flood forecasting has proved to be of great help in issuing warning to the people in flood prone areas, organising flood fighting and safety measures for the engineering works, timely evacuation of people from affected areas and salvation of movable properties besides mobilising relief operations.

It has come to the notice of this Commission that in addition to three existing flood forecasting stations at Basua, Baltara & Kursela on the main river Kosi altogether five more new gauge- discharge stations located at Pachuwarghat, Toksel Ghat, Babua Bazar, Turki Ghat and Majhitar on main tributaries of the river Kosi in Nepal portion have since been installed by CWC sometime in 1991 under an agreement reached between GOI and HMG Nepal. Obviously the flood forecasting at the existing stations in India is likely to further improve by increase in warning time when the new stations installed in the upper catchment in Nepal start functioning.

Although there is wide appreciation of the flood forecasting system and warning issued by CWC, there is very little feed-back on the procedures specified or evolved by the civil administration and the engineering organisation for undertaking relief/rescue/precautionary action on the basis of the forecasts. It is also not known as to how effectively the necessary advice is being given to the people.

On receipt of the forecast, its dissemination to the local population in terms of likely depth of inundation and its duration in the area by the administrative authorities is very important so that affected population, cattle, movable properties etc are evacuated before the area gets submerged by flood waters which cause damage. For this a network of wireless stations and telephone system are necessary in the basin near critical/vulnerable reaches of embankments and towns etc specially where other means of communications are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the level indicated in the flood forecasts. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property. This training programme should become a regular feature before the flood season every year.

c Disaster Mitigation System and Preparedness

This is an important measure which directly influences the damage prevention if managed efficiently at all levels according to the prescribed procedures and guidelines. Improper management could also result directly in increased damage. The Government should, therefore, ensure that all routine exercises and necessary drills are carried out systematically before every flood season and departmental instructions, manuals and rules in this regard should be widely circulated so as to make these available to all concerned. It is observed that disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year. Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the officers and staff of the concerned departments as also in the public and voluntary organisations to deal with flood emergencies.

It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. The training programmes, including education and publicity should be got arranged by the civil authorities with active participation of the officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over all India Radio (Akashvani), Doordarshan or transmitted through other channels and the effective follow up of such messages into appropriate actions should be taught to all people in the flood prone areas.

8.2.10 A map of the Kosi river basin showing the completed, under execution and proposed drainage schemes is enclosed at Drg No 6/04.

9.0 SUMMARY OF RECOMMENDATIONS

9.1 It is observed that hydrometeorological data of the river basin is not being observed, collected, analysed and documented in a systematic manner. There is necessity for establishing more raingauge stations (in Nepal portion) in the catchment of the river Kosi with adequate number of self recording raingauges amongst them. The network of gauge discharge sites should be designed as per standard norms and adequately met with by opening more sites at suitable locations as quickly as possible. The records of shifting of the main river course after every flood, areas liable to floods and drainage congestion in various reaches of the basin alongwith areas actually flooded with crop details are not being observed and properly recorded. The areas flooded from the over-bank spills of the river should be marked separately from those which get submerged due to drainage congestion on account of heavy precipitation coinciding simultaneously with the high stages in the outfall channels. In order to cover more details about the Kosi and its morphology, systematic observation, collection, analysis and maintenance of relevant data should be attended to immediately and all such historical data be procured/ retrieved from the concerned sources, studied, analysed and documented for finding out better and quicker long term solutions and for future use. The State Government may consider allotment of sufficient funds under plan head for establishing data collection units with the primary objective of collection of data/information on a continuing basis, so that it is useful for the future planners.

[Para 4.5, 4.7.3, 4.8.1, 4.8.2, 5.5.1, 5.6.9, 6.2.2]

9.2 The seriousness of the silt problem in the basin leading to shifting, erosive and aggradation tendency of the river in India deserves urgent attention. Suitable soil conservation measures along with watershed management in the catchment area lying in Nepal are required to be undertaken on priority basis. The state Government may take up this issue with the Government of India for appropriate action in consultation/co-operation with the HMG, Nepal.

[Para 4.9.2]

9.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guidelines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankment, the design of a project should be determined for the time being on flood frequencies suggested.Meanwhile necessary step may be taken for eventual application of benefit cost criterion for fixing the design."

The summary of recommendations as accepted is as follows:

"In the case of embankment schemes, the height of the embankment and corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such time as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 year frequency in the case of predominantly agricultural areas and for flood of 100 year frequency for works pertaining to town protection and protection of Industrial and other vital organisations"..

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of vital industrial establishments.

9.4 In the light of the fact that the river slope immediately downstream of the barrage being almost stable, Dr S V Chitale of CWPRS, Pune advocated an idea which suggested for shortening of length of the river Kosi by joining it with the river Ganga near Mansi or a new Channel from Chatra to Kursela be developed to maintain the stable slope. This proposal had been examined by GFCC which had given some comments indicating serious limitations in Dr Chitale's proposal. GFCC in its comments, if Dr Chitale's suggestion are accepted, has apprehended that silt problem would be transferred from the Kosi to the Ganga consequently leading to problems in the Ganga apart from making separate arrangements for the drainage of the Kamla and the Bagmati in the Ganga and inviting serious public objections also. Therefore, this Commission is of the view that the idea propounded by Dr S V Chitale along with the comments offered by GFCC may be investigated thoroughly as well as hydraulic model studies be carried out and final decision may be taken if the techno-economic viability is established on the basis of such detailed studies.

[Para 5.6.6]

9.5 Systematic field investigations should be carried out regularly so as to pin-point areas in the basin which are water-logged due to lack of proper sub-surface drainage.

[Para 6.2.3]

9.6 Post-facto evaluation studies of a few completed drainage schemes in the basin need to be undertaken quickly so that future schemes for removal of drainage congestion in the basin are planned after knowing their usefulness and efficiency. Any modifications if found necessary in order to get the intended benefits or more benefits, should be carried out immediately on priority. Future drainage schemes should be planned, designed and executed on the basis of the results of such evaluation studies carried out carefully.

[Para 6.2.4, 8.2.3]

9.7 It is necessary to carryout review of the adequacy or otherwise of the existing sluices, in the embankments in the basin. Further necessary remedial measures for making them efficient and effective for the purpose for which sluices were constructed may be taken on priority basis following such review. If found necessary more sluices may be provided for proper and efficient drainage of the countryside and for providing irrigation in the protected area in case of drought.

[Para 6.2.5, 8.2.2]

9.8 Regular and systematic observations of ground water structures should be carried out on a continuing basis in the areas in the basin where irrigation facilities are available. This would help in monitoring of the fluctuation in sub-soil water level for use in future planning of measures to combat the problem of waterlogging in the irrigated command area of the basin.

[Para 6.2.6]

9.9 It is observed that the flood damage statistics, which is essentially required for the benefit-cost studies for any proposed flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which donot seem to have been followed. The Commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river/basin wise be carried out every year under the following three separately identified categories-

i Unprotected areas

ii Protected areas due to failure of protection works

iii Areas between the embankments and the river.

The extent of drainage congestion in the protected and unprotected area should be indicated separately. The WRD dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned departments at the end of each year. Such reconciled long term data of flood damage is to be used in economic viability study for any future flood protection/management scheme in the area.

(Para 6.3.4)

9.10 The flood moderation effect along with effective long term solution of the silt problem of the contemplated reservoirs apart from one already proposed at Barahkshetra in the main Kosi river and its tributaries in Nepal is required to be studied in detail after field surveys and investigations and analysis of hydrometeorological data. As the works would be located in Nepalese territory, co-operation of the HMG, Nepal would be necessary for joint exploitation of the prospective reservoir sites for mutual benefits of both the countries. It should be ensured that possible flood control as well as sediment control benefits are taken care of, besides power, irrigation and other benefits, in the finalised project as mutually agreed upon.

[Para 8.2.1]

9.11 A permanent river model of the reach where the river is seriously threatening by extensive erosion and particularly below Koparia on the left bank which is still unembanked, should be laid out in the Irrigation Research Institute, Khagaul and study of the river morphology and behaviour be carried out in depth to ascertain the reasons for such tendency of the river and to suggest protection measures to be taken up in future to train the river and make its regime stable. Protective measures and anti-erosion works should be carried out on the basis of model studies and effects of such works at other location on the upstream or downstream or on the opposite bank should duly be taken care of.

[Para 8.2.3]

9.12 Further studies in continuation of the studies carried out by the Technical Expert Committee, 1965, may be carried out to find out the inadequacy or otherwise of the waterways in the railway and road bridges and the cross drainage works on the canal system in the basin which are responsible for drainage congestion in the area and further action of extending such inadequate waterways to the required size should be taken up and completed as quickly as possible for removal of drainage congestion caused by such structures.

[Para 8.2.3]

9.13 Low lying pockets in the deepest portions of the 'Mauns' and 'Chaurs', which cannot be drained by gravity should be marked out on the village maps and developed for aquaculture or pisciculture, as the case may be.

[Para 8.2.3]

9.14 Soil conservation and watershed treatment measures are likely to have beneficial impact by way of reduction in the quantities of silt flowing into the river Kosi and to check its meandering tendency. As such an extensive 10 year programme of watershed management in the hilly catchment area in Nepalese territory as suggested by CWC, appears necessary. Land treatment through afforestation and grass development should also be supplemented by structural works in the supper catchment for retarding the velocity of water and detaining silt effectively. Such works would also increase the life of the proposed reservoirs. The cost and benefits of such works should be weighed critically alongwith constraints and difficulties mentioned in paragraph 8.2.4.

[Para 8.2.4]

9.15 The recommendations of the Kosi Technical Advisory Committee, 1965 headed by Sri Kanwar Sain proposing another barrage at Dagmara downstream of Bhimnagar still holds sound and beneficial and therefore, it is suggested that this proposal may be investigated in detail and hydraulic model studies be carried out to find out the usefulness or otherwise of the proposed barrage at Dagmara at the earliest. Proposals for canal system on both banks for irrigation during Rabi and hot weather seasons only to avoid siltation of the canal bed as has happened in the existing Kosi canal system may also be examined to improve the benefit-cost ratio of the proposed scheme.

[Para 8.2.5.1]

9.16 The original Kosi Project Scheme prepared in 1950 and revised in 1953 contained a plan for flood control by construction of a diversion barrage with an objective to revive old and abandoned dhars of the Kosi on the eastern side. In the opinion of this Commission the above abandoned proposal should be examined carefully and all low lying pockets in the old Kosi dhars which can possibly be filled with Kosi flood carrying heavy silt every year, preferably adjacent to the eastern flood embankment, should be identified through detailed survey. A bold and firm decision to declare all such low lying pockets as detention basin during the higher flood stages in the river will have to be taken for operation of this scheme. The pockets will have to be embanked to receive the flood at HFL, linked with the river through link channels passing through low lying alignment through a regulator at its head located on the existing eastern flood embankments. The embanked low lying pockets will also have to be provided with a waste weir to push out silt free water to the nearest drainage channel during flood season, if required, and to drain the flooded pocket completely after the flood season to make the area free for production of Rabi crop. All these pockets will get restricted to only single Rabi crop till the area gets silted up sufficiently to receive irrigation from the nearby canal system.

Preliminary studies of the topo sheets of the area adjoining eastern embankments indicate that the diversion of flood waters of Kosi might be possible through the Berda dhar and Tilawe Nadi and other existing abandoned courses of the river nearby. Further detailed investigations would, however, be necessary to find out the techno-economic viability of such proposal and its usefulness in the long run.

[para 8.2.6]

9.17 A systematic survey and investigation of the existing embankments on both banks of the river is required to be carried out every year after the flood season and encroachment, if any, in the free board in any portion should be made good by raising the height of the embankment correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of the results of the model studies to force the flowing channel away from the embankment.

[Para 8.2.7]

9.18 The suitable retired embankment should be constructed in the portion where embankments have been eroded or are likely to be eroded so that flooding of the protected area is prevented. The top of the embankments should at least be provided with brick soling so as to make it useful for inspection as well as for transporting of materials during emergent situations in the rainy season.

[Para 8.2.7]

9.19 Occupation of embankments and land acquired should be got vacated effectively to avert any danger or risk to the people living in the protected area. Raised platforms above the highest flood level may be constructed, in areas liable to inundation, near villages on the Government or acquired lands. These could also be constructed on the countryside of the embankment abutting the same. Such platforms should preferably be connected with all weather roads and should be provided with facilities to make living on them easy during floods. Such raised platforms should be handed over to local bodies/Panchayats for being utilised as community property and kept free from encroachment.

[Para 8.2.8]

9.20 Flood plain zoning measures will be useful in both protected and unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that heavy damage is not unduly caused in the event of failure of the flood protection measures. Such zoning regulations should be introduced in the unprotected areas first and for developments in the protected areas henceforth.

Flood risk maps of the basin may be prepared showing the areas likely to be flooded for different frequencies of floods such as 100 years, 50 years, and 25 years. Similar risk maps for submersion caused due to drainage congestion corresponding to a 50 year and 25 year rainfall may also be prepared.

[Para 8.2.9 (a)]

9.21 The five more base stations recently installed and located at Pachuwar Ghat, Toksel ghat, Babua Bazar, Turki Ghat and Majhitar in the Nepalese territory need to function regularly and supply data to the CWC authorities so as to increase the lead time available for the existing forecasting stations at Basua, Baltara and Kursela on the river Kosi.

On receipt of the flood forecasts, its dissemination to the local population in terms of the likely depth of inundation and its duration in the areas by the administrative authorities is very important so that necessary action is taken before the area gets flooded and causes damage. For this, a network of the modern communication system is necessary in the basin near critical/vulnerable reaches of the embankments and towns, etc, specially where other means of communication are not dependable or adequate.

Specific advice should be given to the people regarding evacuation of the areas likely to be affected and also about the locations which could be considered safe for the levels indicated in the flood forecasts. Necessary training in this regard should be imparted to the officials concerned on a regular and continuous basis before the flood season every year.

[Para 8.2.9. (b)]

9.22 It is essential that training programmes and exercises are held regularly to improve the disaster preparedness of the officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. Such training programmes should be got arranged by the civil authorities with the active participations of the officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio (Akashvani), Doordarshan or transmitted through other channels and the effective follow-up of such messages into appropriate actions should be taught to all people in the flood prone areas.

[Para 8.2.9 (c)]

Annex 1A

RAINFALL DATA OF RAINGAUGE STATION IN THE KOSI RIVER BASIN MAINTAINED BY INDIA METEOROLOGICAL DEPARTMENT NEW DELHI FRDM YEAR 1948-60

Sl No	Location of Station upper catchment	Mean Rainfall (in mm) (May to Oct)	Monsoon Rainfall (in mm) (June to Sept)
1	2	3	4
1	Aisayalikharka	2232.7	1932.8
2	Angbung	1116.4	882.2
3	Bhojpur	1115.3	940.4
4	Barahkshetra	2131.6	1890.6
5	Chainpur	1183.0	975.7
6	Chatra	2001.6	1762.5
7	Chautara	1818.1	1635.8
8	Chaurikharka	2208.2	1998.5
9	Dhankuta	731.0	620.5
10	Dharanbazar	2155.7	1886.6
11	Dhulikhel	1448.2	1277.7
12	Dingla	1837.1	1553.3
13	Dolaighat	828.6	751.3
14	Dumbuhar	1471.8	1201.9
15	Ghumthang	1427.5	3921.2
16	Kamachin	1052.6	874.7
17	Kalimate	1651.7	1509.1
18	Kundleghat	958.7	855.3
19	Kuruleghat	806.0	709.6
20	Leguaghat	834.0	701.0
21	Langthung	1930.8	1669.0
22	Machuaghat	1185.8	1042.2
23	Manebhanjyang	1117.6	755.7
24	Mamengsagat	1512.0	1279.0
25	Mulghat	735.3	654.3
26	Munga	1113.0	989.5
27	Mamchebazar	797.2	695.9
28	Nepalthok	771.5	638.6
29	Nup	769.1	642.4
30	Okhaldunga	1555.8	1360.7
31	Panglhangdoma	1309.5	1099.5
32	Pekaznas	1629.8	1480.9
33	Phulut	2530.7	2068.9
34	Phaphlu	1589.1	1465.2
35	Ramechap	756.4	663.9
36	Sandakph	2541.7	2255.6
37	Taplethok	2085.9	1764.4
38	Sinduligarhi	1925.9	1631.3
39	Taplejun	1725.7	1442.0
40	Tribeni	1592.0	1429.5
41	Wallung chang	1507.8	1263.3

(Source: Comprehensive plan of Flood Control for the Kosi River System Prepared by the GFCC in 1986.)

Annex 1A contd

YEAR 1951 TO 1987 (in mm)

Sl No	Name of rainfall Station Lower Catchment	Annual rainfall	Highest rainfall 24 hrs	48 hrs	72 hrs	Remarks
1	Bhimnagar	1504.33*	213.36	262.00	279.40	*
2	Narpatganj	1590.51	300.00	300.00	317.00	
3	Forbisganj	1693.07	219.00	270.00	317.80	
4	Madhepura	1259.71	232.00	287.20	381.00	
5	Pratapganj	1376.78*	177.00	238.20	290.00	
6	Supaul	1193.91	175.20			
7	Bhaptiahi	1113.67	194.30			
8	Birpur (Basantpur)	1488.68	257.00			
9	Tribeniganj	1233.12	177.00			
10	Murliganj	1249.66	248.00			
11	Sour bazar	1208.52	257.20			
12	Alamnagar	1012.38	144.00			
13	Sonbarsa	1188.04	172.70			
14	Chausa	1177.78	406.00			
15	Chattarpur	1369.89*	323.00	369.00	369.00	
16	Saharsa	1202.88	242.00			
17	Dhamdaha (West)	1286.87*	265.00	324.60	335.60	
18	Purnia	1500.24	235.80	330.20	379.90	
19	Araria	1536.40	266.70	361.44	397.00	
20	Raniganj	1726.44	240.00	343.20	417.20	
21	Krityanandnagar	1317.00	276.00			
22	Katihar	1234.10	277.60			
23	Dhamdaha (East)	1321.15	283.00	332.40	436.40	
24	Gondwara	1233.60*	183.00	209.55	307.34	
25	Simri Bakhtiarpur	1162.67	263.90			
26	Lankahi	1240.06	233.40			

* 1 Rainfall data for five stations namely Bhimnagar Pratapganj, Dhamdaha (West) and Gondwara are only for the period 1951 to 1970.

2 The data for the period 1971 to 1973 is not available for all the station.

3 The data for stations Sl No 2, 3, 18, 19, 20, 21 & 23 Comprising Purnia District (old) have missing data for 1985 & 1986.

4 Dnly 25% of the stations have almost complete data up till 1987 - others have discontinuous data.

Source: Comprehensive plan of Flood Control for the Kosi River System Prepared by the GFCC in 1986 and State Hydrology Cell of the WRD, Government of Bihar.

ANNUAL/MONSOON RAINFALL DATA FOR THE DISTRICT LYING IN THE CATCHMENT OF THE KOSI RIVER SYSTEM (in mm)

Sl. No	District/	Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987 (June-Oct.)	1988	1989	1990 (June-Oct.)	Remarks
1	Saharsa		–	–	–	–	–	1300.3	1626.4	1440.7	1034.6	1241.7	1496.0	1440.8	–	1817.0	–	–	1183.9	
2	Supaul		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3	Madhepura		1451.8	–	–	1138.7	1874.8	1612.3	1082.7	1355.1	989.9	1528.4	1912.0	1081.0	1551.9	1702.0	1473.4	1834.5	–	
4	Madhubani		–	–	–	–	–	1093.2	1355.5	1173.1	826.1		1326.0	1283.0	1471.6	1412.8	–	–	1061.6	
5	Purnia		1965.8	1461.7	1621.3	2161.2	1480.6	1731.5	2115.1	1666.3	1569.2		1710.3	2107.1	1992.9	1554.3	–	–	1613.4	
6	Bhagalpur		–	–	–	–	–	770.4	1639.8	878.0	1108.7		962.0	1662.8	1099.7	1706.3	–	–	–	
7	Khagaria		–	–	–	–	–	–	–	–	1029.0		1525.9	1306.7	1666.7	1491.9	–	–	–	
8	Darbhanga		1525.5	–	1014.5	891.6	–	1074.1	1208.6	1173.1	921.4	1055.6	1202.8	1633.2	803.7	2082.0	–	–	1103.4	
9	Katihar		1299.1	800.3	1610.6	1037.6	–	1205.0	1599.0	1033.5	962.1	1263.8	1531.8	1811.0	1484.2	1509.8	–	–	–	
10	Araria		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

Source: (1) Directorate of Statistics and evaluation, Government of Bihar for data from 1979 to 1985.
(2) Chief Engineer, WRD, Purnia for data from 1974 to 1978 and 1986 to 1990.

Annex-2

LOCATION OF GAUGE, DISCHARGE AND SILT OBSERVATION SITES IN THE KOSI RIVER SYSTEM WITH MAXIMUM OBSERVED GAUGE AND DISCHARGE.

Sl No	Name of River	Location of Site	Agency which maintains the Site	Danger level in Mtrs	Maximum Guage in Mtrs	Year	Mamimum Discharge in cumecs	Year	Remarks
1	2	3	4	5	6	7	8	9	10
1	Kosi	Barahskhetra (GDS)	Central middle Ganga Divn 4, CWC Patna	120.3	132.18	1968	25856.16	(1968)	Data from 1948 to 1992
2	Kosi	Birpur (GD)	DO	74.7	75.87	1987	12609	(1987)	For gauge data 1975 to 1992 for discharge 1982 to 1992
3	Kosi	Basua (G)	DO	47.75	48.65	1987			1971 to 1992
4	Kosi	Baltara (GDS)	Do	33.85	36.4	1987	12043	(1974)	Data obs. for gauge 1957-1992 and for discharge 1957 to 1982
5	Kosi	Kursela (G)	DO	30	32.1	1982			1987 to 1992

Note: 1 G = Gauge site
GD = Gauge discharge site
GDS = Gauge discharge & Silt site
CWC = Central Water Commission
Five new observation sites in Nepal located at Pachuwar Ghat, Toksel Ghat, Turki Ghat, Babua Bazar and Majhitar in upper catchment above Barahkshetra have also been set up by CWC recently in 1991, but data is still not being received (Para 4.7.1)

Source : Comprehensive Plan of Flood Control for the Ganga sub-basin (Kosi River System) March 1986, prepared by GFCC and Flood report 1989 & 1990 Bihar prepared by SE, Flood Control Planning and Mon. Circle-Patna.

Annex 3

ANNUAL SEDIMENT LOAD IN THE KOSI RIVER SYSTEM FROM THE YEAR 1948 TO 1981 FOR DIFFERENT GRADES AT SITE NO 13 (BARAHKSHETRA) (ON THE RIVER SAPT KOSI)

Year	Total average in MCM	Percentage of sediment to total sediment load		
		Coarse	Medium	Fine
1948	103.611	12.38	33.33	54.29
1949	151.964	7.71	30.52	61.77
1950	93.251	16.01	28.17	55.82
1951	102.748	19.32	29.05	51.62
1952	98.800	20.22	27.22	52.56
1953	81.532	20.27	28.29	51.43
1954	283.453	16.19	24.67	59.14
1955	69.320	23.84	24.73	51.42
1956	68.703	12.75	28.19	59.07
1957	59.699	13.43	32.44	54.13
1958	105.215	32.27	34.70	43.02
1959	87.452	16.78	31.45	51.76
1960	72.153	14.02	28.89	57.10
1961	59.082	17.12	27.35	54.47
1962	83.136	14.99	38.72	57.06
1963	72.898	17.60	29.44	52.96
1964	82.518	10.61	17.79	71.60
1965	57.356	20.43	18.50	61.07
1966	92.634	22.77	23.83	53.40
1967	61.920	16.00	25.90	57.97
1968	172.345	16.17	22.83	60.99
1969	95.224	25.00	20.08	54.92
1970	194.026	18.34	14.81	64.78
1971	92.387	23.90	21.09	55.01
1972	63.153	27.34	15.82	56.72
1973	73.761	22.24	17.34	60.37
1974	82.766	22.95	18.48	58.57
1975	65.377	30.19	18.49	51.32
1976	77.776	16.11	26.33	57.57
1977	55.875	18.64	30.24	50.99
1978	79.436	18.48	26.71	54.81
1979	49.319	24.44	20.47	55.10
1980	161.260	3.52	27.14	44.54
1981	74.884	25.88	25.63	48.49
1982	87.300	28.14	29.40	42.46
1986	64.084	33.39	21.76	44.85
1987	85.827	23.58	20.51	55.91
1988	82.552	22.23	20.34	57.43
1989	58.679	22.00	20.35	57.65
Average 1948-81 & 1985 to 1986	92.48	19.82	24.79	55.39

[Source: Comprehensive Plan of Flood Control for the Ganga Sub-basin (Kosi River System) March 1986 Prepared by the GFCC & Data from 1985 to 1989 from the CE (Birpur)]

Annex 3 contd

MONTHLY AVERAGE SILT DATA FOR THE KOSI RIVER SYSTEM FOR THE YEAR 1969 to 1973, 76 AND 85 TO 1989
SITE – BARAHKSHETRA (ON THE RIVER KOSI)

Month	Total average sediment load gm/litre	Graded percentage of sediment to Total		
		Coarse, in %	Medium, in%	Fine, in %
1	2	3	4	5
January	6.348	35.35	17.37	47.28
Feb	5.435	31.37	18.95	49.68
March	7.486	33.05	11.82	55.13
April	15.370	22.81	12.24	64.95
May	42.435	23.75	16.86	59.39
June	68.456	21.06	21.92	57.02
July	89.510	18.96	21.85	59.19
Aug	67.165	22.88	21.54	55.58
Sept	44.947	23.60	24.62	51.78
Oct	28.814	26.54	21.37	52.09
Nov	15.822	37.98	15.64	46.38
Dec	8.607	38.67	12.20	49.13

SITE : BALTARA

1	2	3	4	5
1973	67.20	4.85	21.86	73.29
1974	112.83	11.63	20.73	67.64
1975	33.37	9.90	21.33	68.77
1976	38.74	1.19	8.64	90.17
1977	28.11	4.09	21.31	74.60
1978	49.68	2.05	23.30	75.64
1979	50.71	0.79	15.01	84.20
1980	75.70	11.45	19.68	68.86
1981	59.93	18.17	23.68	58.15
Average 1973-81	57.35	8.19	19.81	72.00

Source: Comprehensive plan of flood control for the Ganga Sub-basin (Kosi River System) March 1986 Prepared by the GFCC

Annex 4

YEAR WISE PEAK VALUES OF GAUGE AND DISCHARGE DATA

Year	Basua gauge site	Baltara site		Kursela gauge site	Birpur site		Barahkshetra site	
		Gauge	Discharge		Guage	Discharge	Gauge	Discharge
1947								8845
1948							123.52	13476
1949							122.24	11145
1950							122.51	9596
1951							121.90	7219
1952							122.46	8632
1953							121.00	5392
1954							128.06	24091
1955							122.06	7042
1956							120.29	5408
1957		33.585	4367.903				121.97	7493
1958		34.500	5422.910				123.40	10507
1959		33.975	6195.000				120.84	5944
1960		34.735	6695.000				121.10	7155
1961		34.100	6909.000				122.06	8254
1962		34.752	8965.190				122.37	10450
1963		34.482	7163.220				121.24	7606
1964		34.652	9257.260				124.32	10704
1965		34.597	7980.690				121.94	6620
1966		34.952	7226.800				124.80	10760
1967		33.792	5563.620	31.610			123.31	8788
1968		34.642	N.A	N.A			132.18	25856
1969		34.182	5939.840	31.100			123.04	7840
1970		35.085	8814.310	30.330			125.35	13797
1971	47.750	34.872	7095.000	31.700			124.29	12113
1972	48.300	34.334	6849.070	29.815			124.13	10654
1973	48.100	34.682	9055.660	30.425			123.71	9799
1974	48.340	35.352	12042.810	30.549			124.77	11360
1975	47.900	34.662	9630.750	30.735	74.090		123.13	9153
1976	47.545	34.642	7093.760	31.615	74.070		122.64	9432
1977	47.990	34.647	7410.990	30.605	74.570		123.37	7736
1978	48.125	34.972	8035.140	31.845	74.310		123.46	9778
1979	48.440	34.802	6096.920	29.565	74.610		121.73	13102
1980	48.155	35.003	7100.000	31.640	74.370		124.94	9782
1981	48.080	35.202	10500.000	31.762	74.150		121.90	7788
1982	47.680	33.682	4845.200	32.100	74.120	5213	121.30	6933
1983	48.140	34.360		31.360	74.820	8107	121.37	8819
1984	48.270	35.270		31.290	74.850	8025	122.15	13153
1985	47.550	35.160		30.850	74.850	9244	124.89	12942
1986	47.360	34.520		31.010	74.850	7987	123.12	7360
1987	48.650	36.400		31.790	75.400	12609	127.85	14324
1988	48.160	35.550		31.600	75.200	11254	124.92	9964
1989	47.870	34.487		29.800		9273		13393
1990	48.550	35.200		30.740		11333		14429
1991	48.370	35.010		31.300	75.430	8533	124.65	3360
1992	47.990	34.440		30.290	74.850	5569	121.81	6896

Source: Comprehensive Plan of Flood Control for the Kosi River system by GFCC Patna, March 1986 and from C.E Water Resources Department Birpur.

Annex 5

History of Past floods in the River Kosi

Year	Summary
1866	The first recorded famine and scarcity as mentioned in the District Gazetteer of Bhagalpur in 1866. Failure of crops due to heavy rainfall in July 1866 resulted in severe distress in 1866. Prices of essential commodities soared very high. Commonest rice was sold at 11 sears per rupee. There are different reports about mortality statistics. The police had reported 97 deaths due to starvation. 2% to 3% of the population had per-ished from starvation.
1906	There were exceptionally high floods during August September 1906 affecting both Supaul and Madhepura sub-divisions. The distress was severe untill the water had subsided.
1908	Supaul and Madhepura had again a taste of very heavy Kosi floods creating havoc. But the receding water left good silt and there were good crops of bhadai and aghahani in Supaul and Madhepura sub divisions.
1918	This year saw the further west ward swing of the river Kosi from the borders of the Purnia district. There was heavy rain and the high flood of the river Kosi devasteded most of the portion of Madhepura sub-division.
1920-29	During the period 1920-29, Madhepura and Supaul Subdi visions suffered from floods of the Kosi. Kosi floods 1921 damaged the standing crops. The heavy Kosi floods 1927 affected the agriculture of the district.
1930-31	The flood during the period 1930-31 had brought devas tation to many parts the districts. The railway lines used to be frequently breached.
1934	In 1934 there was the Great Bihar Earth-quake which affected river regime. Some of the river beds were raised and few new channels were revived.
1938-39	Due to heavy rains and heavy floods, Supaul & Madhepura subdivisions were badly affected. Kosi river had already become a menace. The railway communication between Mansi and Koparia was suspended till 1954.
1940-41, 1945	Heavy Kosi Floods affected the western part of Supaul & Madhepura.
1948	Gajua Nala and Dhemra dhars and other small streams were silted up during the second flood of the seasons. Berda dhar an absolutely dead channel functioned during the flood and flooded the area to the west of Simrahi and Ganpatganj. The third flood during the month of July was the highest in the year. The rush of water through channels mentioned above combined with spill from Tilaway flooded about 500 Sq Km of usually flood free area of Madhepura district.
1949	The Kosi rose gradually this year. And there was no severe spilling except during the month of July onwards over flooding the country side in the Tilaway and Nirmali belt where the depth of flooding was even 3 mts in this area, but the overall damage were not so much in comparision to the previous year.

1950 Half of the Tilaway dhar flood water passed through a newly developed creek into Parwana dhar which was almost the dead course. This development caused flooding around Madhepura and breached Saharsa Madhepura railway embankment. It was also observed during this year that the flood level was higher in the western channel and lower in the eastern side indicating the westerly movement of the course.

1951 The area affected by this year flood was approximately 3940 Sq Km in Saharsa and Darbhanga districts. In this year Kosi experienced three flood peaks during first week of June, Second week of July & the last week of August. in the main eastern channel the second flood of July opened half the mouth of Dhemra dhar at its offtake, which started feeding its branches lower down ie Kherdha, Tilaway and Parware.

1952 In this year the Majari Dhar took greater share of the discharge than last year and began feeding the river Beti and the Patalia near village Parri, south of Nirmali. The total about 1300 Sq Km area of Saharsa district was badly affected.

1953-54 The Kosi flood of 1953-54 was extremely severe and entire Saharsa district was badly affected. The left out dhars in Purnia district, which were hitherto almost dead, also became active by the severity of the Kosi flood and caused inundation over a large area. The Kari Kosi, the old bed of the Kosi, also swelled to the very high intensity of flood, causing spill and inundation of vast area. In this year, the Kosi carried a discharge of about 24,200 cumecs as observed at Barahkshetra on 24.8.54, whereas the normal flood discharge in Kosi at this point is about 9918.5 Cumecs. Earlier, another peak discharge of 19700 cumecs had been recorded in the Kosi at Barahkshetra on 27.7.54. Earlier peak recorded at this site were 19778 cumecs and 13546 cumecs in the year 1927 and 1948 respectively.

1955 In the year 1955, work on the Kosi project was started, embankment of subtantial length were completed in 1957, which started accruing benefits from the same year. The barrage was completed in 1963 and eastern Kosi canal system was commissioned in July 1964. In the 1968, highest flood discharge ever recorded in the Kosi was observed, but damages were comparatively low and that too, because of four breaches in the lower reaches of the embankment. Had the Kosi embankments not been completed, in 1968, the story of 1954 flood disaster would have been repeated.

1958-59 Scarcity was declared due to flood and draught in the district of Saharsa.

1959-60 The Kosi flood water came as early as 1st week of May. The total estimated damage was approximately 5,00,000 maunds of flood grains. Approximately 373 villages in the district within a radius of about 280 Sq milles, with a total population of about two lakh souls were affected by the flood.

1960-61 During this year an area of 302 Sq miles within the embankments were affected by Kosi floods. A total population of 2,06,933 souls suffered.

1963 Flood is an annual feature in Saharsa district and it is now restricted to the areas lying within the two Kosi embankments. There are 224 villages within the Kosi embankments where floods are the normal feature. There are five anchals, namely, Supaul, Nirmali, Marauna, Birpur & Kishanpur (Supaul subdivision) and two Anchals, namely Mahisi and Dharhara (Sadar subdivision) where floods occur every year and some villages are always affected.

The river Kosi had started eroding the western embank ment from 6th August 1963. Originally the distance of the river from the embankment was 210 ft. The situation took a serious turn and about half a mile embankment was touched.

1985 This year the river started rising from the begining of July and crossed the D L for the 1st time at Baltara on 17th July 85 and continued to flow above D L upto 9th Aug 85 18m length of the spur at 5.3 Km of the eastern embankment was eroded out on 5.9.85 and flood fighting were continued on war footing to control further damage 80m length of inner slope of western embankment in between 356 to 420 Km was also eroded out, which was restored afterwards by flood fighting work on war footing.

1986 The river first crossed its danager level at Kursela on 28th July 86 and continued to flow above danger level up to 10.8. The river again flowed above danager level at Kursela from 22.8 to 1.9 & 8.9 to 21.9. The Kosi also flowed above danger level at Baltara from 1.8 to 10.8 & 27.8 to 23.9.86

The eastern afflux bund of Kosi was subjected to severe erosion between 25-26. In spite of heavy flood fighting works the whole of the river side slope, top width and some parts of country side slope of the embankment was eroded upto 6.8.86 in a length of 100 metre between 26 & 27 Km. At 17 Km also only half of country side slope of the embankment was remained in a length of 300 metre. Flood fighting works were done by State Irrigation Deptt. The situation started improving from 7th August 1986.

1987 In Kosi basin this year the flood situation reached alarming state due to heavy rain fall. The river first crossed the danger level on 30th June 1987 at Barahkshtra and continued the flow above danger level at Barahkshetra from 7.7 to 8.7, 18.7, 21.7 to 5.8 8.8 to 16.8, 27.8, 31.8 to 5.8 and so on upto 29.9 at Birpur on 2.7, 28.7, 9.8 to 13.8, at Basua from 11.8 to 14.8, at Baltara from 27.7 to 2.10 and at Kursela from 14.8 to 28.9.87

In this year the damage was very much on the higher side.

1988 The river Kosi is formed by the confluence of three streams namely Sun Kosi, The Arun Kosi and the Tamur Kosi, all having their origin in the Himalayan region of Nepal and Tibet. The river joins the Ganga near Kursela in Katihar district of Bihar.

There is still problem of flood in the lower reaches where the conbined discharge of the Kamla, Kosi and Bagmati flows. In the first half of August there was widespread rainfall in the area as a result the river crossed the danger mark at various sites in the first half of August 1988.

The same situation continued upto middle of Sept. 88. None of the embankment breached, however, erosion had taken place at many places of embankment. The Kosi first crossed the danger level on 12th July 1988 at Baltara. The river also flowed above danger level at Basua on 14.8, 16.8, 17.8, 17.8 and from 24.8 to 31.8, at Baltara from 12.7 to 19.9 and at Kursela from 4.8 to 12.9.88.

In this year badly effected district were Saharsa, Khagaria, Katihar & Purnia.

Spurs at 5.4, 6.8, 10.9 & 11.9 Km of Kosi Eastern affiux bund on the upstream of Kosi barrage were in danger. Heavy erosion took place at 83.4, 117.5, 78.3 Km at Eastern

Kosi Embankment.

1989 Though the river exerted pressure on left afflux bundh and right Kosi embankment spurs between 5 Km and 7 Km spurs, there was no breaching in embankment and hence no damage was caused to protected areas.

1990 There was heavy pressure on Eastern Kosi embankment between 82.0 and 84.0 Km. The embankment was saved by excavating pilot channel at this point. Both the embankments remaind safe in whole length.

1991 The river flowed above danger level at barrage site from 29.7.91 to 21.9.91. The western Kosi embankment breached in 30m (1000 ft) between 3 and 4 Km on 18.7.91, but no area was inundated on the country side because of water level remaining below NSL. Top officials as well as the Minister, WRD and Chief Minister Bihar visited the site and flood fighting work was started on war footing with the help of Nepalese Military.

1992 The river flowed above danger level at Barahkshetra on 14.9.92, 17.9.92, 24.8.92, 26.8.92 to 28.8.92, at d/s of Birpur from 24.8.92 to 26.8.92, at Basua from 25.8.92 to 27.8.92, at Baltara from 26.8.92 to 31.8.92 and at Kursela from 28.8.92 to 22.9.92 and exerted pressure on anti-erosion works but no damage was done to the two embankments.

1993 A discharge of 3,11,482 cusec flowed in the river on 15.8.93 due to which the spur at 16.8 Km of Eastern Attlux Embankment was eroded in 260m length. The river flowed over the spur, touching the toe of the embankment in 400 ft (90m) length, posing serious threat to the embankment. A possible breach was saved by resorting to heavy flood fighting work. The situation was so grave that there was imminent danger of eastern afflux bundh at 16.8 Km being eroded and all the senior offices of the department including commissioner had to camp there.

FLOOD DAMAGE DATA FOR THE KOSI RIVER BASIN
(CONVERTED FROM THE AVAILABLE FIGURES FOR THE DISTRICTS IN THE BASIN)

Year	Area affected in Lakh ha	area affected in lakh ha	Damage to crops Value in Rs. Lakh At then current price.	Damage to crops Value in Rs. Lakh At 1991 Constt. Price.	Damage to houses Nos	Damage to houses Value in Rs lakh At then current price.	Damage to houses Value in Rs lakh At 1991 Constt. Price.	Cattle lives lost (Nos.)	Human lives lost (Nos.)	Damage to Public Utilities in Rs Lakh At then current price.	Damage to Public Utilities in Rs Lakh At 1991 Constt. Price.	Total Damages In Rs lakh At then current price.	Total Damages In Rs lakh At 1991 Constt. Price.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1968	3.76	0.31	439.12	2728.02	55911	37.19	231.04	5969	7			476.31	2959.06
1979	1.32	0.13	104.70	625.11	9330	15.66	93.50	4	6	3.11	18.57	123.47	737.18
1970	1.45	0.66	420.68	2386.10	9426	16.99	96.37	1		0.55	3.12	438.22	2485.59
1971	6.75	2.44	1597.60	8628.60	199060	290.07	1566.67	1392	12	186.60	1008.20	2074.27	11203.47
1972												0.00	0.00
1973	1.30	0.45	315.65	1360.45	14455	23.57	108.58		2	0.30	1.29	339.52	1470.32
1974	4.90	2.45	4744.91	15904.94	91789	171.18	573.80	33	11			4916.09	16478.74
1975	2.63	1.12	1316.10	4245.74	19951	57.42	185.24	1	3			1373.52	4430.98
1976	3.43	0.66	374.97	1233.65	17049	34.37	113.41	252	6			409.34	1347.06
1977	2.30	0.21	94.61	289.41	6050	15.34	46.93		4	1.38	4.22	111.33	340.56
1978	2.70	1.01	407.43	1249.14	17763	56.21	172.33	3	8			463.64	1421.47
1979	1.80	0.52	151.14	415.14	3611	14.52	39.88			0.14	0.38	165.80	455.40
1980	4.06	2.16	1083.61	2477.13	12826	93.76	214.34	19	14	15.49	35.41	1192.86	2726.88
1981	2.75	1.53	968.03	1971.88	11366	120.26	244.97	3	6	25.86	52.68	1114.15	2269.53
1982	1.24	0.31	934.20	1857.19	8548	86.13	171.23	0	0	0.64	1.27	1020.97	2029.69
1983	5.58	0.88	275.35	506.23	10664	60.07	110.44	3	3	52.26	96.08	387.68	712.75
1984	5.86	4.05	5071.18	8670.86	128036	1331.14	2260.27	43	20	1030.00	1748.94	7432.32	12680.07
1985	2.05	0.36	217.16	348.63	6292	25.95	41.66	0	8	9.24	14.83	252.35	405.12
1986	2.54	0.69	448.40	683.32	7540	50.57	77.06	0	17	3.99	6.08	502.96	766.46
1987	9.27	5.02	13044.00	18697.26	389090	4615.20	6615.42	1570	300	9466.00	13568.56	27125.20	38881.24
1988	3.67	0.95	1050.40	1390.10	2811	19.82	26.23	3	16	7.15	9.46	1077.37	1425.79
1989	1.88	0.41	317.38	393.30	2591	54.96	68.10	0	8	10.18	12.62	382.52	474.02
1990	0.82	0.32	125.31	142.46	2995	29.83	33.69	1	8	0.14	0.16	155.28	176.31
1991	2.39	1.02	372.34	372.34	6928	88.92	88.92	10	15	62.68	62.62	523.94	523.88
1992	0.19	0.13	5.56		1012	7.14		0	4	0.75		13.45	0.00
Average (68-91)	3.10			3188.20			548.88				693.52		4430.60
Avarage (68-92)	2.98	1.11			40917			332	19				

Source: Comprehensive plan of flood control for the Kosi River system prepared by the GFCC in 1986 and from Relief and Rehabilitation Department Government of Bihar.

Annex 7

LIST OF FLOOD CONTROL WORKS COMPLETED IN THE KOSI RIVER BASIN

Sl No	River/ tributrary/ sub-tributary		Name of the Scheme	Nature of the Scheme (eg embankment, anti-erosion etc	Date of Start	Date of completion	Total Length of embankment in km	Remarks
1	2		3	4	5	6	7	6
1	Kosi		Eastern Kosi	Flood Embankment	April 1954	March 1961	125	
2			Western Kosi	,,	,,	,,		
		a	From Bharda to Nirmali				47	
		b	Old embankment between 0 to 18 Km				7	
		c	From Ghoghardiha to Ghoghepur				54	
3			Eastern Earth Dam				1.82	
4			Western Earth Dam				4.00	
5			Eastern afflux bund				32.00	
6			Western afflux bund				12.80	
7			Mahuli Embankment				3.50	
8			Dagmara Marginal Embankment				3.00	
9			Tiljuga Parallel Embankment				6.50	
10			Tiljuga Marginal Embankment				3.50	
11			Sikarhata Majhari Forward Flood Embankment				17.88	
12			Mahadeo Math Ring bund				3.00	
13			Left Panchi Embankment				1.52	
14			Right Panchi Embankment				2.73	
15			Nirmali Ring Bund				4.30	
16			Nirmali Marauna Flood embankment				25.76	
17			Link Road/Flood Embankment From Nirmali to Ghoghardiha				8.50	
18			Balan Marginal Embankment				4.25	
19			Jamalpur Ring Bundh				4.30	
20			Khaptol Paniakoch Embankment				1.82	
21			Kania Bhitgaria Alapur Embankment				66.00	
22			Jania-Kursela Embankment				31.00	
23			Badlaghat Nagarpara Embankment				32.00	
24			Tirmuhani Kursela Embankment				6.20	

(Source : C E, W R D, Birpur, 1992 and Flood Report, WRD, 1992)

Annex 8

LIST OF DRAINAGE SCHEMES COMPLETED IN THE KOSI RIVER BASIN (UNDER DRAINAGE DIVISION SAHARSA)

Sl No	Name of Dhar	Name of Chaur	District	Block	Year of completion	Proposed benefited area	Actual benifited area
1	Parwane (compl)		Saharsa	Pipara Saurbazar	83-84	5007.96	4047.00
2	Jarur (compl)		Madhepura	Madhepura	83-84	1104.83	470.10
3	Mastapar (compl)		Madhepura	Saurbazar Sonebarsha	83-84	4275.65	3237.60
4	Sone (compl)		Madhepura	Madhepura	83-84	3838.58	2630.55
5	Basan (compl)		Supaul	Pipara Triveniganj	83-84	934.85	934.85
6	Baradah (2)		Supaul	Raghopur	89-90	1861-62	1618.80
7	Kater (compl)		Supaul	Nirmali	80-81	121.41	101.17
8		Palel	Saharsa	Saurbazar	82-83	178.07	121.41
9		Aranvishnapur	Saharsa	Saharasa	82-83	190.21	121.41
10		Maheshpur	Supaul	Pipara	82-83	303.52	242.82
11		Tahuria	Saharsa	Saurbazar	82-83	101.17	80.94
12		Hanuman Nagar	Saharsa	Saurbazar	83-84	161.88	121.41
13		Kawai	Supaul	Triveniganj	81-82	76.89	60.70
14		Haripur	Supaul	Raghopur	81-82	161.88	121.41
15		Piparahi Jhil	Madhepura	Singheshwar	81-62	182.11	141.64
16		Panhar	Supaul	Supaul	83-84	121.41	121.41
17		Bardah	Saharsa	Saurbazar	83-84	283.28	283.26
18		Ratanpura	Madhepura	Madhepura	83-84	242.80	182.11
19		Gosai	Supaul	Pipara	83.84	202.35	202.35
20		Parsa Madail	Madhepura	Murliganj	81-62	48.56	46.56
21		Emamgang	Supaul	Raghopur	81-82	248.60	203.35
22		Zarauli	Supaul	Supaul	81-82	203.05	203.05
23		Dinapatti	Supaul	Pipara	83-64	153.78	101.17
24		Ghabaulichap jhil	Saharsa	Saurbazar	81-82	24.28	24.26
25		Ghabauli	Saharsa	Sourbazar	81-82	141.64	141.64
26		Dighara	Saharsa	do	83-64	60.70	40.47
27		Turkahi	Madhepura	Murliganj	83-84	165.92	141.64
28		Rahua	Saharsa	Sourbazar	81-82	113.30	80.94
29		Gamharia	Madhepura	Singheshawar	83-84	80.94	72.84
30		Parsahi	,,	Madhepura	83-84	40.47	40.47
31		Araha Bhinepur	,,	,,	81-82	113.31	80.94
32		Aghari Bhansari	Saharsa	Sourbazar	81-62	40.47	32.37
33		Belar	Mahhepura	Madhepura	83-84	40.47	40.47
34		Maupur Narha	Supaul	Pipra	81-82	202.35	202.35
35		Kaingar	Supaul	Pipra	61-82	323.76	323.76
36		Ramnagar	Madhepura	Madhepura	83-84	60.94	72.84
37		Belkhari	,,	,,	83-84	129.50	121.41
38		Banchaula	Saharsa	Sourbazar	83-84	225.93	248.80
39		Parsa drainage channel	Madhepura	Madhepura	81-82	40.47	32.37
40		Balam Chamrahi	,,	,,	83-84	40.47	32.37
41		Pastadah	,,	,,	83-84	80.94	80.94
42		Dasin	Saharsa	Saharsa	81.82	295.43	263.29
43		Khamdaha	,,	,,	81-82	141.64	141.64

Annex 8 Contd

(DRAINAGE DIVISIDN, SUPAUL)

Sl No	Name of dhar and name of chaur related to dhar	District	Block	Year of complition	Proposed area (in ha)	Actual benefitted area (in ha)
1	Bhenga dhar					
	i Bhenga dhar	Supaul	Basant nagar	From 0 to 40.69 km	3237.60	910.60
		Saharsa	Triveniganj		80.90	80.90
		Roghopur				
		Singheshwar		1987		
		Saharsa				
	ii Laharniya	Supaul	Pipra	1985	174.00	174.00
		Chaur	Sonbarsa	1985	101.20	101.20
2	Ghemara dhar					
	From 0 km to 78.49 km	,,	Pipra			
	A from 35.05 km to 53.95 km	,,	Supaul			
	B From 62.48 km to 78.33 km	Saharsa	Novhatta	1989-90	9308.10	3237.60
	LINK CHAUR DRAIN					
	1 Hatabariya chaur	Supaul	Supoul	1982	485.60	404.70
	2 Ram Nagar chaur	,,	Triveniganj	1982	101.20	101.20
	3 Kusami Karjhel	Saharsa	Simri Baritiyarpur	1990	1335.50	1011.85
	4 Chainpur Bhagawanpur	,,	Saharsa	1990	809.40	404.70
	5 Narha-Saraha	,,	Simri	1987	242.80	242.80
	6 Khuri Chaur	Supaul	Supaul	1983	121.40	121.40
	7 Markurea Chaur	,,	,,	1983	60.70	60.70
	8 Gopalpur Musahariniya	Saharsa	Kahra	1989	465.40	242.80
	9 Telbagha Chaur	,,	Novhatta	1990	161.90	141.60
	10 Dengara Chichraha Chaur	,,	,,	1988	202.40	121.40
	11 Hansa Chaur	,,	,,	1990	40.50	40.50
	12 Uchhawa Chaur	,,	,,	1990	121.40	101.20
	13 Maila-1	,,	Saharsa	1990	40.50	40.50
	14 Simrail Chaur	,,	,,	1990	40.50	40.50
	15 Ghimayani Chaur	,,	,,	1988	202.40	202.40
	16 Kasama Chaur	,,	,,	1982	80.90	60.70
	17 Newalakha Chaur	,,	,,	1983	485.60	364.20
	Subsidiary drain of Dhemara dhar					
3	Patti dhar	Supaul	Supaul from 6.02 km to 19.812 km	1990-91	930.80	404.70
4	Thalaha dhar	,,	,,	1989-90	1092.70	809.40
	Link Sonal Chaur	,,	,,	1988	182.10	161.90
	Kamaldah Chaur	,,	,,	1988	161.90	161.90
5	Kohali dhar					
	i Maricha Chaur-I	,,	,,	1988	1011.80	890.30
		Saharsa	Nauhatta	1988	60.70	40.50
	ii Maricha Chaur-II	Supaul	Supaul	1988	161.90	121.40

Annex 8 Contd

(DRAINAGE DIVISIDN, SUPAUL)

Sl No	Name of dhar and name of chaur related to dhar	District	Block	Year of complition	Proposed area (in ha)	Actual benefitted area (in ha)
6	Gajama dhar	,,	,, From 0 Km to 13.72 km	1989	1497.40	809.40
	1 Phulkaha Chaur	,,	Kishnpur	1989-90	40.50	40.50
	2 Ratanpura Chaur	,,	,,	1989-90	80.90	40.50
	3 Ramchauri Chaur	,,	,,	1989-90	60.70	60.70
	4 Nemmuwa Chaur	,,	,,	1989-90	40-50	40.50
	5 Parallel drain of Eastern Embankment	Supaul Kishanpur	1989-90	202.30	202.30	
7	Burhi Chaubagoha dhar liuk dhar	Saharsa Nauhatta	Supaul	1989-90	1618.80	1011.80
	1 Purain Chaur	Supaul	Supaul	1987	202.40	202.40
	2 Dekuliya Chaur	,,	,,	1988	202.40	202.40
	3 Parauri Chaur	,,	,,	1987	303.50	242.80
	4 Badiya Chaur	,,	,,	1988	121.40	121.40
8	Bora dhar	Saharsa	Nauhatta Mhaishi	1988-89	3035.30	2023.50
	Bora link drain	,,	,,	1988-89	526.10	404.70
9	Pharahi dhar	,,	,,	1988-89	1618.80	1214.10
10	Gai dhar (Maindhar)	,,	Salkhua from 0 km to 1.676 km	1990-91	607.10	283.30

Annex 8 contd

(Drainage Division Banmankhi)

Sl No	Name of Dhar	Name of Chaur	District	Block	Year of completion	Proposed benefited area	Actual benifited area
1	Binauiya dhar	1 Gokulpur	Purnia	Narpatganj	1983	369.1	369.1
	(In compl)	2 Mirghaul (W)	,,	,,	1983	174.4	174.4
		3 Mirghaul (E)	,,	,,	1983	360.2	360.2
		4 Baisandi	,,	,,	1983	155.00	155.00
		5 Kusmaul	,,	,,	1983	180.10	180.10
		6 Mohamadganj Gwalpara	,,	,,	1990	136.00	136.00
		7 Gamhariya	,,	,,	1990	384.50	384.50
		8 Bhawanipur	,,	,,	1990	600.60	600.00
		9 Giradharpatti	,,	,,	1990	194.30	194.30
		10 Sirsiya Balan	,,	,,	1984	712.30	712.30
		11 Ghoriyahi	,,	,,	1990	89.00	89.00
		12 Baijupatti	,,	,,	1990	129.50	129.50
		13 Parihari	,,	,,	1990	392.60	392.60
		14 Khajuri	,,	,,	1990	189.40	189.40
		15 Chakala	,,	,,	1983-84	89.00	89.00
		16 Phatehpur Nathpur	,,	,,	1983-84	235.90	235.90
2	Khutaharidhar	17 Sonapur-Dhaneshari	,,	Banmankhi	1983-84	1376.00	1376.00
	(in compl)	18 Dhima Makhauia Lakshmi pur-2	,,	,,	1983-84	210.40	210.40
		19 Baghawa chaur ,,	,,	1983-84	323.80	323.80	
3	Hahanala	20 Janaki najar-Rikabganj	,,	,,	1983-84	2630.60	2630.60
	(compl)	21 Sitarampur	,,	,,	1984	20.20	20.20
		22 Bhangtola Rupauli	,,	Barhara	1977	930.80	930.80
		23 Gauripur Gopinagar	,,	,,	1980	404.70	404.70
		24 Raghubanshanagar	,,	,,	1983	323.80	323.80
		25 Maldiha-Patraha-Lakshmipur	,,	,,	1990	202.4	202.4
		26 Kadai Nala-1	,,	Rupauli	1987	263.10	263.10
		27 Gulela dhar (compl)	,,	Barhara	1984	3817.90	3817.90
		28 Gulela Pita	,,	,,	1988	152.20	152.20
		29 Shukhia	,,	Banmankhi	1981	202.40	202.40
30	Kadai Nala-2		,,		1984	8737.50	8737.50
		31 Nirpur Singharpatta	,,	Dhamdaha Bhawanipur	1990	4047.00	4047.00
		32 Ghatawa	,,	Rupuali	1975	2185.40	2185.40
		33 Taildiha	,,	,,	1988	101.10	101.10
34	Dudhinagar dhar				1980	2509.10	2509.10
		35 Dhamdaha Tekari Dhimahi	,,	Dhamdaha	1988	1295.00	1295.00
		36 Mantarauni Piranpur	,,		1981	404.70	404.70
		37 Haranur-Piranpur	,,		1984	607.10	607.10
		38 Maeni chaprahi	,,	Rupauli	1987	283.30	283.80
		39 Bardela	,,	Dhamdaha	1983-84	121.40	121.40
40	Khaira-Lachchha dhar		,,		1987	2347.30	2347.30
41	Fariyani dhar		,,	Dhamdaha	1983	283.30	283.30
42	Pakilpar dhar	BrahmaGyani	,,	Rupauli	1976	526.10	526.10
		43 Barhari	,,	Banmankhi	1984	161.90	161.90
		44 Ramjani	,,	,,	1981	242.80	242.80
		45 Akabarpur	,,	Bhawanipur	1981-82	526.10	526.10
		46 Chahabachcha	,,	Barhara	1981-82	87.40	80.90

Annex 8 contd

DRAINAGE DIVISION,UDAKISHANGANJ

Sl No	Name of Dhar	Name of Chaur	District	Block	Year of completion	Proposed benefited area	Actual benifited area
1	Hareli dhar	1 Ajamanagar	Madhepura	Murliganj	1981-82	8080.60	7431.90
		2 Babhangama	,,	,,	1980-81	969.70	969.70
		3 Bisunpur	,,	Alamnagar	1979-80	356.10	242.80
		4 Sinraharpur Kauwakol	,,	,,	1981-82	550.40	550.40
		5 Molama	,,	Udakisunganj	1981-82	121.80	121.80
		6 Phanahan	,,	,,	1975-76	99.20	99.20
		7 Alamnagar	,,	Alamnagar	1981-82	131.90	131.90
		8 Kujari	,,	,,	1983-84	146.50	145.50
9	Basanwara dhar		,,	Alamnagar Udakisungaj	1984-85	1366.30	1366.30
10	Gordhuwa dhar		,,	Murliganj	1987-88	2692.90	165.90
11	Goladhar		,,	Alamnagar	1983-84	882.70	586.80
12	Beldaur dhar		,,	Sonbarsa			
		13 Kumralichaur	,,	,,	1981-82	1192.70	505.90
		14 Harallichaur	,,	,,	1981-82	323.80	282.90
15	Gamaildhar		,,	Kishanganj	1983-84	4203.2	3498.60
		16 Hariaundha chaur	,,	,,	1983-84	1051.40	1010.50
		17 Dumrail chaur	,,	Chosa	1981-82	79.30	79.30
		18 Rauta chaur	,,	,,	1981-82	89.80	89.80
		19 Bala Tola	,,	,,	1981-82	92.30	92.30
		20 Muracha chaur	,,	,,	1984-85	453.30	453.30
		21 Musharia chaur	,,	,,	1981-82	647.50	647.50
		22 Dighi chaur	,,	Udakisunganj	1973-74	70.80	70.80
		23 Balatola(E)	,,	Chosa	1981-82	53.80	53.80
24	Chikanidhar		,,	Kumarsand	1984-85	202.40	80.90
		25 Nirmali chaur	,,	,,	1978-79	293.40	293.40
		26 Balukhadrainage Nala	Supoul	Basantpur	1983-84	283.30	283.30
		27 Baluwakarjain	,,	,,	1983-84	404.70	404.70
		28 Kewla chaur	,,	..	1983-84	41.70	41.70
		29 Jibachhpur	,,	Chhatapur	1983-84	80.90	80.90
		30 Rajabara	,,	Pratapganj	1975-76	80.90	80.90
		31 Lahariniya	,,	Tribeniganj	1981-82	174.00	174.00
		32 Mirchaibari	,,	Banmankhi	1981-82	101.20	101.20
		33 Baitare chaur	,,	Murliganj	1984-85	271.10	202.40
		34 Sisawa chaur	,,	,,	1984-85	319.70	319.70
		35 Akabarpur chaur	,,	,,	1978-79	770.50	728.50
		36 Tamaut Parsachaur	,,	,,	1982.83	275.20	267.10
		37 Baghiniya	,,	,,	1983-84	590.90	404.70
		38 Bailichamagarh Gamhariya chaur	,,	,,	1982-83	1376.00	858.00
		39 Vishwanathpur chaur	,,	Sonbarsa	1978-79	50.20	50.20
		40 Kamaldah chaur	,,	Supaul	1980-81	623.20	323.80
		41 Harpur Bhada	Supaul	Sonbarsa	1981-82	376.40	255.00
		42 Haraili chaur	,,	,,	1981-82	80.90	80.90

Annex 8 contd

DRAINAGE DIVISION,UDAKISHANGANJ

Sl No	Name of Dhar	Name of Chaur	District	Block	Year of completion	Proposed benefited area	Actual benifited area
		Scheme Under Phase-2					
43	Chausa dhar From 0 Km to 18.288 Km				1989-90	566.60	566.60
		44 Bachhiya Tola chaur			1989-90	290.60	290.60
		45 Logachhiya chaur			1989-90	207.20	141.60
		46 Gosai Tola chaur		Pipra	1989-90	214.50	214.50
47	Gamailchaur From 4.389 Km to 8.870 Km				1989-90	704.60	80.70
		48 Lakshmipur drain			1989-90	314.50	314.50
49	Gudia dhar			Kumarkhand	1989-90	814.70	299.50
50	Chikani Bajar dhar			Chhatapur	1989-90	204.80	97.10
51	Kasanajar dhar						
		52 Goradhua chaur			1989-90	107.20	107.20
		53 Bajraha chaur (1)			1989-90	137.60	137.60
		54 Bajraha chaur (2)			1989-90	129.90	129.90

Annex 9

LIST OF PROPOSED DRAINAGE SCHEMES IN KDSI RIVER BASIN

Name of Scheme	District	Length (Km)	Drainage area (in ha)	Estimated cost in Lakh Rs	Submergence area (in ha)		Area proposed to be drained (in ha)		Remarks
					Kharif	Rabi	Kharif	Rabi	
WESTERN KOSI CANAL SYSTEM – Review of Existing Drainage System									
Main natural drains									
Phase-I				NA	NA		NA		
Ghordah		5.5							
Arbisia		98.5							
Panchi Nadi		10.5							
Dharam Nadi		24.5	39000						
Dhananjey		19.0							
Bihul		13.15							
Total		161.15	39000	NA	NA		NA		
Phase-II									
Sone Nadi		40.00							
Tugerue Nadi		74.00							
Bhamti		–							
Balan Nadi		10.00	95000						
Soni		27.00							
Mamla		–							
Total		151.00	95000	NA	NA		NA		
Phase-III A									
		427.00	133000						
Total		427.00	133000	NA	NA		NA		
Phase-III B									
Bachharia									
Thamane									
Dhot									
Darbhanga Bagmati		453.00	108000						
Karch									
Other samall Rivers									
Total		453.00	108000	NA	NA		NA		
Abstract of Drainage System in Western Kosi Canal									
Nos of Drains									
I- 6		312.15	39000						
II- 7		151.00	95000						
III-A9		427.00	133000						
III-B6		453.00	108000						
Total 28 Nos		1343.15	375000	NA	NA		NA		

(Source : CE, WRD. PP Cell, Patna)

Annex 9(contd)

DETAILS OF CHAUR LINK DRAIN UNDER DRAINAGE DIVISIDN, SUPAUL (KDSI PHASE – II)

Sl No	Name of Dhar	Name of Chaur		Length in Km	Submergance area in ha
1	Bonga Dhar	1	Maheshpur Chaur	4.267	339.9
		2	Jaipura Chaur	2.438	294.6
		3	Latona Mathnus Chaur	3.048	416.4
		4	Marakhap Chaur	2.743	310.8
		5	Barhari Chaur	1.219	97.1
		6	Barbana Chaur	2.438	226.6
		7	Hasanpura Sonbarsa Chaur	6.096	641.0
		8	Lalpur Chaur	1.828	101.2
		9	Jirba Chaur	4.572	373.9
		10	Sekhpura Sadowa Chaur	6.096	315.7
		11	Bharahi Chaur	2.438	155.4
				37.185	3272.8 ha
2	Dhomra Dhar	12	Gopipur Chaur	6.096	202.4
		13	Simrail Chaur	0.914	202.4
		14	Telhar Chaur	1.524	121.4
		15	Satarwar Chaur	1.524	404.7
		16	Tirmuhara Chaur	1.828	121.4
		17	dumrahi Chaur	2.438	101.2
		18	Jogin Chaur	3.048	121.4
		19	Bafipur Chaur	1.524	101.2
		20	Baghmari Chaur	0.609	182.1
		21	RATauli	2.438	121.4
		22	Jarauli (Jolahania)	1.066	60.7
		23	Kataiya Ninmali Chaur	0.914	60.7
		24	Lour Bishanpur Chaur	7.315	161.9
		25	Bonaina Chaur	1.371	141.6
		26	Bataram I	1.828	101.2
		27	Bataram II	1.828	101.2
		28	Bhalani	2.743	202.4
		29	Ekma Kuchahia	1.219	60.7
		30	Purikh	1.524	121.4
		31	Barail	1.828	101.2
		32	Pakaria	1.219	50.6
		33	Balairpattti	1.219	40.5
		34	Bahwarth	0.609	40.5
		35	Bhanar	1.828	60.7
		36	Barasain	1.219	80.9
		37	Uchhkhwa	1.219	60.7
		38	Toibagha Chaur	9.144	40.5
		39	Rahiya Chaur	0.609	38.4

Annex 9(contd)

Sl No	Name of Dhar	Name of Chaur		Length in Km	Submergance area in ha
		40	NarainChaur	0.914	50.6
		41	Hansa Chaur	1.066	40.5
		42	Koria Chaur	0.609	40.5
		43	Lakhajha Dabar Chaur	0.914	60.7
		44	Yoga Chaur	0.609	80.9
		45	Dynia Chaur	0.914	40.5
		46	Nagari Chaur	1.066	40.5
		47	Baiywala Chaur	1.066	40.5
		48	Kamauni Chaur	3.048	44.5
		49	Belahi Chaur	1.524	40.5
		50	Pathara II	1.219	40.4
		51	Tibra	1.524	60.7
		52	Bileshpatti	1.219	60.7
		53	Tohia	1.524	142.5
		54	Lakhan Khanka Dabor	1.828	40.5
		55	Barahmotar	1.371	40.5
		56	Balwa	1.524	60.7
		57	Bahurbarwa	1.524	40.4
		58	Nomua	0.914	80.7
		59	Yoga Baidy	3.657	161.9
		60	Chanpur Bhagwanpur	3.291	809.4
		61	Yaila Chaur	1.828	161.9
		62	Punhar and Dhamina	1.828	80.9
		63	Gopalpur Musharnia	6.644	593.3
		64	Sadanandpur Kalyanpur	5.852	465.4
		65	Pipra Chaur	4.450	445.2
		66	Baidi Chaur	2.133	101.2
		67	Kusumi Karjhail Balana Chaur	5.791	1335.5
		68	Gochahara Chaur	0.914	121.4
		69	Gidha Chau	1.219	141.6
		70	Kaparfora Chaur	2.438	182.1
		71	Bhalwa Chaur	2.133	121.4
		72	Goriyari Chaur	0.914	161.9
				128.290	8932.9 ha
3	Bochaha Dhar	73	Bhagwanpur Chaur	1.829	691.2
		74	Bahai Chaur	5.486	232.7
		75	Chakla Chaur	2.438	388.5
		76	Bhalukap Chaur	3.048	129.5
		77	Hulash Chaur	2.438	362.6
		78	Tintolia Chaur	2.438	194.3
4	Thalha Dhar	79	Thakurahi Malikana	1.219	40.5
		80	Kuchnari Chaur	0.762	40.5

Annex 9(contd)

Sl No	Name of Dhar	Name of Chaur		Length in Km	Submergance area in ha
		81	Ninmali	0.914	40.5
		82	Barkurba Chaur	0.914	40.5
		83	Kumhara Chaur	0.914	40.5
		84	Bhutha Chaur	1.219	40.5
		85	Nhonjaraha III	0.914	40.5
		86	Water legged at Parsarna	0.304	20.3
5	Kohli Dhar	87	Telwa Chaur	1.524	80.9
		88	Bhelahi Chaur	1.524	60.7
6	Patti Dhar	89	Maldahia Chaur	2.133	80.9
		90	Pathara Chaur	1.219	60.7
		91	Kariha Chaur	3.048	80.9
		92	Labaki Chaur	1.829	80.9
		93	Purandani Chaur	1.219	101.2
		94	Bina Chaur	0.914	60.7
		95	Ekma Chaur	1.219	40.5
		96	Chouri Chaur	1.829	121.4
		97	Rampur Chaur	1.066	80.9
		98	Barail II Chaur	1.219	80.9
		99	Jagatpur Chaur	1.219	60.7
		100	Garbaki Chaur	1.829	80.9
		101	Waterlegged at Parsarma	1.524	40.5
7	Baluaha Dhar	102	Pora Chaur	1.127	50.6
		103	Bhartha Chaur	2.438	121.4
		104	Phapahi Chaur	2.286	157.8
		105	Basana Chaur	1.524	40.5
		106	Paharpur I	0.609	40.5
		107	Paharpur II	0.609	40.5
8	Matha Dhar	108	Dumrahi Manga Chaur	1.219	48.6
		109	Naradaha Chaur	3.656	64.7
		110	Batauna Chaur	1.524	52.6
		111	Purani Chaur	1.524	52.6
		112	Harowa Chaur	3.048	582.8
		113	Barthanya Chaur	1.219	48.6
		114	Dhap Chaur	0.914	52.6
9	Farhi Dhar	115	Karhada Rohwa Chaur	3.656	121.4
		116	Bariahi Chaur	3.656	222.6
		117	Singhwa Chaur	2.134	45.3
		118	Bharauli Chaur	1.829	121.4
		119	Sarha Chaur	1.829	404.7
		120	Barha Chaur	1.829	50.6
		121	Gangia Chaur	2.438	141.6
				248.686	18691 ha

Annex 9 (contd)

DETAILS OF CHAUR LINK DRAINAGE(UNDER DRAINAGE DIVISION BANMANKHI)
(KOSI PHASE – II)

Sl No	Name of Dhar	Name of Chaur Link Drain		Length in Km	Submergance area in ha
1	Binania Dhar	1	Bhawanipur Chaur	1.828	600.0
		2	Girdharpatti Chaur	6.401	194.2
		3	Mahammadganj Chaur	1.524	136.0
		4	Gamharia Chaur	2.012	384.5
2	Pakilpar Dhar	5	Dhina Makhna Chaur	14.203	404.7
3	DudhiNagar Dhar	6	Mali Baraha Itahari Chaur	4.389	283.3
		7	Bardola Chaur	1.451	121.4
		8	Jaro[ir {romlar	1.524	607.1
		9	Bhonel Chaur	1.372	202.4
4	Gulella Dhar	10	Aurahi Laukahi Chaur	10.059	809.4
5	HahaNalaDhar	11	Kanalpur Chaur	2.743	121.4
		12	Laoecraha Ladugarh Chaur	4.023	80.9
		13	Urlaha Jainagara Chaur	5.029	364.2
		14	Jankinagar Ekraha Rikabganj	7.620	2630.5
		15	Kajhwa Chaur	2.286	323.8
6	Sapha Dhar	16	Paragahi Chaur		
		17	Laxmipur	12.878	2711.5
		18	Lalkuria		
7	Mogla Dhar	19	Khutha Chaur	0.762	242.8
8	KadaiNala II	20	Mainua Chaur	1.993	242.8
		21	Katalmari	1.950	242.8
		22	Laharauni Chaur	1.829	202.4
		23	Tilangawa Chaur	4.877	607.1
		24	Askatia Chaur	7.620	1011.8
		25	Bhurkunda Chaur	1.829	647.5
		26	Phulbaria Chaur	2.499	40.5
		27	Pobha Chaur	4.694	161.9
9	Khutha Dhar	28	Dhaneshwari Chaur	4.877	607.1
		29	Maria Group of Chaur	25.908	3177.3
		30	Other Chaurs	38.953	1167.6
			Total	177.028	21848.1

Annex 9 (contd)

STATEMENT OF LINK CHAUR DRAIN UNDER UDAKISHUNGANJ DRAINAGE DIVISION

Sl No	Name of Dhar		Name of Chaur	Length in Km	Submergance area in ha
1	Kashuagar Dhar	1	Telhar Chaur	1.372	216.0
		2	Godarma Chaur	1.372	172.0
		3	Bagraha Chaur	1.524	212.5
		4	Kashuagar Chaur	0.604	68.8
		5	Chilrahi Chaur	1.219	109.3
		6	Mahinath Chaur	0.832	117.4
		7	Tindova Chaur	0.975	80.9
		8	Pirnagar Chaur (East)	1.170	93.1
		9	Pirnagar Chaur (West)	1.649	206.4
		10	Jobha Chaur	2.374	93.1
		11	Kainjari DovaChaur	4.724	523.8
2	Gola Dhar	12	Jhaghari Chaur	2.682	275.2
		13	Saruni Chaur	1.524	102.4
		14	Ladauna Chaur	1.067	103.2
		15	Nimua Chaur	1.280	168.0
		16	ramnaganj Chaur	6.706	113.3
		17	Karauti Chaur	1.219	55.8
		18	Chhrapti Chaur	1.524	32.4
		19	Akoha Chaur	1.828	
		20	Jhagraba Chaur	1.372	384.4
		21	Hanodumaria Chaur	1.219	98.3
		22	Ladma Chaur	1.524	202.4
		23	Patoria Chaur	0.914	00.9
3	Basanbara Dhar	24	Basah Chaur	1.524	121.4
		25	Saguntela Chaur	5.486	89.0
		26	Bagora Chaur (East)	2.438	121.4
		27	Bagora Chaur (West)	0.609	105.2
		28	Sahjadpur Chaur	0.914	40.5
		29	Baijnathpur Purandeha Chaur	2.286	234.7
		30	Bela Chaur	1.828	137.6
		31	Khunhar Chaur (West)	1.219	40.5
		32	Khunhar Chaur (East)	0.533	105.2
		33	Agail Chaur	1.524	122.6
		34	Chakmaniabasa South Chaur	2.012	24.3
		35	Flodrahal Chaur	1.828	80.9
		36	Parmanandpur Chaur	3.048	344.0
		37	Chakla Chaur	1.524	121.4
		38	Kaparfora Chaur	1.905	202.4
		39	Ladma Badhauna Chaur	3.658	708.2
4	Beldaur Dhar	40	Siktiyahi BasaChaur	0.914	101.2
		41	Kursela Chaur	0.533	161.9
		42	Docharsi Chaur	1.219	101.2
		43	Bela Chaur	3.505	60.7
		44	Barbighi Chaur	3.505	121.4
		45	Khairabasa Chaur	3.505	40.5
		46	Beldaur Chaur	3.505	80.9

		47	Sohia Chaur	3.505	80.9
		48	Pachaut Chaur	1.828	101.2
		49	Golaganj Chaur	1.828	101.2
		50	Dighour Chaur (West)	1.676	121.4
		51	Dighour Chaur (East)	1.828	121.4
		52	Sakrohar Chaur	3.444	200.0
5	Chausa Dhar	53	Badia Chaur	4.572	113.3
		54	Mahimudin Chaur	1.219	404.7
		55	Karman Chaur	0.609	40.6
		56	Baswanpur Chaur	1.219	250.9
		57	Noga chhia toal Chaur	2.133	208.4
		58	Ghosal Chaur	2.438	214.5
		59	Ghosal Chaur	1.219	279.2
6	Guria Dhar	60	Guria Chaur-I		
		61	Guria Chaur-II	0.457	80.9
		62	Topra Chaur-I	3.657	398.6
		63	Topra Chaur-II	0.914	131.5
		64	Jaduapatti Chaur	1.219	32.4
		65	Dhungra Chaur	1.067	40.5
7	Chikni Basar Dhar	66	Dhania Chaur	2.743	80.9
		67	Manganj Chaur-I	1.097	147.7
		68	Manganj Chaur-II	1.036	153.8
		69	Chikni Chaur	0.609	70.8
8	Surdhua Dhar	70	Raghunathpur Chaur	3.048	384.5
		71	Raishree Chaur	1.524	297.5
		72	Sarhadganj Chaur	0.914	129.5
		73	Srinagar Chaur	1.219	176.0
		74	Umlakhi Chaur	1.524	303.5
		75	Dunga Chaur	1.524	176.9
		76	Topra Chaur-I	3.658	202.4
		77	Goria Chaur	8.534	404.7
		78	Haripur Chaur	4.267	54.6
		79	Dighi Chaur	1.219	93.1
		80	Ramani Chaur	0.914	263.1
		81	Gopali tota Chaur	1.219	398.6
		82	Hanumanpatti Chaur	0.914	49.0
		83	Baghaili Chaur	0.914	49.0
		84	Morhanpur Chaur	0.609	32.8
		85	Baghi Chaur	1.524	32.8
		86	Baghanpatti Chaur	1.524	40.9
		87	Bishunpur Chaur	2.438	57.5
		88	Kewatgama Chaur	1.524	71.2
9	Hareli Dhar	89	Bnbhangama Chaur	3.048	84.5
		90	Bishunpur Chaur	1.828	45.7
		91	Sinhar Koakol Chaur	6.706	222.6
		92	Alannagar Chaur	4.572	53.4
		93	Phanhan Chaur	1.828	40.1
		94	8hanaili Chaur Drai	1.189	202.4
		95	Rangurai Ajgara Chaur	2.286	174.0
				195.072KM	14,638.4 ha

Annex 9 contd

DETAILS DF DRAINAGE SCHEMES UNDER DRAINAGE INV. CIRCLE, PURNEA WHEN NET AREA FREED FRDM WATER LOGGING

Sl No	Name of Scheme	Area to be freed from water logging (in ha)	Area freed in first phase (in ha)	Balance for 2nd phase (in ha)
1	Saura drainage scheme	7770.2	3569.5	4200.8
2	Bhaisana dhar drainage sch	2547.6	1543.9	1003.7
3	Saura subsidiary drain sch	1914.2	398.6	1517.6
4	Sursuni dhar drain sch			
5	Pemadhar drainage sch	1463.0	797.3	665.7
6	Old Kosi drainage sch	404.7	50.6	758.8
7	Darin dhar drainage sch	625.3	625.3	–
8	Tengraha dhar drainage sch	999.6	596.9	352.1
9	Karikosi drainage sch	2832.9	–	2832.9
		18911.6	7590.0	11331.6
10	Tinpania dhar drainage sch	4751.2	4451.7	299.5
11	Libri Branui dhar drainage sch 1230.3	186.2	1044.1	
12	Bora dhar drainage sch	1032.6	847.8	234.7
13	Larha dhar drainage sch	576.7	121.4	455.3
14	Kamla dhar drainage sch	16714.1	–	16714.1
		43266.5	13187.1	30079.3

[Source : Chief Engineer, WRD, Purnia, 1993.]

Annex 9 contd.

DETAILES OF CHOURS IN DIFFERENT TRUNK AND SUBSIDIARY DHARS
(UNDER DRAINAGE DIVISION, SAHARSA)
(KOSI PHASE-II)

Sl No	Trunk Dhar & Subsidiary Dhar	Name of Chaur Link drain		Length in Km	Submergance area in ha
1	Sone Dhar	1	Dighra Chaur	1.463	202.4
		2	Sapha Chaur	1.829	80.9
		3	Barsam Chaur	3.170	404.7
		4	Hanuman Nagar Kothaila Chaur	5.547	404.7
		5	Bancholha Chaur	1.767	202.4
		6	RamNagar Chaur	1.524	202.4
2	Tilawe dhar No 2	7	Basaha Chaur	0.914	222.6
		8	Chitti Chaur	1.219	303.5
		9	Makana Chaur	0.457	64.8
		10	Bhatrandha Chaur	0.609	60.7
		11	Aran Bishanpur Chaur	0.822	182.1
		12	Baluaha Chaur	1.066	161.9
		13	Samada Chaur	0.914	141.6
		14	Patuaha Chaur	1.219	141.6
		15	Markahi Chaur	0.914	202.4
		16	Dasin Chaur	1.676	404.7
		18	Shirha Chaur	0.304	101.2
		19	Rup Nagar Chaur	0.914	161.9
		20	Sahuria Chaur	1.371	101.2
		21	Narha Chaur	0.914	64.8
		22	Galharia Chaur	0.914	30.4
		23	Pirha Chaur	1.524	24.3
		24	Simri Chaur	1.676	141.6
		25	Lav Chaur	4.572	404.7
		26	Taraba Chaur	2.743	303.5
3	Jaroor Dhar	27	Tarhi Chaur	0.914	50.6
		28	Jagbani Chaur	0.914	30.4
		29	Larha Sonbarsa Chaur	0.914	101.2
		30	Dori Chap	0.457	101.2
		31	Barahi Jheel Chaur	2.133	218.5
		32	Hasanpur Chaur	2.438	121.4
		33	Narha Chaur	2.438	131.4
		34	Bhaun Goriyahi Chaur	1.828	445.2
4	Dhasan Dhar	35	Kabaiya Chaur	0.944	76.9
		36	Songaria Bolha Chaur	0.670	80.9
		37	Harnagara Chaur	3.962	105.2
		38	Asthana Bovar	1.219	68.8
		39	Dandari Chaur	0.548	36.4

		40	Pakari Kamargava Chaur	6.096	259.0
		41	Gopalpur Chaur	3.352	125.5
		42	Malghwari Chaur	0.548	28.3
		43	Tosion Chaur	0.335	20.2
		44	Bahinga Chaur	0.335	20.2
		45	Burahwa Chaur	2.438	101.2
		46	Rampatti Chaur	0.853	48.6
5	Kamak Dhar	47	Kamak Chaur	0.743	259.0
		48	Dhabauli Chaur	1.828	501.8
6	Parwana Dhar	49	Chakala Chaur	0.609	202.4
		50	Imamganj Chaur	4.419	242.8
		51	Haripur Chaur	1.828	161.9
		52	Kaingar Chaur	1.402	323.76
		53	Bhatani Chaur	0.518	44.5
		54	Panhar Chaur	0.579	202.4
		55	Raghopur Nayagaon Chaur	–	202.4
		56	Mokaria Chaur	–	222.6
		57	Maheshpur Chaur	6.858	303.5
		58	Kalari Chaur	–	182.1
		59	Dahla Chaur	–	202.3
		60	Parsa Chaur	1.524	242.8
		61	Dhar Near Village Anandipatti (Gosaidhar)	–	161.9
		62	Narha Chaur	–	182.1
		63	Batran Chaur	–	161.9
		64	Satkadaria Chaur	–	202.3
		65	Othora Chaur	1.164	101.2
				94.799	11013.9 ha
		66	Link Drain between 10 Km to 17 Km of E F E	3.048 97.847 km	

Total length of Chaur link drains = 98 km

Annex 10

SALIENT FEATURES OF THE KOSI PROJECT

a	Catchment area upto barrage site	61,816	Sq Km	23,858 Sq miles
b	Maximum designed flood flow	26,904	cumec	9,50,000 cusec
c	Maximum observed flood flow 1968	25,828	cumec	9,12,000 cusec

UNIT I – BARRAGE

a	Total length aboutment faces	1,149	m	3,770 ft
b	Crest level of barrage			
	i weir	EL61.628	m	EL (235.00 feet)
	ii Under sluice	EL70.10	m	EL (230.00 feet)
c	Road level	EL77.724	m	EL (255.00 feet)
		6.858	m	(22'-9") Width
d	Width or roadway	1.447	m	(4'-9") walk way on one side
e	Gates			
	i Spillway	18.288x6.400	m	46 No of (60'x21') size each
	ii Under sluice	18.288x7.924	m	10 No of (60'x26') size each
f	Length of Eastern Earth dam	1,985.246	m	6,218 ft
g	Length of Western earth dam	3,718.560	m	12,200 ft
h	Length of Eastern Afflux bund	13,106.400	m	43,000 ft
i	Length of Western Afflux bund	13,483.437	m	44,237 ft
j	Present pond level	74.676	m	EL (245.00 ft)
k	Future pond level	77.724	m	EL (255.00 ft)
l	Top of pier	79.248	m	EL (260.00 Ft)
m	Top of gate over-bridge	90.830	m	EL (298.00 ft)
n	Maximum design discharge through Eastern (left) Kosi Head-regulator	488.52	cumec	17,250 cusec
o	Gates of left Head-regulator	12.192	m	No of (40 ft) size each
p	Maximum discharge through Western (right) Kosi Head regulator	240.72	cumec	8500 cusec
q	Gate ofright Head regulator	12.192	m	3 no. of (40 ft) size each
r	Submerged area due to ponding encluding river bed	41.456	Sq Km	16 Sq mile

UNIT – II EMBANKMENTS

a	Length of Eastern embankment	144.90	km	90 miles
b	Length of Western embankment	123.97	km	77 miles
c	Distance between embankment	4.73 to 6.10	km	3 to 10 miles
d	Area protected from floods	2,65,078	ha	6,55,000 acres
e	No of spurs (impermeable) constructed on Western side	52	Nos	
f	No of (imprmeable) spurs on Eastern side	232	Nos	

UNIT-III EASTERN KOSI CANAL SYSTEM (including drainage)

a	Length of canal system			
	i Main canal	43.47	km	27 miles
	ii Murliganj Branch canal	64.40	km	40 miles
	iii Jankinagar Branch canal	82.11	km	51 miles
	iv Purnea Branch canal	64.40	km	40 miles
	v Araria Branch canal	57.96	km	36 miles
	vi Distributaries & Minors	2727.34	km	1694 miles
b	Gross Comand area	742220	ha	18,34,800 acres
c	Culturable command area	494948	ha	12,23,000 acres
d	Annual irrigation	668180	ha	16,51,050 acres
e	Additional yield of crops expected annually			
	i Food crop	13,64,991	m Tonne	13,43,495 Tons
	ii Non food crop	5,57,875	m Tonne	5,49,090 Tons
f	Monetary value of additional yield per year	Rs 592.59	million	

Annex 10 contd

EAST NEPAL CANAL (OFF-TAKE FROM CHATRA)

a	Discharge	38.770	cumec	1,369 cusec
b	Culturable area	0.364	Lakh ha	3.37 lakh acre
c	Culturable area	0.619	Lakh ha	1.53 lakh acre
d	Annual Irrigation	0.736	Lakh ha	1.82 lakh acre

UNIT – IV RAJPUR CANAL SYSTEM

a	Length of canal system			
	i Rajpur Branch canal	9.66	km	6 miles
	ii Length of sub-branch Canals	326.83	km	203 miles
b	Gross command area	1,75,640	ha	4,34,000 acre
c	Culturable command area	1,17,363	ha	2,90,000 acre
d	Annual Irrigation	1,77,805	ha	4,39,350 acre
e	Additional Yield crops expected annually			
	i Food crop	3,92,161	MT	3,85,985 Tons
	ii Non food crop	34,899.60	MT	34,350 Tons
f	Monetary value of additional yield per year	Rs 161.932	milion	

UNIT – V WESTERN KOSI CANAL SYSTEM

a	Length of main canal			
	i Length of main canal (Lined) in Nepal	35.13	KM	
	ii Length of main canal (lined) in India	56.50	KM	
	iii Length of main canal (unlined) in India	20.0	KM	
b	Gross command area			
	i In Nepal	25,496	ha	63,000 acre
	ii In India	3,75,570	ha	9,28,020 acre
	iii Above contour 145' in India	2,44,439	ha	6,04,000 acre
c	Culturable command area in India	1,62,689	ha	4,02,000 acre
d	Additional yield of cross expected annually (in India)			
	i Food crop	5,10,957.50	m tons	5,02,911 Tons
e	Monetary value of additional yield per year (in India)	Rs 228.301	million	

COST ESTIMATE

Unit I	Barrage	Rs 456.00	million
Unit II	Embankment	Rs 418.32	million
Unit III	Eastern Kosi Canals system (including drainage)	Rs 1042.48	million
Unit IV	Rajpur canal system	Rs 251.70	million
Unit V	Western Kosi Canal system	Rs 1364.80	million
	Total :	Rs 3533.30	million
	Say	Rs 3533	milion

ALLOCATION OF COST

Flood Control	Rs 646.32	million
Irrigation	Rs 2886.98	million

FINANCIAL FORECAST

1	Benefit cost ratio at 10 per cent rate of interest for Unit I, II, & III	7.36
2	Benefit cost ratio at 10 per cent rate of interest for Unit IV	6.08
3	Benefit cost ratio at 10 per cent rate for interest for Unit V	1.57
4	Over all Benefit cost ratio of the project at 10 per cent rate of interest	3.89
5	Internal rate of return	31.0 %

KOSI HIGH DAM PROJECT SALIENT FEATURES

1	**LOCATION**	
	a Dam	1.6 Km upstream of Barahkshetra on Kosi River in Nepal
	b Barrage	Near Chatra Village, 8 km downstream of Barahkshetra Dam site.
2	**HYDROLOGY**	
	i Catchment at the Dam site	59539 Sq Km (22988 Sq Miles)
	ii Mean annual rainfall	1586 MM (62.44")
	iii Probable maximum flood	42475 Cumec (15 Lakh Cusec)
3	**DAM & APPURTMENT WORKS**	
	i Type of Dam	Straight Gravity concrete dam with Power House in the body of the Dam.
	ii Maximum height above rock	269 M (883 ft) foundation
	iii Top of dam	EL 342 M (1122 ft)
	iv F.R.L.	EL 335.25 M (1100')
	v MWL	EL 338.3 M (1110 ft)
	vi M.D.D.L.	EL 259.00 M (849.50 ft)
	vii Gross Storage	13.45 Millian MCM (10.908 Maft)
	viii Live Storage	9.37 Millian MCM (7.60 Maft)
	ix Dead Storage (storage upto	4.087 Millian MCM the expected N.Z.E. of (3-3 Maft) 100 Years at 861 ft
4	**POWER HOUSE**	
	i Installed capacity of Dam	3000 MW (6 units of Power House 500 MW each)
	ii Installed capacity of canal Power Houses	300 MW (3 Power Houses each having 2 units of 50 MW)
	iii Type of Dam Power House Turbine	High Speed vertical shaft francis Turbine
	iv Type Canal Power House Turbine	Pulb Turbine
	v Length of the Power Canal	45 Km (28 Miles)
	vi Drop available at each Power House	12.2 M (40 ft)
	vii Annual Power Generation:	
	a Dam Power House	15.732 TWh
	b Canal Power House	1.875 TWh
5	**BARRAGE**	
	Length	969.9 M (3182 ft)
6	**IRRIGATION**	
	(Command Areas)	
	i G.C.A.	15.22 Lakh Ha (37.59 Lakh Ac)
	ii C.C.A.	12.17 Lakh Ha (30.07 Lakh Ac)
	iii Gross Command Area in Nepal	5.46 Lakh Ha (13.49 Lakh Ac) (including firming up to 0.9 Lakh Ha (2.24 Lakh Ac) under existing in-undation irrigation
	iv Gross Command Area in India	9.76 Lakh Ha (24.10 Lakh Ac)
7	**CROPPING PATTERN AND INTENSITY OF IRRIGATION**	
	Paddy	75 %
	Wheat	30 %
	Sugarcane	2.5 %
	Jute	12 %
	Hot Weather Paddy	5 %
	Total	124.5 %

Annex 10 contd

8	**FINANCIAL ASPECTS**	
i	Estimated cost	Rs 4074 Crores
	Power Sector	Rs 2677 Crores
	Irrigation Sector	Rs 1347 Crores
	Watershed Management	Rs 50 Crores
ii	B.C. Ratio Power	17.03 Paise per KWH (at bus bars)
	Irrigation	1.54
iii	Cost per KW installed	Rs 8112
	Cost per ha/Ac of Annual Irrigation	Rs 8887/ Rs 3598

[Source : Comprehensive Plan of Flood Management of Kosi River Basin Prepared by GFCC in 1986]

REPORT ON RECONNAISANCE OF FLOOD CONTROL PROBLEMS IN NORTH BIHAR BY M/S LEOPOLD AND MADDOCKS JR OF U S TECHNICAL CO-OPERATION MISSION TO INDIA, APRIL, 1955

"Our own observations on natural rivers and experiments in the laboratory have led us to conclude that the primary cause of river braiding is selective deposition. When the load introduced into the reach is relatively small in quantity, bed particles tend to move in a band over the centre of the channel, the width of the band increasing with increasing quantity of sediment introduced. When the load includes particles slightly too coarse to be kept in motion, these come to rest near the middle of the channel and in doing so, trap or hide some of the finer particles by this process, a central bar is gradually build up, which on the average is some what coarser than the mean of the introduced load. Despite the decrease of depth immediately over the central bar, velocity actually remains the same or increases some what at that place, as a result of decreasing roughness over the bar and the particles continue to move over the bar instead of the deeper portions of the channel, which flank the central bar. The building of the bar is also accompanied by increasing water surface slope. As the bar builds closer to the water surface, the velocity then decreases bed sediment movement over the bar ceases, at which time the band of moving sediment is diverted into one of the deeper sediments flanking the bar. At such a time, essentially two channels exist separated by a bar, which becomes an island when the water surface is low.

These central bars force the flanking channels to erode the channel boundaries with the result that discrete channels saparated by islands are formed. The central bars grow by addition at their down stream ends and are often cut across by new channels as the process of channels shifting is continued. The shifts often made separate channels rejoin, so the net result is a limited number of channels continually dividing and rejoining.

That the slope of such a braided stream should be steeper than that for a single channel carrying the same total water and the same size of particles follows from the general consideration that channel slop tends to vary inversely as a power function of discharge.

Thus a channel becomes braided because of progressive deposition of the coarse portion of the debris load, and the slope of the braided channel generally is determined by the load and the flow pattern rather than vice versa. A braided pattern characterizes portions of nearly all the rivers of North Bihar. The kosi is braided from Chatra at least up to Supaul".

"In the monsoon season, the Kosi at Barahkshetra averages a concentration of 50 percent by volume, and this concentration has decreased to 40 at Hanumannagar. These figures are certainly not precise because of the short period of record and the limitations of the 6/10 depth sampling procedure. Yet they do confirm what can be inferred from the river slopes that the coarse portion of the Kosi load is deposited on the upper portion of the debris fan. The slope of each portion of the debris fan or cone depends on the coarse fraction of the load being brought to that portion of the fan, for a debris cone, on which discharge does not appreciably increase downstream, the flattening of the slopes in the downstream direction is a function of the progressive deposition of successively finer fractions of the load. The coarsest is deposited near the head of the cone and the finer farther from the mountains. Each segment of the debris cone of the Kosi has a slope commensurate with the size of the material being transported. In such a short distance as the 130 miles from Chatra to Dhemraghat, abrasion or breaking can have but minor influence on the size of the particles and can not be the cause of the flattening of slopes downstream. Sorting or selective deposition must be the explanation. Thus on a debris fan such as that of the Kosi, the greater the range of particle size in the sediment coming from the gorge, the more concave is longitudinal profile.

In such a concave longitudinal profile, terminating in a real flat area such that near Dhemraghat, there is no opportunity to carry away progressively the coarser fragment end,therefore, the debris cone aggrades. As the river shifts laterally through geologic time from one portion of the cone to another, it lays down a blanket of sediment, coarser near the mountain front and finer near the foot of the debris cone".

"The Kosi delivers to the Ganga at present only a portion of its load and only the finest size fraction. All the rest is deposited on the fan or in the low area in the vicinity of Dhemraghat. This means a much greater rate of net aggradation than if important portions of the load were progressively carried away from base of the fan. On this basis it might be expected that when the Kosi flowed directly south to the Ganges, it probably was less unstable than now and shifted its course at a less rapid rate. This appears to be verified by the known rate of westward movement of the river,for in the period from 1807 to 1873, when such a course existed, the average rate of migration was much smaller than in the period after 1883. In fact, Ghosh (p.138) cites reports that the river remained stationary for all of that seventy- years period.

A braided stream will tend to shift laterally at a rate dependent on the rate of accumulation of material being deposited. As one course becomes higher than possible adjacent paths, the river will shift. No other explanation for the observed shift of the Kosi is necessary, though the continual movement in one direction during the period of observation is somewhat surprising. Nevertheless the river must be expected over a long period to occupy every part of its debris cone".

"Nearly all channels, including many braided ones tend to develop relatively flat flood plains from the lateral movement of channels due to the process of point-bar deposition at bends. Our own studies of the process of flood plain formation lead to the conclusions that overbank deposition is far less important in flood plain formation than point bar deposition on bends. Much of the deposition which has resulted in the near Gangetic plain probably was developed by this process. We have studied the relation of the flood plain level to the river channel in terms of the frequency of over bank flow and found that there is widely different size location and characteristics. Our data shows that the flood plain is built at such a level that on the average the annual flood having a recurrence interval of about 2 years will just over-flow the flood plain. In other words even in a non-monsoonal climate flood plains are over flowed by all flows greater than the mean annual flood (average of the largest flood event of each year over a period of years)".

"The considerations outlined above, imply that braided rivers may be expected to migrate over their depositional surface more rapidly than meandering or other non-braided river types. Because braided channels characteristically have steeper slopes than meandering ones for the same bankful discharge, a braided river emerging from a mountain front to an alluvial plain will tend to develop a cone or fan sloping rapidly from the apex. The slope of each portion of the cone will be commensurate with the discharge and the sediment size. The rate of aggradation of various portions of the cone will depend upon the total amount of each size fraction carried out of the mountain gorge by the river. As we see it, the various slopes of the Kosi at different distance from Chatra are dependent on the size distribution of the load and these slopes cannot be considered either over steepened or difficult. By deposition, the Kosi will tend to build up the slopes in these reaches untill there exists a closer balance between sediment inflow and outflow."

RECOMMENDATIONS OF THE TECHNICAL EXPERTS COMMITTEE 1965 ON THE PROBLEMS OF DRAINAGE CONGESTION ON KOSI RIVER SYSTEM CAUSED BY THE INADEQUACY OF WATERWAYS IN THE RAILWAY AND ROAD BRIDGES

1 For drainage of low lying areas the base period may continue to be taken as 20 days, as at present with the drainage channels being designed for double the average discharge to account for the gradually decreasing flow depth.

2 Drains in agricultural lands should be designed for 3 days maximum rainfall of 15 years return period which comes to 11" (27.94 CM). The infiltration rates may be taken as 0.1" (0.25 CM) per hour for storm period of 3 days of rainfall, from which the applicable runoff factor works to 35% of total rain-fall. Masonary structures on the drain should be designed for 3 days maximum rainfall of 50 years return period, which comes to 14" (35.56 CM) and the corresponding runoff factor may be taken as 50%.

3 Cut sections of drains in agricultural areas having entire catchment area in plains should be designed for a discharge of 10 cusecs per sq mile (0.11cumec/sq km) Masonary structures on the drains should be designed for a maximum discharge of 18 cfs/sq mile (0.190cumec/sq km). From economic considerations, the construction may be phased, started with a discharge of 5 cfs/sq mile (0.055 cumec/sq km)

4 Various types of river training and conservancy works either singly or in combination should be implemented such as removal of obstructions by dredging, blocking of undesirable channels, providing cut offs to eliminate meanders and develop easy curvatures. These should from an important part of annual maintenance programme.

5 Growing of suitable plants should be taken up on a large scale in consultation with the Forest Department for protecting embankment.

6 Suitable variations in agricultural practices and cropping pattern should be adopted to make the best of the cultivable land within the embankments based on intensive study of the problem.

7 The proposed embankment on the right bank of the Ghugri river from Badlaghat to Paharpur by the Bihar State Irrigation Department endorsed by the Kosi Technical Committee (headed by Sri kanwar Sain) will be useful in protecting the area on the right bank, However its effects on the left bank on account of reduction of valley storage and subsequent rise in the flood height should be examined in detail before taking up construction of the above embankments.

8 The construction of embankment on the left bank of the Ghugri river (Kosi) is not desirable as it will lead to drainage congestion due to the existence of numbers of 'dhars' and also it is not justified on economic considerations.

9 Continuous studies of sediment load, area of deposition of various sizes and relations between load and channel characteristics should be carried out.

10 Investigations for Planning anti-waterlogging and drainage schemes as detailed out in the report should continue.

11 Some ground water table recorders should be installed at important locations with the assistance of the Geological Survey of India, since the open well observations do not sometimes correctly reflect the ground water condition at the site.

12 A phased programme of drainage of low lying areas as a Central work of reclamation should be prepared. Existing numerous courses of the river should be resectioned and recorded where ever necessary so that these may function effectively as trunk drainage channels for carrying the surface drainage of the irrigated sub-surface drainage may be taken up in the next stage and when found necessary.

Detailed soil survey and systematic collection of necessary data should be initiated now. Drainage channels should be constructed where necessary on the basis of the recommendations contained in para 5.3.2.2 Volume I of the report.

13 Only a rail-cum-road bridge with suitable quide boundary be constructed at Dagmara instead of a Barrage-cum-rain and road bridge, recommended by the Kosi Technical Committee.

14 An extension of 1040 rft (317.07 meter) of water way is required on nine important roads of the Kosi basin. This does not include the extension or construction of new bridges on the roads which are yet to be improved and where the data of existing bridges is not available.

15 A total of 1870 rft (570.12 meter) of waterway is required on the roads, where the data of existing bridges is not available.

16 An extension of 160 rft (48.78 meter) of water way under railway bridges is required in the Kosi basin.

17 Discharging capacity of the CD works of the easternmain Kosi Canal will require to be increased by 9,706 cft (273.40 cumecs)

18 Self recording rain gauge stations should be set up at Tribeniganj and at Kishanganj in addition to the two stations at Kuruleghat and Gumthong proposed by IMD.

19 Gauge sites at close intervals of 5 km (8.5 miles) upstream of the barrage and at 8 km (5 miles) down stream of the barrage with a view to determine the siltation of the river bed should be set up early.

20 One more discharge site should be set up in the lower reaches of the Kosi river when it is not confined within embankments, ie, near Koparia.

21 The discharge observation at the Railway bridges of Mansi Supaul Section lying between Kosi and Bagmati embankment should continue for a further period of 5 years.

22 As recommended by the Committee for flood forecasting and warning techniques, two additional discharge sites one each on the Sun Kosi and Tamur should be set up.

23 Silt observation sites on the Trijuga at Bisarlaghat, on the Bhutani Balan at Chausi and on the Kosi Just downstream of the barrage and at Bhanti should be set up with a view to have an idea of site contribution of the tributaries and deposition of silt in different reaches.

24 As far as possible aerial surveys should be done in years of very high floods or whenever there is a violent change in the river regime affter a flood with a view to save time and planning river conservancy work in time.

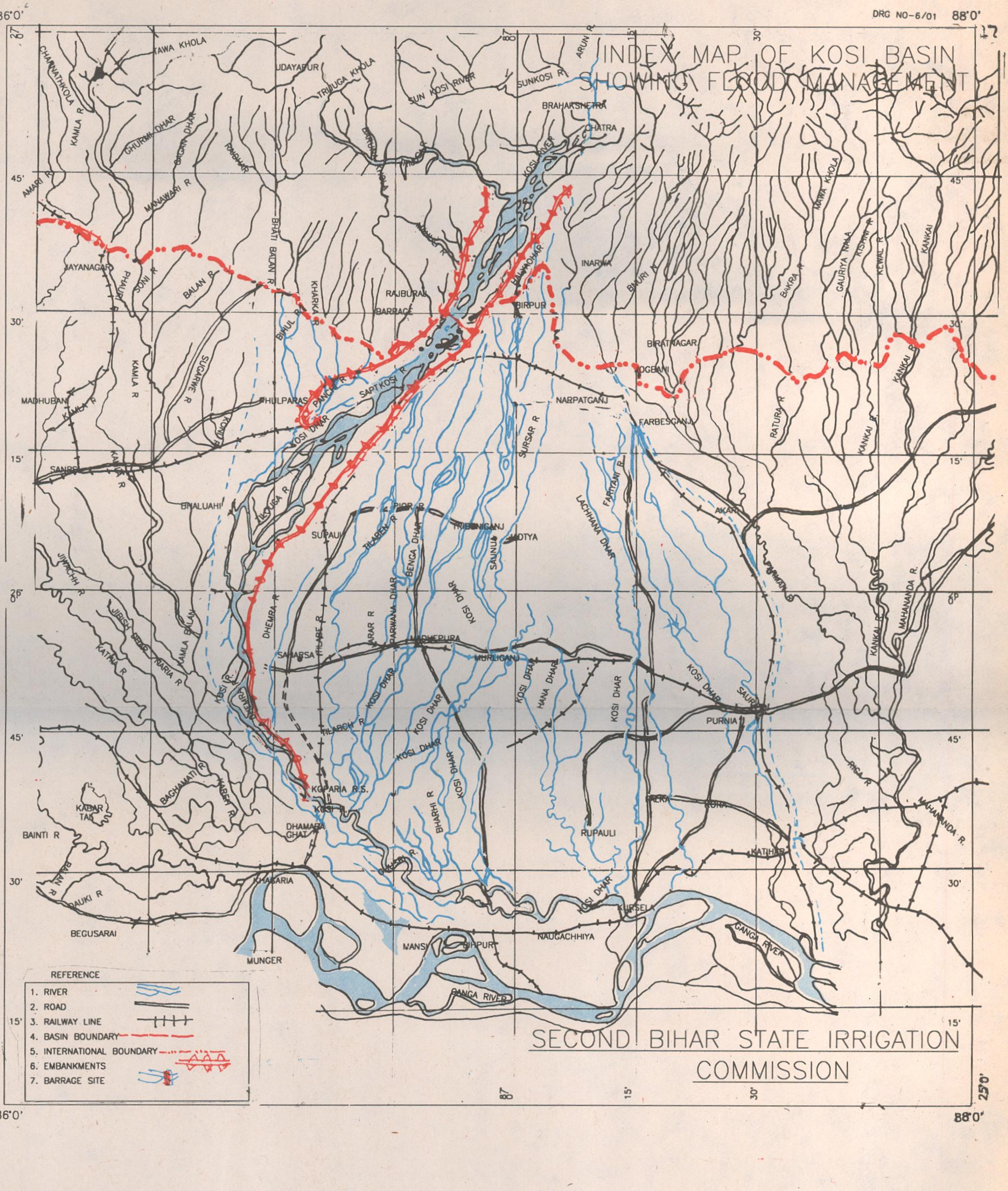
25 Below Koparia the problem of inundation is still there. The flood damage data should be collected on scientific lines as finally accepted by the Government based on recommendations of the

report of the National Council of Applied Economic Research, 1966, in this connection.

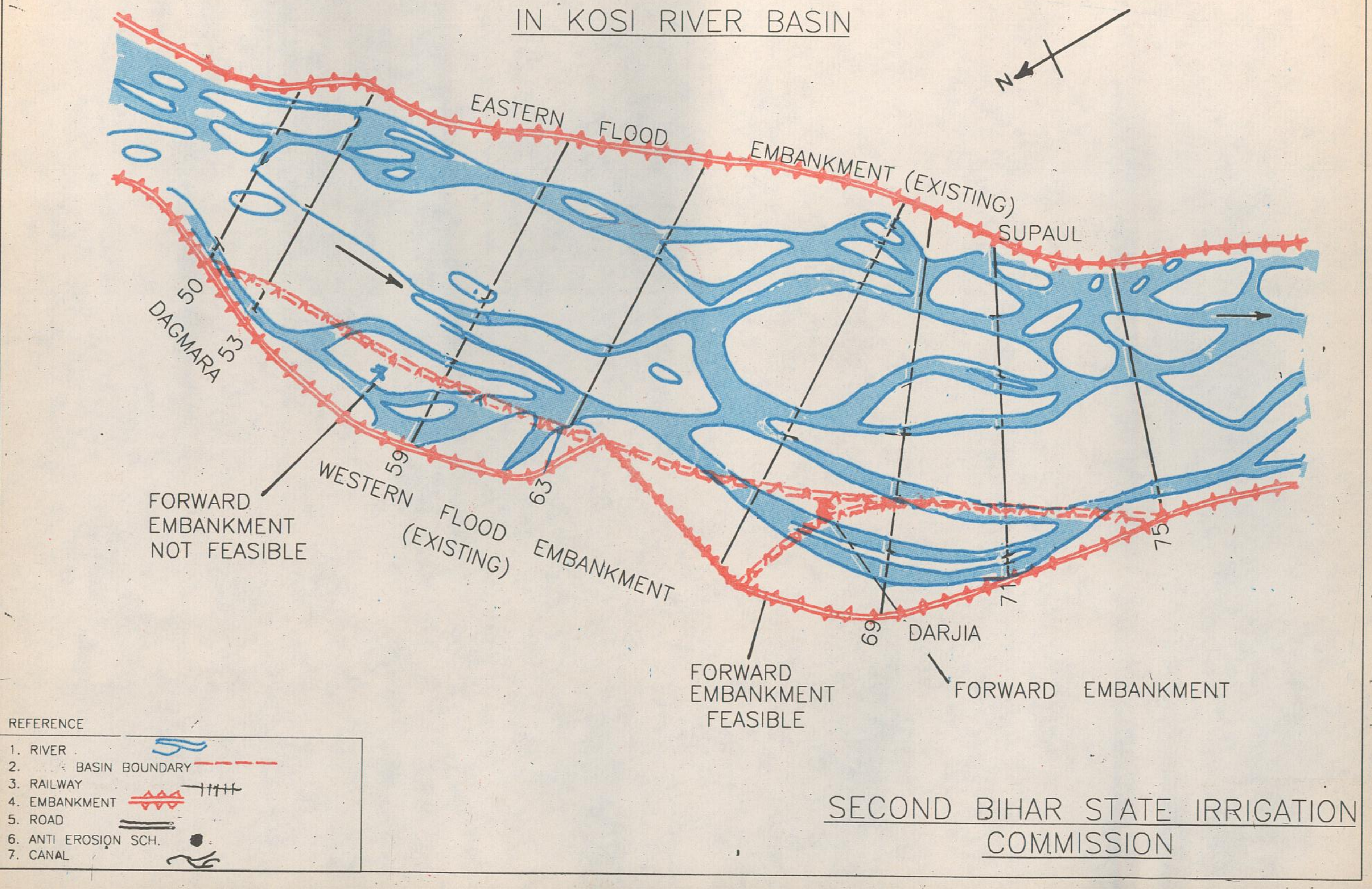
26 An extensive effort should be made for collection of data in the form of land use surveys, erosion surveys, of the areas which need soil conservation treatment. The Tamur catchment should receive priority, as it contributes to 26 per cent of the coarse silt of the Kosi though its catchment is only 10 per cent of the total Kosi catchment.

27 Model studies for evolving cheaper methods of protection of the affected reaches of the river and for proper river training works should be taken up. The required data should be forwarded to the CW & the PRS, Poona.

28 The work of preparation of basinwise report of the Kosi basin should be taken up by the State Government without delay".


DRG NO-6/01
INDEX MAP OF KOSI BASIN
SHOWING FLOOD MANAGEMENT
SECOND BIHAR STATE IRRIGATION
COMMISSION
REFERENCE
1. RIVER
2. ROAD
3. RAILWAY LINE
4. BASIN BOUNDARY
5. INTERNATIONAL BOUNDARY
6. EMBANKMENTS
7. BARRAGE SITE
86°0'
88°0'
25°0'
KOSI RIVER
SUN KOSI RIVER
SUNKOSI R
ARUN R
BRAHAKSNETRA
CHATRA
TAWA KHOLA
UDAYAPUR
TRIJUGA KHOLA
KAMLA R
JAYANAGAR
BIRPUR
BIRATNAGAR
JOGBANI
NARPATGANJ
FARBESGANJ
FULPARAS
MADHUBANI
SAPTKOSI R
KOSI DHAR
SUPAUL
TRIBENIGANJ
SAHARSA
MADHEPURA
MURLIGANJ
PURNIA
KATIHAR
KURSELA
NAUGACHHIYA
KHAGARIA
MUNGER
BEGUSARAI
GANGA RIVER
MAHANANDA R.
KANKAI R
LACHHANA DHAR
SURSAR R
KOPARIA R.S.
DHAMARA GHAT
RUPAULI
DHEMRA R
BHALUAHI
SUGARWE R
KABAR TAL
BAINTI R
BAGHAMATI R
KAREH R
RATURA R
SAURA
BAKRA R
INARWA
RAJBURAJ
BARRAGE

FEASIBILITY OF FORWARD EMBANKMENTS AS PROPOSED BY GFCC IN KOSI RIVER BASIN

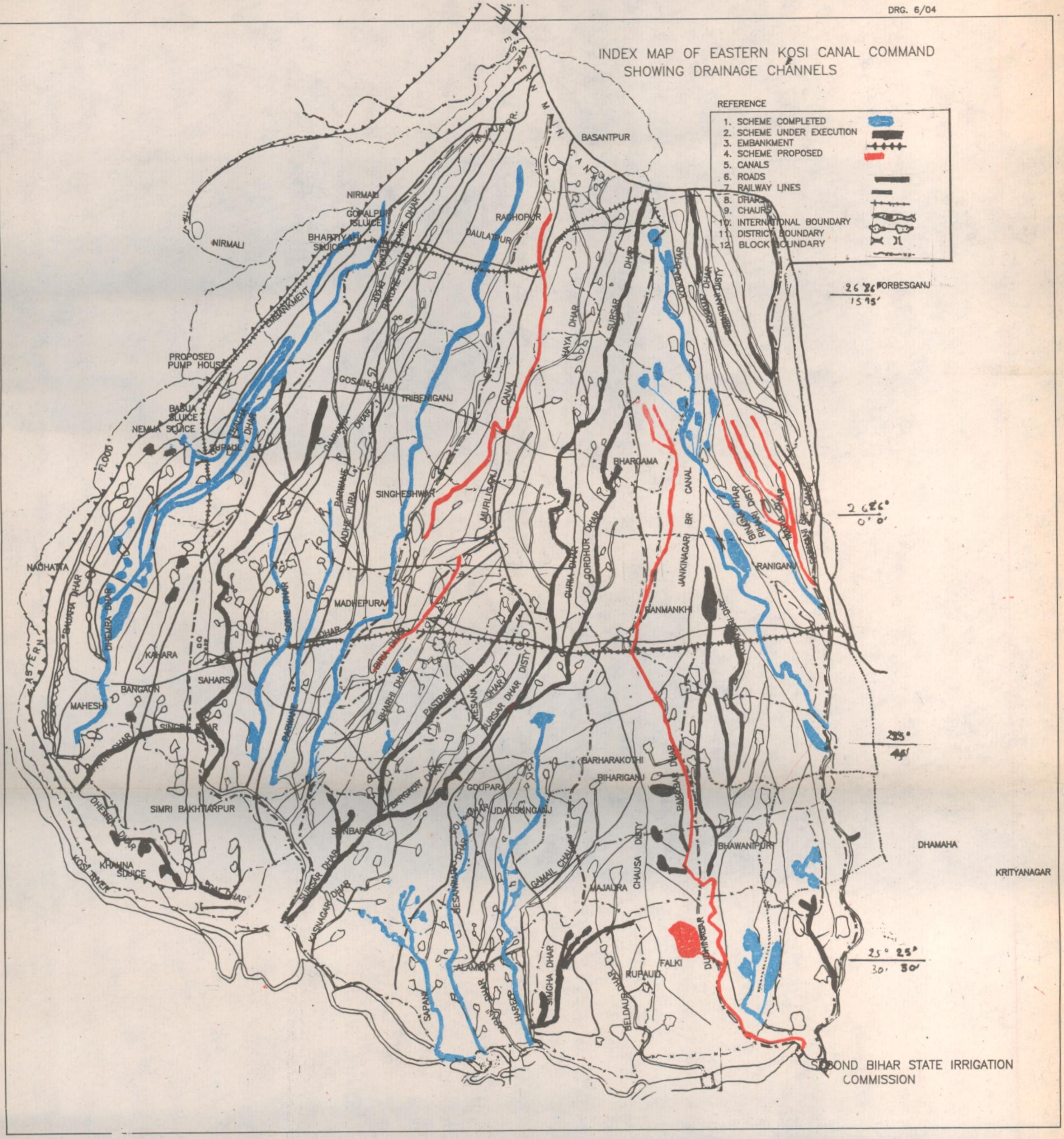


SECOND BIHAR STATE IRRIGATION COMMISSION

DRG NO.6/02

DRG. 6/04

INDEX MAP OF EASTERN KOSI CANAL COMMAND SHOWING DRAINAGE CHANNELS



APPENDIX 7

MAHANANDA BASIN

AT A GLANCE
PLAN FOR FLOOD MANAGEMENT IN THE MAHANANDA RIVER BASIN (IN BIHAR)

I	Salient Features of the Basin			
	1	Total Drainage Area	23,700	Sq Km
	2	Drainage Area in Bihar	6,150	Sq Km
	3	Population in Bihar	36.79	Lakh
	4	Water resources (Surface water)	9880	MCM
	5	Average Annual Rainfall(in Bihar)	1563	mm
	6	Total lenghth of Main River	376	Km
	7	Cropped Area in Bihar	3.66	Lha
II	Flood Damage (Average for 26 years, 1966-91)			
	1	Total Area Affected	1.77	Lha
	2	Cropped Area Affected	0.58	Lha
	3	Damage to Crops	Rs 1651	Lakh
	4	Total Damage	Rs 2663	Lakh
	5	Human lives lost	6	Nos
	6	Cattle Heads lost	272	Nos
	7	Average Population Affected	5.04	Lakh
III	Progress Of Flood Protection Measures (1954-92)			
	1	Length of Embankments	247.80	Km
	2	Area protected	1.21	Lha
IV	Eighth Plan Proposals (1992 - 97)			
	1	Length of Embankments	Total 98	Km in the State
	2	Additional area to be benefitted by flood control, Drainage and Anti water-logging measures	Total 1.00	Lha in the State
	3	Total Outlay for Flood Control measures in the State (1992-97)	Rs 35230	Lakh

AN APPROACH TO PROBLEMS OF FLOOD AND DRAINAGE CONGESTION AND REMEDIAL MEASURES IN THE MAHANANDA RIVER BASIN (IN BIHAR)

1 INTRODUCTION

1.1 The Ganga sub-basin which extends over an area of 8.614 lakh Sq Km within India is the largest river basin in the country and is a part of the main Brahmputra-Meghna-Ganga river basin. Flat terrain, high intensity of rainfall and poor drainage condition combine to cause flooding and drainage congestions almost every year in a large part of this sub-basin, particularly in the portions lying in the Eastern Uttar Pradesh and Bihar. The flood damage in this sub-basin accounts for a major part of the total flood damage of the country.

1.2 The state of Bihar is situated in the central portion of the Ganga sub-basin. The portion lying on the northern side on the left bank is known as North Bihar and the area lying on the southern side on the right bank is known as South Bihar. The northern region has a very flat topography and is subject to serious flooding almost every year. A number of major tributaries like the rivers Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc which originate from the Himalayas, join the river Ganga in this region.

1.3 The major rivers like the Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc flow through a considerable length in Nepal and a large part of their catchment falls in the glacial regions of the great Himalayas. These rivers are snowfed and hence perennial. The river Mahananda, is one of the important tributaries of the river Ganga and has a total catchment area of 23,700 Sq Km.

1.4 Floods and droughts are regular features in the state of Bihar due to the vagaries of climate and rainfall. While one part of the state is under the grip of severe floods due to excessive rainfall, the other part suffers from drought caused by poor rainfall.

1.5 Floods have caused devastation and intense human suffering too frequently since the dawn of civilization and the man has had to live with floods since his existence. The impact of floods was not perhaps felt to the same extent in the past as is felt now.

This was due to the fact that in the past much smaller number of people were living as also the pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem has been accentuated by the ever increasing encroachments on the flood plains by the growing population to meet its requirements of food and fibre. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements have also caused changes in the river regime. All these have resulted in an anomalous situation where in spite of the protection measures carried out so far in the state with an investment of Rs 611 crore (approx) and 28.34 lakh ha having been afforded reasonable degree of protection, the flood damages have gone on increasing in stead of decreasing.

2 THE MAHANANDA BASIN

2.1 The river Mahananda is a major northern tributary of the river Ganga passing through Nepal, India (Bihar and West Bengal) and Bangladesh. The Mahananda originates from Mahalidram hills of the Himalayas at Chimali at an altitude of 2060 m at north latitude 26°53' and east longitude 88°19' and about 6.4 km north east of Kurseong town in the Darjeeling district of West Bengal. It is also known as Mahanadi river in its hilly catchment. After flowing 20 kms in the hills at Darjeeling the river enters the plains near Siliguri and crosses the National Highway No 31 and the metre gauge railway line of North-East Frontier Railway near Siliguri. River Balason joins this river below Siliguri on its right bank.

It then flows in a south westerly direction forming more or less the boundary between India and Bangladesh between Phansidewa and Titlya. The old Balason river joins Mahananda on its right bank upstream of Sonapur hat. Another tributary the Chenga joins Mahananda on its right bank about 3.2 km upstream at Taiabpur Railway bridge.

Flowing further in south westerly direction this river is joined by Mechi river on its right bank near Rupadhar. Another stream known as the Donk meets the river Mahananda on its left bank near Belwa village.

The Eastern Kankai, a major tributary joins Mahananda on the right bank at about 1 km downstream of its crossing with Kishanganj-Bahadurganj PWD road.

The Western Kankai, another major tributary carrying discharge higher than Mahananda, joins the Mahananda river on its right bank about 3.2 km upstream of Dhengraghat road bridge on National Highway No 31.

The river bifurcates into two branches near Bagdob in Bihar. The western course known as phulhar (Jhaua) carries about 75 per cent of the total discharge of Mahananda river and is joined downstream of Bagdob on the right side by Parman, a major tributary. The eastern branch known as Barsoi branch carries the remaining 25 per cent discharge of the Mahananda.

The river Barsoi after bifurcating from the Mahananda travels in south easterly direction through Sudhani, Barsoi, Kachna and is joined by the river Nagar at Jugiamer and travels up to Subarnapur. The Barsoi branch also bifurcates into two channels, down stream of Barsoi, one is the active eastern channel and the other is the dying western channel. Both these channels again meet on the upstream of Subarnapur. The Phulhar branch ultimately flows into the Ganga at Surmara. The Kalindri takes off from the Phulhar at short distance upstream from its outfall into the Ganga. The Kalindri which has a rather tortuous course ultimately falls into the Barsoi branch near Nimasarai R.S. The Barsoi branch is joined by Mara Mahananda at Pirganj and then it is augmented by a major tributary, the Tangon at Aiho, there after, the Mahananda flows into Bangladesh and joins Ganga (Padma) at Godagarighat. River Pagla joins Mahananda on its right bank near Nawabganj. Seasonal tributaries like Kullick, Gamari, Chiramati meet Mahananda on its left bank. The total length of Mahananda from its origin to outfall point in the river padma near Godagrighat is 376 kms.

2.2 TRIBUTARIES OF THE MAHANANDA

Details of different rivers of the Mahananda drainage basin in India are given below :

Sl No	River	Bank Left (L) Right (R)	Out fall river
1	New Balason	R	Mahananda
2	Old Balason	R	do
3	Mechi	R	do
4	E. Kankai	R	do
5	W. Kankai	R	do
6	Nagar	L	Out fall into Mahananda (Barsoi Branch)
7	Kulik	L	Out fall into Nagar
8	Gamari	L	Out fall into Mahananda (Barsoi Branch)
9	Tangon	L	do
10	Parman	R	Outfall into Mahananda (near Bagdob)

2.2.1 The Balason River

The river Balason originates from Lapcha Jagat at Latitude 26°16' and Longitude 88°16' of Ghumsimra ridge a few Kilometres south west of Darjeeling. It flows in southern course till it enters the terrai, where soon after, it splits into two streams. Dne is called the New Balason and the other old Balason. The new Balason Joins the Mahananda on its right bank about 4 km down stream of Siliguri. The old Balason continues to flow south-wards till it crosses the terrai, joining the Mahananda at its right bank near Damadangi upstream of Sonapur hat.

2.2.2 The Mechi River

The river Mechi is one of the major tributaries of Mahananda. It rises at Lat 26°54' and Long 88°7' under the Rangbhanaspur in the Singalela ridge at an elevation of 3066 m. The river runs almost south before it is joined by its major tributary Siddikhola on its right bank. The river forms the border of West Bengal and Nepal for a total length of 52.8 km after which it enters the state of Bihar and is joined by another tributary known as the Burhi Kankai Khola down stream of Dubba.

After flowing for another 56 km it joins the river Mahananda near Rupdharghat on the right bank. The total length of the river is about 108.8 km.

2.2.3 The Eastern Kankai River

The river Eastern Kankai known as the river Biring in Nepal is one of the major tributaries of the Mahananda. It originates from the outer Himalayas in the district of Itam in Nepalese territory. The river enters the Indian territory near village Doria in the district of Kishanganj and flows north to south and crosses through the road bridge in Araria-Thakurganj road near Dubha. The river then crosses the Kishanganj Bahadurganj PWD road through a small wooden pile bridge near village Dhanpura. The river ultimately falls into the river Mahananda, 1 km down stream of PWD road bridge. The total length of the river is about 108.8 km out of which 59.2 km falls in Nepal and the rest 49.6 km in India.

2.2.4 The Western Kankai River

The river Western Kankai is another major tributary of the Mahananda. It originates from the foot hills of Mahabharat Lake in the territory of Nepal at an elevation of 3630 m and is known as Kankai Mai in Nepal. It emerges from the foot hills at a distance of about 4 km upstream of East West highway (Mahendra Rajpath) in Nepal and crosses the highway at 61 kms east of Itahari. After crossing the East West highway, the river bifurcates into two channels at about 3.2 km down steam of the highway crossing. The western course of the river is known as the Sikandra branch and enters the Indian territory at about 6.4 km upstream of village Singhimari. The eastern branch known as the Haribitha channel enters the Indian territory at about 2 km upstream of village Haribitha. The two channels again merge into one channel near village Birpur Chainpur. It ultimately falls into the river Mahananda about 3 km up stream of Dhengraghat road bridge on National Highways 31. The total length of the river from its origin to outfall is 211.2 km out of which 112 kms falls in Nepal and the rest 99.2 km falls in India.

2.2.5 The Parman River

The river Parman is also one of the major tributaries of the river Mahananda. The river originates from Dankutta series of hills in the Nepalese territory at an altitude of 1982 m at latitude 26°48' and Longitude 87°22'. In the hilly region it has a number of branches. The prominent branches are Burhi and Kesal. Burhi and Kesal join each other in the Indian territory above Bathnaha. After the confluence, the river is known as Parman river. The river crosses the Jogbani-Purnia state high-way near Bathnaha and again crosses the Basantpur-Bahadurganj lateral road near Araria.

At about 52.8 km below the lateral road, it is joined by the river Bakra. The river bifurcates into two channels down stream of chainpur. The left channel is known as the Parman which finally meets river Mahananda down stream of Bagdob. The right branch of the river Parman is popularly known as Panar or Riga. It meets the Jhaua branch of Mahananda upstream of Jhaua railway bridge. The river Rajai, Noona are the main tributaries of the river Parman.

2.2.6 The Kalindri River

The Kalindri river derives its flow from jhaua or Phulhar course of the Mahananda which itself assumes the name of Kalindri from Bishnupur, shortly before its entry into Malda district in West Bengal. The Kalindri is connected with the Ganga by a navigable channel taking off a few km above Rajmahal. The flood water of the Ganga flows into this channel. Practically all the Mahananda water flows down into the Ganga in the dry season and the Kalindri becomes almost a dead channel. When the main channel of the Ganga flows towards the Rajmahal bank, the channel to the east of Bhuttni diara becomes shallow and large sandy shoals form on that side of the river consequently when the level of the Ganga drops at the end of the rainy season direct access of the Ganga water into the Kalindri is prevented by sand bars at its mouth.

2.2.7 The Pagla and Bhagirathi Rivers

Both the Pagla and Bhagirathi are spill channels of the Ganga. The Bhagirathi takes off from the Ganga at about 3.2 km below Rajmahal. It is augmented by the flow of the Pagla near Mahidipur. The combined flow falls into the Mahananda near Nawabganj in Bangladesh. Both streams become insignificant during the dry season and are rendered non-navigable. In the rainy season these streams receive back waters of the river Ganga.

2.2.8 The Nagar River

The Nagar river rises from the North of Madhupur and flows in a southern direction. It forms the boundary between India and Bangladesh up to about Haripur. It meets the Barsoi branch of the Mahananda on its left bank at Jugiamer.

2.2.9 The Tangon River

The Tangon river rises in Bangladesh. It falls into the Mahananda on its left bank at Aiho. During the rainy season the river overflows its bank. The spilling of the Tangon river further aggravates due to back water effect of the Mahananda and floods the low areas lying along its bank.

2.2.10 The Punarbhaba River

The Punarbhaba is said to be a branch of the Tista river in past. At present after originating in Bangladesh it enters west Dinajpur district at Mallikpur, 32 km lower down the river bifurcates into two, creating another branch on the south west. This branch known as Brahmani, flows for a distance of 28.8 km before joining the parent channel in Malda district. A few kilometres below Gangarampur the two channels are connected by another channel. The river runs through a stretch of low lying land called Duba. Afterwards it enters Bangladesh and joins Mahananda on its left bank at Makdumpur hat. Due to back flow of the Ganga in Mahananda and high stage in the river itself, the Punarbhaba overflows its bank and causes flooding in low lying areas on its bank. The problem is aggravated due to high precipitation in the upper areas near by.

2.3 The river Mahananda drains a total catchment area of 23,700 Sq Km out of which 6,150 Sq Km lies in Bihar, 5,560 Sq Km in Nepal and the rest in Bangladesh and West Bengal. The drainage basin consists of a hilly area of 4803 Sq Km with thick forest in upper reach, out of which about 523 Sq Km only falls in India.

Three-fourth of the upper part of the catchment area is more or less rectangular in shape up to Minahat below Lava and the remaining one fourth part is more or less triangular converging at its confluence with Ganga. The northern part of the river system is hilly and the southern part is all plain lands. The salient features of the Mahananda river basin is enclosed as Annex 1.

2.4 The Mahananda river basin is bounded by the Himalayas in the north, the ridges separating it from Tista river system in the east, the Ganga on the south and the Kosi river system in the west. The river bed slope in the terai region in the hills of Darjeeling is very steep and is flat in the plains of Bihar and West Bengal. The average bed slope of the river Mahananda and its tributaries in different reaches is enclosed at Annex 2.

2.5 The important places of Bihar falling in the drainage area of the river Mahananda are Kishanganj,Araria,Purnia and Katihar. The important commercial centres are Purnia,Katihar and Forbesganj.

2.6 ECONOMICS

2.6.1 Population

The area of the Mahananda river system in Bihar is 6,150 Sq Km falling in four districts of Araria, Kishanganj, Purnia and Katihar. According to the 1991 census the population is 36.25 lakh in the Mahananda river system in Bihar. The density of population in the river system (according to 1991 census) is 590 persons per Sq Km as compared to 497 for Bihar and 267 for whole of the country. The population is likely to cross 45 lakhs in 2001 AD.

2.6.2 Minerals

Since almost the entire catchment except the upper portion of Darjeeling district, is made up of alluvial soil, no significant mineral is found in the basin. Only in the upper region of Darjeeling district copper and iron ores and limestones are found which have not been exploited so far.

2.6.3 The Important Industries in the River System are Described Below

1	Large scale industies	: Jute mills and Match factories
2	Medium and small-scale industries	: Rice mills, oil mills, rerolling mills, steel fabrication mills, Hume pipe mills, straw board and flour mills ..

In addition, there are a number of smaller units manufacturing, soaps, fountainpen, ink, candles etc, but dispite this agriculture is the mainstay of living in the Mahananda river system.

2.6.4 Communication and Transport

The Mahananda river system is served by the network of North Eastern and North East Frontier Railways. The Barauni-Katihar-Malda section of the railway passes through the lower reach of the catchment. The Barsoi-Siliguri section of the railway together with a meter gauge line side by side is the main railway communication towards north east region of the Indian territory. The National Highway No 31 runs across the catchment and NH 34 runs along the lower part of the catchment. Generally, the lower and the north eastern-most part of the river system has better communication facilities. The existing rail and road communications in the basin are indicated below:

Sl No	Communication		Discriptions	Remarks
1	Roads	i	Araria-Bahadurganj Thakurganj road	A part of Lateral Road Project (LRP)
		ii	Taibpur-Galgalia road	
		iii	Manihari-Katihar-Araria Jogbani road	
		iv	Purnia-Garbanaili Sontha-Kishanganj road	District road
		v	Purnia-Dhengraghat-Aluabari-Sonapurhat-Siliguri-Kalimpong road NH -31	
		vi	Kishanganj-Sonapurhat-Taibpur road NH -34	
		vii	Dhengraghat-Gazol-Malda road	
		viii	Raiganj-Kaliaganj-Gazol road	
2	Railways	i	Katihar-Labha-Nimasarai-Farakka section (Broad gauge)	
		ii	Nimsarai-Màlda-Nawabganj section (Broad gauge)	
		iii	Babupur-Barsoi-Siliguri section (Broad gauge)	
		iv	Barsoi-Kishanganj-Taibpur-Galgalia-Naksalbari-Siliguri section (Metre gauge)	
		v	Katihar-Jhaua-Barsoi section (Metre gauge)	
		vi	Barsoi-Raiganj-Radhikapur section (Metre gauge)	

2.6.5 Agriculture and Irrigation

Agriculture is the main occupation of the people in the basin. Kharif and Rabi are the main crops grown in the Bihar portion of the catchment. Several tea gardens exist in the upper reach. The existing cropping pattern is as under :

Name of crops	Percentage of different crops in upper region	Percentage of different crops in lower region
Kharif	71.7	75
Rabi	5.8	30
Hotweather	2.9	7
Jute	22.9	15

The basin is so well placed that practically the entire area of the river system lying in the plains can be provided with irrigation facility if projects to use available water resourses are planned and implemented. But there is no major independent irrigation scheme at present in this river system in Bihar, except some irrigation under the command area of Kosi project in the western part of the Mahananda river system. The distribution system of eastern Kosi canal provides irrigation to an area of about 89,000 ha in the districts of Katihar and Purnia.

There is ample scope for the construction of diversion structrues at suitable location in the basin with a network of canal systems for providing irrigation facility in the area enclosed between Parman and Western Kãnkai, Western Kankai and eastern Kankai and Mechi.

The area between Mahananda and Katihar-Siliguri railway line having a command area of about 36000 ha can be irrigated through a barrage on the river Manananda on the upstream of the Taibpur railway bridge with a network of distribution system. Further downstream on Mahananda there is a scope for construction of barrage at about 3 km, upstream of Bagdob. This is expected to provide irrigation facility to the area up to Bihar-West Bengal border which has been protected from floods. This scheme is likely to benefit a culturable area of more than one lakh ha.

2.6.6 Utilisable ground water potential is available in plenty in the entire basin and specially in the plains. But the present utilisation level is very low which leaves a very good scope for further utilisation in the future. The utilisable ground water potential of this basin in Bihar is 755.07 MCM in Katihar district and 2830.64 MCM in Purnia district,against this only 130.44 MCM in Katihar and 285.82 MCM in Purnia are being utilised presently in shape of domestic, irrigation and industrial uses.

2.6.7 Land Use Pattern

Of the total area of 7,606 Sq Km of the Mahananda river system in India, 523 Sq Km is hilly lying in the Darjeeling district of West Bengal. The rest of the river system is a part of Gangetic plain except in area like the Tal area. The river system is fairly intensively cultivated. Bumper crop of rice and jute are obtained when weather is favourable.

Very little area and that too only in the hilly region is covered by forest. The land use pattern of the Mahananda river system in Bihar is reported to be as follows :

Sl No	Category			Area in ha	Percentage
1	Forest Land			1,978	0.32
2	Land under miscellaneous trees and grooves			17,347	2.82
3	a	Current fallow	59,821 ha		
	b	Other fallow	15,968 ha	79,371	12.90
	c	Culturable waste	3,582 ha		
4	Net area under cultivation			3,65,766	59.47
5	Barren land and permanent pastures			49,574	8.06
6	Area under non-agricultural use			1,00,970	16.43
			Total	6,15,006	100.00

[Source : Directorate of Statistics and Evaluation, Government of Bihar].

3 GEOLOGY

3.1 The geological formations of the Mahananda river system in the hilly area of Darjeeling district consist of unaltered sedimentary rocks confined to the hills on the north consisting of different grades of metamorphic rocks over the rest of the area. The outcrops of the various rocks form a series of bonds more or less to the general line of the Himalayas, dipping one below the other into the hills.

The characteristic feature of the southern area is that the older formations rest on the younger formations showing complete reversal of the original order of superposition.

The great range was elevated during the tertiary period above the site of an ancient sea that had accumulated sediments of different geological ages. The mountains are made of folded rocks piled one over another by a series of north-south horizontal compression movements and tangential thrusts which also folded the strata on the sea floor and caused their up-heaval by stages. At many places, the formations have been intruded by granites. Frequently, the strains within the range are invested due to the overturning of the folds and their dislocation. Such upheavals bringing the older beds above the younger constitute a feature which characterises the whole length of the outer Himalayas.

The present relief of high peaks and deep valleys has been carved by three principal agents of denudation namely, Wind, Water and snow. The resulting products of disintegration of mountains are swept over the sub-mountainous tract as the rivers enter into the plains. The terai and the plains at the foot of the Himalayas have assumed their present form after the final up-heavals of the range and consist of almost the horizontal layers of unconsolidated sand, silt, pebbles and gravel, Igneous, Metamorphic rocks are the varieties available all along the range, which are commonly known as Darjeeling gneiss and are composed of mica, schists and gneiss. The sedimentary variety of Darjeeling gneiss contains minerals, such as garnet, sillimanite kyanite etc, the presence of which indicates that the rocks were subjected to higher temperature and pressure.

3.2 SOIL

In the river system falling in Darjeeling district, the terai is composed of alluvium, light sandy loam being the most common. There are also considerable tracts of sandy or gravelly soils unsuitable for cultivation. In the hills, cultivators recognise only three kinds of soil i.e. white, red & black. The black soil is the richest, the white is the poorest. The red soil occupies an intermediate position requiring heavy manuring for as good an outturn as the black. The black soil is often found among large rocks and is suitable for dry crops such as 'Maize and Marua' owing to the rich vegetable mound it contains.

The part of the river system lying in Jalpaiguri district in West Bengal is covered with alluvium ranging from pure sand to clay, the soil in most part being sandy loam.

The soil in Purnia district is all alluvial and mostly loamy. A different soil encounter mostly in south east is a clay soil known as "Karari".

The soil of the north eastern portion of the river system in West Dinajpur district of West Bengal is a light coloured sandy loam known as the 'Paly' changing gradually as one goes south, to a stiff clay of similar colour known as 'Khiyar'. The paly is very retentive of moisture and is capable of producing two crops. The Khiyar oridinarily bears only a single crop. The southern portion of the river system in Malda district in West Bengal receives the silt of the Ganga and is the most fertile part and next in order comes the northern portion, both these areas being largely double cropped. The least fertile portions are the higher portions of the basin which have only been recently cleared of jungle, the poor soil of the duba in Bamangela and Habibpur thanas and tal common soils of the later alluvium are clay with small mixture of sand called matiyal or matal, dorash or doaslea, a mixture of matiyal and sand. The mixture of Ganga mud and fine sand known as Masina, Chama, sandy soil with a somewhat hard crust, is only suitable for occassional cropping. Basta and rangamati are the names of the clay soils of the basin which are blackish and red respectively.

4 HYDROLOGY

4.1 During the monsoons, a low pressure area is normally observed in the weather map extending from west to east in the upper half of the country.

Abnormally heavy rainfall spells are generally associated with depressions or cyclonic storms moving across the various parts of India during the south-west monsoon period. In the Mahananda river system the rainfall, though varying from region to region is dominated by south west monsoon from June to September. Rainfall is more irregular in September than in other monsoon months.

Comparatively a dry weather may alternate with a very heavy dose of rainfall which at times gives rise to floods.

4.2 According to the norms laid down by the Bureau of Indian standards (IS-4987) one raingauge for a drainage area up to 520 Sq Km is sufficient for plains. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser particularly in the upstream. In the not-too-elevated region with average elevation one kilometer above sea level, the required network density is one raingauge station for every 260 to 390 Sq Km area. The Indian Meteorological Department have, however, prescribed atleast one raingauge station for every 500 Sq Km of the drainage area. It also specifies that at least 10 % of such raingauge stations should be self recording. This has to be increased to 20 per cent as recommended by the Rashtriya Barh Ayog (RBA).

4.3 According to the norms laid down by the World Meteorological Organisation (WMO), the following densities are required.

Sl No	Type of terrain	Density Ideal	required (one station for) Acceptable
1	Flat regions of temperate mediterranean and tropical zones	600-900 Sq Km	900-3000 Sq Km
2	Mountainous regions of temperate mediterranean and tropical zones	100-250 Sq Km	250-1000 Sq Km
3	Arid and Polar zones	1500- 10000 Sq Km	Depending on the feasibility

10 per cent of the raingauge stations is required to be self recording in order that the intensities of rainfall in the area could be known.

4.4 In the Mahananda river system there are 30 (19 in West Bengal and 11 in Bihar) ordinary raingauge stations in India and 9 in Nepal as observed from the IMD toposheets. In addition to these there are five self recording raingauge stations at Taiyabpur, Dhengraghat, Jhaua, Chargharia and Galgalia established by the IMD in Bihar and one ordinary rain gauge station at Barsoi in Purnia maintained by Govt of Bihar and two self recording rain gauge stations at Siliguri and English Bazar in West Bengal. Out of these 36 raingauge stations in India, 7 stations are located in the hilly areas of Darjeeling district of West Bengal and rest all 29 are in the plains of West Bengal and Bihar.

4.5 Out of the total catchment area of 15,910 Sq Km of the Mahananda river system in India only 523 Sq Km is hilly in West Bengal and the remaining 15,387 Sq Km falls in the plains of West Bengal and Bihar.

It would, therefore, appear that the existing rain gauge stations in the hilly region are sufficient as per standard norms. In the plains the density of raingauge stations works out to be 236 Sq Km for one station. The Bureau of Indian Standards recommends 520 Sq Km for one station in the plains. Thus, the number of raingauge stations in India are almost more than twice as per Bureau of Indian Standards, both for ordinary as well as self recording stations. However, the number of self recording raingauge stations has to be increased to 20 per cent in Bihar portion of the basin the number of raingauge stations should be 12 as per norms against which 11 numbers are already existing and the self recording raingauge stations should be 3 as per RBA recommendations against which 5 numbers are already existing which is sufficient to suit the recommendations of the RBA.

4.6 RAINFALL

4.6.1 Average annual rainfall observed at different raingauge stations is shown in Annex 3.

4.6.2 The average annual rainfall in the Mahananda river system in India is about 1563 mm. About 80 per cent of this rainfall occurs during the monsoon months (June-September). The usual direction of moisture laden current is generally north ward. The annual rainfall in the upper catchment of the river system ranges from 1000 mm to 6000 mm. The normal annual rainfall recorded at Kurseong close to the origin of the Mahananda river is 4052.3 mm and at Malda is 1453.1 mm.

The district average rainfall in the Mahananda river system is as follows:

Sl No	State		District	Average annual rain fall mm	Average monsoon rainfall mm
1	Bihar	i	Purnia	1585	1293
2	West Bengal	i	Malda	1540	1210
		ii	Darjeeling	3092	2478
		iii	West Dinajpur	1635	1283

The maximum value of 24 hours rainfall of 50 years frequency is 320 mm and it occurs near the Indo-Nepal border. This value remains in the range of 280 mm to 200 mm also in the other portion of the river basin.

4.7 GAUGE AND DISCHARGE

4.7.1 There are 17 gauge sites, 33 gauge and discharge sites and 11 gauge-discharge and silt sites, maintained by the Central Water Commission, and the State Governments of Bihar and West Bengal, in the Mahananda river system. The breakup of the sites maintained by the different organisations is as follows:

1	CWC	13
2	Govt of Bihar	41
3	Govt of West Bengal	7
	Total	61

4.7.2 According to the norms prescribed by the WMO, one gauge- discharge site is required for every 300 Sq Km of the drainage area in the hilly portion and for every 1000 Sq Km in the plains. Accordingly, the existing hydrometeorological stations in the Mahananda river system can be considered adequate. On observation of data of 44 sites of the Mahananda river system till 1986 it was found that the gauge and discharge data of most of the sites were of short duration and were also inconsistent at places. Therefore, analysis of the data of nine sites as given below were made, out of which four sites were maintained by the CWC and the remaining five by the Govt of Bihar.

Name of Sites

1 Mauzabari (Mahananda)

2 Dhengraghat (Mahananda)

3 Bagdob (Mahananda-Jhawa Branch)

4 Barsoi (Manananda-Barsoi Branch)

5 Lava (Mahananda-Jhawa Branch)

6 English Bazar (Mahananda-Barsoi Branch)

7 Taibpur (Mahananda)

8 Gosainpur (Western Kankai)

9 Jogbani (Parman)

But the data from the following four CWC sites could only be available for analysis.

1 English Bazar,

2 Dhengraghat,

3 Lava,

4 Taibpur.

It is thus apparent that although there are a number of hydrological observation sites in the catchment, availability of data from these sites for hydrological studies is far from desirable. One of the reasons for such a situation may be that the data collection is not systematic and regular in most cases. The data collected are not being properly recorded and maintained at the desired offices. Therefore, it is considered extremely necessary to ensure systematic and regular collection of data from a well-designed network of stations besides its scrutiny, analysis and proper recording.

Annual peak gauges and discharges of different sites for the Mahananda river are given at Annex 4 & 5.

4.7.3 The maximum and minimum discharges observed by the CWC of eight existing sites on the river Mahananda between 1956 to 1990 are as follows:

Sl No	Location	Discharge in cumecs			
		Maximum	Year	Minimum	Year
1	Taibpur	2053.45	1988	602	1971
2	Mauzabari	3190	1981	755	1980
3	Dhengraghat	2810	1978	920	1986
4	Bagdob	6427	1981	287	1973
5	Jhawa Rly Bridge	6426	1981	936	1971
6	Barsoighat	8912	1981	127	1970
7	Lava	7802.94	1989	1480	1971
8	English Bazar	4779	1971	905	1982

4.8 RUNOFF FACTOR

4.8.1 Finding out the runoff factor of catchment is essential to know the runoff likely to result from short duration heavy rains. In order to find out the total runoff during the monsoon period for planning schemes for drainage of accumulated water, it is necessary to determine the runoff factor applicable for the monsoon period as a whole. In order to conduct such a study and analysis, rainfall data for the stations spread over the entire drainage area of the basin and runoff data of suitable locations on the river for a sufficiently longer period (at least 20 years or more) are considered a necessary input.

4.8.2 The Ganga Flood Control Commission (GFCC) was able to get hold of the rainfall data at 16 raingauge stations situated in India. No data had been made available for raingauge staions in the Nepalese territory of the Mahananda river basin. It is for this reason that rainfall-runoff relationship could not precisely be established. It is, therefore, suggested that the Water Resources Department of the State Government should make all out efforts to collect the rainfall and runoff data in the basin for as many years as available and carry out further studies to establish precise rainfall-runoff relationships at suitable locations on the river Mahananda for future use.

4.9 SEDIMENT CHARACTERISTICS

4.9.1 The past history of the river Mahananda indicates that the river is of a meandering nature. The Mahananda being a Himalayan river is not stable and erosion in the steep hilly catchment, transportation of sediment in the river and its subsequent progressive deposition lower down in the river having flatter slopes is a continuous process. The river emerging from mountains into the plains carries heavy silt load and a part of it is finally transported to the Ganga after the deposition of silt either in the bed or in the flood plains through over bank spills. The bed slopes of the Mahananda river and its tributaries are steeper in its upper reaches even in the plains, as compared to the lower reaches. The river has, therefore, more carrying capacity for the silt load in the upper reaches in the plains as compared to the lower reaches.

The river bed, just after it debouches into the plains, consists of shingles and sand where as further down in the flatter plains it mainly contains of coarse and medium silt.

4.9.2 The silt observation stations on the Mahananda are located at Siliguri, Sonapurhat and English Bazar in West Bengal and Taibpur, Dhengraghat and Jhawa Railway bridge in Bihar. The sites at Siliguri, Sonapurhat and English Bazar are maintained by the CWC and the sites Taibpur, Dhengraghat and Jhawa railway bridge are maintained by the Water Resources Department of the Government of Bihar. The sediment data are available for the following sites for the period noted against each and the sediment load analysis of the above data brings out the following facts:

Site	Period	Composition in % of total load		
		Coarse	Medium	Fine
Taibpur	1962 to 1970	29.72	47.27	23.01
English Bazar	1963 to 1970	1.15	6.37	92.48

[These data are enclosed at Annex 6 and Annex 7]

5 FLOOD FREQUENCY ANALYSIS

5.1 Frequency analysis is carried out to interpret the past records of the hydrologic events like the precipitation, runoff, flood levels etc to predict the probabilities of such occurences in the future. For a quantitative assessment of the maqnitude of flood problem, it is essential to evaluate or estimate the frequencies of rainfall, floods, etc. Such studies are necessary inputs for proper design and location of hydraulic structures as well as other related studies.

5.2 CRITERIA OF DESIGN FLOOD

5.2.1 The Minister's Committee on Floods and Flood Relief constituted by the Government of India in 1970 had recommended that "As most of the embankments have been constructed on the inadequate and meagre hydrological data which were available, it is necessary that the existing embankments are reviewed to see that these are safe for a flood of 50 years frequency for major rivers and at least 25 years' frequency for small tributaries. Similarly all the future proposals of embankments should also be based on the above criteria".

5.2.2 The Rashtriya Barh Ayog gave the following broad criteria to be adopted in the country:

i For predominantly agricultural areas, 25 years' flood frequency (in special cases, where the damage potential justifies a higher design flood, maximum observed flood may be adopted for the embankment.

ii For town protection work important industrial complexes assets and lines of communications, 100 years flood frequency (for larger cities, the maximum observed flood or even the maximum probable flood) should be considered for adoption.

iii Meanwhile, studies should be undertaken to review the basis of these flood frequencies and attempts made to collect the data and appoint the necessary personnel, so as to enable the application of the benefit-cost criterion in due course.

5.2.3 The relevent recommendations made by the Ministry of Irrigation , Government of India in the guide lines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankments, the design of a project should be determined for the time being on flood frequencies suggested. Mean while necessary steps may be taken for the eventual application of benefit cost criterion for fixing the design".

The summary of recommendations as accepted is as follows.

"In the case of embankment schemes the height of the embankment and the corresponding cost to be worked out for various flood frequencies and also the benefit cost ratio taking into account the damage likely to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 years frequency in the case of pre- dominantly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of important industrial and other vital organisations".

While endorsing the decisions of the Ministry of Irrigation,Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of vital industrial establishments.

5.3 ANALYSIS OF AVAILABLE DATA

5.3.1 For flood frequency analysis two types of data are generally selected :

(i) The partial duration series and (ii) the extreme values series.

The partial duration series is obtained from daily stage or flow values, by selecting values greater than a certain base value. The extreme value of annual series is obtained by selecting maximum value of the daily flow values of every year. The partial duration series contains a greater number of values than does the annual series and as such, it can improve the reliability of the analysis of events for longer return periods when the available data is limited. However, the main difficulty with the partial duration series is regarding the debatable independence of events. This is more likely to be achieved in an arid area rather than in a humid area like the Mahananda basin. It is for this reason that the maximum annual gauge and discharge data, ie extreme value series have been used for the frequency analysis in the present study.

The actual and theoretical treatments of extreme value distribution show that they are inherently skewed rather than symmetrical. The comparision of the results by the two methods can be made. It may be noted that the skewness in the gumbel distribution is fixed at 1.14 while in the Log-Pearson type III, this is also a parameter besides mean and variance common to both the distributions.

For this reason, the Log Pearson Type III distributions is generally adopted. Gumbel distribution is generally used for the sites having reliable data for at least more than ten years in order to get fairly accurate and reliable prediction.

5.3.2 The frequency analysis of the observed peak discharges have been carried out by the Log-Pearson Type III to estimate discharges for 25, 50 and 100 years return periods at selected sites in the river Mahananda are indicated below:-

Sl No	River	Site	Flood discharge of return period of			Highest observed discharge
			25 years	50 years (in Cumecs)	100 years	
1	Mahananda	Mauzabari	3670	4150	4610	3190
2	Mahananda	Dhengraghat	2665	3045	3115	2810
3	Mahananda Jhaua Br	Bagdob	6140	6510	6850	6427
4	Mahananda Barsoi Br	Barsoi	4020	6360	9880	6912
5	Mahananda Jhaua Br	Lava	6160	7540	9180	7800
6	Mahananda Barsoi Br	English Bazar	3490	4015	4575	4780
7	W Kankai	Gosaipur	860	860	860	1490
8	Parman	Jogbani	1505	1920	2410	1678
9	Mahananda	Taibpur	1990	2165	2205	2055
10	Mahananda Jhaua Br	Jhaua Rly bridge	6280	7130	7960	6425

5.3.3 There is no alternative to the use of one of the emperical formulae for calculating the discharge to be adopted for designing any flood control measure for rivers for which data availability is not of enough duration to carry the frequency analysis. The Technical Expert Committee on Drainage and Water way (1967) had in its report relating to the Mahananda river basin, recommended the following values of 'C' in Dicken's formula for calculating design flood:

Sl No	Description of Zone	Zone No	Land slope from the source	Recommended value of Dicken's 'C'
1	Area above 61.0m contour	I	9%	850
2	Area between 61.0m to 45.7m contour	II	7%	700
3	Area between 45.7m to 38.1m contour	III	6%	600
4	Area between 38.1m to 30.5m contour	IV	5%	500
5	Area below 30.5m contour	V	Below 5%	400

5.4 UTILITY OF FLODD FREQUENCY STUDIES

5.4.1 The result of flood frequency studies are useful in delineating the flood-prone area on the contour map in order to be aware of the situation in the unprotected area at defferent stages of the river during floods. To make this study useful, it is essential to have the contour map (with contour at suitable interval) of the area prone to floods preferably in a scale of 1:15000. These studies will be further useful in formulation and planning of the flood control projects in the basin in the future.

6.0 FLDOD AND DRAINAGE PROBLEM

6.1 FLODD PRDBLEM

6.1.1 The records available in the district Gazetteers of Purnia, Katihar and Kishanganj as well as in the Irrigation and Revenue Departments of the State Government indicate that flood data are available for the Mahananda river basin since the year 1886. The river Mahananda and its tributaries pass through the two States, ie, Bihar and West Bengal. The Mahananda river flows through Bihar in the reach from Bihar-West Bengal border near Titalya to its outfall into the Ganga, through its Phulhar branch. The tributaries of Mahananda namely Parman, Western-Kankai, Eastern-Kankai and Mechi join the right bank of the Mahananda river and their catchments except the hilly catchments in Nepal, fall in the Eastern most part of the Bihar State. During the monsoon season heavy precipitation occurs in the Himalayan catchment of the tributaries and brings floods down these rivers in Bihar with very high velocities. Due to steep nature of the hills the rain waters cause landslips and landslides in the unstable Himalayan formation. As a result, the flood waters bring huge quantities of detritus consisting of shingles and sand and deposit in the upper reaches of these tributaries in Bihar. The sediment is carried down these tributaries further depending on the carrying capacity of their channels. The river has flatter slopes in the plains. Deposition of the sediment load along the bed and banks of the rivers in the plains has reduced their bankful capacities.

In the main Mahananda also the flood waters come down from its hilly catchment in Darjeeling district and in Nepal. The important tributary Mechi which forms the Indo-Nepal border joins the Mahananda in Bihar about 19 km upstream of Kishanganj. In this river also the flood waters bring detritus from the hilly catchments and the sediment load of specific grade passes down stream and a part of rediment gets deposited on the bed and banks and also on the flood plains.

6.1.2 The bankful capacity of the Mahananda is also not sufficient to carry the heavier floods. As a result the flood water spills over the banks in its middle reaches from Bihar West Bengal border upto Bagdob. The Mahananda river breaks up into two main channels, called the Phulhar branch and the Barsoi branch below Bagdob. At present, the Phulhar branch carries about 75% of the total discharge brought by the Mahananda. The Mahananda outfalls into the Ganga through these two branches with their flatter slopes. The plains between Bagdob and the Ganga experiece heavier floods as compared to the upstream courses. Their bankful capacities are also quite inadequate to carry the flood water.

Consequently, the flood water spills heavily over the banks causing submergence of low lying areas. The magnitude of the floods in this reach is also considerable due to heavy collection of the materials brought down from the hills slopes of its upstream catchment spread over a considerable area.

6.1.3 The river Mahananda brings enormous amount of silt from the Himalayas. The major part of silt load is deposited in the bed as the river travels in plains. This causes the river to spill its banks and shift its course. Due to excessive deposition of silt the capacity of the river channel has been gradually reduced and lots of shoals and islands have been formed in the bed of the river. During the process of meandering in the alluvial plains, the river course goes on shifting with the change of meandering pattern with consequent bank erosion at different places. The Mahananda river had been subjected to vast changes in its courses from the past to the present. The erosive tendency of the river is also not confined to some fixed point but keeps on shifting from year to year.

6.1.4 With the construction of flood embankments in Bihar and West Bengal along both banks of the Phulhar branch & the right bank of the Barsoi branch the areas on the countryside of the embankment have been protected from flood spilling. But the areas falling on the left bank of the Barsoi branch in Bihar and West Bengal are still facing extensive flooding.

6.1.5 The history of past floods as available from the records of the district Gazetteers of Purnia, Katihar and Kishanganj as well as Irrigation and Revenue Department of the State Government has been summarised in the statement at Annex - 8.

6.1.6 The flood problem in the Mahananda river system may be broadly categorised as under:

a) Overbank spilling during floods resulting in the inundation of the low lying areas.

b) Risk of avulsion of the river and changes in its course leading to damage to developed areas.

c) Erosion of the river banks.

6.2 DRAINAGE PROBLEMS

6.2.1 Till the different river courses of the Mahananda and its tributaries were unembanked, there was little of drainage problem in this basin. But after the construction of embankments along both banks of the Mahananda and the right bank of the Barsoi branch, drainage congestion is being experienced in certain pockets. The lower portion of Mahananda river system is experiencing serrious water logging in the Amdabad block of Katihar district in Bihar. The whole area of this block is surrounded by Katakosh Naurasia and Topra-Chaukia embankment in the south Lava chaukia-Paharpur embankment in North East and Manihari to Walipur Nima road in the West. All these embankments have aggravated drainage congestion in low-lying chaurs namely, Chama, Kamalpur, Narbanna, Karuadhab, Naurasia, Jalyari, Charguha, Kalaktari, Digha and Naurasiab. The total water logged area of these chaurs measures 2880 ha (approx). A few sluices already existing in the embankment for draining out these areas are not functioning properly due to inadequate maintenance. Some of them are even reported to have blocked due to neglect.

6.3 FLOOD DAMAGES

6.3.1 The damages caused by floods and drainage congestion are classified broadly into the following two categories :

a) Direct damages and

b) Indirect damages.

6.3.2 The direct damages are those which are caused due to the direct physical contact with flood water. These include losses to

a) Growing and preharvest crops

b) Houses and household assets

c) Public utility works

d) Public buildings and

e) Human lives and livestock.

6.3.3 The indirect damages are not susceptible to quantification, therefore an approximate monetary evaluation can only be done for such damages. These generally include :

a) Loss of earning in agrobased industry and trade.

b) Loss of revenue to the road and rail transport system due to disruption of services.

c) Loss of earnings to small shopkeepers and other daily wage earners and

d) Loss of employment to the daily wage earners in the public and private sectors.

6.3.4 The flood damage data are collected by the Revenue (Relief and Rehabilitation) Department of the State Government and passed on to the various concerned organisations of the State and Central Government. The Central Water Commission (CWC) is collecting and compiling such damage data of all flood-prone States at the national level.

It is observed that the flood damage statstics, which is essentially required for the benefit-cost studies for any proposed flood management measures are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river basin wise be carried out every year under the following three separately identified categories :

(i) Unprotected areas.

(ii) Protected areas due to failure of protection works.

(iii) Areas between the embankments and the river.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data in order to eliminate any inconsistancy,the flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long-term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area.

The Central Flood Control Board had decided that the Flood Control Department of the States should compile basinwise flood damage data with effect from 1960. This is not being followed in Bihar and the flood damage data still continues to be collected districtwise (not basinwise) by the Revenue Relief and Rehabiliation Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of immediate requirements of relief operations that becomes necessary on account of current damage caused by floods. As such, the need for compiling the annual flood damage data according to the administrative jurisdiction in district and blockwise category in the State cannot be denied. On the other hand planning of the flood control measures are to be on basin and sub-basinwise. It is, therefore, necessary that such data are collected by the Revenue authorities with the active co-operation of the staff of the Water Resources, Agriculture and Roads and Building Construction Departments and the data are processed and compiled both districtwise and basin/sub-basinwise by the Statistical Organisations at the district and the State level for future use for planning of relief measures and flood management respectively.

The available flood damage data for the Mahananda river basin are enclosed at Annex 9.

6.3.6 From the perusal of the data processed by the Revenue Department it is noticed that damages to property of the Central Government, such as Railways, Post and Telegraphs, etc are not properly accounted for. On the other hand the cost of relief and rehabilitation measures grant of loan, remission of land revenue, etc is added to flood damage. This does not appear to be in proper order.

6.3.7 It would be evident from the available flood damage data of the basin (Annex 9) that average annual area affected by flood is 1.77 lakh ha. The average annual damages to the crops, houses and public utilities at the 1991 constant price level work out to be Rs 1650.98 and Rs 1012.00 lakh respectively, totalling to Rs 2662.89 lakh. The same values at 1987 constant price level are Rs 1329.64 lakh and Rs 885.25 lakh respectively with a total of Rs 2214.98 lakh. It is seen from the data for the period for which these are available that the maximum damages amounting to Rs 22126.57 lakh occurred during the year 1987 and the minimum damage of Rs 15.98 lakh occurred during the year 1990 at the 1991 price level.

7.0 PAST APPROACH AND ACHIEVEMENT

7.1 Efforts to mitigate damages from floods originate from the basic human urge for self-preservation. With the development of society and civilization, these efforts of a community, in a cumulative manner, initiated the first human interprises on flood protection work. Almost all the civilizations which flourished over the fertile river valleys in ancient times have left behind accounts and legends of progressive flood protection works. These ancient flood protection works were mostly embankments with some instances of channel improvements. Embankments, as a flood protection measure were the most obvious solution for preventing damages from river spills and entirely suited to the technology and resource of those days.

The suitability and effectiveness of embankments as measure of flood control has, however, been a matter of controversy since long. In India, opinions have differed from State to State and from time to time. Opinion in Bihar was against the embankments in the 1920s and 1930s of the present century.

In recent years the Government have been in favour of construction of embankments after adequate investigation and planning and embankments in large lengths have been constructed particularly after the devastating floods of 1954. Flood Protection measures on a limited scal were undertaken in this country from the early times by individuals. Government interest in the problem developed chiefly during the past century, when a number of well-planned embankments were constructed on some of the rivers which were causing damages from the recurrent flood. The severe and devastating floods of 1954 attracted the attention of the public and Parliament and brough into sharp focus the inadequacy of the measures taken against floods till that time. A programme of flood control was therefore, launched at the national level in the same year. It was considered essential to provide protection to all the people in the flood affected areas. In order to achieve this objective methods had to be chosen which while achieving the objectives could also be carried out expeditiously. Accordingly, it was decided to undertake a countrywise programme of flood contol under three phases namely (i) Immediate,(ii) Short-term and (iii) Long-term phase.

7.2 Various Committees were set-up by the State and Central Governments from time to time in the past to review and suggest appropriate flood protection measures to meet the requirements of flood problems. Their recommendations concerning the Mahananda river system are briefly described below.

7.2.1 The Government of West Bengal had appointed a Landslides Enquiry Committee in 1950, when severe landslides had occurred in the eastern Himalayas after abnormal rainfall of 865 mm in two days on 11th and 12th, June,1950. In the opinion of this Committee, the following factors were considered as the possible causes of such landslides:-

a The intense stresses are set-up by the folds and thrust movements leading to deformation of original physical characteristics as seen in joining shearing and imprecating structures.

b Erosion and chemical weathering which loosens up such strained rocks along the fracture and joint planes and gradually widen gaps between the walls.

c High rainfall and lack of proper drainage conditions, which reduce the frictional resistances to sliding of the loose and former rocks, thereby increasing the chamces of land slides.

d In a metamorphic country, there is often an alternation of hard compact strata, such as quartzite and marble with softer aggrilaceous rocks, such as slates and phyllites. When such strata have steep dip they offer a suitable condition for rock slides, the harder strata slides over the softer rocks lubricated by moisture.

7.2.2 High Level Committee on Floods (1957-58)

This Committee was appointed by the Government of West Bengal to study the problems of the rivers in North Bengal. This Committee had made the following observations relating to the Mahananda river basin in its report:

a Heavy silt-charge is observed due to denudation of forest and faulty land management in the upper reaches.

b Spilling is experienced in the central reaches.

c Bank erosion is noticed in the lower reaches.

The Committee had suggested that the following measures be taken:

a The State's (West Bengal) proposal to execute a few town protection schemes in addition to the anti-erosion protection works in the towns of Siliguri, Saktigarh, English Bazar and Phensideva already executed and also the proposal of flood detention dams in the hilly region may be taken up if found technically and economically feasible after investigation.

b Soil conservation measures and proper land management in the catchment.

c Implementation of emergent schemes like anti-erosion works on temporary basis wherever necessary since the flood detention dams and the soil conservation measures are long-term.

d Channel improvement in the middle reaches of the river Mahananda and its tributaries in West Bengal where there is considerable spilling over their banks. Embankment schemes wherever necessary may also be taken up.

e Waterways on the railway and road bridges on the river Mahanada and its tributaries need to be checked and increased wherever necessary.

7.2.3 The following suggestions/observations were made in the Eighth Meetting of Ganga-Brahmputra River Commission held at Dibrugarh in November, 1958:

a Reactivation of the dormant Barsoi branch of the Mahananda river was not a practical solution.

b Reconnaissance and investigation for flood detention dams in the Mahananda basin may be carried out.

7.2.3.1 After a joint reconnaissance survey of the Mahananda catchment by the Bihar and West Bengal engineers on 7th February, 1959, the following dam sites for flood control were suggested:

i	Mahananda	45.75 m	high dam
ii	Balason	137.25 m	high dam at site no II (at Bunkulang suspension bridge and Manama), 122 m high dam at site no III (near longview); 61 m high dam at site IV (0.8 km down stream of the suspension bridge near Longview Teagarden.
iii	Mechi	106.75 m	high dam
iv	Kankai	76.25 m	to 91.5 m high dam

7.2.3.2 Based on the following catchment areas and the percentage distribution of the run-off in the Mahananda and its tributaries, the flood detention dam on the Kankai and the Balason which together contribute 70 per cent of the total flood flow for controlling floods in the plains were suggested:

Sl No	Name of river	Catchment area in Sq km	Percentage of discharge
1	Panar and other small tributaries	233	10
2	Kankai	1243	50
3	Mechi	130	13
4	Balason	222	20
5	Mahanadi	70	7
	Total	1898	100

Detailed investigations of these two dam sites on the Kankai and Balason were suggested in the first instance. However the Kankai dam site with the dam height of 76 to 92 m (approx) was considered more promising.

7.2.4 Report of the Technical Experts Committee on drainage and Waterways of Railways and Road bridges in North Bihar (1967).

The following road and railway embankments of the Mahananda river system which run across the catchment were examined by the Committee:

Sl No	Roads/Railways	Total lenght(km)	Remarks
	Roads		
1	Araria-Bahadurganj-Thakurganj-Galgalia Road	90	A part of Lateral Road
2	Purnia-Garhbanaili-Sonta-Kishanganj road	60	District Board Road
3	Purnia-Dhengraghat-Darjeeling road	32	
4	Purnia-Sonali-Azamnagar Balrampur road	80	
5	Taibpur-Galgalia road	19	
6	Katihar-Amadabad road	39	
	Railways		
1	Katihar-Jhawa-Barsoi section	41.8	Meter gauge
2	Katihar-Lava-Malda section up to Lava crossing	27.3	Meter gauge
3	Aluabari-Taibpur-Thakurganj-Galgalia section	32	Meter gauge

The following important border roads and railways run along the country slopes:

Sl No.	Name of Road/Railway	Length in km
	Roads	
1	Araria-Sikta road	29
2	Jokehat-Palasi-Dahibhat road	34
	Railways	
1	Kishanganj-Taibpur section	36
2	Aluabari-Dalkola-Barsoi section	87

The Committee had made the following recommendations in its report:

1 No extension of the waterways of the road bridges is required in case of the lateral road and NH 31 (Ganga-Darjeeling portion) in the basin. Additional waterway of 41.78 m is necessary on the spills of the Dauk Nala between mile 6 & 7 of Katihar-Taibpur-Thakurganj-Galgalia road. Besides, a bridge of 129 m is already under construction on the Dauk. The total waterways required for the road bridges is 2708.4 m, less already existing, as the details of the existing waterways are not available.

2 No extension of waterways on railway bridges is required. However, when embankments on the Mahananda are spaced at 183 m apart, the clearance on Lava railway bridge remains only 0.579 m which is considered permissible by the Chief Engineer, NEF railway.

3 Setting up of three more raingauge stations in Nepal and five stations in Bihar.

4 Implementation of the proposal formulated by the IMD for installation of two self-recording raingauge stations at Farbesganj and Purnia in North Bihar as early as possible.

5 Setting up of gauge and discharge sites on the tributaries at points slightly upstream of their confluence with the Mahananda for assessment of their runoff. In addition, setting up of the gauge cum discharge sites at the bridge sites across the important live channels along the Galgalia-Darjeeling road. Three more discharge sites on the ten bridges located on the Panar, and its spill channels crossing the Purnia-Darjeeling road.

6 One more silt observation site was suggested on the main river at Dhengraghat in addition to

the existing three silt observation stations at Siliguri, Taibpur and Jhaua. One silt observation site was suggested on each tributaries ie the Panar, the Mechi and the Kankai at Araria, Rupadharghat and Gaurihar respectively.

7 A hydraulic survey such as L-Section and cross-section of the main river and for important tributaries every third year suggested.

8 Necessity of soil conservation was not felt due to lack of silt content of Mahananda in its reach lying in Bihar. Silt data for the tributaries should be collected. Based on the study of the silt data, the necessary erosion survey of the apparently eroded catchment should be started. Investigations for ascertaining necessity of soil conservation measures in the Kankai catchment should receive priority.

9 Collection of flood damage data in the Mahananda basin on uniform and rational basis should be carried out on the lines suggested in the draft report on the " Scientific procedures for assessment of flood damages in North Bihar prepared by National council of Applied Economic Research."

10 Model experiment may be carried out quickly to devise suitable measures to counteract the possibility of any imbalance being created in the distribution of discharges by the river Mahananda between its two branches below the Bagdob.

11 The Mahananda basin report with the data up to 1955 prepared by the Central Water and Power Commission may be updated to enhance its usefulness at an interval of 5 years .

7.2.5 The outline plan of flood control in the Ganga basin prepared by the Ganga Flood Control Commission in 1973.

The outline plan for the portion of the Mahananda river system identified the flood problem for different reaches of the Mahananda and its tributaries and the following measures were suggested:-

I Construction of the following embankments on the Mahananda (Upper reach) and its tributaries namely the Mechi, the Ratua, the Bakra and the Panar with their approximate costs and benefits.

Sl No	Name of the embankment	River	Right bank (R) or Left bank (L)	Length in Km	Approx esti-mated cost in (Lakh Rs)	Approx area protected in Lha
1	Sonapurghat to Rupadhar	Mahananda	R	44	66.00	
2	Rupadhar to Barmasia	-do-	R	30	45.00	0.50
3	Sonapurghat to Bagdob	-do-	L	96	144.00	
4	Thakurganj Bahadurganj road to Chakia (near Rupadhar)	Mechi	R	20	30.00	0.20
5	Galgalia to Chakia (near Rupadhar)	Mechi	L	40	60.00	0.20
6	Araria to Jhaua	Panar	L	64	96.00	0.24
7	Taragachi to Surajpur	Ratua	L	50	75.00	
8	Taragachi to Surajpur	-do-	R	48	72.00	0.20
9	Madanpura to Purnia-Bahadurganj road	Bakra	R	30	45.00	
10	Patna-Purnia Bahadurganj road	-do-	L	48	72.00	0.18

II Proposal of a barrage to irrigate an area of 0.6 lakh ha on the Western Kankai which will also check the shifting tencency of the river.

III Proposal to construct a barrage on the Mechi to act as a control structure and to utilise it for irrigation purpose.

IV To improve the drainage congestion existing in the Ramjan Nala outfalling into the Mahananda which will protect the Kishanganj Town from flooding at an estimated cost of Rs 25.00 lakh.

V The probable dam sites on the Mahananda and its tributaries with their probable reservoir capacities etc, for flood control based on the reconnaissance report on water resources development of the Mahananda river system prepared by the Irrigation Department of Bihar in collaboration with West Bengal and Central Water and Power Commission are listed as under-

Sl No	River	Site at	Reservoir capacities in million cum	Height (m)
1	Mahananda	Confluence of Sirakhola with Mahanadi	3.08	45.72
2	Balason	Near Marha tea estate or at confluence of Torykhola	45.7	76.20
3	Balason	Near Long view tea Estate	123.3	121.92
4	Mechi	Confluence of Sodakhola or Loharghat hills	95.4	106.68
5	Kankai	Mainachule	1005.0	91.44

Out of the above sites, two dam sites one each on the river Kankai and the river Balason, which contribute 70 per cent of the total discharge for controlling floods in the plains down stream were suggested.

These proposals were subsequently discussed in the meeting of the State Technical Committee of the Bihar State Flood Control Board held in 1980 and it was felt that the reservoir schemes could not be pursued further on the ground that a moderate flood is good for jute cultivation and as such a moderate flooding of the catchment is not harmful. Further, the cost of such high dams may be prohibitive from the flood control point of view only and it may take many decades before these dams are investigated for other benefits such as power which may justify that cost. However, it was suggested that the data should be collected for construction of embankment, improving drainage and raising of villages so that these measures could be taken up. Since the proposed dam on the Western Kankai is located in Nepal co-operation of that country will be essential.

vi Soil conservation measures may be implemented in an area of about 560 Sq Km in Nepal to check the meandering and shifting tendencies of the channels in the Mahananda river system and to stabilise their couses.

vii Waterways of rail and road bridges may be provided in accordance with the recommendation of the Technical Experts Committee, 1967.

7.2.6 Master Plan of Flood Control in Bihar (Prepared by the Irrigation Department Government of Bihar in 1974)

It is indicated in the above Master Plan that the river Mahananda and its tributaries inundate an area of about 3.54 lakh ha in the Purnia district almost every year and the damage due to flood caused by these rivers is to the tune of Rs. 1446.35 lakh annually. This huge annual loss calls for the solution of the problem on an urgent basis.

The main flood problem of the river system is attributed to the low bankful capacities of the tributaries of this river system, siltation of their beds, changes of river courses, heavy spilling and bank erosion at several places.

The following flood control and protection measures were suggested in the above master plan.

i Construction of embankments on the Mahananda and its tributaries as indicated below:

Sl No.	Name of scheme	Approx cost in lakh Rs	Approx area to be protected in lakh ha	Remarks
1	Mahananda flood control scheme (continuing Sch.) 211.5 km embankments on both banks of the river Mahananda	404.00	1.00	Total cost Rs 670 lakh
2	Kankai embankment scheme (95.5 km)	332.00	0.48	
3	Eastern Kankai embankment scheme (95.5 km)	138.00	3.56	
4	Upper Mahananda flood embankment sch. (170 km)	255.00	0.50	
5	Mechi embankment scheme (60 km)	90.00	0.20	
6	Ratua embankment scheme (98 km)	47.00	0.20	
7	Bakra embankment scheme (78 km)	96.00	0.24	
8	Panar embankment scheme	96.00	0.24	
9	Panighata dam on river Balason and eastern Kankai	600.00	-	The cost of dam on the Balason proposed to be shared between the Govt of West Bengal and Bihar
10	Village raising scheme	20.00	150 to 200	
11	Soil conservation measures in Nepal	280.00		
12	Extension of Waterways in road and rail bridges	25.00		
13	Araria town protection sch	50.00		
14	Chaur drainage scheme	25.00	0.12	

ii Setting up of atleast five more raingauge stations in Bihar located at Dehibhat, Digha bank, Galgalia, Dhantola and Deoragawa.

iii Setting up of two self-recording raingauge stations at Farbesganj and Purnia as proposed by IMD.

iv Setting up of discharge observation sites at points slightly upstream of the confluence of various tributaries with the river Mahananda in order to make a realistic assessment of runoff contribution and flood drainge of the tributaries. Establishment of ten gauge and discharge sites at road bridges on all important live channels on Galgalia-Darjeeling road was also suggested.

v Setting up of one more silt observation site on the Mahananda at Dhengraghat and three more sites at Gardankatta, Gosainpur LRP bridge and Araria on the rivers Mechi, Kankai and Panar respectively.

The Central Water Commission is maintaining the flood forecasting station at Dhengraghat on the river Mahananda since May, 1973.

vi To establish another flood forecasting centre on the river Mahananda at Taibpur (where gauge and discharge site already existed) to augment existing flood forecasting station at Dhengraghat on the river Mahananda.

7.2.7 Preparation of Comprehensive Master Plan for North Bihar Rivers Jointly with Nepal

In order to tackle the problem of floods in the common rivers, Government of India and HMG, Nepal have agreed to jointly prepare comprehensive plans, for flood management of North Bihar rivers originating in Nepal outlining both short-term and long-term measures. An Indo-Nepal joint group has been set up in pursuance of the above decisions. The Nepalese side will be headed by the Director, Central Region Irrigation Directorate, while Chairman, GFCC will be the leader of the Indian side. The master Plan of the Mahananda river system amongst others, is likely to be prepared by this group very soon. The finalisation of such a plan will pave the way for co-ordinated execution of flood management measures including extension of embankment into Nepalese territory for tying them to higher grounds in order to prevent flooding of the protected area in the Indian territory from the over bank spills coming from the Nepalese territory.

7.3 The mahananda river system in north estern vicinity of the river Ganga experiences intensive and extensive flooding frequently. Some flood protective measures have already been taken by the State Government in this basin. These are described briefly in the following paragraphs:

7.3.1 After the devastating floods in the year 1971, the Government of Bihar framed the Mahananda Embankment Scheme at an estimated cost of Rs. 530 lakhs (approximate). This scheme envisaged construction of 240.47 km length of embankments with adequate number of drainage sluices. The embankment on the Phulhar branch was planned starting from Mahendrapur (near Belagachhi) along the right bank of the tributary Riga up to the outfall of the Riga into the Phulhar branch at Jhaua railway bridge (length 22.4 km) and then continued along the right bank of Phulhar branch. Below Manihari-Bhaluka PWD road the Phulhar branch gets closer to the Ganga and this embankment is tied with the railway embankment at Chaukia-Paharpur over the left bank of the Ganga. From Jhaua Rly Bridge upto Chaukia-Paharpur, length of the embankment is 86.6 km. The railway embankment between Chaukia-Paharpur and Manihari provides protection from the flood spills of the river Ganga between these places. A 26.85 km long embankment has been constructed on the right bank of the Kosi Dhar.

Further, the entire right bank of the Phulhar branch in Bihar from Bagdob up to Bihar-West Bengal border at Babupur and the entire left bank of the Barsoi branch from Bagdob to the Bihar-West Bengal border near Kushida were embanked in a length of 40.6 km and 47.09 km respectively. The major portion of this scheme was completed in 1982 which benefits an area of 1.2 lakh ha approximately.

The salient details of the existing embankments on the Mahananda river system are given below:-

Sl No	Name of Scheme	Copmponents of the Scheme	District	Length in km	Estimated original cost in lakh Rs	Area benefited (Lakh ha)	Remarks
1	2	3	4	5	6	7	8
1	Mahananda embankment Scheme in Bihar	i Embankment on the right bank of Jhaua branch from village Mahendrapur to Jhaua railway crossing	Purnia	22.4			
		ii Embankment on the right bank of Jhaua branch from Jhaua railway crossing to Chaukia Paharpur	Katihar	86.6	530.13	1.21	Scheme was almost completed by 1982.
		iii Embankment on the left bank of Ganga from Chaukia Paharpur to Topra.	Katihar	15.6			
		iv Embankment on the left bank of Ganga from Topra to Manibarighat railway station.	Katihar	1.33			
		v Embankment on the left bank of Kosi Dhar from Manihari railway station to Katihar town.	Katihar	26.85			
		vi Embankment along the left bank of Jhaua branch from Bagdob to West Bengal border opposite Lava.	Purnia and Katihar	47.09			
		vii Embankment along the right bank of Barsoi branch from Bagdob to West Bengal-Bihar border near Kusidha.	Purnia	40.6			
			Total	240.47 km			

7.4 ON-GOING SCHEMES

There is no embankment scheme on-going in Bihar at the moment except, of course, the small remaining portions of the Mahananda embankment scheme and works for protection of the existing embankments which are carried out almost every year.

8 FUTURE APPROACH

8.1 Management of floods should be considered in the context of the overall plan for management of the water resources of a given river basin. The approach to the flood problem has to take into account the state of our socio-economic conditions and the resources position. The approach, therefore, cannot be static but should be dynamic and flexible, so as to accommodate phasewise implementation as well as future technological innovations in the reviews from time to time.

The measures to be adopted in any particular situation for affording the maximum relief from the flood problem should depend on factors like the techno-economic conditions, the social needs and local aspects, etc. Each measure has also its own merits and demerits. It is, therefore, obvious that any particular measure may not necessarily be the most suitable solution under all possible combinations of situations. The Rashtriya Barh Ayog has extensively dealt with the relative merits and demerits of the measures in Chapter III of its report indicating the circumstances under which a measure or a set of the measures would be most suitable as compared to the others and the specific points which require to be particularly gone into when a specific measure is being considered for adoption.

The flood management schemes of the Mahananda basin in Bihar have been planned in accordance with the general guidlines of the Rashtriya Barh Ayog for this purpose.

8.2 In Pursuance of the 1954 National Flood Policy, vigorous action was initiated by the Central and the State Governments to undertake intensive programmes of collection of basic data, surveys and investigation and execution of urgent flood control measures to protect areas in need of immediate relief. But before the devastating flood of 1971 nothing substantial was done in the shape of flood protection measures in the Mahananda basin.

After 1971 flood, the Mahananda embankment scheme envisaging construction of about 240 km long embankment with adequate number of antiflood sluices was framed at an estimated cost of Rs. 530 lakhs. This was expected to provide a reasonable degree of protection to an area of about 1.21 lakh ha from flooding. Major portion of the scheme was completed in 1982. But even after construction of this embankment, the basin is still confronted with flood and drainage problems which are identified as follows:

i Spilling of banks due to substantial discharge and silt load as compared to the carrying capacities of the river sections and flooding of low lying areas close to the river banks.

ii Bank and bed erosion of natural channels.

iii Risk of avulsion of the river and consequent changes in its course resulting in opening of new branches or spill channels causing damage to developed areas.

iv Inadequacy of the existing drainage system.

v Inadequacy of waterways under roads and railways.

vi Flooding of towns, cities, etc, located on the river banks.

8.3 Mitigation of damage caused by flood and damage congestion has been identified as the main goal of the future planning.

8.4 POSSIBLE FUTURE MEASURES

The Rashtriya Barh Ayog has identified 25 defferent measures of flood management, out of which 11 are structural measures (engineering methods), and the rest are nonstructural measures (administrative measures). Out of the 11 structural measures the following measures have been considered suitable for the Mahananda river system and are being dealt with in subsequent paragraphs.

8.5 RESERVOIR

8.5.1 According to numerous experts, a properly operated flood control reservoir, combined with efficient flood forecasting, offers the most dependable flood control. Reservoirs, in general, even without specific flood cushion have a beneficial effect on the flood problem of a basin. The effectiveness of reservoirs in moderating flood would depend upon the capacity available for absorbing the flood run off. Because of their high cost, the reservoirs are not economically viable or justified exclusively for flood control purpose but a multipurpose reservoir to provide irrigation, power, domestic water supply, recreation and other benefits along with flood moderation would be economically viable.

8.5.2 The construction of multipurpose reservoirs on the Mahananda and its tributaries would not only reduce flood and sediment charge, but also offer immense possibilities for economic regeneration of the areas in the Mahananda river system through intensive and extensive irrigation facilities and impetus to industrial development.

8.5.3 Some sites have been identified by a team of Engineers of Bihar and West Bengal after reconnoitoring the hilly areas in India and Nepal in February 1959. The team had selected four storage sites, one each on the Mahananda, the Balason, the Mechi and the Kankai.

8.5.4 The site across the western Kankai considered to be more promising than the other sites by the said team. The team had also worked out roughly, the approximate height and storage capacities which are as follows:

River	Reservoir sites	Bed level (m)	Height of dam (m)	Catchment area in (Sq Km)	Storage (M.ham)
Mahananda	Gayabari	305	45.75	69.93	0.003
Balason	Site no.III	333.5	122.00	222.74	0.012
Mechi	Site no I	335.5	122.00	129.50	0.012
W. Kankai	Site no I	137.25	167.75	1108.52	0.088

It is evident from the above that the dam site on the Western Kankai just above the Mahendra Rajpath in Nepal has large catchment and considerable storage capacity, as compared to the other three storage sites.

8.5.5 There is no record to show as to what happened after these details were available to the State Governments of Bihar and West Bengal. The Commission suggests that the detailed investigation may be carried out, in co-operation with the HMG, Nepal for techno-economic feasibility of the aforesaid reservoir sites for multipurpose uses (including flood control to the extent possible).

8.5.6 It appears from the comprehensive plan of flood management in the Mahananda river system prepared by the GFCC that the Government of Nepal have taken up execution of a barrage across the Western Kankai and is also contemplating of constructing a storage reservoir on the upstream. It is, therefore, considered necessary that the Government of India be requested to obtain the necessary details of the above proposal from the Government of Nepal to find out its impact on the existing schemes in India and also to come to an understanding with the Government of Nepal for a joint project for mutual benefits of the two counties.

8.6 EMBANKMENTS

8.6.1 Construction of embankments is the foremost and quickest measure which is generally adopted for flood protection. Although embankments suffer from a number of drawbacks yet this measure has been adopted for flood management in this river basin also. The main drawbacks are as follows:

a Prevention of silt laden water from spilling over the land resulting in reduced moisture and fertility.

b Embankments are considered a satisfactory measure of protection only when the river is non-aggrading and the embankments are properly designed, executed and maintained.

c It is also apprehended that the embankments may shift the problems of flood from one area to another.

d Reduction of the cross-sectional area of the flow of the channel in the post-embanked condition.

e Cutting off the valley storage, previously available for flood moderation during the pre-embanked condition.

f Interference in country-side drainage.

g Drainage congestion at tributary junctions.

h Vulnerability of embankment due to bank erosion, breaches, etc.

8.6.2 The north-eastern part of the Mahananda river system in Bihar consisting of the Parman, the eastern Kankai, the western Kankai and the Mechi river systems is covered by a vast sheet of water on a number of days during the monsoon season every year. To check spilling over the banks and to give a reasonable degree of protection to this area from floods, it is considered necessary to construct embankments on both banks in the spilling reaches of these rivers. This would cover their entire length in Bihar and also a few kms within the Nepalese territory in some of the tributaries. The length of such embankments in Bihar would be around 340 km approximately. On both banks of the Parman and its tributaries 200 km on both banks of the western Kankai and its tributaries, 90 km on both banks of the eastern Kankai and 60 km on the Mechi. The breakup of these embankments in different reaches is indicated in the statement at Annex -10. These embankment schemes on completion, are likely to provide a reasonable degree of protection to an additional area of 2.79 lakh ha (approx) at an estimated cost of Rs 13800 lakh (approx). It is seen from Annex-10 that almost all the proposed embankments start from the Indo-Nepal border. In order to rovide protection from the flood spills coming from the Nepalese territory, these embankments will have to be tied up to a high ground in the Nepalese territory. It is, therefore, felt necessary to move the Government of India for taking up this issue with the Government of Nepal with necessary details for extending the embankments up to a high ground in the Nepalese territory for mutual benefits to both the countries.

8.6.3 In the upper reach of the main Mahananda river the embankments have been proposed on its both banks in Bihar. In the lower reaches, the Phulhar branch, although already fully embanked is having a gap in a small stretch on the right bank. An embankment from Bagdob to Jhaua measuring 19 km on the right bank of the Phulhar branch is proposed in order to close this gap. In addition an embankment from Barsoi to Subarnpur measuring 24 km on the left bank of the Barsoi branch in Bihar has also been proposed. It may, However, be pointed out that while working out the detailed schemes for construction of embankments on both banks in the unembanked reaches of the river Mahananda and its tributaries, special care has to be taken to provide suitable sluice structure having adequate waterways at the junction of the two rivers in order to remove drainage congestion from the jacketted portion on the countryside of the embankments as soon as the river stage permits. Alternatively, gaps may have to be left at the junction points with ends of embankments fully armoured with stone pitching so as to provide quick drainage of the area to be protected. The better of the two alternatives may be adopted.

8.6.4 The Government of Bihar has identified approximate lengths of the embankments required to be constructed on various rivers in the Nepalese territory which will reduce flooding in both Nepal and Indian territories.

The details of proposed extension of embankments in Nepal for the Mahananda river system are given below:

Sl No	Name of the river	Length of embankment required in Nepal (km)	
		Left bank	Right bank
1	Ratua	9.00	10.00
2	Western Kankai	-	12.00
3	Parman	4.00	4.00
4	Bakra	6.00	13.00
5	Mechi	-	4.00
6	E.Kankai	-	5.00

These are the proposals in the Mahananda basin given to the standing Committee on Inundation problems between India and Nepal and are only rough indications at this stage. Precise details can be worked out only after detailed srveys and investigations are carried out in the Nepalies territory.

It has also been observed that even in the embanked portion, there remains danger of breaches due to bank erosion which cause much more damage in the affected area than what would have happened in the unembanked condition primarily due to the occupation of flood plains and subsequent development activities. The embanked portion is threatened with breaches at certain vulnerable location due to river bank erosion. The Commission recommends reassessment of design flood and checking of the adequacy of waterways between the embankments on both banks as per prevalent practice to be carried out in detail and to utilise the results of such detailed analysis suitably to tackle the problem of river bank erosion. The " Nag Committee" in its report on the breaches in flood embankments during the floods of 1974 and 1975 in North Bihar had given its view on the breaches on the following lines:

a The causes of these breaches have been different at different points, though failure through piping action had predominated.

b From the manner in which the breach occurred it was apparent that the weakness was not in the body of the embankment but in its foundation. The foundation material was more pervious than the consolidated material in the embankment and required a cover over the flatter hydraulic gradient that was provided.

8.6.5 The embankments are being frequently threatened due to bank erosion at various points/

reaches and sometimes embankments have breached due to this reason in the past. Although, from time to time, various anti-erosion measures had been taken and are still being taken at specific vulnerable locations, the river starts attacking at another locations. It is, therefore, felt that anti-erosion/ river training works should not be executed on an adhoc basis as are being done from year to year at present but they should be planned and executed on the basis of results of model studies carried out in totality so as to avert possible disaster at a location other than those protected by such works. The shortcut method approach in such situations is likely to be cost-prohibitive and may not solve the problem permanently.

8.6.6 It is observed that the flood embankments on the river Mahananda have been sited rather too close to the banks in this regard. Normally, spacing between the flood embankments should not be less than about three times the Lacey's width worked out for the maximum design discharge and the distance between the toe of the embankment and the river edge should also be not less than the Lacey's width. Contrary to this, the embankments have been constructed quite close to the river at many places. This might be one of the possible causes of bank erosion at different locations. Erosive action of the river has resulted in breaches in the embankments in the past, leading to its retirement ultimately.

8.6.7 In the existing situation, the Commission feels that a physical model of the entire river reach including un-embanked portions in the upper reach be laid out and studies be carried out for evolving,

i Suitable flood management measures to be undertaken in the unembanked reach of the river.

ii Efficacy and appropriateness of the alignment of the existing flood embankments and, if necessary, the need to retire the embankments suitably at some cardinal points in order to economise expenditure being incurred annually on costly anti-erosion works.

iii Raising and Strengthening of embankments in vulnerable reaches.

iv Diversion of a part of the peak flood discharge through abandoned spill channels to relieve pressure on the embankments. The spill channels may be resectioned to carry the desired descharge within their bankful capacities to prevent inundation in the protected areas.

8.6.8 There are a number of sluices constructed in embankments to prevent entry of flood spills into the protected area through the existing drains and also to relieve pressure on the embankments during high floods by releasing regulated discharge through them. Several anti-flood sluices have also been provided for draining out accumulated water on the contryside as soon as the river level permits in order to remove drainage congestion from the protected area.

The conditions of most of these existing sluices have seriously deteriorated making them completely ineffective. This is due to choking of their vents, intentional close blocking of vents, malfunctioning of gates or silting of the channels on the river side or river edge having been moved far-away from the embankments. The rise in the river side bed level has further aggravated the problem as the countryside ground level has become lower than the river side.

The Commission suggests that detailed studies be undertaken to find out the effectiveness and adequacy or otherwise of the existing sluices in the embankments and remedial measures be taken on priority basis to make them function properly as and when necessary. If found necessary, more sluices may be provided for proper and efficient drainage of the countryside and also for providing irrigation to the areas on the countryside in the case of drought.

8.7 INTERBASIN TRANSFER

8.7.1 Almost all the rivers of North Bihar rise from the foothills of Himalayas or adjoining areas. Owing to heavy precipitations in hilly areas, floods mostly occur simultaneously in all the basins. However, sometimes the flood of a greater magnitude occurs in one basin while the adjoining basin faces a flood of a lesser magnitude. In such cases, there is always a possibility of diverting part of the flood of the severely affected basin to the lesser flood affected basin. Premilinary studies for such a possibility of inter-basin transfer of water has been made on the basis of available maps of the Mahananda basin. The western boundary of this basin is the Kosi river basin. There appears to exist a possibility of diverting the flood discharge in part from the Mahananda basin to the Kosi basin through an existing channel as discribed below:

The Parman, a right bank tributary of the Mahananda having a catchment area of 3840 Sq Km, joins the Mahananda near Bagdob. A channel, named Bhaisama, offtakes from a place near Chainpur, which is very close to the Parman and joins an old Kosi dhar on the upstream of Katihar town. This old Kosi dhar meets the river Ganga on the upstream of Manihari between Azampur Bundh. It appears possible to divert some flood discharge from the Parman river to the Ganga through the Bhaisama river and the old Kosi dhar. It is, however, necessary to carry out detailed investigation for ascertaining this possibility and also to find out its techno-economic viability before taking final decison in the matter. The quantum of such diversion should also be as- certained keeping in view carrying capacity of the channel after suitable resectioning.

8.7.2 In case, after detailed and thorough investigations, this turns out to be technically feasible and economically viable, then the existing flood and drainage problem in the Mahananda river system is likely to ease considerably. The diversion channel has to be planned and executed so as to carry the diverted quantity of flood discharge within its bankful capacity to prevent any flooding of the area protected by the Mahananda embankment scheme.

8.8 TRANSFER WITHIN BASIN

8.8.1 Normally, the embankments on both the banks of the Phulhar branch of the Mahananda river have been designed for 50 years flood frequency but flood of a larger magnitude may come any time. In such eventualities there is always a danger of breaches in these embankments which may occur at vulnerable places, causing greater damages to life and property. The Commission, therefore, suggests that either breaching sections or controlled escape structures may be provided at suitable locations to be dicided after proper investigation and study of the contour map of the area, along the embankments so that the pressure on embankments is reduced considerably by release of part of the flood discharge through such structures. Such excess flood discharge may be dropped in the same river further downstream. This is likely to reduce the pressure on the vulnerable sections of the existing embankment to ensure greater safety and reduce the damages to life and property. Suitable sites for such diversion and surplussing works have to be selected after detailed surveys and investigations. The old dhars in the basin should be made use of in such works by suitable resectioning and regrading for obvious reasons.

8.8.2 There are large number of chaurs and swamps in this basin, which, though small in capacity individually but taken together, constitute a significant capacity. The Commission, therefore, suggests that detailed surveys and investigations be carried out to use such chaurs and swamps as detention basins during the period of high stages in the river. The flood waters accumulated into these chaurs and swamps may be drained into the river during its lower stages at suitable locations where outfall conditions permit so that these are drained off well before the Rabi season. This arrangement is likely to fill the depressions in due course with silt and will be helpful in raising a bumper Rabi crop besides ensuring safety to the embankments which protect valuable lives and properties.

8.8.3 On a preliminary study of the basin map of the river Mahananda, prima facie, the following proposals for transfer of flood waters of the river during high stages to reduce pressure on the embankments appear feasible:

i The North Bihar Technical Experts Committee (1967) had roughly estimated the percentage distribution of the Mahananda flood discharges below the Bagdob as 75 percent and 25 percent in the Phulhar and the Barsoi branches respectively based on the data available for the period from 1960 to 1966. However, during recent years, viz in the last three years the Barsoi branch has been receiving a lesser share of the total discharge than what was anticipated. A barrage on the Mahananda just below the bifurcation point at the Bagdob contemplated for the purpose of irrigation should also be designed to ensure an equitable distribution of discharge between the Phulhar and the Barsoi branch. This will ensure a better flood management in the Barsoi branch of the Mahananda river system.

ii The offtake point of the river Jalai is very near the river Phulhar and it joins the same river Phulhar lower down near Babupur. Some flood spill of the Phulhar could be diverted through the Jalai during emergency to reduce pressure on the embankments on the downstream.

iii The offtake point of the river Kamla is very near the river Parman, a major tributary of the Mahananda, above the confluence of the Parman and Mahananda,and joins the river Phulhar in the lower reach. There appears to be a possibility of diverting some flood discharge of the river Parman into the lower reach of the river Phulhar through the river Kamla by providing suitable structure in the proposed embankment.

iv In addition to the above, there is also a possibility of diverting flood water into small detention basins like chaurs and swamps in the plains between the tributaries, such as the Parman, the Western Kankai and the Eastern Kankai in the upper plains. The doab between the Phulhar branch and the Barsoi branch below Bagdob consists of several 'Beels' and low lying lands. The capacity of chaurs and swamps could be increased by providing embankments along their peripheries. However, these proposals should be formulated in a proper form and their usefulness should be ascertained only after proper and detailed surveys, investigation and planning.

8.8.4 The above are a few examples cited for embanking upon studies and investigations in the first stage on a priority basis. Detailed investigations for further such possibilities may also be carried out and their technical feasibility and economic viability be ascertained before taking up execution. If found feasible, these are likely to ensure safety of the existing embankments on the river.

8.9 DRAINAGE IMPROVEMENT

An acute drainage problem exists in the Mahananda basin due to the low bankful capacity of the river Mahananda and its tributaries, siltation of the river bed and inadequacy of waterways in road and rail bridges. The smaller rivers and natural drainage channels need to be resectioned in order to carry their peak discharges at levels lower than the prevailing high flood level to prevent overtopping of banks while carrying high flood discharge. Possible measures in this regard which are relevant to the Mahananda river system are being discussed below:

8.9.1 Channelisation of the River and Control Points

The rivers carry varying discharges. A single combined channel can be designed for a particular discarge to transport the sediment load. It does not, however, appear possible to design a regime channel section with varying slopes of the river to cater for the sediment load carried at different discharges since the sediment transporting capacity of the channel is dependent upon the flood discharge and the slope of the river.

It would ,therefore, be desirable to train the river to form a single channel with sufficient waterways to pass the maximum flood discharge with safety. This can be achieved by the closure of some of the existing spill channels, construction of marginal embankments, provision of spurs or other protective measures at appropriate locations, desilting of new channels to fit in with the suitable alignment of the river course.

Training of the entire lengths of the river Mahananda and its tributaries into one single channel is an ideal that is not possible to be achieved even in the distant future. It may be possible to train the rivers into suitable alignments at suitable locations along their course by the utilisation of structures required for other purposes, such as weirs, barrages, roads and railway bridges. Such structures can be sited and provided with waterways consistent with the requirement of a suitable centralised channel for the river. Such structures will serve as control points if these can be located at suitable intervals so as to achieve the objective of stabilising the river course in the central channels. It is learnt that the State Government is contemplating construction of barrages on the tributaries of the Mahananda near the Indo-Nepal border. Another proposal to construct a barrage at Bagdob with the mutual consent of Bihar and West Bengal Governments for the Purpose of irrigation is also in the offing. This is likely to further serve the purpose of dividing the Mahananda discharge equitably between the Phulhar and the Barsoi branches as a flood control measure. It will be relevant to mention here that the efficacy of the control point in checking the meandering tendency of the other rivers was studied by the Central Water and Power Research Station, Pune, which has expressed the view that the control points may not be effective for the purpose intended due to the possibility of the river being aggrading in nature. However, it needs to be pointed out here that the Mahananda is a more stable river than the Kosi throughout its couse. The establishment of control points merely as training works is not considered economically viable. Public utility structures like road and railway bridges and barrages could be utilised as control points to control and direct the river channel. Two barrages have been proposed on two branches of the Western Kankai to serve as control points to guide the river. The usefulness of these control points would depend upon the additional component work guiding the river and their subsquent proper maintenance.

8.9.2 Dredging

Dredging at best can be employed at the bifurcation point (Bagdob) of the Mahananda into two channels, viz. the Phulhar branch and the Barsoi branch. Further, the Barsoi channel itself splits into two channels, eastern and western, which again joins back. Out of the two channels, the eastern channel is active and the western channel is practically dead. Dredging can be resorted to activate the dead channel. Dredging of the Barsoi channel will enable it to carry more discharge.

8.9.3 Inadequacy of Waterway under Rail and Road Bridges

Inadequate waterways under rail and road bridges are the major causes leading to drainage congestion, besides heavy damages to the roads and railways themselves. The Commission suggests that such inadequacies be identified after taking up detailed surveys and investigations and further action to remove these bottlenecks may be taken on the basis of their technical feasibility and economic viability.

The Mahananda basin area in Bihar and West Bengal has been covered by a network of roads and railway lines. Because of inadequate waterways under the bridges in some of these roads and railways running across the basin, the period of flooding gets prolonged. Recommendations made by various Committees in the past to increase the waterways in rail and road bridges in the Mahananda basin are reproduced below:

The High-level Committee on floods (1958) suggested that waterways on the railway and road bridges on the river Mahananda and its tributaries need to be checked up and increased wherever neccessary.

The Technical Expert Committee on Drainage and Waterways on Railway and Road Bridges in North Bihar (1967) examined the adequacy of waterways under the bridges of road and railways which were likely to interfere with natural drainage and gave specific and exhaustive recommendations, which are placed at Annex 11.

8.9.4 The lower portion of Mahananda river system is experiencing an acute water logging problem in Amdabad block of Katihar district in Bihar. The area of this block is surrounded by the Kata Kosh-Naurasia and Topra-Chaukia embankment in the south, Lava-Chaukia embankment in the south east, Lava-Chaukia Paharpur embankment in the north east and Manihari to walipur-Nima road in the west, making the area "U" shaped. These embankments have increased drainage congestion in low-lying chaurs namely, Chama, Kamalpur, Narbanna, Karuadhab, Naurasia, Jalyari, Charguha, Kalaktari, Digha and Naurasia B. The total water-logged area of these chaurs measure 290 ha and average water depth observed is about 2 metres and Maximum depth of water is 3.3 metres. Although many sluices have been constructed to drain out water from these chaurs, yet the desired results have not been achieved. Details of existing sluices are indicated below:

Lava-Chaukia Embankment

Chainage	Discharge in cumec	Sill level in M	Waterway	Remarks
401	1.6	23.3	1x1m (dia)	In working condition
508	11.4	23.7	4x1.65x1.2m	-do-
569	11.4	-	-	Proposed
715	NA	NA	NA	Washed away
Gobindpur retire line (ch 690 to 780 of Lava Chaukia embankment)				
55	14.3	-	-	Proposed
808	5.7	23.4	2x1.65x1.2m	Due to high sill level sluice is not working

No sluice has been provided in the Topra Chaukia embankment at present. The result is that this embankment is being frequently cut by the villagers almost every year at defferent locations to drain out the water accumulated in the countryside of the embankment. The details of such cuts are reported as follows:

Year	Embankment	Chainage	Remarks
1985	Topra Chaukia	496.6 to 503.6	
1987	-do-	490 to 504	
1987	Kata Kosh retire line of Topra Chaukia Embankment	0 to 6	
1987	-do-	35 to 40	
1987	-do-	56 to 61	
1987	K.K.N. retire line	150 to 162	
1988	Topra Chaukia	401 to 404	
1989	-do-	471.3 to 473.75	
1991	-do-	476 to 479	

Keeping the aforesaid unauthorised cuts almost every year in mind, the Chief Engineer, W.R, Purnia has formulated a scheme which envisages construction of a sluice at ch 508.5 on Lava-Chaukia embankment to drain out the water from the chaurs, namely Karwadhab, Naurasia, Jalyari, Charguha, Kalaktari and Digha by constructing the trunk and link channels, linking these chaurs.

Another proposal for construction of a sluice at ch. 473 of Topra-Chankia embankment to drain out the water from the chaurs nemely, Chama, Kamalpur and Narbanna by constructing the trunk and link channels linking these chaurs has also been formulated.

8.9.5 There is an existing sluice with its sill at 23.7 m at ch 508 of Lava-Chaukia embankment and a new proposal to construct a sluice at ch 508.5 with its sill at 22.8 is not considered desirable as it would be too close to the existing sluice and may not serve the desired purpose. The present drainage scheme needs improvement after due consideration of the problems of the area. It is suggested that the scheme may be reviewed meticulously and modified and sanctioned as early as possible so that this area is relieved of the drainage congestion as soon as the river stage permits and the villagers are no tempted to cut the embankments for drainage of the area.

8.10 WATERSHED MANAGEMENT

8.10.1 The importance of watershed management in reducing the entry of silt into the river and moderating the run-off from the catchment to some extent is generally recognised. This measure particularly in the Mahananda assumes special significance, because of the high silt discharge of the river and its meandering tendency in the lower reach. As such, an extensive programme of watershed management is required to be chalked out for this system after properly evaluating the beneficial aspects.

8.10.2 Afforestation/Soil conservation measures needed for reducing the silt charge in a river are to be undertaken for providing forest coverage in the hilly portions of the catchment which reduces the impact of heavy rains over the ground so that the surface rainfall does not carry away the soil-cover from the surface into the river and ultimately flow down into the plains. The hilly catchments of the Himalayas contribute a huge amount of detritus during the rainy season and these rivers after debouching into the plains shed heavy material in the submountainous reach (Terai) and the course, medium and fine silt travel further lower down in the plains. Due to the flatness of the river slope much of the sediment load gets deposited on the river bed, thereby decreasing its carrying capacity further. During this process the river tries to carve itself on into new channels after abandoning its old course. This is the basic problem associated with all the alluvial rivers in the Gangetic plain which originate from the Himalayas.

8.10.3 An extensive programme of watershed management in the hilly catchment area of the river Mahananda which lies in the Nepalese territory, is considered necessary for the effective management of the river. Land treatment through afforestation and gross land development should also be supplemented by structural works in the upper catchment for retarding the velocity of water and detaining silt effectively. Such works would also increase the life of the reservoirs proposed to be constructed in the future.

8.10.4 The following points, however, need special attention:

a Watershed treatment works are to be carried out in the Nepalese territory, for which the co-operation of the HMG, Nepal will be necessary.

b The works proposed will be small in size and scattered over a large area without suitable and proper approach to the sites. Under such conditions, the transport of materials, effective supervision and quality control are likely to be a tough proposition.

c The maintenance of these works is likely to be difficult and costly due to the reasons indicated at (b) above.

d Adequate co-operation and proper response from the local population is essential for the success of such a programme. Special efforts will be necessary to secure public co-operation, in a foreign country (Nepal).

8.10.5 The difficulties mentioned above, however, should not outweigh the benefits expected from the watershed management programme. The major proportion of the benefits like afforestation and prevention of soil erosion will accrue to Nepal. These benefits in the Indian territory would be limited to less flow of silt into the river and consequent improvement in river behaviour leading to less expenditure on the maintenance of the embankments. The cost and benefits of such works would, therefore, have to be weighed critically alongwith constraints and difficulties mentioned in the above paragraphs.

8.11 Maintenance of Existing Works

8.11.1 While new structural measures as suggested above are necessary for solving the residual flood and drainage problem in the basin, it is equally important to properly and adequately maintain the assets already created so that they can withstand the pressure exerted due to excessive discharge being carried through the river and consequent rise in flood levels. Besides regular supervision and necessary repair of embankments well before the onset of the monsoon season, the following points deserve special attention.

8.11.2 During past few years the highest flood stages in the river at different locations have been noticed to have gone up resulting in encroachment in the free board of the existing embankments. A systematic survey and investigation of the existing embankments on both banks of the river is required to be carried out every year after the flood season, and encroachment, if any, in the free board in any portion should be made good by raising the height of embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of hydraulic model studies, to keep the flowing channel away from the embankment. In the portion where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or atleast be provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently during emergent situations.

8.12 CONSTRUCTION OF RAISED PLATFORMS

8.12.1 During the flood season, breaches occur sometimes in the embankments, as a result of which protected areas get flooded. Submergence of the protected areas is also caused due to heavy precipitation on the country side coinciding with high stages in the outfall channels. The affected persons take shelter on the embankments alongwith their livestock and properties in such situations. As a result, not only the embankments get damaged but the works like flood fighting and rehabilitation get hampered. Generally, people do not go back to their original living place even after the flood subsides and continue to live on the embankments endangering its safety and hampering regular maintenance.

8.12.2 In view of the above situation, it is felt that:

i Occupation of embankments and the lands acquired should be got vacated effectively to avert any danger or risk to the flood management embankments and to the people living in the protected areas.

ii Raised Platforms above the highest flood level may be constructed in areas liable to inundation near villages on Government or acquired lands. These could also be constructed on the country side of the embankments abutting the same. Such platforms should preferably be connected with all-weather roads and should also be provided with necessary facilities for warehousing, community living, sanitary and potable water supply installations, space for keeping cattle and storing fodder, telecommunication facilities etc, in order to obviate likely inconveniences to the people residing on such platforms during floods. These should be handed over to the local bodies/Panchayats for being utilised as community property and kept free from encroachment.

8.13 NON-STRUCTURAL MEASURES

8.13.1 Flood Plain Zoning

The question of introducing flood plain zoning measures has been under consideration for a long time. In view of the increasing pressure of population and consequent greater encroachment of flood plain, zoning has assumed added significance. The flood damage in recent years is primarily due to greater encroachment into flood plains. The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that undue heavy damage is not caused in the event of failure of flood protection measures. As a considerable portion of flood prone area in the Mahananda river basin is protected from flood such zoning regulations should be introduced in the unprotected areas first and for development in the protected areas henceforth. This is all the more necessary in the present state of affairs in the basin where a long-term solution of the problem appears to be a distant goal because of the involvement of a foreign country.

It would be neesary to procure contour maps of the flood prone area of the basin to a scale of 1:15,000 with contour interval of 0.3 m for implementation of this measure. Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydroulic computation to identify areas prone to flood for defferent frequencies of floods, such as 100 yeas, 50 years and 25 years. Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain, corresponding to a 50 years and 25 years rainfall, will also have to be prepared.

8.13.2 Flood Forecasting and Flood Warning

Flood forecasting and warning has proved to be a great help in issuing warning to the people in flood-prone areas, organising flood fighting and safety measures for the engineering works, timely evacuation of people from affected areas and salvation of movable properties besides mobilising relief operations.

There are only two flood forecasting sites at present both on the river Mahananda in this river system. These sites are Dhengraghat and Jhaua. The flood forecasts of river stages at Dhengraghat and Jhaua are issued daily by the Central Water Commission and communicated to all concerned by wireless, telephones, radio and Doordarshan news bulletins.

Forecast for Dhengraghat is done using gauge to gauge correlation of Taibpur on the Mahananda and Chargharia on the Western Kankai, and that of Jhaua by use of change in stage of Dhengraghat on the Mahananda and of Araria on the Parman. Parman joins the Jhaua branch of the Mahananda below Dhengraghat, upstream of Jhaua.

It is, however, felt necessary to install a few more flood forecasting sites in the Mahananda river system with base stations in the upper catchment in Nepal so that adequate lead time is available for the flood forecasts in the Indian territory to take required safety measures against likely floods. The State Government may request the Government of India for installation of more sites in Nepal as well as India in order that the flood damages are reduced appreciably.

On receipt of the forecast, its dissemination to the local population in terms of likely depth of inundation and its duration in the area by the Administrative Authorities is very important so that affected population, cattle, movable properties etc., are evacuated before the area gets submerged by flood waters thus causing much damage. For this a network of wireless stations and a telephone system are necessary in the basin near critical/vulnerable reaches of the embankments, towns, etc. specially where other means of communication are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the level indicated in the flood forecasts. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well-versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to life and property. This training programme should become a regular feature before the flood season every year.

8.13.3 Disaster Mitigation System and Preparedness

This is an important measure which directly influences the damage prevention, if managed effeciently, at all levels according to the prescribed procedures and guidelines. Improper management could also result directly in an increased damage. The Government should, therefore, ensure that all routine exercises and necessary drills are carried out systematically before every flood season and departmental instructions, manuals and rules in this regard should be widely circulated so as to make these available to all concerned. It is observed that the disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year. Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the officers and staff of the concened departments, as also in the public and voluntary organisations to deal with flood emergencies.

It is essential that the training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation . The training programe, including education and publicity, should be got arranged by the Civil Authorities with active participation of the Officers incharge of Flood Management and voluntary organisations.

The interpretation of distress codes and signals and flood warning messages being broadcast over the All-India Radio (Akashvani), Doordarshan or transmitted through other channels and the effective follow up of such messages into appropriate actions should be taught to all people in the flood-prone areas.

9 SUMMARY OF RECDMMENDATION

9.1 It is observed that hydro-meteorological data of the basin is not being observed, collected, analysed and documented in a systematic manner. The existing number of raingauge stations in India and Nepal portion is found to be sufficient as per standards laid down by the Bureau of Indian Standards both for ordinary as well as self-recording. But the number of self recording raingauge stations has to be increased to 20 percent both in the India and Nepal portion to be in line with the recommendations of the RBA. It presupposes an understanding between the HMG Nepal and Government of India for observation as well as regular exchange of such available data. In case of gauge and discharge sites it is felt very necessary that a system of systematic and regular collection of data from a well-designed network of stations as per standards laid down by the WMO/Bureau of Indian Standards be established in the catchment and the data be observed accurately in the prescribed manner processed, analysed and recorded properly for use in the planning of water conservation and water utilisation schemes in the basin. Government of India may be requested to take up the issue of establishment of adequate number of sites in the upper catchment in Nepal and exchange of hydrometeorological data of the basin between the two countries for their mutual benefits and use in future.

[Para 4.5 , 4.7.2]

9.2 In order to find out the total run-off during the monsoon period for planning schemes for drainage of accumulated water, it is necessary to determine the run-off factor applicable for the monsoon period as a whole. In order to conduct such study and analysis rainfall data for the stations spread over the entire drainage area of the basin and run-off data at suitable locations on the river for a sufficiently longer period are necessary. Rainfall data for the raingauge stations in Nepal could not be made available due to which rainfall-runoff relationship could not be established. The commission, therefore, suggests that the State Government should make all out efforts to collect the rainfall and run-off data in the basin for as many years as available and carry out further studies to stablish precise rainfall-runoff relationship at suitable locations on the Mahananda river basin for future use.

[Para 4.8.1 ,4.8.2]

9.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guidelines and instructions for implementation of the recommendations of RBA are reproduced below- "In the case of embankment, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile necessary step may be taken for eventual application of benefit cost criterion for fixing the design."

The summary of recommendations as accepted is as follows-

"In the case of embankment schemes, the height of the embankment and corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such time as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 year frequency in the case of predominantly agrivultural areas and for flood of 100 year frequency for works pertaining to down protection and protection of industrial and other vital organisations."

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for work pertaining to town protection of vital industrial establishments.

[Para 5.2.3]

9.4 FLOOD DAMAGE ASSESSMENT

It is observed that the flood damage statistics, which are essentially required for the benefit-cost studies for the proposed flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The Commission suggests that the recommendations of the RBA should be followed strictly and a realistic evaluation of flood damage, river basin-wise, should be carried out every year under the following three separately identified categories:

i Unprotected areas

ii Protected areas due to failure of protection works

iii Areas between the embankment and the river (on the river side).

The Water Resources Department dealing with flood management should be associated with collection and compilation of the flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned departments at the end of each year. This reconciled long-term data of flood damage is to be used in economic viability study of any future flood protection management scheme in the area.

[Para 6.3.4]

9.5 FUTURE APPROACH

The flood moderation effect of the contemplated reservoirs in the Mahananda river system having provision for flood storage specially across the Western Kankai river in the Nepalese territory is required to be studied in detail after proper field survey and investigation and analysis of the hydrometeorological data. As the work would be located in Nepalese territory, co-operation of the HMG Nepal would be necessary for joint exploitation of the prospective reservoir sites for mutual benefits of both the countries. It should be ensured that possible flood control and sediment control benefits are taken care of, besides power, irrigation and other benefits in the finalised projects, as mutually agreed upon.

[Para 8.5.3, 8.5.4 and 8.5.5]

9.6 The Government of Nepal has taken up the execution of the barrage across the western Kankai and is also contemplating to construct a storage reservoir on the upstream. It is, therefore, suggested that the Government of India be requested to obtain the necessary details of the above proposals from the Government of Nepal so that an integrated basin plan of flood management is prepared which might culminate into an understanding for a joint multipurpose project for mutual benefits of the two countries.

[Para 8.5.6]

9.7 Embankments on both banks of the main river and its tributaries with complementary sluices and regulators may be completed on a priority basis in the portions which are prone to flood spill at present. In order to provide protection against the flood spills coming from the Nepalese territory the embankments will have to be tied up to a high ground in the area (Nepalese territory). It is, therefore, necessary to move the Government of India for taking up this issue with the H.M.G. of Nepal for tagging the embankment to a high ground in Nepalese territory for mutual benifits of both the countries.

The embanked portion is threatened with breaches at certain vulnerable locations due to river bank erosion. The Commission recommends reassessment of design flood and checking of the adequacy of waterway between the embankments on both banks as per prevalent practices to be carried out in detail and to utilise the results of such detailed analysis suitably to tackle the problem of river bank erosion.

[Para 8.6.2, 8.6.4]

9.8 It has been observed that the flood embankments on the river Mahananda appear to have been sited too close to the banks in violation of the standard norms, causing river attack at various points and breaches in the embankments. It is, therefore, recommended that a physical model of the entire river reach, including unembanked portions in upper reach, be laid out in the Irrigation Research Institute, Khagaul and the river behaviour be studied every year after floods to evolve flood management measures to be undertaken in the unembanked reach, where as study of the efficacy and appropriateness of the alignment of existing flood embankments and type, design and locations of antierosion works is to be taken up before the next flood. If necessary, embankment should be retired suitably at some cardinal points in order to economise annual expenditure on antierosion works, etc.

[Para 8.6.6, 8.6.7]

9.9 It is necessary to undertake detailed study to find out the effectivness and adequacy or otherwise of the existing sluices in the embankments in the basin and remedial measures be taken on priority basis to make them function properly as and when necessary. If found necessary, more sluices may be provided for proper and efficient drainage of the countryside and also for providing irrigation to the areas on the countryside in case of drought.

[Para 8.6.3, 8.6.8]

9.10 The Mahananda basin has been bounded by the Kosi basin on the west. There exists a channel through which it is possible to divert part of the flood discharge from the Mahananda basin into the Kosi basin. The Parman is the right bank tributary of the Mahanada which joins the Mahananda near Bagdob. The Bhaisana river offtaking from a place near chainpur which is very close to Parman, joins the old Kosi dhar which meets the river Ganga on the upstream of Manihari. Prima facie, there appears a possibility of diverting some flood discharge from the Parman river to the Ganga through Bhaisama and the old Kosi dhar. It is, therefore, recommended that detailed investigation should be carried out to ascertain the possibility of diverting part of the flood water of the Parman river into the river Ganga. The quantum of such diversion should also be ascertained, keeping in view the carrying capacity of the channel after suitable resectioning and its technical feasibility and economic viability should be examined before taking final decision in the matter. If this scheme works out to be technically feasible and economically viable, the diversion channel has to be planned and executed so as to carry the diverted quantity of flood discharge within its bankful capacity to prevent any flooding of the area protected by the Mahananda embankment scheme.

[Para 8.7.1, 8.7.2]

9.11 Normally, the embankments of Mahananda have been designed for a 50 years flood frequency but floods of larger magnitude may come any time and cause breach at vulnerable locations causing greater damages to life and property. It is, therefore, suggested that either breaching sections or controlled escape structures should be provided at suitable locations to be decided after proper investigations and study of the contour map of the area along the embankment to reduce the pressure on the embankment by releasing part of flood discharge through such structures. Such excess flood discharge may be dropped in the same river further downstream. It is further suggested that detailed survey and investigations should be carried out for diversion of part of the flood discharge into Chaurs and Swamps which may function as detention basins during the period of high stages in the river such. Such waters accumulated during floods will have to be drained back to the river during the lower stage of the river so as to raise bumper Rabi crops as well as to reduce pressure on the embankments.

[Para 8.8.2, 8.8.3]

9.12 The Mahananda river basin is experiencing an acute drainage problem due to low bankful capacities of the river Mahananda and its tributaries, siltation of the river bed and inadequacy of waterways under the railway and road bridges.

For tackling the drainage problem in the Mahananda river basin, it is suggested that the river should be trained to form a single channel with sufficient waterways to pass the maximum flood discharge with safety by closing some of the existing spill channels, construction of marginal embankments providing spurs or other protective measures at appropriate locations making of new channels to fit in with the suitable alignment of the river course. The proposals of construction of barrages on the tributaries of the river and another proposal of a barrage near Bagdob on the river mahananda itself should be surveyed and investigated in detail and its technical feasibility and economic viability should be studied before taking final decision in the matter. The barrage near Bagdob is likely to serve the purpose of irrigation as well as divide the Mahananda discharge equitably between the Phulhar and Barsoi branches for the management of floods. It is further suggested that dredging can be employed at the bifurcation point near Bagdob which will improve the carrying capacity of the Barsoi branch.

[Para 8.9.1, 8.9.2]

9.13 Further studies, in continuation of the studies made by the GFCC, may be carried out to find out the inadequacy or otherwise of the waterways under the railway and road bridges in the basin which are responsible for drainage congestion in the area and further action of extending such inadequate waterways to the required size should be taken up and completed as quickly as possible for removal of drainage congestion caused by such structures.

[Para 8.9.3]

9.14 It has been observed that the Topra-Chaukia embankment is cut almost every year by the villagers due to the acute water logging problem in the lower reach of the Mahananda river basin in the Amdabad block of the Katihar district. It is reported that a drainage scheme envisaging construction of two sluices at ch 508.5 of Lava-Chaukia embankment and ch 473 of Topra-Chaukia embankment and link and trunk drains has been proposed by the Chief Engineer WRD Purnia. The Commission suggests that the scheme may be scrutinised and further action taken on it quickly for its implementation so that the problem of drainage congestion in the area is remedied.

[Para 8.9.4, 8.9.5]

9.15 Soil conservation and watershed treatment measures are likely to have a beneficial impact by way of reduction in the quantities of silt flowing into the river Mahananda and checking its meandering tendency. As such, an extensive programme of watershed management in the hilly catchment area in the Nepalese territory is considered necessary. Land treatment through afforestation and grass land development should also be supplemented by structural works in the upper catchment for retarding the velocity of water and detaining silt effectively. Such works would also increase the life of the proposed reservoirs. The cost and benefits of such works should be weighed critically alongwith constraints and difficulties mentioned in paragraph 8.10 above.

[Para 8.10]

9.16 A systematic survey and investigation of the existing embankments on both banks of the river is required to be carried out every year after the flood season and encroachment, if any, in the free-board in any portion should be made good by raising the height of the embankment correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of the results of the model studies to keep the flowing channel away from the embankment without causing any harm to other locations.

A suitable retired embankment should be constructed in the portion where embankment are eroded or likely to be eroded so that flooding of the protected area is arrested. The top of the embankments should have a water bound macadam road or at least be provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently during emergent situation.

[Para 8.11.2]

9.17 Occupation of embankments and land acquired should be got vacated effectively to avert any danger or risk to the people living in the protected area. Raised platforms above the highest flood level may be constructed in areas liable to inundation, near villages on Government or acquired lands. These could also be constructed on the countryside of the embankment abutting the same. Such platforms should preferably be connected with all-weather roads and should be provided with facilities to make living on them easy during floods. Such raised paltforms should be handed over to the Local Bodies/ Panchayats for being utilised as community property and kept free from encroachment.

[Para 8.12]

9.18 Flood plain zoning measures will be useful in both protected and unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. Such zoning regulations should be introduced in the unprotected areas first and for development in the protected areas henceforth. This is all the more mecessary in the present state of affairs in the basin where long term solution of the problem appears to be a distant goal because of the involvement of a foreign country. It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour interval of 0.3 m for implementation of this measure.

Flood risk maps of the basin may be prepared showing the areas likely to be flooded for different frequencies of floods, such as 100 years, 50 years and 25 years. Similar risk maps for submersion caused due to drainage congestion corresponding to a 50 years and 25 years rainfall may also be prepared.

[Para 8.13.1]

9.19 At present there are only two flood forecasting sites, namely, Dhengraghat and Jhaua in the Mahananda river system to cater for the forecasting needs of the embankment of the Mahananda river. It is however, felt necessary to install a few more flood forecasting sites in the basin with base station in upper catchments in Nepal so that adequate lead time is available for the flood forecasts in Indian territory to require adequate safety measures against that flood. The State Government may request the Government of India for installation of more sites, in Nepal as well as in India in order that the flood damages are reduced appreciably.

On receipt of the flood forecasts, its dissemination to the local population in terms of the likely depth of inundation and its duration in the area, by the administrative authorities is very important so that necessary action is taken before the area gets flooded causing damage. For this a network of wireless stations and telephone system are necessary in the basin near critical vulnerable reaches of embankments, towns, etc, specially where other means of communications are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address systems or in its absence by beat of drums.

Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the levels indicated in the flood forecasts. Necessary training in this regard should be imparted to the officials concerned on a regular and continuous basis before the flood season every year.

[Para 8.13.2]

9.20 It is essential that the training programme and exercises are held regularly to improve the disaster preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. Such training programmes should be got arranged by the civil authorities with the active participation of the officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over the All-India Radio (Akashvani), Doordarshan or transmitted through other channels and the effective follow-up of such messages into appropriate action should be taught to all people in the flood prone areas.

[Para 8.13.3]

Annex 1
[Para 2.3]

Salient Features of the Mahananda River System

Sl No	River		Reach from origin up to	L/R bank	Name of District	Length Km	Catchment area (Sq Km)	Remarks
1	2		3	4	5	6	7	8
1	Mahananda	i	At the confluence of Balason		Darjeeling W Dinajpur (W.B)	376	997	
		ii	Taibpur Railway Bridge		Kishanganj	1386		
		iii	At the confluence of river Mechi		Kishanganj	2507		
		iv	Dhengraghat		Purnia	7150		
		v	Up to Katihar-Barsoi railway section		Katihar	12114		
		vi	At the junction of Kalindri		Malda (WB)	19156		
		vii	Its outfall into the Ganga (Padma)		Bangladesh	23700		
2	New Balason		Outfall into Mahananda	R/bank	Darjeeling	41.8	264	
3	Old Balason		Outfall into Mahananda	R/bank	Darjeeling	44.4	456	
4	Mechi		Outfall into Mahananda	R/bank	Darjeeling/ Purnia	108.8	1054	
5	Dauk		Outfall into Mahananda	L/bank	W Dinajpur/ Purnia	97.2	717	
6	W Kankai		Outfall into Mahananda	R/bank	Purnia	211.2	3924	
7	E Kankai		Outfall into Mahananda	R/bank	Purnia	108.8	384	
8	Nagar		Outfall into Mahananda (Barsoi branch)	L/bank	W Dinajpur/ Katihar	151.3	1580	
9	Kulik		Outfall into Nagar	L/bank	-do-	54.1	1091	
10	Gamari		Outfall into Mahananda	L/bank	W Dinajpur/ Malda	43.1	1091	
11	Tangon		Outfall into Mahananda	L/bank	W Dinajpur/ Malda	142.3	2427	
12	Parman		Outfall into Mahananda (Near Bagdob)	L/bank	Purnia/ Katihar	163.5	3840	
13	Rajai		Outfall into Parman (Near Sorigaon)	L/bank	Purnia	34.1	707	
14	Bakra		Outfall into Parman (Near Rasilighat)	L/bank	Purnia	119.7	1603	
15	Noona		Outfall into Bakra (Near Dehatighat)	L/bank	Purnia	42.5	779	

[Source: Comprehensive Plan of Flood Management for the Mahananda river system prepared by the GFCC in June 1992.]

Annex 2
[Para 2.4]

Bed slope of the River Mahananda and its tributaries in different reaches

Sl no	Name of the Reach	Length (km)	Bed/Slope (m/km)	Remarks
A	**Mahananda**			
1	Origin to Siliguri	16	79.95	
2	Siliguri to Sonapurhat	37	1.57	
3	Sonapurhat to Taibpur Railway bridge	13.7	0.72	
4	Taibpur railway bridge to 7.5 km upstream of confluence with Dauk	32	0.54	
5	7.5 km u/s of confluence with Dauk upto 5.7 km d/s at Kuttighat	25.5	0.15	
6	5.7 km d/s at Kuttighat to Dhengraghat	23.3	0.44	
7	Dhengraghat to Bagdob	16.00	0.12	
8	Bagdob to Sobemaral (in Phulhar branch)	92.8	0.12	
9	Bagdob to Maharajpur (in Barsoi branch)	117.7	0.14	
B	**Chenga**			
C	**Mechi**			
1	Galgalia to ch 216	216 ch	0.50	
2	ch 216 to ch 432	216 ch	0.80	
3	ch 432 to ch 648	216 ch	0.50	
4	ch 648 to ch 864	216 ch	0.76	
5	ch 864 to ch 1080	216 ch	0.47	
6	ch 1080 to ch 1296	216 ch	0.53	
7	ch 1296 to ch 1512	216 ch	0.70	
8	ch 1512 to ch 1656	216 ch	0.40	
D	**Eastern Kankai**			
1	Indo-Nepal border near Garbandanga to ch 580	580 ch	0.74	
2	ch 580 to ch 1360 near Dhanpura road bridge	580 ch	0.41	
3	ch 1360 to ch 1890 at outfall into Mahananda	530 ch	0.39	
E	**Western Kankai**			
1	From Indo-Nepal border to the meeting place of	1.30		
	the two branches of Western Kankai namely Sikandra branch and Haribhitha branch at Birpur	0.70		
2	From Indo-Nepal border near Khuniabad to confluence with river western Kankai of Ratua tributary	0.44		
3	Birpur to confluence with Mahananda	0.21		
F	**Parman**			
i	**Noon tributary**			
1	Indo-Nepal border near Barmasia to Madanpur	0.40		
ii	**Bakra tributary**			
1	Indo-Nepal border near Majrakh to confluence with Parman at Rasailighat	3000 ch	0.28	
iii	**Rajai tributary**			
1	Indo-Nepal border to near Sonamani godown to confluence with Parman at Soirgean	450 ch	0.454	
iv	**Parman**			
1	Indo-Nepal border near Jogbani to LRP road bridge near Araria	2400 ch	0.22	
2	From LRP road bridge at Araria to confluence with Mahananda near Bagdob	3100 ch	0.16	
3	Rasailighat to confluence with Phulhar branch of Mahananda (Belagachi branch of Parman)	2750 ch	0.11	

[Source: Comprehensive plan of Flood Manangement for the Mahananda river system prepared by the GFCC in June, 1992.]

Annex 3
[Para 4.6.1]

Normal Annual Rainfall at various Stations in Bihar in Mahananda River System

Sl No	Site	Period of data analysis	Normal annual rainfall (mm)
1	Purnia	1891-1973	1492.6
2	Farbesganj	1892-1973	1535.8
3	Bahadurganj	1930-1973	1926.6
4	Barsoi	1891-1973	1331.1
5	Araria	1891-1973	1692.2
6	Kishanganj	1891-1973	2177.4
7	Manihari	1933-1973	1309.4

[Source: Comprehensive plan of Flood Management for the Mahananda river system prepared by the GFCC in 1987.]

Annex 4
[Para 4.7.2]

Yearly peak Gauge Data of the River Mahananda (Gauge in Metre) at different sites

Year	Taibpur	Mazabari	Dhengra-ghat	Bagdob (Jhaua) Br	Jhaua Rly Br	Barsoi Rly Br	Lava	English Bazar	Jhaua
1951	66.19	NA	NA	NA	NA	NA	NA	NA	NA
1952	66.34	"	"	"	"	"	"	"	"
1953	65.82	"	"	"	"	"	"	"	"
1954	66.79	"	"	"	"	"	"	"	"
1955	66.57	"	"	"	"	"	"	"	"
1956	65.67	"	"	"	31.19	31.92	"	"	"
1957	67.01	"	36.22	"	31.73	31.86	"	"	"
1958	66.24	"	37.33	"	31.67	31.90	"	"	"
1959	65.57	"	35.95	"	31.11	30.75	"	"	"
1960	NA	"	36.50	"	32.25	31.91	"	22.02	"
1961	65.15	"	35.77	"	31.83	30.89	"	22.48	"
1962	66.35	"	35.83	"	32.03	31.41	"	22.63	"
1963	66.06	"	36.37	"	32.15	31.47	27.95	22.69	"
1964	66.43	"	37 52	"	31.95	31.78	28.20	21.94	"
1965	65.76	"	38.11	"	31.87	31.47	27.78	21.26	"
1966	66.93	"	36.96	"	32.38	31.01	28.50	21.30	"
1967	66.34	"	36.35	"	31.64	31.31	27.81	21.43	"
1968	67.25	"	36.29	"	32.07	31.96	27.66	21.81	"
1969	65.73	"	36.12	"	31.34	NA	27.74	22.42	"
1970	65.75	"	36.35	"	32.21	"	27.95	22.18	"
1971	65.82	"	36.28	"	31.93	"	28.65	24.47	"
1972	66.25	41.04	36.53	33.30	32.03	30.77	27.71	20.11	"
1973	66.22	47.03	36.51	31.22	NA	30.60	28.53	21.90	"
1974	66.61	47.27	36.54	34.55	"	32.00	29.31	22.82	"
1975	66.38	46.62	36.26	34.05	"	30.84	28.92	20.68	"
1976	66.45	46.79	35.97	34.29	34.29	35.70	29.13	22.41	"
1977	66.76	46.80	36.38	35.51	34.51	31.75	29.46	21.39	33.40
1978	65.91	46.05	35.84	34.22	34.22	31.64	28.01	21.73	31.50
1979	66.11	46.87	N.A	35.08	35.00	31.35	28.95	20.94	32.42
1980	65.99	46.75	35.92	34.84	34.76	NA	29.28	22.90	31.83
1981	65.59	47.55	35.96	35.25	35.25	31.60	29.56	21.42	32.55
1982	65.89	46.25	35.79	33.50	33.50	NA	27.99	21.09	31.25
1983	66.61	46.48	35.60	33.85	33.70	NA	29.05	22.33	31.77
1984	66.50	46.72	36.30	34.10	34.10	31.04	30.24	22.26	32.51
1985	66.215	NA	36.252	NA	34.45	31.08	29.68	21.573	32.156
1986	65.99	"	35.695	"	NA	NA	28.775	21.573	31.496
1987	66.57	"	37.17	"	"	"	30.53	21.11	33.510
1988	66.875	"	36.43	"	"	"	29.955	23.57	32.080
1989	66.42	"	36.44	"	"	"	21.25	29.445	32.300
1990	66.3	"	36.13	"	"	"	29.08	21.20	32.020
1991	66.97	"	36.87	"	"	"	NA	NA	33.40
1992	65.50	"	35.16	"	"	"	"	"	30.62

[Source: Comprehensive plan of Flood Management for the Mahananda river system, prepared by the GFCC in June 1992 and Flood Report 1991 & 1992 by Water Resources Department Government of Bihar.]

Annex 5
[Para 4.7.2]

Yearly peak Discharge Data of the River Mahananda Discharge in Cumecs at different sites

Year	Taibpur	Mazabari	Dhengra-ghat	Bagdob (Jhaua) Br	Jhaua Rly Br	Barsoi Rly Br	Lava	English Bazar	Jhaua
1956	1154	-	-	-	1607	394	-	-	
1957	1293	-	-	-	1966	538	-	-	
1958	1135	-	-	-	2293	605	-	-	
1959	795	-	-	-	1149	391	-	-	
1960	-	-	-	-	2409	1330	-	2501	
1961	-	-	-	-	1450	350	-	2251	
1962	1220	-	-	-	2495	403	-	2246	
1963	1365	-	-	-	1127	713	2061	2606	
1964	1692	-	-	-	2247	1278	3185	1762	
1965	821	-	-	-	2264	753	2108	1428	
1966	1722	-	-	-	2246	1201	2125	1804	
1967	1284	-	-	-	2414	161	2270	1684	
1968	1597	-	-	-	4173	338	2769	1927	
1969	927	-	-	-	2504	-	1736	2552	
1970	705	-	-	-	2863	127	2976	2021	
1971	602	-	-	-	936	600	1480	4779	
1972	910	3061	2527	3720	2216	246	2185	948	
1973	1662	1888	2606	287	-	454	2413	1332	
1974	1570	1813	2437	2794	-	453	2534	2236	
1975	1181	1300	2217	4461	-	327	1892	1098	
1976	-	2575	1955	4500	4500	1664	2920	1882	
1977	-	1924	2461	4136	4736	183	3570	1353	
1978	-	1457	2810	4061	4062	281	2934	1143	
1979	-	2737	-	4627	4627	207	3300	1198	
1980	-	755	2748	4249	3940	-	2211	2318	
1981	-	3190	2710	6427	6426	8912	2430	1538	
1982	-	809	-	2898	2898	-	2652	905	
1983	-	1128	2698	4380	4053	-	4099	1451	
1984	-	1338	2683	5316	5012	1213	4436	1780	
1985	1542.3	-	-	2470	-	-	4720	1438.14	
1986	1314.8	-	920	-	-	-	1999.92	1450.55	
1987	1322.04	-	1930	-	-	-	2590	2852.74	
1988	2053.45	-	1960	-	-	-	6320	2346.88	
1989	1779.67	-	2320	-	-	-	7802.94	1294.66	
1990	1479.00	-	1920	-	-	-	5421.99	982.18	

[Source: Comprehensive plan of Flood Management for the Mahananda river system prepared by the GFCC in June, 1992.]

Annex 6
[Para 4.9.2]

Yearly Suspended Sediment Load Passing Through the River Mahananda at Taibpur from 1962 to 1970

Year	Suspended sediment Load in ha m
1962	249.152
1963	324.463
1964	318.351
1965	200.186
1966	255.929
1967	187.275
1968	185.253
1969	371.627
1970	289.355
Total	2381.630
Average	264.62

Average Monthly Total Suspended Sediment Load of the River Mahananda Taibpur in Average Year for the period from 1962 to 1970

Months	Total suspended sediment load in ha m
January	0.704
February	0.432
March	0.405
April	0.409
May	0.790
June	20.125
July	88.283
August	76.302
September	48.936
October	24.862
November	2.384
December	0.979

Annual Average Percentage Distribution of Graded Sediment Load for River Mahananda at Taibpur

Year	Percentage Graded Sediment to total sediment Load (per cent)			
	Coarse	Medium	Fine	Remarks
1962	34.384	54.394	11.221	
1963	34.702	63.798	1.498	
1964	30.698	67.035	2.266	
1965	26.725	49.553	23.92	
1966	36.519	45.146	18.334	
1967	38.626	42.084	19.288	
1968	37.540	52.192	10.267	
1969	20.121	35.219	44.658	
1970	8.207	16.203	75.589	
Average	29.72	47.27	23.01	

[Source: Comprehensive plan of flood Management for the Mahananda river system, prepared by the GFCC in June 1992.]

Annex 7
[Para 4.9.2]

Yearly Monsoon (July to October) surface Average Surface Runoff and Suspended Sediment Load Passing Through the River from 1963 to 1970 at English Bazar

Year	Runoff thousand ha m	CC/Litre	Total Sediment thousand ha m
1963	1487.972	12.77	18.85
1964	1074.087	15.735	16.91
1965	564.665	11.554	6.51
1966	593.173	12.429	7.36
1967	589.160	27.933	16.41
1968	1022.202	16.49	16.88
1969	1026.675	18.725	19.21
1970	933.563	10.296	10.20
Total	7351.497	Total	112.33
Average	918.937	Average	14.041

Average Monthly total Suspended Sediment Load of the River Mahananda at English Bazar during the Monsoon Period (July to October) from 1963 to 1970

Year	Runoff thousand ha m	CC/Litre	Suspended Sediment load thousand ha m
July	178.843	13.4984	2.41
August	348.722	21.7139	7.56
September	295.057	17.0445	5.03
October	152.225	8.5028	1.29

Annual average percentage distribution of graded sediment load for river Mahananda during the Monsoon period of 1963 to 1970 at English Bazar

Year	Graded Sediment to total Sediment Load (Per cent)			Remarks
	Course	Medium	Fine	
1963	1.38	4.54	94.1	
1964	0.18	0.69	99.23	
1965	0.80	3.85	95.45	
1966	0.75	1.92	97.33	
1967	0.39	8.94	90.77	
1968	1.29	10.21	88.50	
1969	1.23	8.74	90.03	
1970	3.19	12.05	84.76	
Average	1.15	6.37	92.48	

[Source: Comprehensive plan of Flood Management for the Mahananda River System, prepared by the GFCC in June, 1992.]

Annex 8
[Para 6.1.5]

HISTORY OF PAST FLOODS IN THE RIVER MAHANANDA IN BIHAR

The History of Past Floods is being presented here on the basis of flood records available since 1886. The flooding in the river system during years of heavy floods is briefly described as under

Year	Summary
1886	Heavy rains and floods had all but destroyed both cattle and man crops in Purnia district.
1892	Between Barsoi and Kishanganj there were 19 breaches in Rly track.
1906	There was more serious inundation in Bihar when both Kosi and Ganga were in High floods and Mahananda also rose high
1909	The Kishanganj sub-division of Purnia suffered severely from floods in June, some damage to crops was caused at the end of August by excessive rains and floods in Parts of Purnia.
1910	There was a high flood in July in the Panar in Purnia district but no damage was caused.
1917 & 18	There was some erosion on the right bank of the Panar which slightly damaged the spurs.
1922	Floods occurred in North Bihar which were mainly local.
1929 & 30	Floods damaged the crops of low-lying lands in certain areas of Purnia and Bhagalpur
1931 & 32	There were to some extent, heavy rains and floods in Purnia.
1933 & 34	There were excessive rains and floods in Purniad district.
1935 & 36	There was heavy rain in North Bihar in the second half of September (rainfall from 16th to 23rd September), nearly in the whole of the sub-mountaineous tract starting from Purnia in east to Saran in the west, ranging between 38.1 and 63.5 cm. It was more unusual to have such heavy rains so late in the season. Part of Purnia had severe flooding.
1937 & 38	There were floods in Bihar between June and September which affected the standing crops in Purnia district.
1938 & 39	The floods caused much distress to the people in Purnia district. The Jute crop was affected by excessive rains and floods in the district.
1949	The floods were reported this year in the Parman in Purnia district from the middle of June to the end of August. The depth of inundation was above 1.5 m, on an average. The whole area between the Parman and the Mahananda was flooded upto Bagdob.

1950 There were three floods in the river Parman in Purnia district between the Second week of July and the last week of August. The ar s south of Basantpur were flooded. The depth of inundation was 0.61 to 0.91 m. in the higher reaches. The water rose to the Peak gauge in 2 to 3 days and receded in about 10 days. Areas of about 166.40 Sq Km and 215.04 Sq Km along the eastern and western banks were flooded. The intensity was slightly severer than in 1949. But comparing with Kosi, this flood was minor. A survey report of Western bank of Mahananda in Purnia district showed that areas from Nepal border upto Bangora were flooded.

1951 The Parman river had three floods in Purnia district in middle of July and August. The floods were generally 0.305 m lower than the flood in 1950. Between Basantpur and Bangora, the flood water on the east mingled with those of Mahananda. An area of 26 Sq Km had 0.61to 1.22 m of water for about 2 months. Further south an area of 26 Sq Km. North of Jhaua railway station was flooded, the greater part of the flood being on the eastern side. The duration varied from about 1 to 3 months. The Mahananda had two floods in Purnia district in July and August. The flooding in the area began just north of Kishanganj and extended almost upto Bangora.

1952 The Parman had two floods in Purnia district in July and September. Lower down the waters of Parman and the Mahananda mingled causing greater damage on the eastern bank. An area of about 204.81 Sq Km experienced flooding of 0.61 to 0.91 m. Maximum duration of flooding was 3 months. The western bank had comparatively lower flooding. Both sides of the Ganga-Darjeeling road were under water. The Mahananda overflowed its banks three times in Purnia district. The flood was severe about 0.61 m higher than in 1951 and that was highest in the last 5 years. In the north, a strip of 3.22 to 6.44 km on the western bank was under 0.61 to 0.91 m of water for about 2 months and on eastern banks flood extended to about 1.6 km in width below Kishanganj.

1953 There was moderate flood in the Mahananda river system.

1954 In Purnia district the Mahananda and the other rivers were in spate recording the highest level.

1955 The floods in the river system caused less damage thatin 1954 though the peak gauge recorded was higher than in 1954 due to non-cynchronisation of the flood in the tributaries and main Mahananda river.

1956 In June a flood of mild intensity was caused in the Purnia district by the over-flooding of the river and also by accumulation of rain water the western Kankai flowing via Birpur shifted its course and came nearBahadurganj P.S. A completely new channel was carved out through village Plasmani, as a result of which about one fourth of the village Palasmani went into the river bed.

1967 The rivers were in floods, thus bringing about inundation in the districts of Purnia and Katihar. The total area inundated in Bihar was 2243 Sq Km.

1968 All the rivers were in high spate and flooded vast areas along the banks of the river. About 38 blocks of Purnia and Katihar were inundated. About 5745 Sq Km areas was affected by floods in Bihar.

1969 About 883 Sq Km area was inundated in Bihar.

1970 The rivers were in spate and about 1655 Sq Km area was inundated.

1971 Large areas of the river system were heavily inundated. The inundated area was 7002 Sq Km.

1973 Districts of Purnia and Katihar were flooded to the extent of 9974 Sq Km.

1974 Heavy floods were experienced in the rivers in Bihar and the total area innundated in the districts of Purnia and Katihar was 12,391 Sq Km.

1975 The area in the upper reaches of the river system experienced moderate flooding due to the spill of the tributaries. But lower reaches could be saved due to the timely closure of gaps in Mahananda embankment. The Belgachi-Jhaua embankment was cut by villagers near National Highway no 31 and thus flooded about 32 Sq Km of lowlying area in Purnia district.

1976 Due to breach between ch 80 to 82 in the left embankment of Phulhar branch below Jhaua on 21st morning, an area of 22 Sq Km in Bihar was flooded. 27 villages in Azamnagar block and 6 villages in Kadwa block with a Population of 18,500 were affected. Due to prolonged and heavy flood in the month of August, 1976 in the nagar, Kullick, seven Panchayats and 33 villages were affected in Barsoi block in Bihar along right bank of river Barsoi.

1978 Severe flooding occurred this year. The year experienced three waves of floods. At Dhengrghat, 153.4 mm of rainfall was recorded on 16.7.1978. The danger level was crossed at this site on 21.7.1978 and thereafter the river remained in high flood for the full month of July 1978.

1982 The year was particularly not affected by floods. However, severe erosion at dhabaul and breaching of embankment, were reported. A retired line was constructed and this prevented flooding of the countryside. The river is reported to have caused erosion of its embankment at numerous points.

1984 Fairly good amount of monsoon rain had occurred this year throughout the catchment. At Taibpur total monsoon rainfall of 1968 mm had been recorded. A flash flood at the begining of the monsoon season (mid June 84) came in the river and damaged the second retired line in left Mahananda embankment near Dhabaul on 17.6.84. At Jaki the level was above danger level for a number of days in the second half of July & third week of September. Left bank of Mahananda breached at Dhabaul on 17.6.84 making ultimately 884 m long gap in the embankment and submerged an area of 1200 ha in Katihar district. There was cut in the embankment in the right bank of the Parman also. The river mahananda also caused persistent erosion problems at Azamnagar, Sikatia etc.

1985 The left embankment was under severe attack at Govindpur-Sikatia and at Kursela. Heavy flood fighting works were carried out at these places to save the situation. The left Mahananda embankment was also attacked at Dhabaul, Ajamnagar and Baharkhal washing away the nose of spurs constructed at these places. Mahananda crossed warning level in the first week of July at Dhengraghat and in the second week of July at Jhawa and remained above warning level for 54 days and 50 days respectively at different intervals. It maintained water level above danger level for 15 days at Dhengraghat and 14 days at Jhawa and flowed above the red mark by 0.632 & 0.871 m respectively at these sites.

1986 In Jhawa Dilli-Diwanganj portion of the left Mahananda embankment, the existing anti-erosion works at ch 614 of the main embankment, at Azamnagar and at Baharkhal was damaged. In Jhawa-Belagachi portion of the right Mahananda embankment, anti-erosion works were damaged at ch 1007 at Kharsel and at ch 1004-1004.5. A major portion of the embankment at Govindpur over the right Mahananda embankment (Lava-Topra-Chaukia-Paharpur embankment) was eroded away.

1987 The river Mahananda crossed the danger level on 10th July 87 at Taibpur and Dhengraghat. The river flowed above danger level at Taibpur on 10.7.87, 2.8.87, & 4.8.87, 7.8.87 & 14.8.87 at Dhengraghat 10.7.87 to 11.7.87, 2.8.87 to 6.8.87, 11.8.87 to 18.8.87 and on 9.9.87 and at Jhawa from 11.7.87 to 12.7.87, 2.8.87 to 20.8.87, 9.9.87 to 10.9.87 and 13.9.87. The Mahananda crossed the previous highest flood (30.40 m in 1977) at Jhawa on 14.8.1987 at 07 hrs attaining 33.51 m level.

1988 The river first crossed the danger level on 9th July,88 at Dhengraghat, it also flowed above danger level at Dhengraghat on 22.7.88, 23.7.88, from 13.8.88 to 16.8.88, 23.8.88 to 1.9.88 and 7.9.88 at Jhawa from 24.8.88 to 2.9.88. Mahananda embankment was eroded at Chaukia-Paharpur, Kari Kosi and Jaunia.

1989 The Mahananda crossed the danger level at Dhengraghat and Jhawa on 16th June and remained above the danger level up to 20th June at Jhawa. It also flowed above danger level at Dhengraghat on 17.6.88, 19.6.88, 15.7.88 to 20.7.88, 5.9.88 to 8.9.88, 18.9.88 to 24.9.88, 28.9.88 to 2.10.88. The Lava-Chaukia-Paharpur embankment on right bank of Mahananda was damaged at Gobindpur slope of the Belagachi Jhawa embankment between 992 km to 998 km was also damaged. Ring bund at Ajamnagar also got affected.

1990 The Mahananda first crossed the danger level at Dhengraghat on 8th July and remained above the danger level up to 9th July. The river again flowed above the danger level (35.65m) at the same place from 19.7.88 to 21.7.88, 11.8.88 to 15.8.88 & on 27.8.88. The river also flowed above the danger level at the same place from 19.7.88 to 21.7.88, 11.8.88 to 15.8.88 & 27.8.88. The river also flowed above the danger level at Jhawa (31.40m) from 20.7.88 to 22.7.88 & 12.8.88 to 16.8.88. Thus, the Mahananda flowed above the danger level at Dhengraghat for 11 days and at Jhawa for 8 days. Spurs of the embankment at Zero chain near Baharkhal had been damaged in the first week of August '90 also, damage was caused to stud near Kharsel.

1991 There was moderate flood in this river. However, bank erosion took place below ch 715 near Govindpur and near Baharkhal site in Mahananda right and left embankment respectviely. Pressure was seen on the fourth retired embankment in Jaunia-Kursela embankment, which was protected by flood fighting measures. Right embankment of Mahananda was cut by the villagers near ch 655 Topara-Chaukia-Paharpur embankment was also cut by the villagers to drain out countryside water into the river Ganga.

FLOOD DAMAGE STATEMENT FOR THE MAHANANDA RIVER SYSTEM, BIHAR

Sl no	Year	Area affected in L ha	Damage of Crop Area in ha	Value in Rs lakhs		Damage of houses			Cattle lives lost nos	Human lives lost nos	Damage to Public utility in Rs lakh		Total damages in Rs lakh	
				At then current price	At 1991 constant price	Nos	Value in Rs lakh				At then current price	At 1991 constant price	At then current price 5+8+12	At 1991 constant price Col 6+9+13
							At then current price	At then constant price						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1966	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	1967	"	"	"	"	"	"	"	"	"	"	"	"	"
3	1968	3.19	0.16	216.61	1300.28	22621	8.22	49.34	2339	4	"	"	224.83	1349.62
4	1969	0.49	0.09	83.53	476.04	4356	45.53	259.47	3	2	0.69	3.93	129.75	739.44
5	1970	0.92	0.01	16.72	90.14	845	2.19	11.81	Nil	Nil	N.A	N.A	18.91	101.95
Total	1966-70	4.60	0.26	316.86	1866.46	27822	55.94	320.62	2342	6	0.69	3.93	373.49	2191.01
Average	1966-70	1.53	0.09	105.62	622.15	9274	18.65	106.87	781	2	0.69	3.93	124.50	730.34
6	1971	3.88	1.74	1284.53	6889.86	87148	143.4	769.16	1978	9	157.55	845.05	1585.48	8504.07
7	1972	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	1973	0.32	0.31	65.85	271.01	1276	3.17	13.04	Nil	1	NA	NA	69.02	284.05
9	1974	2.74	1.57	2081.8	6798.75	46264	59.60	194.64	4	5	"	"	2141.40	6993.39
10	1975	1.37	0.42	263.76	870.09	4560	13.49	44.50	1	1	"	"	277.25	914.59
Total	1971-75	8.31	4.04	3695.94	14829.71	139248	219.66	1021.34	1983	16	157.55	845.05	4073.15	16696.1
Average	1971-75	20.8	1.01	924.00	3707.43	34812	54.92	255.34	496	4	157.55	845.05	1018.29	4174.03
11	1976	1.88	0.45	243.75	860.66	12922	20.75	73.27	Nil	2	N.A	N.A	264.50	933.93
12	1977	1.17	0.13	47.99	148.75	5723	12.12	37.57	"	6	1.75	5.43	61.86	191.75
13	1978	0.66	0.11	114.46	358.06	10556	28.53	89.25	"	1	N.A	N.A	142.99	447.31
14	1979	0.48	0.16	44.06	129.94	1036	5.20	15.33	"	Nil	0.17	0.50	49.43	145.77
Total	1976-79	4.19	0.85	450.26	1491.41	30239	66.60	215.42	Nil	9	1.92	5.93	518.78	1718.76
Average	1976-79	1.05	0.21	112.57	374.35	7560	16.65	53.86	Nil	2	0.96	2.97	129.70	429.69

Annex 9 Contd

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	1980	1.81	0.88	576.59	1528.57	22803	108.64	288.00	Nil	Nil	22.87	60.63	708.10	1877.20
16	1981	1.43	1.03	347.88	807.09	5353	14.79	34.32	1	1	5.46	12.67	368.14	854.08
17	1982	0.16	0.11	336.3	742.64	7399	73.99	163.39	0	0	Nil	Nil	410.29	906.03
18	1983	2.47	0.45	143.43	283.02	7270	33.59	66.28	0	0	32.67	64.47	209.69	413.77
Total	1980-83	5.87	2.47	1404.20	3361.32	42825	231.01	551.99	1	1	61.00	137.77	1696.22	4051.08
Average	1980-83	1.47	0.62	351.05	840.33	10706.25	57.75	138.00	0.25	0.25	15.25	34.44	424.05	1012.77
19	1984	7.96	1.33	2334.67	4192.01	3550.86	166.32	294.64	N.A	1	184.04	330.45	2685.03	4821.10
20	1985	0.73	0.10	56.29	98.49	2745	5.16	9.03	"	1	NA	NA	61.45	107.52
21	1986	0.44	0.21	126.87	211.25	2155	8.19	13.64	"	20	4.13	6.88	139.19	231.77
22	1987	0.85	2.80	7079.78	10145.32	164612	1266.84	1815.38	843	53	7094.12	10165.87	15440.74	22126.57
Total	1984-87	9.98	4.40	9597.61	14647.07	524598	1446.51	2136.69	843	75	7282.29	10503.2	18326.41	27286.96
Average	1984-87	2.50	1.11	2399.40	3661.76	131149.50	361.63	534.17	843	18.75	2427.43	3501.07	4581.60	6821.74
23	1988	1.75	0.47	935.14	1237.54	287	2.84	3.76	2	5	NA	NA	937.98	1241.30
24	1989	2.77	0.34	252.74	313.21	1225	12.06	14.94	2	3	12.98	16.08	277.78	344.23
25	1990	2.09	0.06	4.65	5.29	586	7.19	8.17	NA	NA	2.22	2.52	14.06	15.98
26	1991	1.15	0.42	214.46	214.46	7329	82.15	82.15	4	8	2.72	2.72	299.33	299.33
Total	1988-91	7.76	1.29	1406.99	1770.5	9427	104.24	109.02	8	16	17.92	21.32	1529.15	1900.84
Average	1988-91	1.94	0.32	351.75	442.63	2356.75	26.06	27.26	2.67	5.33	5.97	7.11	382.30	475.21
Total	1966-91	40.71	13.35	16871.86	37972.47	774159	2123.96	4355.08	5177	123	7521.37	11517.2	26517.2	53844.75
Average	1966-91	1.77	0.58	733.56	1650.98	33659	92.34	189.35	272.47	5.6	537.24	822.65	1363.14	2662.98

Annex-10
[Para 8.6.2]

PROPOSED EMBANKMENT IN THE MAHANANDA RIVER SYSTEM

Sl	River	Name of Scheme	Length km
		Parman River system	
1	Parman	Parman right embankment from Indo-Nepal border to Bagdob	90
2	Parman	Parman left embankment from Jogbani road bridge to Bagdob	83
3	Parman/Rajai	Rajai right embankment from Indo-Nepal border to Soirgaon	10
4	Parman/Rajai	Rajai left embankment from Indo-Nepal border to Soirgaon	10
5	Parman/Bakra	Bakra right embankment from Indo-Nepal border to Barbatta	51
6	Parman/Bakra	Bakra left embankment from Indo-Nepal border Barbatta	51
7	Parman/Noona	Noona right embankment from Indo-Nepal border to Dehtighat	21
8	Parman/Noona	Noona left embankment from Indo-Nepal border to Dehtighat	22
			338
		Western Kankai river system	
9	W Kankai	W Kankai right embankment from Indo-Nepal border to Bagdob	77
10	W Kankai	W Kankai left embankment from Indo-Nepal border to Gauihar	67
11	W Kankai/Ratua	Ratua right embankment from Indo-Nepal border to Gosainpur	27
12	W Kankai/Ratua	Ratua left embankment from Indo-Nepal border to Gosainpur	26
			197
		Eastern Kankai river system	
13	E Kankai	E Kankai right embankment from Indo-Nepal border to Kuttighat	48
14	E Kankai	E Kankai left embankment from Indo-Nepal border to Kuttighat	45
			93
		Mechi river system	
15	Mechi	Mechi right embankment from Indo-Nepal border to Rupadharghat	23
16	Mechi	Mechi left embankment from Galgalia to Rupadharghat (Bihar)	36
			59
		Main Mahananda river	
17	Mahananda	Mahananda right embankment from Bihar-West Bengal border (Sonapurhat to Gaurihar) Bihar	78
18	Mahananda	Mahananda left embankment from Bihar-West Bengal border (Sonapurhat to Lalbari and from Jalkola to Telta) Bihar	86
19	Mahananda/ Phulhar Br	Phulhar right embankment from Bagdob to Jhawa	19
20	Mahananda/ Barsoi Br	Barsoi left embankment from Barsoi to Subarnpur (Bihar)	24
21	Barsoi Br/ Nagar	Nagar right embankment from Balrampur-Raiganj road to Subarnpur (Bihar)	26
			233

Annex-11
[Para-8.9.3]

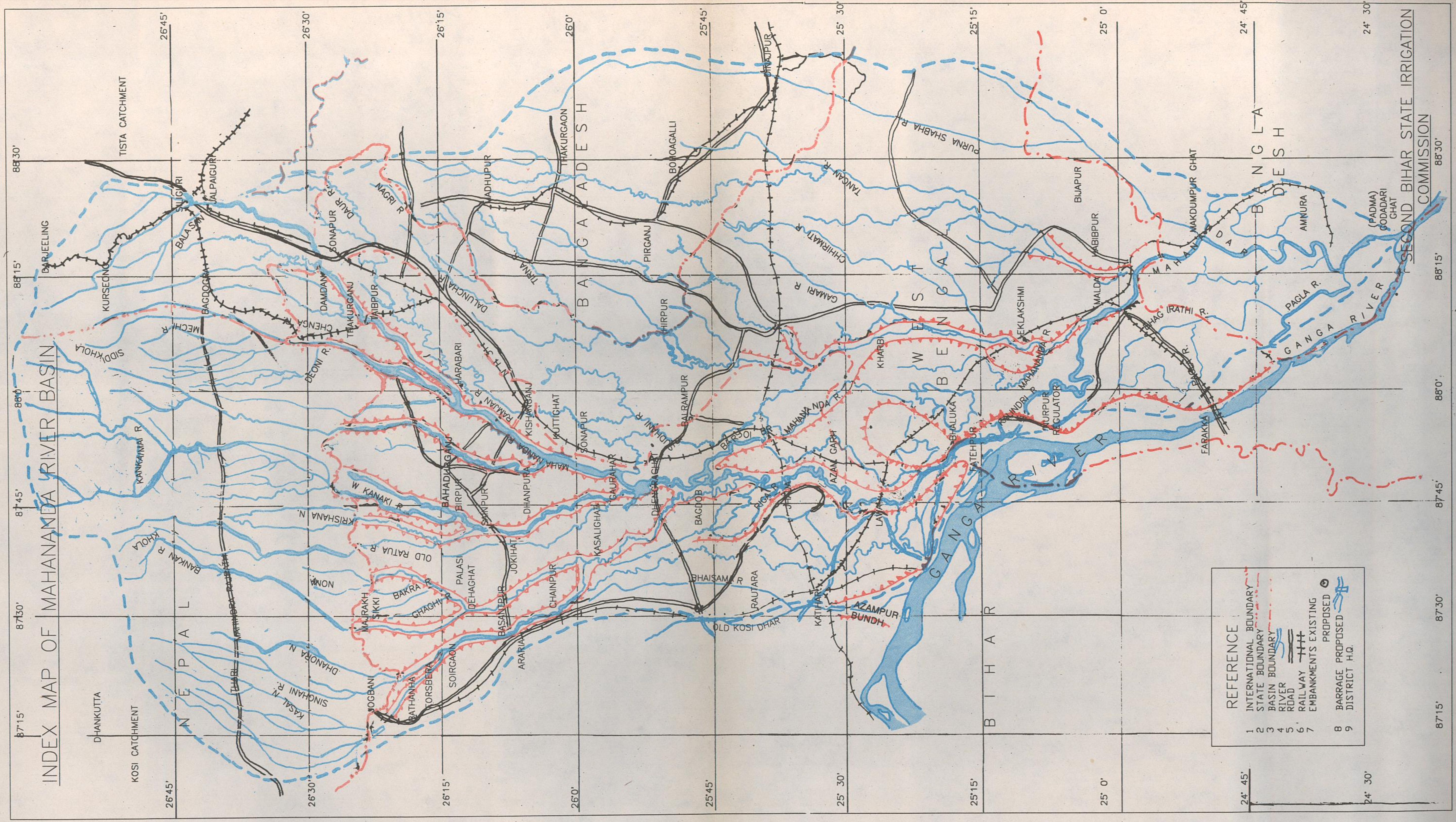
SUMMARY OF RECOMMENDATIONS OF THE TECHNICAL EXPERT COMMITTEE ON DRAINAGE AND WATERWAYS OF RAILWAY AND ROAD BRIDGES IN NORTH BIHAR (1967)

Sl No	Name of Road and Railway	Extension of waterway			Constn of New bridges			Remarks
		Exisiting	Extra proposed	Milage	Exisitig w way	Total required	Milage	
1	2	3	4	5	6	7	8	9
	Road							
1	Araria-Bahadurganj -Galgalia Road	Nil			The water way provided is adequate			
2	Purnea-Garbanaili Sontha-Kishanganj Road				N.A	220	0-6	Milage measured from Purnea. Net waterway recommended is total required as at Col 6 waterway existibg in a particular reach..
					"	760	6-10	
					"	680	10-14	
					"	600	14-17	
					"	530	17-20	
					"	180	20-28	
					"	750	28-31	
					"	140	31-34	Paralled and close to the proposed embankment (Milage measured for Purnea).
					"	990	34-36.5	
					"	320	2-8	
					"		8-18	
3	Purnea-sonaly Bazar Azamgarh Barsoi-Balrampur Road.				"	190	18-30	
					"	1050	30-31	
					"	180	31-39	
					"	410	39-40	Net waterway recommended is total required as at Col 6. Waterway exisiting in a particular road.
						170	40-50	
4	Purnea/Dhengraghat -Darjeeling Road (NH 31)	–	Nil	–	The waterwy provided is adequate			
5	Kishanganj-Taibpur Thakurganj-Galgalia Road	423	137	6-7	25	27	–	On Donk nala (in 1966 there has been over topping spills in millage 13, 18, 19, 20, 21, 24, 25, 27 & 31) and on the Mahananda at Taibpur.
6	Katihar-Amadabad Road				NA	280	0.9	Ghasla crosses at mile 5th in 1966 there has been damaged to wooden bridge at mile 5th & 6th
7	Araria Sikti Road				NA	270	9-18	Local catchment
						450	5-6	Danaskila Crossing spills of Danaskhila
						260	9-10	
8	Jokihat Palasi Dahibhat Road				NA	450	16-17	Rahia Nala crossing
					Total		8880	

Annex-11 Contd

1	2	3	4	5	6	7	8	9
	Railways							
1	Katihar-Jhaua Baroi Section	900	Nil	1105 to 109.5	NA	210 650	102-99	Between the proposed embankment The milage starts from Siliguri. An extension at 180' is required on the basis at lacey PW.But by area velocity method existing w/w is adequate with afflur of about 1.25'
2	Katihar-Lava-Malda Section	900	Nil	16-17				The milage starts from Katihar. Between the proposed embankment. Extension of 180' is required on the basis of lacey PW, but by area velocity method existing w/w is adequate with afflur of about 0.3'.

[Source: Comprehensive plan of flood Management for the Mahananda river system Prepared by the GFCC in June, 1992.]



DRG. 7/01
INDEX MAP OF MAHANANDA RIVER BASIN
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NEPAL
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MALDA
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DINAJPUR
PURNA SHABHA R.
TANGAN R.
NAGRI R.
DAUK R.
PAGLA R.
BHAGIRATHI R.
MAKDUMPUR GHAT
GODADARI GHAT (PADMA)
AMNURA
FATEHPUR
MANIHARI
88°30'
88°15'
88°0'
87°45'
87°30'
87°15'
26°45'
26°30'
26°15'
26°0'
25°45'
25°30'
25°15'
25°0'
24°45'
24°30'

APPENDIX 8

SONE BASIN

AT A GLANCE
PLAN FOR FLOOD MANAGEMENT IN THE SONE RIVER BASIN (IN BIHAR)

I	Salient Features of the Basin			
	1	Total Drainage Area	70,228	sq km
	2	Drainage Area in Bihar	15,820	sq km
	3	Population in Bihar	40.50	lakh (approx)
	4	Water Resources (Surface)	17,935	MCM
	5	Average Annual Rainfall	1,350	mm
	6	Total Length of Main River	881	km (226 km in Bihar)
	7	Cropped Area in Bihar	652857	ha
II	Flood Damage (Average for 24 years (69-93)			
	1	Total Area Affected	0.52	Lha
	2	Cropped Area Affected	0.206	Lha
	3	Damage to Crops	Rs 450.88	Lakh
	4	Total Damage	Rs 687.93	Lakh
	5	Human lives lost	23	Nos
	6	Cattle Heads Lost	12	Nos
	7	Average Population Affected (1984-92)	2.09	Lakh
III	Progress of Flood Protection Measures (1954-92)			
	1	Length of Embankments	52	km
	2	Length of Drainage Channels	NIL	
	3	Towns/Villages Protected	2	(one town + one village)
	4	Areas Protected	0.21	Lha
	5	Total Expenditure (1954-92)	Rs	398.45 lakh
IV	Eighth Plan Proposals (1992-97)			
	1	Length of Embankment	98	km in the State
	2	Additional Area to be Benefited by Flood Control, Drainage and Anti Water Logging Measures	1.00	Lha in the State
	3	Total Outlay for Flood Control Measures in the State	Rs	35.230 Lakh.

AN APPROACH TO THE PROBLEMS OF FLOOD AND DRAINAGE CONGESTION AND REMEDIAL MEASURES IN THE SONE RIVER BASIN(IN BIHAR)

1 INTRODUCTION

1.1 The Ganga sub-basin which extends over an area of 8.614 Lakhs Sq Km within India is the largest river basin in the country and is a part of the main Brahmaputra-Meghna-Ganga river basin. Flat terrain, high intensity of rainfall and poor drainage conditions combine to cause flooding and drainage congestions almost every year in a large part of this sub-basin, particularly in the portions lying in the Eastern Uttar Pradesh and Bihar. The flood damage in this sub-basin accounts for a major part of the total flood damage of the country.

1.2 The State of Bihar is situated in the central portion of the Ganga sub-basin. The portion lying on the northern side on the left bank is known as North Bihar and that lying on the southern side on the right bank is known as South Bihar. The northern region has a very flat topography and is subject to serious flooding almost every year. A number of major tributaries like the rivers Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc which originate from the Himalayas, join the river Ganga in this region. The southern region has a steeper slope in upper region while the slope is 1latter in lower portion causing flood in that portion. A number of tributaries like the rivers Karamnasa, Sone, Punpun, Kiul-Harohar, Badua-Chandan etc join the river Ganga in this region.

1.3 The major rivers joining the Ganga on left bank such as the Gandak, Ghaghra, Bagmati, Kosi, Mahananda etc flow through a considerable length in Nepal. Large part of their catchment areas fall in the glacial regions of the great Himalayas. As such they are snowfed and hence perennial.The important rivers joining Ganga on right bank are the Karamnasa, Sone, Punpun and Kiul-Harohar. These rivers, originate from non-glacial hills and are non-perennial in nature. The river Sone, which flows through the states of Madhya Pradesh, Uttar Pradesh and Bihar, joins the river Ganga at Maner 32 Km upstream of Patna. It is one of the most important right bank tributaries of the river Ganga and has a total catchment area of 15818 Sq Km in Bihar.

1.4 Floods and droughts are regular features in the State of Bihar due to vagaries of climate and rainfall. While one part of the State is under the grip of severe floods due to excessive rainfall, the other part suffers from drought due to poor and unevenly distributed rainfall.

1.5 Floods have caused devastations and acute human sufferings too frequently since the dawn of civilization and the man has had to live with floods since his existence. The impact of floods was not perhaps felt to the same extent in the past as is felt now. This was due to the fact that much smaller number of people were living and pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem has been accentuated due to over increasing encroachments on the flood plains by the growing population to meet its requirements of food and fibre. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements have also caused changes in river regime. All these have resulted in an anomalous situation where, inspite of the protection measures carried out so far in the state with an investment of Rs 611 crores (approx) and 28.34 Lakh ha having been afforded reasonable degree of protection, the flood damages have gone on increasing instead of decreasing.

2 THE SONE BASIN

2.1 The river Sone originates from Amarkantak high lands in the Maikala range of hills in the Bilashpur district of Madhya Pradesh at an elevation of 640 metres (above MSL) at Lat 20° 44'N and Longitude 82°04'E. The location of the origin is known as Sonebhadra. The river Sone bears its name from the golden colour of sand which it carries. The total length of the river is 881 Km, out of which 574 Km falls in the State of Madhya Pradesh, 81 Km in UP and 226 Km in Bihar. At origin, the river flows in northern direction for a short length, then north-west direction and passes through the district of Shahdol (MP) where many streams join it on either sides. An important left bank tributary, the Johilla, meets it near village Borawali. Up to the confluence of Johilla, the river Sone is known as Upper Sone. Then the river flows in meandering condition upto Sarai where the river Mahanadi joins it. At this point, the river takes an acute angle turn and flows in the north-east direction forming boundaries between Satna and Shahdol districts of Madhya Pradesh. Then the river Banas forming boundaries between Shahdol and Sidhi districts meets it just upstream of Demba. Flowing through the Sidhi district it receives the river Gopad at Burdi which is on the upstream of the Kuldah bridge. The river then runs west to east and enters Uttar Pradesh. Here the river Rihand meets it just upstream of Chopan. The river Ghaghar joins it on its left bank on the downstream of Chopan. Another important tributary of the Sone is the river Kanhar which flows south to north in its upper reach and in the middle reach almost forms the boundary of Bihar and MP, after which it enters UP and outfalls in the Sone, 6 Km east of Chopan. Below its confluence with the Kanhar, the river Sone enters the State of Bihar and after traveling about 46 Km in Bihar, the river North Koel joins on its right bank near Haidar Nagar. The river thereafter takes a sharp north-east turn and finally joins the river Ganga 16 Km upstream of Danapur at latitude 25°44' N and longitude 84°42' E.

2.1.1 The river North Koel which is the second largest tributary of Sone originates in Ranchi district at an elevation of 900 m, Latitude 23° 04'N and Longitude 84° 28'E, 48 Km above Netarhat town. In the beginning, the river flows in northern direction through the narrow valley of Bishunpur in Palamu district and thereafter turns towards west and flows for about 32 Km. It then takes an almost right angle turn through a gorge at Kutku and flows in north-east direction upto its confluence with Auranga. It then flows towards north-west and is met by the Amanat river downstream of Daltenganj. After flowing for another 30 to 40 Km in this direction, it turns towards north and meets the river Sone at an elevation of 140 m in Palamu district, a few Kms north-west of Haidar-Nagar, opposite the famous fort of Rohtasgarh (Latitude 24°30'N, Longitude 83°55'E). The total length of the river is 235 Km and it drains an area of 10574.36 Sq Km. It has three important tributaries, namely the Auranga, the Amanat and the Tahle.

2.2 The Sone river system drains a total catchment area of 70228 Sq Km which spreads over the states of MP, UP and Bihar having catchment areas as 48,831 Sq Km, 4911 Sq Km and 15820 Sq Km respectively. The Sone catchment in Bihar including North Koel is spread over the districts of Palamu, Gumla, Lohardaga, Hazaribagh, Aurangabad, Jehanabad, Bhojpur, Rohtas and Patna. The upper catchment of this river lies in hilly region while lower portion falls in alluvial fertile lands. Though eight major tributaries join the river Sone on either banks, North Koel is the only river the entire catchment area of which is located in Bihar. The Kanhar is the other tributary having a total catchment area of 5904 Sq Km, out of which about 1097 Sq Km lies in Bihar State.

2.3 The Sone basin in Bihar is bounded by the Ganga in the north, Sankh-South Koel-Karo river system and Madhya Pradesh state boundary in the south, Punpun, Kiul-Harohar, South Koel-Karo and Damodar river basin in the east and UP Bihar border and the Karmnasa river basin in the west. The upper portion of the North Koel catchment lies in hilly region and the rest portion of the Sone river system in Bihar lies in flat terrain. The slope of this river near its confluence with the Ganga is of the order of 0.5 metre per kilometre.

2.4 The important places of Bihar falling in the drainage area of the river Sone are Daltenganj, Garhwa, Japla, Banjari, Rohtas, Indrapuri, Dehri-on-sone (Dalmianagar), Aurangabad, Barun, Nasriganj, Bihta, Koelwar, Maner etc Garhwa, Daltenganj, Dalmianagar, Nasriganj etc are some of the important commercial centres in the Sone basin in Bihar.

2.5 Different rivers of the Sone-drainage basin are described below:-

Table No 1

Sl No	River	Bank (Left/Right)	Origin	Outfall	River Condition
1.	Johilla (242.5 Km)	Left	Maikal range in MP Altitude-1080m Lat. 22°42'N Long. 82°16'E	Borawali (MP)	Drainage channel
2.	Mahanadi (246 Km)	Left	Mandala Dist in MP Altitude-670m Lat. 28°07'N Long. 81°59'E	Sarai (MP)	Drainage channel
3.	Banas (165 Km)	Right	Vindhyan mountain in MP Alt. 800m Lat. 23°32'N Long. 81°54'E	Demba (MP)	–do-
4.	Gopad (252 Km)	Right	Surguja in MP Alt. 200m Lat. 23°32'N Long. 32°32'E	Burdi Village (MP)	-do-
5.	Rihand (322 Km)	Right	Surguja in MP Alt. 900m Lat. 22°38'N Long. 83°00'E	Chopan (UP)	–do-
6.	Ghaghar	Left	Mirzapur in UP Alt.560m Lat. 24°33'N Long. 83°23'E	D/S of confluence of Rihand with Sone (UP)	-do-
7.	Kanhar (252 Km)	Right	Surguja in MP Alt. 960m Lat. 23°03'N Long. 83°55'E	6 Km east of Chopan (UP)	-do-
8.	North Koel (235 Km)	Right	Ranchi Dist in Bihar Alt. 900m Lat.23°04'N Long.84°28'E	Palamu Dist N-W of Haidar Nagar, opposite Rohtasgarh fort (Bihar)	-do-

2.6 The Sone river system is a significant part of the Ganga Sub-basin and also an inter state river system. The upper reaches of the river Sone traverses through hilly tracts and steep slopes whereas the lower reaches runs through the alluvial fertile lands of the Gangetic plain.

2.6.1 The Sone river basin falls in the semi-humid region with considerable variation in temperature, humidity and other meteorological parametres. North-westerly winds of Arabian sea affect the rain greatly. The average temperature in the catchment is 26.4°C the lowest being 0.9°C in January at Hazaribagh and the highest being 44.8°C in June at Gaya. The average annual relative humidity is 65.08 per cent. The annual maximum and minimum mean daily sunshine duration in the catchment is 8.2 and 7.7 hrs respectively. The annual average wind speed varies from 4.5 Km/hr to 7.7 Km/hr. The highest observed is 10.2 Km/hr in the month of May and the lowest is 2.5 Km/hr in the month of December. The Maximum and Minimum annual evaporation in the basin in Bihar are 1533 mm and 1358 mm respectively, of which, about 28 per cent takes place between March to May.

2.7 ECONOMICS

2.7.1 The total population of the basin in Bihar as per 1991 census report is about 40.50 Lakhs which is expected to cross 50 Lakhs mark by the end of the year 2000 AD with a growth rate of 23.49 per cent per decade. The density of population of the basin in Bihar is about 256 persons per Sq Km against State average of 497. About 91 per cent population lives in rural areas and about 9 per cent of the population live in urban areas.

2.7.2 The important industrial places in the Sone catchment in Bihar are Dalmianagar, Dehri-on-Sone, Japla (Cement Factory) and Banjari (Kalyanpur Cement Works) etc. The Dalmianagar industrial complex had got great importance in the previous years due to being a production centre of sugar, cement, vanaspati,paper and asbestos etc. The catchment is rich in minerals and basic raw materials needed for industrial development. In view of the availability of these raw materials, there is good scope of setting up of industries based on cement, ceramics, pig-iron and refractories in the catchment of this basin. The basin has a bright future for industrial development due to likely availability of good power potential (both hydel and thermal).

2.7.3 The important highways and railways lying in the basin in Bihar are indicated below :-

Highways:

1 Grand Trunk Road (G T Road) NH 2

2 Dehri-on-Sone-Indrapuri-Banjari-Rohtas fort-Kadwan-Belauri (on UP border) – Chopan

3 Ara-Mohania Road

4 Patna-Bihta-Bikram-Aurangabad-Daltenganj Road

5 Patna-Ara-Bikramganj-Sasaram Road

6 Bikramganj-Nasriganj-Dehri Road

Railways: (Eastern Railway)

1 Howrah-Moghalsarai Grand Chord Section (part)

2 Dehri-on-Sone-Barawadih Section

3 Danapur-Moghalsarai Section (part)

2.7.4 The entire Sone basin has got tremendous capacity of generating hydro and thermal power due to favourable topography, abundance of coal and ready and cheap source of water. Apart from Rihand and Obra reservoir projects in Uttar Pradesh which have existing generating capacity of 105 MW, and 33 MW respectively, the Bansagar reservoir (in MP) and the North Koel reservoir in Bihar having hydel power capacity of 227 MW and 24 MW respectively are under advance stage of constructions. Lots of thermal power stations have also come up around the basin in MP and UP. The Sone Canal systems in Bihar is likely to generate about 30 MW of power from different falls depending upon the availability of the desired full supply discharge in the canals. Hydel Power to the extent of about 3.82 MW are already being generated in the Sone Main Canals. The total hydro power potential of the existing, ongoing and proposed hydel projects in the entire basin is around 610 MW. The total thermal power potential in the Sone basin has been estimated as 25,000 MW.

2.7.5 In Bihar the irrigation system in Sone basin was developed after construction of an Anicut at Dehri on the river Sone with a network of Canals in 1874. Subsequently the old and outlived Anicut was replaced by construction of a barrage at Indrapuri in 1967-68. This system provides annual irrigation to about 7.679 Lakh ha of land. The culturable command of the system is 6.242 Lakh ha.

North Koel and Auranga reservoir schemes are under execution and Kanhar, Amanat, Tahle and Kadhwan reservoir projects are proposed for early execution for providing irrigation benefits to the drought prone areas of the Aurangabad and Palamu districts besides enabling the use of Bihar's share of water in the Sone Basin in accordance with the Bansagar agreement for its use for stabilising irrigation in the existing Sone Command area.

The scheme for Modernisation of the Sone canal system at an estimated cost of Rs 1425.43 crores (1985-86 price level) is in the pipeline for securing external aid for its execution. Chausa Pump Canal scheme (already completed) and Zamania Pump Canal scheme (under execution) are meant for utilisation of the Ganga waters in the tail ends of the existing Sone Command.

2.7.6 Ground water potential is an important factor to be considered while planning for optimum utilisation/management of the available water resources of a river basin. It is an important source of irrigation in India especially in the alluvial plains where there is paucity of suitable surface water storage sites. Its mode of occurrence mainly depends on the type of formation ie geology of the area.

The total ground water potential of the basin is 1,72,492 Ha m out of which 23,058 Ha m is reserved for domestic and industrial uses and 53,917 Ha m is available for irrigation purpose. So for only 16,142 Ha m have been tapped for irrigation uses and the balance 1,18,575 Ha m is still available for future such use.

2.8 The following is the land use pattern in the Sone river basin in Bihar:

Table No 2

Land Use Pattern (Sone basin) in Bihar

Sl No		Category		Area in ha	% of total area
1		Geographical area		15,82,830	--
2		Forest land		5,76,638	36.45
3		Land under miscellaneous trees and grooves		6,961	0.44
4	(a)	Current fallows	2,21,570 }		
	(b)	Other fallows	1,40,957 }	3,94,339	24.93
	(c)	Culturable waste	31,812 }		
5		Net area under cultivation		4,31,287	27.26
6		Barren lands & Permanent pastures		80,096	5.06
7		Area under non-agricultural use		92,709	5.86

Paddy and Rabi (Wheat, Gram etc) are the principal crops in the area.

3 GEOLOGY

3.1 The upper portion of the Sone river basin is full of hilly tracts while lower portion is of alluvial soils. The geological study of the river system reveals existence of all variety of rocks from igneous and metamorphic to sedimentary and semi-consolidated to unconsolidated alluvium and of all ages from the oldest Archaean to the most recent.

3.2 The hill features of the river system is unique in character. A long arcuade belt of quartzitic to schistose rocks of Bijawar affinity extends from the NE corner of Jabalpur district, broadening ENE and estwards through the Sone basin as far as the western edge of Palamu district of Bihar. To the south, it is bounded in the middle by Archaean gneissic granite, overlain at both ends by Gondwana group of rocks. To the north, it is overlain by lower Vindhyan rocks intervened by gneissic belt in the central part. The lower elevations of the Sone basin are occupied by granite, gneiss, quartzites, slates, chlorite schists, porcellanite, sand stones, shales and limestone mainly. The higher elevations are occupied by up-Vindhyan-sandstones, Deccan Trap rocks, laterite etc. Gondwana rocks are present on both ends.

3.3 The Sone river system in its catchment has huge quantity of rich minerals of which the two most important ores ,coal and limestone are available in abundance. The other minerals like Dolomite, Bauxite, Asbestos, Fireclay and China clay, Pyrite, Graphite, Zinc etc are also found in small quantities in Bihar portion of the basin.

3.4 SOIL CLASSIFICATION

The catchment of this river system in Bihar consists of red loam soil followed by alluvial, forest and hill soils. The characteristics of these soils are given below -

3.4.1 Red Loam Soils

The red loam soil is derived from metamorphic rocks and from acidic rocks like Biotite gneiss. The p_H value ranges from 5.0 to 8.0. The red colour of the soil is due to iron and other compounds. The red soil has low water holding capacity. This is profitable for different types of crops such as wheat, cotton, bajra, pulses and vegetables.

3.4.2 Alluvial Soils

Alluvial soil is fertile soil and its colour varies from pale brown on the surface to dark brown underneath.The soil is very deep, well drained slightly acidic (p_H = 7.0 to 9.0) and low to medium inorganic matter. This soil has fairly good water holding capacity. Alluvial soil is fertile and responds well to irrigation and fertilizers.

3.4.3 Forest and Hill Soils

The colour of the forest and hill soil are brickish red to brown. These soils are fertile containing more of nitrogen and organic compounds. These are found in neutral to slightly acidic conditions but contain bases in abundance. These soils are suitable for vegetable and fruit growth.

4 HYDROLOGY

4.1 The Sone river basin is the major sub-basin of the river Ganga. On account of the location of the catchment being situated in the low pressure zone, the basin receives 85 to 90 per cent of the annual rainfall during monsoon period. Contribution of rainfall during post monsoon period such as hot weather (March to May) is negligible. However, due to late movement of depressions across the catchment, the monsoon ends late, so post monsoon rains in the months of October to May are sometimes significant. Some rainfall also occurs during winter months, but it is very small in quantity.

4.2 According to the norms laid down by Bureau of Indian Standards (IS 4987), one raingauge for a drainage area upto 520 Sq Km is sufficient for plains. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser, particularly in the up stream. In not too elevated region with average elevation one kilometre above sea level, the required network density is one raingauge station for every 260-390 Sq Km area.

India Meteorological Department have, however, prescribed at least one raingauge station for every 500 Sq Km of the drainage area. It also specifies that at least 10 per cent of such raingauge stations should be self recording. This has to be increased to 20 per cent as recommended by the Rashtriya Barh Ayog (RBA).

4.3 According to the norms laid down by the World Meteorological Organisation(W M O) the following densities are required:

Table No 3

Sl no	Type of terrain	Density required (one station for)	
		Ideal	Acceptable
1	Flat regions of temperate mediterranean and tropical zones	600-900 Sq Km	900-3000 Sq Km
2	Mountainous regions of temperate, mediterranean and tropical zones	100-250 Sq Km	250-1000 Sq Km
3	Arid and Polar zones	1500-10000 Sq Km	depending upon the feasibility

10 per cent of the raingauge stations are required to be self recording to know the intensities of the rainfall in the area.

4.4 According to the norms of the IMD, 141 raingauge stations are considered necessary in the drainage area of the river Sone, of which 33 such stations are required in Bihar portion only including the catchment of North Koel basin. If North Koel basin is excluded the number required will be 11 only. Against this requirement, there are 168 raingauge stations in the entire Sone catchment. Out of these 122 stations are located inside the catchment and the rest 46 are outside the catchment but are mostly situated on its fringes. Out of these 168 stations, 85 are maintained by IMD, 62 by MP Govt, 7 by UP Govt, 1 by Bihar Govt, 8 by CWC and 5 by unknown agency, the list of which is enclosed at Annex 1.

4.4.1 The number of stations existing and the same required as per above norms are indicated below for comparison:-

Table No 4

Sl no	Catchment area in Sq Km	Existing rain gauge stations	Adopted norms		Requirement as per norms		Remarks
			Ideal	Acceptable	Ideal	Acceptable	
1	Plain area (47,596)	114	@800Km^2	@1500Km^2	59	32	*
2	Hilly area (22,632)	50	@200Km^2	@500Km^2	113	45	**

* The plain area has got more than adequate number of raingauge stations.
** The hilly area has inadequate number of raingauge stations for ideal condition but is within acceptable norms.

In addition to above, ideal requirement of self recording raingauge stations is six in the whole of the plain area and 11 in the whole of the hilly area while three such stations in the plain and four stations in hilly area may also be acceptable. There are eleven self recording raingauge stations in the entire Sone river system.

4.4.2 The erstwhile Sone River Commission while attempting to design network of raingauge stations had observed that though there are several methods for finding optimum number of raingauge stations, the most commonly used method is that based on special variability of the historic rainfall data in which the number of raingauge stations are decided on the basis of standard deviation and co-efficient of variation of rainfall data. The optimum number of raingauge station for whole river system on the basis of above computation works out to 93.

4.5 From facts mentioned in 4.4.1, it is clear that the number of raingauge stations in hilly area is less than required which may be increased to conform to the prescribed norms. The number of self recording raingauge stations is also less which may also be increased in order to get reliable rainfall data including intensity of rainfall for sufficiently long period for detailed hydrological studies of the basin in future.

4.6 RAINFALL

4.6.1 Rainfall data of the aforesaid raingauge stations, maintained by the IMD or other agencies, for the period upto 1970 were collected and analysed by the Ganga Flood Control Commission while preparing a comprehensive plan of flood control for the Sone River system in 1989. Data beyond 1970 were not computerised then and hence not made available. We have also not been able to get any further rainfall data from IMD. Districtwise annual rainfall data are available with the Director of Statistics, Govt of Bihar from the year 1974. The rainfall data made available are enclosed at Annex 2.

4.6.2 The annual rainfall in the catchment varies between 954.0 mm at Paliganj and 1817 mm at Netarhat. The lower catchment receives less rainfall than that of the upper catchment. The monthly mean rainfall during four monsoon months is 280.7 mm. The maximum rainfall recorded in the month of August is about 725 mm and minimum in months of June or September is around 25 mm only. The southern part of the Sone basin is more wet than the northern part and there is a gradual decrease of rainfall from south to north. The western and eastern sectors also receive more rainfall than central part. Thus the central-northern part and northern lower most reach of the basin are the zones of comparatively low rainfall.

4.6.3 Based on the meteorological features of the basin, the climate of the basin can be divided into four groups. The average percentage of rainfall during each period are mentioned below:-

(a)	South-west monsoon period (June to Sept)	87.0 %
(b)	Post-monsoon period (Oct to Dec)	5.5 %
(c)	Winter (Jan to Feb)	4.0 %
(d)	Hot weather (March to May)	3.5 %

The average monthly contribution to the average annual rainfall for the entire Sone basin is as follows: June-11.9 per cent, July-29.5 per cent, August-29.8 per cent, September-16.1 per cent, October-4.1 per cent, November-0.9 per cent, December-0.5 per cent, January-2.0 per cent, February-2.1 per cent, March-1.3 per cent, April-0.8 per cent, May-1.0 per cent. The co-efficient of variation ranges from 102 per cent to 138 per cent and is maximum in the month of March. In the southern part, there are pockets which receive more rainfall than the average but as the total rainfall is quite low, its effect is insignificant. Sone basin receives 85 to 90 per cent precipitation during the four months of monsoon period. The maximum monthly rainfall is either in July or August and minimum monthly rainfall is either in April, May or December. About 60 per cent of the total average rainfall occurs in the months of July and August only.

4.7 GAUGE AND DISCHARGE

4.7.1 According to the norms prescribed by the WMO one gauge discharge site is required for every 300 Sq Km of the drainage area in hilly portion and for every 1000 Sq Km in the plains. Accordingly 121 gauge-discharge sites are necessary in the whole basin (74 nos. for hilly & 47 for plain). Against this only 70 sites are available, details of which are given below :-

Table No 5

Sl No	Catagory of sites	Number of sites maintained by					Total
		CWC	Earstwhile SRC	MP Govt	UP Govt	Bihar Govt	
1	Gauge site	–	1	13	–	8	22
2	Gauge and Discharge site 3	8	7	2	13	33	
3	Gauge, Discharge and silt site	–	2	5	–	–	7
4	Gauge, Discharge, silt and water quality site	8	–	–	–	–	8
Total	11	11	25	2	21	70	

[Source:- Comprehensive Plan of Flood Management for Sone River system, prepared by GFCC in 1989]

Out of the above 11 sites maintained by CWC, 5 are situated in Bihar. Some of the hydrological sites mentioned in the above table either do not exist now or are not being maintained properly as per I S specifications. The location of these sites, their danger level, maximum observed gauge and discharges etc are shown in the statement at Annex 3. The number of existing sites in plains is 57 whereas that in hilly area is 13 in the entire catchment.

4.7.2 From the above statement, it is quite clear that the Sone river system as a whole has adequate number of gauge and discharge sites in plains but very inadequate in hilly area which needs to be strengthened further.

The earstwhile Sone River Commission had attempted to design a network of hydrological observation sites in consultation with the CWC and finally framed its recommendations which are as follows:-

Table No 6

Recommended Network of Hydrological observation site in Sone River System

Sl No	Name of tributary	Recommended number of sites (According to I S standard)	Number of existing sites to be upgraded as per IS Norms	Number of existing sites	Additional sites required
1	Mahanadi	5	2	1	2
2	Johilla	1	1	–	–
3	Main Sone	6	2	1	3
4	Banas	2	1	1	–
5	Gopad	4	2	–	2
6	Rihand	9	2	3	4
7	Kanhar	5	–	3	2
8	North Koel	7	3	4	–
9	Intervening catchment	12	5	5	2
	Total	51	18	18	15

[Source:- Comprehensive Plan of Flood Management for Sone River System prepared by GFCC in 1989]

4.7.3 The maximum and minimum discharges observed upto 1988 of the sites falling in Bihar are given in the table below :-

Table No 7

Sl No	Name of site	Name of tributary	Maximum discharge in cumecs	Year	Minimum discharge in cumecs	Year	Average
1	Japla	Sone	26130	1975	740	1972	8320 (65-88)
2	Nasriganj	Sone	30745	1987	4110	1981	11090 (70-88)
3	Daltenganj	North Koel	3165	1987	400	1973	940 (70-88)
4	Mohammedganj	North Koel	8730	1987	600	1983	1875 (60-88)
5	Koelwar	Sone	36820	1971	3610	1966	10865 (60-88)
6	Indrapuri	Sone	20430	1978	4150	1981	12000 (78-91)

[Source:- Comprehensive Plan of Flood Management of Sone River system, prepared by GFCC in 1989 and state Hydrology Cell of WRD Govt of Bihar.]

4.8 RUN OFF FACTOR

4.8.1 Finding out run-off factor of the catchment is essential to know the run-off likely to result from short duration heavy rains. In order to findout the total run-off during the monsoon period for planning schemes for drainage of accumulated water, it is necessary to determine the run-off factor applicable for the monsoon period as a whole. In order to conduct such study and analysis, rainfall data for the stations spread over the entire drainage area of the basin and run-off data at suitable locations on the river for a sufficiently longer period (at least 20 years or more) are considered necessary inputs.

4.8.2 The Ganga Flood Control Commission (GFCC) were able to get hold of the rainfall data of 69 raingauge stations situated in this river basin as a whole. The period of availability of rainfall data varies from 1901 to 1970 for different raingauge stations in the entire catchment spread over Bihar, UP and MP. The availability of data is not continuous for all the raingauge stations in the basin for a reasonably long period. It is for this reason that rainfall-runoff relationship could not be precisely established. It is ,therefore, suggested that the State Government should make all out efforts to collect the rainfall and run-off data in the basin for as many years as available and carry out further studies to establish precise rainfall runoff relationship at suitable locations on the river Sone for future use.

4.9 SEDIMENT CHARACTERISTIC

4.9.1 The basic source of stream sediment are erosion of the deforested and denuded soil cover of upper catchment. The land in this catchment has generally steep slope, the average being more than 2 per cent. A slope of 5 per cent or more is also not very uncommon. This steep slope is instrumental in accelerating the soil erosion process and formation of gullies etc. Another cause of soil erosion is the prevalent practice of unterraced cultivation. The problem of erosion does not remain confined to the catchment area alone but extends to the river reaches, where the excessive silt charge puts the river regime in disarray creating problems like floods, drainage congestion, rise in bed level, meandering of river course resulting in loop formation and bank erosion etc.

4.9.2 There are seven existing silt observation sites in the Sone River system where observations are taken regularly. These sites are located at Chopan, Kuldah-bridge, Kota, Jhukoo, Japla, Mohammedganj and Koelwar and are maintained by the CWC. Out of these sites Japla, Mohammedganj and Koelwar falls in Bihar portion of the basin.

The availability of sediment data are indicated below:

Table No 8

Sl No	Name of observation site	River	Maintained by	Data available	Remark
1	Chopan	Sone	CWC	1963-88	
2	Kuldah Bridge	Sone	CWC	1981-88	
3	Kota	Kanhar	CWC	1980-88	
4	Jhukoo	Gopad	CWC	1983-88	
5	Japla	Sone	CWC	1978-86	
6	Mohammadganj	North koel	CWC	1981-86	
7	Koelwar	Sone	CWC	1962-86	

The available silt data of sites in Bihar are enclosed at Annexure 4.

4.9.3 The maximum silt load of each site (mentioned above) are given below:

Table No 9

Sl No	Site	Year	Maximum silt load (Lakh tonnes)	Remarks
1	Chopan	1974	582.71	
2	Kanhar	1982	7.87	
3	Kuldah Bridge	1984	78.12	
4	Koelwar	1971	3380.67	
5	Jhukoo	1987	27.27	
6	Japla	1984	376.81	
7	Mohammedganj	1984	95.40	

It would appear from the above table that maximum silt load occurred at Koelwar site in the year 1971.

A perusal of the silt data enclosed at Annex 4 indicates that the increase or decrease in annual silt load does not follow a regular pattern.

5. FLOOD FREQUENCY ANALYSIS.

5.1 Frequency analysis is carried out to interpret the past records of the hydrologic events such as precipitation, run-off, flood levels etc to predict the probabilities of such occurrences in future. For quantitative assessment of the magnitude of flood problem it is essential to evaluate and estimate the frequencies of rainfall, floods etc. Such studies are necessary inputs for proper planning, design and location of hydraulic structures as well as other related studies.

5.2 CRITERION OF DESIGN FLOOD

5.2.1 Ministers Committee on Floods and Flood Relief constituted by the Government of India in 1970 had recommended as follows:

"As most of the embankments have been constructed on the inadequate and meager hydrological data which are available, it is necessary that the existing embankments are reviewed to see that these are safe for a flood of 50 years frequency for major rivers and at last 25 years frequency for small tributaries, Similarly all future proposals of embankments should also be based on the above criteria."

5.2.2 The recommendations of the Rashtriya Barh Ayog (RBA) constituted by the Government of India in 1976 (which submitted its report in March 1980) regarding the degree of protection by embankments are as follows:

"The use of benefit cost criterion would require (i) damage data with respect to different flood frequencies (ii) data on damages due to probable failure of embankments, and (iii) expertise to carry out alternative benefit cost and trade off exercises. These are not available at present. Hence for the time being we recommend, as a general guide, adoption of the following criteria based on flood frequencies:-

(i) For predominantly agricultural areas 25 years flood frequency (in special cases where the damages potential justifies, a higher design flood/maximum observed flood may be adopted).

(ii) For town protection works, important industrial complexes etc 100 year flood frequency (for larger cities like Delhi, the maximum observed flood, or even the maximum probable flood should be considered for adoption).

Meanwhile studies should be undertaken to review the basis of these flood frequencies and attempts made to collect the data and appoint the necessary personnel, so as to enable the application of Benefit-cost criterion in due course."

(para 13.5 of RBA report)

5.2.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guide lines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankment the design of a project should be determined for the time being on the flood frequency suggested. Meanwhile necessary step may be taken for eventual application of Benefit-cost criterion for fixing the design."

The summary of recommendations as accepted is as follows:

"In the case of embankment schemes the height of the embankment and the corresponding cost can be worked out for various flood frequencies and also the benefit cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 year frequency in the case of predominantly agricultural areas and for flood of 100 year frequency for works pertaining to town protection and protection of industrial and other vital organisations."

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to protection of towns and vital industrial, defence establishments etc.

5.3 ANALYSIS OF AVAILABLE DATA.

5.3.1 At present, gauge, discharge and silt data are being observed by the CWC at seven (7) sites in the Sone river system. These are Chopan, Kuldah bridge, Kota, Jhukoo, Japla, Mohammedganj and Koelwar. Besides these there are four sites where only gauge and discharge are observed by CWC. These are Phaphund, Nawria, Nasriganj and Daltenganj. At these sites, gauge data are observed thrice a day including the gauge at the time of discharge observation. During monsoon period hourly gauges are observed. In addition to the above hydrological sites there are three more sites in the lower reaches of the catchment on the main river Sone, one maintained by Government of Bihar, Water Resources Department is situated at Indrapuri Barrage where inflow, outflow and canal releases are being observed. Two other gauge sites are situated at Maner and Dighaghat and maintained by CWC. These two sites are affected by the flow in the Ganga also and observations are made only during the monsoon season for recording hourly gauges only for the purpose of flood forecasting. Out of the aforesaid hydrological sites only 8 namely Japla, Mohammedganj, Koelwar, Nasriganj, Daltenganj, Indrapuri, Maner and Dighaghat are situated in Bihar. The yearly peak gauge and corresponding computed discharge as well as observed peak discharge of the sites located in Bihar portion only are enclosed at Annex 5.

5.3.2 The frequency analysis of the above available data carried out by GFCC using Log Pearson Type III and Gumble's distribution method for discharge of return period of 25, 50 and 100 years gave the flowing results:

Table No 10

Flood Discharges in the River Sone

Sl No	Site	Period of data availability	Flood discharge in cumecs corrosponding to Log Person Type III method 25 yrs	50 yrs	100 yrs
1	Japla	1965-88	18822.10	21242.87	23482.90
2	Nasriganj	1970-88	31195.60	37879.40	45308.10
3	Daltenganj	1970-88	2597.05	3081.53	3601.86
4	Mohammedganj	1961-88	7306.37	9566.53	12248.80
5	Koelwar	1960-88	31218.50	39655.00	49744.50

Table No 11

Sl No	Site	Period of data availability	Flood discharge in cumecs corrosponding to Gumble 25 yrs	distribution 50 yrs	method 100 yrs	Absolute peak discharge corresponding to observed peak gauge
1	Japla	1965-88	20924.80	24348.70	27747.50	20385.00
2	Nasriganj	1970-88	31833.30	37006.70	42142.80	25496.00
3	Daltenganj	1970-88	2758.31	3199.95	3638.36	2258.00
4	Mohammedganj	1961-88	9770.39	11751.30	13717.60	16359.00
5	Koelwar	1960-88	31847.90	37150.20	42413.70	32363.00

[Source Comprehensive plan of Flood management for Sone River System (prepared by GFCC in 1989)]

5.3.3 It is observed from the available annual peak discharges of chopan and Koelwar sites that the discharges at upper sites are more than lower in most of the years. One of the possible cause might be spilling of the river during floods above the koelwar site. However, this needs to be investigated in details in order to pin piont the exact reason in order to establish the reliability of the recorded observed data.

5.3.4 The flood discharges of the river Sone at Koelwar of 50 years frequency and 100 years frequency are 26.77 per cent and 59 per cent more than the flood discharge of 25 years flood respectively. Similarly, it is found that the flood discharge of 100 years frequency is 25 per cent more than the that of 50 years frequency.

For Nasriganj site, the flood discharge of 50 Years frequency and 100 years frequency are 21.42 per cent and 45.24 per cent more than that of 25 years respectively. Flood discharge of 100 years frequency is about 20 per cent more than the 50 years frequency.

5.4 UTILITY OF FLOOD FREQUENCY STUDIES

The results of flood frequency studies are useful in delineating the flood prone area on the contour map in order to be aware of the situation in the unprotected area at different stages of the river during floods. To make this study useful, it is essential to have the contour map (with contour at suitable interval) of the area prone to floods preferably in a scale of 1:15000.

The next utility of these studies will be in formulation and planning of future flood protection and management schemes in the basin.

6.0 Flood And Draingage Problem:

6.1 Flood Problem:

6.1.1 The flood is an annual feature causing extensive damage to crops, lives and other properties in Bihar. The rivers of north Bihar spill over their banks in several reaches causing considerable damage. In recent years, some rivers of south Bihar such as the Sone, the Punpun, the Falgu, the Harohar-kiul etc have also been causing floods. These rivers have negligible discharge during the non-monsoon period. The ratio of discharge of monsoon to non-monsoon period is quite large. On account of heavy precipitation in their catchments combined with their inadequate bankful capacities, the rivers spill over their banks frequently. These rivers are aggrading in several reaches and are flowing almost on the ridges in lower reaches. At places, these are contained within Embankments constructed by local Zamindars to protect corresponding localised areas. Their design is structurally weak and even flood of medium nature cause breaches and consequential inundation of the adjoining protected areas.

The Ganga remains in high stages for considerable periods during monsoon months which results in flood locking in its tributaries. During this period, even small rise in flood levels of tributaries result in spilling of their banks and flooding of the nearby areas. Heavy outbrust of the storm during monsoon in the catchments of various rivers of Bihar is not uncommon. Such heavy rainfall causes flooding in south Bihar plains also, particularly in the lower reaches.

6.1.2 All major floods in the catchment of the Sone basin have been caused due to heavy rainfall in the upper catchment of the river and its tributaries. These heavy rainfalls occur due to monsoon depressions and cyclonic storms originating from the Bay of Bengal moving in North and North-westerly direction crossing Orissa and West Bengal coast. Depending upon their intensity and track of movement, they cause heavy to very heavy widespread rainfall over the Sone catchment. This river system experienced extremely severe floods in the years 1900, 1911, 1913, 1917, 1919, 1921, 1925, 1931, 1934, 1946, 1950, 1956, 1971 and 1975 which affected the Sone catchment and also adjoining areas.

6.1.3 The areas of the Sone catchment lying in Madhya Pradesh and Uttar Pradesh are almost free from floods. The flood problem in the Sone river system is mainly confined to lower reaches of the river, after it comes out of the hilly region and flows down through the Gangetic plain. The Sone river generally spills in Bihar below Danwar on left bank. The spilling problem is more acute further down below the koelwar bridge which affects the low lying areas of Ara town and Maner. The main reasons of overbank spill are the heavy rainfall in the upper catchment and congestion at the outfall due to high stages in the river Ganga. The problem becomes more acute whenever the flood in the river Sone synchronises with that in the Ganga causing serious drainage congestion which prolongs the duration of flooding in the lower catchment. The flood slope in the river Sone is 0.5 m per Kilometre below Koelwar while the flood slope in the Ganga near its confluence with Sone and downstream is 0.1 metre per Kilometre. This difference in flood slopes creates heading up of water of the Ganga near their confluence particularly in the reach from Maner to Digha. This results in higher flood level of the river Ganga at Digha during high stages in the river Sone. It is found that flood levels in Maner-Digha reach of the river Ganga are influenced more by the stages and discharges of the river Sone. As a result of the extremely high flood level at Digha in the year 1975 the combined water of Ganga and Sone overtopped the entire road from Digha to Maner, excepting highlands near villages to the extent of about 30-60 cm, and there was a sheet flow from Sone and Ganga towards the low lying areas in the countryside of Patna and Digha. There were seven breaches on the road during this flood. The river Sone also spilled over the right bank between Koelwar and Maner, thereby causing 11 breaches in the Maner distributary. This water also entered the Patna-Danapur areas. The combined water entered Patna township in the night of 24th August, 1975 causing large scale damages to lives and properties in Patna and its suburban areas.

6.1.4 The river Sone brings considerable amount of silt resulting from erosion of the deforested and denuded soil cover in the upper catchment. The surface slope in the catchment is generally steep. It accelerates the soil erosion resulting in heavy silt charge. The excessive silt charge puts the river regime in disarray creating problems like floods etc. The capacity of the river channel is gradually reduced due to such excessive deposition of silt in the river bed which leads to spilling of the banks whenever there is heavy precipitation in the basin. The problem of over bank spill causing flooding of the area is limited to the lower most reach of the basin below Danwar.

6.1.5 Although no serious problem of bank erosion occurs in this basin even in lower reaches, some erosion does take place at some locations for which schemes have been formulated such as (i) Dehri Town Protection Scheme and (ii) Anti-erosion Scheme near village Kharawn between Ch 215 to 240 of Sone Left Embankment (iii)Anti-erosion Scheme near village Sahar between Ch 407 to 457 of Sone Left Bank Embankment (iv) Fuha Anti-erosion Scheme between Koelwar and its confluence with Ganga (v) Mahadeva Anti- erosion Scheme near Nasriganj and (vi)Nauhatta Anti-erosion Scheme opposite the confluecne of North Koel river with Sone. The Dehri Town Protection Scheme includes protection of valuable lands of Water Resources Department of the state government, Industrial state and Bihar Military Police establishments etc. The erosive tendency is reported to have developed after construction of a number of important structures located upstream and downstream of old Dehri Anicut such as Indrapuri Barrage,old GT Road causeway, new GT Road bridge and railway bridge on Eastern Railway etc. The portion of town situated downstream of the Anicut has been protected to some extent by executing anti-erosion works in past years but the area lying upstream of the Anicut had faced erosion problem a few years back during which it is reported that about 20 ha of land belonging to Water Resources Department had been eroded by the river action.

6.1.6 History of past flood shows that the flood problem in the Sone river basin is mainly confined to lower reach. There is hardly any problem of this nature in upper reaches. The flood problem of the river received greater attention after the floods of 1971, A brief history of past floods have been indicated in the statement at Annex 6.

6.2 DRAINAGE PROBLEM

6.2.1 The Sone river basin does not suffer from serious drainage congestion. Some drainage problems are reported to exist in the lower most reach near the confluence with the Ganga. Drainage congestion is created only when its upper catchment experiences heavy precipitation and is followed by blockage at outfall into the river Ganga during the high stage period of the river Ganga. The problem becomes acute whenever the flood of the river Sone synchronises with that of the Ganga causing drainage congestion due to which the depth as well as duration of flooding in the tail end of the basin considerably increases. This basin inspite of intensive irrigation facility from Sone canal system does not record any rise in ground water table. The record of ground water table taken from year 1886, a few year after inception of irrigation from Sone canal system, to 1992 supports the above statements. No other surface or underground drainage problem has been reported from anywhere else in this basin in Bihar.

6.3 FLOOD DAMAGES

6.3.1 Generally the damages caused by floods and drainage congestions are broadly classified into the following categories:-

(a) direct damages and (b) indirect damages.

6.3.2 The direct damages are those which are caused due to direct physical contact with flood water. These includes losses to (a) growing and preharvest crops ,(b) houses and household assets, (c) public utility works, (d) public buildings and (e) loss of human lives and livestocks.

6.3.3 The indirect damages are not susceptible to quantification. Therefore, approximate monetary evaluation can only be done for such damages. These generally include :-

(a) loss of earning in Agro-based industry and trade,

(b) loss of revenue to the road and rail transport system due to disruption of services,

(c) loss of earnings to small shopkeepers and other daily wage earners and

(d) loss of employment to the daily wage earners in the public and private sectors.

6.3.4 The flood damage data are collected by the Revenue (Relief & Rehabilitation) Department of State Government and passed on to the various concerned organisations of the State and Central Government. Central Water Commission (CWC) is collecting and compiling such damage data of all flood prone areas of States at national level. It is observed that the flood damage statistics, which is essentially required for the benefit-cost studies for any proposel flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The Commission recommends that the recommenations of the RBA should be followed strictly and realistic evaluation of flood damage river basin wise be carried out every year under the following three separately identified categories:-

I Unprotected areas;

II Protected areas due to failure of protection works;

III Areas between the embankments and the river.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data in order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long-term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area.

The Central Flood Control Board had decided that the Flood Control Departments of the States should compile basinwise flood damage data with effect from 1960. This is not being followed in Bihar and the flood damage data still continue to be collected districtwise (not basinwise) by the Revenue (Relief & Rehabilitation) Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of immediate requirement of relief operations that become necessary on account of current damage caused by floods. As such, the need for compiling the annual flood damage data, according to administrative jurisdiction in district and blockwise category in the state can not be denied. On the other hand, planning of the flood control measures are to be on a basin and sub-basinwise manner. It is, therefore, necessary that such data are collected by the Revenue authorities with active co-operation of the staff of Water Resources, Agriculture, and Road & Building construction Departments and the data are processed and compiled both districtwise as well as basin/sub-basinwise by the Statistical Organisations at district and State level for future use, for planning of relief measures and flood management works respectively.

6.3.6 The annual flood damage data for the Sone River basin converted from available districtwise figures are enclosed at Annex 7. Proportionate damage in accordance with area has been accounted for in case of the districts which partially lie in the basin.

6.3.7 From the perusal of the data processed by the Revenue Department it is noticed that damages to property of Central Government such as railways, posts and telegraphs etc are not properly accounted for. On the other hand, the cost of relief and rehabilitation measures, grant of loans, remission of land revenue etc is added to flood damages. This does not appear to be in order and needs to be looked into.

6.3.8 COMPARATIVE STUDY OF ANNUAL DAMAGE FIGURES

The figures of average annual flood damage from 1969 to 1988 in the Sone river system have been compared with those of Ganga sub-basin and the country as a whole by the GFCC as indicated in the table given below. This comparative study shows that the average annual damage in the Sone river system is about 0.755 per cent and 1.424 per cent of the total average annual damages of the country (as a whole) and Ganga sub-basin respectively whereas the geographical area of the Sone river system is 2.166 per cent and 8.272 per cent of the country and Ganga sub-basin respectively. This reflects that the flood problem in this river system is comparatively less than that in the Ganga sub-basin and the country as a whole.

Comparative study of average annual flood damage figures (at then current price level) with that of the country as a whole and the Ganga sub-basin.

Table No 12

Sl No		Item	All India	Ganga basin	Sone River system
1		Total area affected (in Lakh hactares)	92.33	47.82	0.4054
2		Total pupulation affected (in Lakh nos)	298.53	169.24	2.3701
3	(a)	Total crop area affected (in Lakh ha)	39.86	22.72	0.1591
	(b)	Damage to crops (in Rs Lakh)	26132.30	16239.27	206.47
4	(a)	Number of house damaged	1105705	638432	6351
	(b)	Damage to houses (in Rs Lakh)	7067.68	3965.37	132.108
5		Damage to public Utilities (in Rs Lakh)	13633.35	4646.17	15.232
6		Human lives lost (Number)	1434	401	26
7		Cattle lives lost (Number)	105490	11061	11
8		Total damages (in Rs Lakh)	46833.33	24851.15	353.810
9		Total Geographical Area (in Sq Km)	3290000	861400	71259

[Source: Comprehensive Plan of Flood Management for Sone River Basin, prepared by GFCC in 1989]

6.3.9 TREND OF DAMAGES

The flood damage distribution over various time periods has been computed from annual damage data furnished at Annex 7 for block years 1969-73, 1974-78, 1979-83, 1984-88, and 1989-93. The trend of damage distribution of various components such as crop damage, damage to houses and damage to public utilities during different block years are given below in the table.

Table No 13

Sl No	Type of damages	Trend of damage during the Periods				
		1969-73	1974-78	1979-83	1984-88	1989-93
1	2	3	4	5	6	7
1	Damage to crops	79.9% (516.0353)	66.05% (1271.2223)	96.53% (341.77)	48.08% (2003.52)	89.11% (1088.37)
2	Damage to houses	18.75% (121.1064)	33.94% (653.1003)	3.44% (12.1567)	44.7% (1855.7925)	5.05% (61.69)
3	Damage to Public utilities	1.35% (8.6825)	0.01% (0.2268)	0.03% (0.1127)	7.12% (295.6168)	5.83% (71.31)
	Total damages	100% 645.8269	100% 1924.550	100% 354.049	100% 4151.7613	100% 1221.37

Note: The figures under bracket indicate the value of damages in Lakh Rupees.

[Source : Comprehensive Plan of Flood Management for Sone River Basin prepared by GFCC in 1989 upto column No 6 and Relief and Rehabilitation Department of Government of Bihar for Column No 7]

From the above table, it is seen that the damages to crops, to houses and to public utilities are roughly 76 per cent, 21 per cent and 3 per cent respectively. Rashtriya Barh Ayog (RBA) had reported that more than 60 per cent of total damages used to be on account of damages to crops. This assessment holds good in the case of this river system as is evident from the above table except in the block year 1984-88. It is also seen from the above table that damages to crops is maximum in block year 1979-83 while damage to houses and public utilites are maximum in block year 1984-88.

6.3.10 It is obvious from the available flood damage data of the basin that average annual area affected by flood is 0.52 Lakh hactare. The average annual damages to crops, houses and public utilites at the 1991 price level work out to be Rs 450.88 Lakh, Rs 213.56 Lakhs and Rs 23.49 Lakhs respectively totalling to Rs 687.93 Lakhs. During the period 1969-93 for which the data are available, the maximum damages amounting to Rs 4193.90 Lakhs occurred during the year 1976 and the minimum damages of Rs 6.36 Lakhs occurred during the year 1969 (at 1991 price level).

7.0 PAST APPROACH AND ACHIEVEMENTS:

7.1 In early days embankments were constructed to prevent damage to the agricultural lands, properties and inhabited area from the over bank spills of the rivers. Such embankments were generally constructed by the local Zamindars in localised reaches in scattered manner to protect their lands and properties from inundation. No clear cut flood control policy was laid down in earlier years but Committee of Experts were appointed to examine the problems and to suggest remedial measures when ever flood of severe intensity causing large scale damages occurred. Most of the suggestions made by such committees could not be implemented either for want of funds or for other reasons. One of the worst and devastating floods occured in the country in the year 1954 and Bihar was no exception. The Govt of India announced a national policy on flood control and launched a national programme of flood control in the year 1954. This policy stressed the need for collection of data and formulation of plans, implementation of short term measures like embankments and channel improvements and long term measures like construction of storage reservoirs on tributaries in conjunction with embankments, all under an outline of time-bound programmes. No long range plan could, however, be immediately formulated for want of survey and investigation as well as historical data but emergent schemes were prepared and executed to provide a reasonable degree of protection from the ravages of floods to the areas concerned. These schemes have served their desired purpose.

7.2 Before 1971, only a small bund about 4.85 Km long, was constructed on the river Sone. The banks of canals and distributaries of the Sone canal system also worked as embankments. These existing embankments were hardly able to provide protection to the flood prone areas of the basin. The 1975 floods in the lower reaches of the river Sone combined with high stages in the river Ganga at its outfall point caused severe damages to Patna township,Danapur cantonment and suburban areas. The State Government formulated a scheme for protection of the areas, lying in the lower reach of the Sone basin including Patna and Danapur towns, from floods. Some of these schemes have already been executed, a few are under execution and the remaining are still in proposal stage. Such schemes are broadly classified under various categories like Embankment schemes, Reservoir schemes and Town/ village protection schemes. A list of such schemes is enclosed at Annex 8

7.3 EXPERTS COMMITTEES AND THEIR RECOMMENDATION

As already described earlier the flood problem of the Sone basin is not acute. No committee on flood control in the Sone river basin was constituted prior to devastating floods of 1975. Tripathy committee under the Chairmanship of Shri J.Tripathy, Member (Floods & Drainge), CWC was constituted by the State Government after 1975 floods in Patna. The Committee was required to suggest measures to be undertaken for the protection of Patna town, which was severely affected in 1975 by the flood of the river Sone. The Committee gave its recommendations under two priorities. It was recommended that the works under Priority I should be completed before 1976 monsoon, while those under Priority-II might spill over beyond 1976 monsoon. Following are the contents of the Priority I & II proposals:

Priority-I

(i) **(a)** Construction of an embankment -cum-masonry wall on the south bank of the river Ganga from Digha to Maner along with bank revetments at vulnerable places.

(b) Construction of sluices in the proposed embankment at the crossing of the drainage channels.

(ii) Construction of an embankment-cum-masonry dowel on the south bank of the Ganga from Digha to the tail end of left embankment on the river punpun wherever necessary.

(iii) Construction of a new embankment from Maner to Saidabad along right bank of the river Sone.

(iv) Closure of the lock gate on the Patna canal and provision of a gate with proper seals at the junction of Patna canal with the Ganga.

(v) Construction of an escape channel from Patna canal upstream of Naubatpur through Khajuri distributary and Panchahua Nala with ancillary works.

(vi) Restoration to original sections of Patna canal and Maner distributary. To ensure provision of a free board of 0.9 metre above 1975 HFL in the left bank embankment of the Maner distributary.

(vii) Raising and strengthening of Danapur distributary and construction of new embankment in its tail reach to prevent the entry of drainage waters from rural areas lying on the west towards Patna.

(viii) River training works for preventing erosion of existing Patna protection works at vulnerable places against erosion from the river Ganga.

(ix) Improving and remodelling the existing urban drainage in Patna and construction of sluices with gates on the drainage channels proposed for augmenting the capacities of the existing ones as per new proposals.

Priority- II

(i) Remodelling the drainage system in the rural areas by excavating new channels, remodelling of the existing channels and raising of the roads/ distributaries wherever and to the extent necessary for segregating drainages of different sectors.

(ii) Raising and strengthening of the left embankment of the Punpun as well as construction of new embankment in its upstream reaches upto the escape channel.

Out of the above recommendations, the schemes Nos (i) a & b, vi & vii under priority-I relate to Sone/ Ganga basin and scheme No. iii of Priority-I relates to Sone basin and other recommendations are not relavent to Sone river basin.

The recommendations of the Tripathy Committee relating to construction of embankments on Sone river have been completed.

The total length of embankments on river Sone to be constructed is 67.87 Km to provide protection to an area of 30.77 thousand ha out of this, as per Administrative report of 1991-92 of Water Resources Department of Government of Bihar, 51.64 Km length has been completed and 21.27 thousand ha area have been provided with reasonable degree of protection from flood so far. The total amount spent upto 1991-92 is Rs 398.45 Lakhs on Sone Embankments.

7.4 EMBANKMENT SCHEMES:

There are three important embankment schemes in this river system which are (i)Buxar-

Koelwar Embankment scheme (sector A) (ii) Sone left embankment scheme (From Koelwar to Harpur lock (iii) Sone right embankment scheme.

7.4.1 Buxar Koelwar Embankment Scheme :- It has been planned into three sectors, namely 'A','B' and 'C'. Sector 'A' of this scheme envisages construction of the following works.

(i)	Sone embankment (from Koelwar upto confluence with Ganga)	14.66 Km
(ii)	Koelwar ring bundh	2.38 Km
(iii)	Ganga Embankment(from Samaria Pararia to Bishunpur)	9.08 Km
(iv)	East Gangi Right Embankment (Jamira to Samaria Pararia)	19.05 Km
(v)	East Gangi Left Embankment (Jamira to Gyanpur)	5.79 Km
(vi)	Ara Town Protection scheme	7.68 Km

Out of the above works, the Sone Embankment and Koelwar Ring Bundh relates to Sone river basin.This scheme was started in the year 1973-74 to provide protection from flood to approximately 10,000 hectares of land lying between the rivers Sone on the east, the Ganga on the north, the Gangi in the west and Patna- Mughalsarai section of Eastern Railway line in the south. The construction of all the above embankments have almost been completed except some minor works in the other portions.

Sector 'B' and 'C' relates to Ganga main stem basin and provides protection from the floods of the river Ganga and West Gangi etc.

7.4.2 Sone Left Embankment Scheme (from Koelwar to Harpur Lock):

This scheme envisages construction of three embankments as given below :

(i) New embankment from Koelwar to Nansagar.

(ii) Raising an strengthening of existing Trikol bundh from Nansagar to Sandesh having a length of 4.88 Km.

(iii) Raising and strengthening of right bank of koelwar distributary from Sandesh to Harpur lock having a length of 36.30 Km.

This scheme was proposed to provide protection from flood to the area lying on the left of the river Sone from Nansagar to Harpur lock. Upstream of saidabad, flooding of vast tracts of irrigated land was also being caused due to breaches in canal banks on both banks of the river sone. As such, the high level Expert's Committee suggested that the canal banks may be raised and strengthened to act as flood embankment. The present status of these schemes are indicated below :

7.4.2.1 Nansagar-Koelwar Embankment

The Nansagar-Koelwar embankment is a part of Sone left embankment scheme. This embankment has been constructed in a length of 14.95 Km to protect the area lying on the west side of the river Sone between Nansagar and Koelwar. Almost entire length of embankments have already been constructed. The total cost of the scheme was Rs 324.28 Lakhs.

7.4.3 Sone Right Embankment Scheme

7.4.3.1 (From Mair to Ranitalab)

This scheme envisages construction of flood protection works on right bank of the river Sone from Maner to Ranitalab. The scheme forms a part of the comprehensive "Patna Flood Protection Scheme". The estimated cost of the scheme was Rs 431.69 Lakhs. This scheme is providing protection to 16,187 hectares of lands and comprises of the following components :

(i) Raising and strengthening of left bank of Amra distributary from Maner to Amra in a length of 21.05 Km.

(ii) Construction of new embankment from Amra to Baidrabad connecting Patna canal and Amra distributary in a length of 9.15 Km.

(iii) Raising and strengthening of left bank of Patna Canal from Baidrabad to Ranitalab in a length of 16.78 Km. Such work in a length of 8.2 Km of Patna canal has been taken up separately under the name of " Arwal Protection Scheme ".

7.4.3.2 (From Ranitalab to Maner)

This scheme envisages construction of flood embankment on right bank of the river Sone from Ranitalab to Maner. This embankment also forms a part of "Patna Flood Protection Scheme".The scheme comprises the following components :

(i) Construction of new embankment from Saidabad to Maner.

(ii) Raising and strengthening of left bank of Maner distributary from Ranitalab to Saidabad.

Both the components have been completed under Patna Flood Protection Scheme.

7.5 RESERVOIR SCHEMES

In the past the following reservoir schemes have been executed on this river system.

A Existing Schemes

(1) Rihand Multipurpose Project (UP)
(2) Obra Reservoir Scheme (UP)
(3) Dhandhraul Reservoir Scheme (UP)

B Ongoing Schemes

(1) Bansagar Multipurpose Project (MP)
(2) North Koel Project(Kutku dam) (Bihar)
(3) Kanhar Irrigation Project (UP)

Out of the above mentioned Projects, only North Koel (Kutku dam) Project lies in Bihar which is almost complete. None of the other completed projects are located in Bihar, but they certainly have impact on flood moderation in this basin on areas lying in the tail end reach in Bihar.

7.5.1 North Koel Project (Kutku Dam)

This project envisages construction of a 68m (approx) high concrete-cum-masonry dam across the river North-Koel near village kutku and a pick-up-barrage at Mohammedganj 96 Km downstream of the dam site. The dam and the barrage are in advance stage of construction and are likely to be completed within a couple of years. A 108 Km long canal with head discharge of 85 cumecs takes off from the right side of the barrage. It envisages release of water from the reservoir in a regulated manner so as to be picked up at Mohammedganj Barrage to feed the proposed North Koel canal and to release water excess over its requirements through the barrage to be picked up at Indrapuri barrage on the river Sone for supply of water to the existing Sone canal system. It is also proposed to take advantage of the regulated water discharge and the artificial head available to generate about 24 MW of hydroelectricity. The salient features of the scheme is enclosed at Annex 9.

7.6 TOWN/VILLAGE PROTECTION SCHEME

Apart from some village protection schemes which have been formulated in this basin, some Town Protection Schemes have also been taken up. Important town protection schemes are Dehri Town Protection Scheme and the Patna Town Protection Scheme. While only a portion of work in Dehri Town Protection Scheme has been completed so far, the Patna Town Protection Scheme has almost been completed. Although the Patna Town Protection Scheme does not fall in the Sone river basin, it envisages construction of embankments on right bank of the river Sone. It has, therefore, been discussed in this report in the following paragraph.

7.6.1 PATNA TOWN PROTECTION SCHEME

The Patna township had been threatened many times in the past by floods of the rivers Sone, the Ganga and the Punpun but fortunately the peak floods of these rivers had never synchronised simultaneously with each other earlier. Patna was threatened with flood in the year 1971 and the situation was very serious. It was due to great effort that the Patna town could be saved from the ravages of floods that year. But shortly again, after a lapse of four years Patna township and the adjoining areas experienced unprecedentated flood in the year 1975 resulting in the inundation of large areas of township complex on the western sector to a depth varying from two to four metres.

Considering the seriousness of the situation, the State Government constituted a committee to prepare an outline plan for flood protection scheme for Patna to prevent recurrence of such flood in future. A series of measures were recommended by the committee and acordingly various schemes were formulated and executed:

The following portions of the above scheme related to protection from flooding caused by the river Sone :-

(a) Construction of embankment cum masonry wall/ Dowel along with sluices along the south bank of Ganga from Digha to Maner (estimated cost Rs 514.30 Lakhs).

(b) Construction of earthen embankment from Maner to Saidabad along right bank of the river Sone and raising & strengthening of left bank of Maner distributary from Saidabad to Ranitalab (Estimated cost Rs 486.24 Lakhs).

(c) Rural drainage schemes for the areas to the south of embankments from Digha to Maner (Estimated cost Rs 432.93 Lakhs)

The schemes described in (a) and (b) above have been completed.

7.7 OTHER MEASURES

7.7.1 Irrigation Schemes

7.7.1.1 Sone Canal System

Sone basin and surrounding area were used to face frequent drought. In order to provide relief to the people the British Government took up execution of Sone irrigation scheme which included Dehri- Anicut (a weir), and network of canal system known as Sone canal system and completed it in 1874. This project consisted of an Anicut (weir) across the river Sone at Dehri and two canals namely western and eastern main canals taking off on either side of the Anicut. With the passage of time the headwork at Dehri had outlived its life and hence during the second plan period, the State Government constructed a barrage at Indrapuri across the river Sone about 8 Km up stream of the Anicut at Dehri to meet the increasing demand for water in the command area of the Sone canal and to improve the existing irrigation system. The construction of barrage was also considered necessary as a replacement to the existing Anicut which had outlived its life, so that the existing irrigation in the command of Sone canals did not suffer on account of the failure of the Anicut.

The existing canals were connected to the barrage by means of western and eastern link canals of 10.45 Km and 10.86 Km lengths respectively. The scheme also included remodelling of the old Sone canals. The work on the project was completed in the year 1967. Subsequently two high level canals (eastern & western) taking off on both sides of the Sone Barrage for making use of the regulated discharge released from the Rihand dam in U P to provide additional irrigation of 1.62 Lakh ha were also constructed. The total culturable area commanded by the existing Sone canal system is 6.24 Lakh ha. In order to make optimum use of the available scarce water resources in the basin, a scheme for modernisation of existing Sone canal system has been finalised and is being executed in accordance with the availability of funds.

In addition to Sone canal system, there are 8 medium irrigation schemes existing in Bihar portion of the basin providing irrigation to about 27000 ha. In addition there are fifteen minor irrigation schemes in this basin in Bihar.

7.7.1.2 Among the ongoing projects, only one major scheme i.e. North Koel (Kutku dam) Project is under construction in Bihar. This is expected to provide irrigation to an area of 0.46 Lakh ha lying in drought prone Palamu and Aurangabad districts of Bihar.

7.7.2 Anti Erosion Schemes

There are a few anti-erosion schemes on the left bank of the river Sone. Only one of such schemes namely Fuha Anti Erosion scheme is reported to have been completed.

7.7.2.1 Fuha Anti-Erosion Scheme

The Sone embankment (from Koelwar to its outfall point into the Ganga) on the left bank is subjected to erosion near village Fuha during the floods as the river Sone is flowing very close to the embankment, at that place. Hence Fuha anti-erosion scheme had been taken up to protect the flood embankment from erosion in this zone. This scheme was cleared by the Scheme Review Committee formed by the State Flood Control Board for execution before the flood of 1990 at a cost of Rs 2.0 Lakhs only.

7.7.3 Soil Conservation

The Sone catchment falls under the eastern red soil region. Deforestation and overgrazing resulting in heavy sheet erosion is the main problem of this region. Itensive gullying and stream bank cutting are other two special problems of this region.

The erstwhile Sone River Commission has indicated the following in its comprehensive basin plan of the Sone River basin.

"The Government of India have recommended treatment for soil conservation to only very high and high priority areas spread over 28.57 Lakh ha. As per information made available from the Ministry of Agriculture, Department of Co-operation, Government of India, 23400 ha, 6807 ha and 20544 ha of areas have been covered under centrally sponsored schemes of integrated watershed management in the catchments of this river system in Madhya Pradesh, UP and Bihar respectively. The total estimated cost on soil conservation measures of the treatable area is about Rs 42,800 Lakh out of which Rs 28,800 Lakh, Rs 3200 Lakh and Rs 10,800 Lakh is required in MP, UP and Bihar respectively. The left over works need to be implemented on priority."

8.0 FUTURE APPROACH

8.1 On the policy objective of flood control, the Rastriya Barh Ayog (RBA) has observed that :-

"Flood control should not be considered as an end in itself, rather it is the means to an end. Flood control has to be viewed within the broad context of the economic and soicial development in the country. Comprehensive approach to the problem of floods must form part of the overall comprehensive approach for obtaining the best possible utilisation of our land and water resources for optimum production of food, fibre, fodder and fuel to meet the needs of the growing population. Management of flood should be considered in the context of the overall plan for management of water resources of a river basin. The approach to the flood problem has also to take into account the state of our economy, our social conditions and the availability of resources. The approach, therefore, can not be static, but should remain dynamic and flexible so as to accommodate future improvements in policy, if called for in subsequent reviews."

The above commendable policy objective would however, need a multi-facet, multi-disciplinary, overall development plan of a river basin, in which comprehensive plan for flood control would be integrated.

8.2 While planning for a flood management scheme the following processes are to be followed :-

- i Assessment of problem
- ii Identification of the goals
- iii Alternative measures possible
- iv Consideration of the criterion to be adopted
- v Evaluation of the alternatives
- vi Decision of a single or combination of alternatives
- vii Fixing priorities of the schemes.

8.2.1 The losses from the fury of flood year after year are quite alarming for a developing country like India. Where, out of the meagre resources so badly needed for development works, large amounts have to be spent every year for flood relief and restoration of damage to public properties. As such, the goal is to minimise the flood damage in the flood prone areas of the river through structural and non-structural measures.

8.2.2 Flood in any river basin is a natural phenomenon and although it has a predominantly destructive capability, it exerts a favourable influence in the post flood period in certain circumstances. With these perspectives, Planning for flood management does not involve absolute control of floods but implies management of flood in the most beneficial manner for given situation.

The structural measures which are widely used for modifying the floods may involve construction of embankments, reservoirs, natural detension basins, channel improvements, emergency flood ways, river diversion works, inter basin transfer,bank stablization, anti-erosion measures, ring bundhs and under ground storages. The non structural measures meant to modify susceptibility of flood damage includes (i) Flood plain zoning,(ii) Flood forecasting and warning and (iii) Disaster mitigation system and preparedness.

8.2.3 The problem of floods in this river system is not very significant and whatever is existing, is mainly due to spilling over the banks in the lower reaches of the river through the gaps left in the embankments due to one reason or the other. These gaps should be closed at the earliest to prevent any flooding through them during high floods. The main reason of flooding is heavy rainfall in the upper catchment and drainage lockage at its outfall in the Ganga river when the river Ganga is in high stages.

8.3 In order to find suitable solution to the flood problem the following measures could be considered:

8.3.1 Reservoirs

According to numerous experts, properly operated flood control reservoir/ reservoirs combined with efficient flood forecasting, offers the most dependable flood control.The national policy on flood of 1954 also recommended dams on tributaries as a long term measures of flood control. Reservoirs, in general, even without specific flood cushion have a beneficial effect on the flood problem of a basin. The effectiveness of reservoirs in moderating flood would depend upon the capacity available for absorbing flood run-off. Because of their high cost, the reservoirs are not economically viable or justified exclusively for flood control purpose but a multi-purpose reservoir to provide irrigation, power, domestic water supply, recreation and other benefits along with flood moderation could be economically viable.

Salient details of possible reservoir sites in the basin with their storage capacity are indicated in the following table :

Table No 14

LIST OF PROPOSED SCHEME

Sl No	Name of schemes	State	Live storage capacity in MCM	River/Tributary
1.	Kanhar Reservoir Scheme	Bihar	524	Kanhar
2.	Kadhwan Reservoir Scheme	do	2420	Sone
3.	Simdih Hydroelectric Project	MP	330	Sone
4.	Churhat Hydroelectric project	do	1075	Sone
5.	Nagunra Hydroelectric Project	do	360	Gopad
6.	Gurdah Hydroelectric Project	UP	2050	Sone
7.	Pasai Hydroelectric Project	MP	422	Rihand
8.	Duniadih Hydroelectric Project	do	484	Rihand
9.	Joka Hydroelectric Project	do	215	Joka
10.	Karni Hydroelectric Project	do	11	Rihand
11.	Kharanli Hydroelectric Project	do	587	Mahan
12.	Diadol Hydroelectric project	do	52	Gopad
13.	Other Reservoirs on the tributaries Mahan Amanat, Auranga, Tahley etc. Bihar		936	......

Reservoirs at Bansagar on the main Sone (in MP), Kutku on the Northkoel (in Bihar), Auranga on the Auranga (in Bihar) and Amwar on the Kanhar (in UP) are under construction at present and lingering since long. All out efforts are required to be made to ensure their early completion within shortest possible time from now to avoid any further time and cost overrun besides accrual of the desired benefits which are not being availed inspite of huge investments already made.Reservoirs on the tributaries of North Koel namely the Amanat and Tahle and on Kanhar, upstream of Amwar site are also proposed in Bihar . Construction of these reservoirs should be taken up as early as possible as these are awaiting final sanction since tast two decades.

8.3.1.1 The erstwhile Sone River Commission had also idendified nineteen additional feasible reservoirs sites for various purposes. Eleven out of them have been investigated and their prefeasibility reports had been prepared. These reservoirs are expected to be constructed in near future depending upon the availability of funds.

8.3.1.2 Total storage provided or likely to be provided in the above mentioned reservoirs will be of the order of 2511 MCM. This magnitude of storage on creation may be capable of absorbing all medium floods and would considerably reduce the major flood peaks by carefully integrated operation of the reservoirs for irrigation and flood control and hydroelectric power generation. Systematic study on these lines needs to be planned and carried out.

8.3.1.3 The salient features of some of the proposed reservoir schemes in this basin are enclosed at Annex 10

8.3.2 Embankments

The embankments so far constructed or planned to be constructed have already been discussed earlier in paragraph 7. It is apparent from the same that the State Government has already constructed embankments on both banks of the river Sone to prevent over-bank spilling of the river during high stages. However, it has been reported that the following gaps are existing in the embankments due to some reason or the other, which are not technical but mainly administrative :-

I 244 m of masonary dowel wall in Koelwar Ring Bundh

II Sone Left Embankment between
Km 5.02 to 5.95
Km 6.95 to 7.13
Km 8.36 to 8.47
Km 10.06 to 10.61
Km 10.91 to 12.31
Km 13.67 to 13.87
Km 22.07 to 22.25

These gaps need to be plugged at the earliest in order to ensure the effectiveness of the embankments in serving their desired purpose. In the existing situation construction of any further embankment on the river Sone is not considered necessary.

8.3.3 Drainage Improvement

The river sone flows almost on a ridge in the lower reach as a result no tributary joins the river sone in this portion. It is however, reported that some drainage congestion takes place in the lower most reach near its confluence with Ganga. Tripathi Committee constituted by State Government after 1975 Patna floods, to suggest measures for protection of Patna which is affected by the Sone, the

Ganga and the Punpun, had recommended some drainage schemes out of which one, namely Channel No 1 of sector.II of Patna Town Protection Scheme under Rural drainage scheme relates to the Sone basin. The scheme was included in the approved Patna Town Protection Scheme but this work has not yet been executed. From the reports received from the concerned Chief Engineers the necessity of either this or any new drainage scheme in this basin is not prima facie established. It is, therefore, suggested that the drainage problem of the basin in its tail reach near its confluence with the Ganga be investigated in detail and appropriate technically feasible and economically viable remedial measures be planned and executed at an early date, if found necessary in the existing situations.

8.3.4 Soil Conservation

Prior to advent of civilisation, the hilly terrain of the river system and the Gangetic plains were originally covered with the jungles and forests. Due to increase in density of population the needs of food, fuel and fibre have increased considerably which has resulted in large scale deforesation and removal of plantations for conversion into agricultural fields and human habitation. This has resulted in large scale denudation in the entire catchment of the river system and precious top soil cover is being eroded easily leading to higher sediment load being carried down the river. Restoration of the vegetative cover to check soil erosion is required for long term management of the problem of sediment in the river system. Soil conservation work may be taken up by land treatment through afforesation and crop land development supplemented by structural work for retarding the velocity of water over land and detaining silt. This may also include general afforesation, grazing control, terraced cultivation, gully plugging and contour bunding as feasible in particular area. These measures will be helpful in modifying minor and medium floods over small area. For this, priority areas have to be identified through preparation of priority delineation maps on the basis of reconaissance survey and taking help of aerial photographs and sattelite imagery.

In Bihar, 15 head water dams, 62 detention dams and 262 farm ponds have been proposed in this river system. In addition, other works, such as bench terracing of agricultural lands, horticulture development, grass land development, protective afforestation, gully stream banks, land slide control etc have also been proposed. The area likely to be benefitted by these schemes in Bihar is about 13.21 Lakh ha.

8.3.5 Maintenance of Existing Works

While new structural measures as suggested above are necessary for solution to the residual flood and drainage problem in the basin, it is equally important to properly and adequately maintain the assets already created so that they can withstand the pressure exerted during floods. Besides regular supervision and necessary repair of embankments well before the onset of monsoon season, the following points deserve special attention.

A systematic survey and investigations of the existing embankments is required to be carried out every year after the flood season and encroachment, if any, in the free board in any portion should be made good by raising the height of the embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of the results of hydraulic model-studies to keep the flowing channel away from the embankment. In the portion where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or at least provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently under emergent situations.

8.3.6 Non-Structural Measures

8.3.6.1 Flood Plain Zoning

The question of introducing flood plain zoning measures has been under consideration for a long time. In view of the increasing pressure of population and consequent greater encroachment of flood plain, zoning has assumed added significance. The flood damage in recent years is primarily due to greater encroachment into flood plains. The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As major portion of flood prone area in the Sone basin is protected by embankments, such zoning regulations should be introduced in the unprotected areas first and thereafter for the protected areas.

It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour interval of 0.3 metre for implementation of this measure. Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of floods such as 100 years, 50 years and 25 years. Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain, corresponding to a 50 years and 25 years rainfall will also have to be prepared.

8.3.6.2 Flood Forecasting and Flood Warning

Flood forecasting and warning has proved to be a great help in issuing warning to the people in flood prone areas, organising flood fighting and safety measures for the engineering works, timely evacuation of people from affected areas and salvation of movable properties besides mobilising relief operations.

At present there are two flood forecasting sites on the Sone river in Bihar namely Koelwar and Maner where daily forecasts are issued by the Central Water Commission during monsoon season when the river stage is at or above the warning level which is generally about one metre below the danger level. It is considered desirable to have arrangements for inflow forecasting at, and making available the quantum of actual outflows from, the reservoirs like Bansagar, Rihand, Kutku and other proposed ones like Kadhwan etc in the Sone river system This would increase the lead time of the flood forecast for Koelwar and Maner sites considerably.

It is necessary to progressively refine and update the techniques of collection and processing of data and forecasting arrangements by way of improving communication systems and using telemetering devices so as to obtain increased warning time and reliable forecasts. Methods of observation of rainfall & runoff and their communication to the control rooms should be improved with the use of latest available technology.

Although there is wide application of the flood forecasting system and warnings issued by CWC, there is very little feed back on the procedure specified or evolved by the Civil Administration and the Engineering Organisation for undertaking relief/rescue/ precautionary action on the basis of the forecast. It is also not known as to how effectively the necessary advice is being given to the people.

On receipt of the forecast its dissemination to the local population in terms of likely depth of inundation and its duration in the area, by the Administrative authorities is very important so that affected population, cattle, movable properties etc are evacuated before the area gets submerged by flood waters which would cause damage. For this, a network of wireless stations and telephone system are necessary in the basin near critical vulnerable reaches of embankments and towns etc, specially where other means of communication are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the location which could be considered safe for the level indicated in the flood forecast. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property. This training programme should become a regular feature before the flood season every year.

8.3.6.3 Disaster Mitigation System and Preparedness

This is an important measure which directly influences the damage prevention, if managed efficiently, at all levels according to the prescribed procedure and guidelines. Improper management could also result directly in increased damage. The State Government should, therefore, ensure that all routine exercises and necessary drills are carried out systematically before every flood season. Departmental instructions, manuals, and rules in this regard should be widely circulated so as to make these available to all concerned. It is observed that disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year. Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the officers and staff of the concerned departments as also in the public and voluntary organisations to deal with flood emergency.

It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develope confidence amongst all concerned to manage any emergency situation. The training programmes, including education and publicity should be got arranged by Civil Authorities with active participation of the officers-in-charge of flood management and Voluntary Organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio (Akashwani), Doordarshan or transmitted through other channels and the effective follow up of such messages into appropriate actions should be taught to all people in the flood prone areas.

8.4 The maps of the Sone River Basin showing the completed, under execution and proposed flood management and drainage schemes are enclosed as Drawing No 8/01, 8/02.

9.0 SUMMARY DF RECOMMENDATIONS

9.1 It is observed that the hydrometeorological data of this basin are not being observed, collected, analysed and documented in a systematic manner. India Meteorological Department have suggested at least one raingauge station for every 500 Sq Km of the drainage area of the basin. It also specifies that at least 10 per cent of such raingauge stations should be self recording. This has to be increased to 20 per cent as recommended by Rashtriya Barh Ayog (RBA). The number of raingauge stations in hilly area is less than required which may be increased to conform to the prescribed norms. The number of self recording raingauge stations is also less which may also be increased in order to get reliable rainfall data including intensity of rainfall for sufficiently long period for detailed hydrological studies of the basin in future.

[Para 4.2, 4.4.1, 4.5]

9.2 According to the norms suggested by WMO, 121 gauge-discharge sites are necessary in the whole basin (74 nos. for hilly & 47 for plain). Against this, only 70 sites are available out of which 13 nos. are in hilly areas and 57 nos. are in plains. From this, it is quite clear that the Sone river system as a whole has adequate number of gauge and discharge sites in plains but very inadequate in hilly area which needs to be strengthened further.

[Para 4.7.1, 4.7.2]

9.3 The availability of data is not continuous for all the raingauge stations in the basin for a reasonably long period. It is for this reason that rainfall run off relationship could not be precisely established. It is, therefore, suggested that the State Government should make all out efforts to collect the rainfall and run-off data in the basin for as many years as available and carry out further studies to establish precise rainfall-run-off relationship at suitable locations on the river Sone for future use.

[Para 4.8.1, 4.8.2]

9.4 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guidelines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankment, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile necessary step may be taken for eventual application of benefit cost criterion for fixing the design."

The summary of recommendations as accepted is as follows:

"In the case of embankment schemes, the height of the embankment and corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio,taking into account the damage likely to occur for the relative flood frequencies. However, till such time as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 year frequency in the case of predominantly agricultural areas and for flood of 100 year frequency for works pertaining to town protection and protection of industrial and other vital organisations".

While endorsing the decisions of the Ministry of Irrigation, Govt. of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to protection of towns and vital industrial, defence establishments etc.

[Para 5.2.2, 5.2.3]

9.5 It is observed from the available annual peak discharges of Chopan and Koelwar sites that the discharges at upper site are more than lower in most of the years. One of the possible cause might be spilling of the river during floods above the Koelwar site. However, this needs to be investigated in detail in order to pinpoint the exact reason in order to establish the reliability of the recorded observed data.

[Para 5.3.3]

9.6 The results of the flood frequency studies are useful in delineating the flood prone area on the contour map in order to be aware of the situation in the unprotected area at different stages of the river during floods. To make this study useful, it is essential to obtain the contour map (with contour at suitable interval) of the area prone to floods preferably in a scale of 1:15000. These studies can also be made in formulation and planning of future flood protection and management schemes in the basin.

[Para 5.4]

9.7 It is observed that the flood damage statisticss, which is essentially required for the benefit-cost studies for any proposed flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The Commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river basin wise be carried out every year under the following three separately identified categories:

i Unprotected areas;

ii Protected areas due to failure of protection works;

iii Areas between the embankments and the river.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data in order to eliminate any inconsistency. The flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long-term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area.

As such the flood damage data should be collected by the Revenue authorities with active co-operation of the staff of Water Resources, Agriculture and Road & Building Construction Departments and the data should be processed and compiled both districtwise as well as basin/sub-basinwise by the Statistical Organisations at district and State level for future use, for planning of relief measures and flood management work respectively.

[Para 6.3.4, 6.3.5]

9.8 From the perusal of the data processed by the Revenue Department it is noticed that damages to property of Central Government such as Railways, Posts & Telegraphs etc are not properly accounted for. On the other hand, the cost of relief and rehabilitation measures, grant of loans, remission of land revenue etc is added to flood damages. This does not appear to be in order and needs to be looked into.

[Para 6.3.7]

9.9 Reservoirs at Bansagar on the main Sone (in MP), Kutku on the North Koel (in Bihar), Auranga on the Auranga (in Bihar) and Amwar on the Kanhar (in UP) are under construction at present and lingering since long. All out efforts are required to be made to ensure their early completion within shortest possible time from now to avoid any further time and cost overrun besides accrual of the desired benefits which is not being available inspite of huge investments already made. Reservoirs on the tributaries of North Koel namely the Amanat and Tahle and on Kanhar upstream of Amwar site are also proposed in Bihar. Construction of these reservoirs should be taken up as early as possible as these are awaiting final sanction since last two decades.

[Para 8.3.1]

9.10 Total storage provided or likely to be provided in the existing or proposed reservoirs in the Sone basin is expected to be of the order of 2511 MCM. On creation, this magnitude of storage may be capable of absorbing all medium floods and would considerably reduce the major flood peaks by carefully integrated operation of the reservoirs for irrigation, flood control and hydroelectric power generation. Systematic study on these lines needs to be planned and carried out.[Para 8.3.2]

9.11 It has been reported that the following gaps are existing in the embankments due to some reason or the other which are not technical but mainly administrative.

i 244 m of masonry dowel wall in Koelwar Ring Bundh.

ii Sone Left Emabnkments between Km 5.02 to 5.95, Km 6.95 to 7.13, Km 8.36 to 8.47, Km 10.06 to 10.61, Km 10.91 to 12.31, Km 13.67 to 13.87 and Km 22.07 to 22.25.

These gaps need to be plugged at the earliest in order to ensure the effectiveness of the embankments in serving their desired purpose. In the existing situation construction of any further embankment on the river Sone is not considered necessary.

[Para 8.3.2]

9.12 The Tripathi Committee constituted by State Government after 1975 Patna floods to suggest measure for protection of Patna, had recommended some drainage schemes out of which one namely Channel No 1 of sector II of Patna Town Protection Scheme under Rural Drainage Scheme relates to the Sone. This scheme was included in the approved Patna Town Protection Scheme but construction work has not yet been taken up. From the reports received from the concerned Chief Engineer, the necessity of either this or any new drainage scheme in this basin is not primafacie established. It is, therefore, suggested that the drainage problem of the basin in its tail reach near its confluence with the Ganga be investigated in detail and appropriate technically feasible and economically viable remedial measures be planned and executed at an early date if found necessary in the existing situation.

[Para 8.3.3]

9.13 Restoration of the vegetative cover to check soil erosion is required for long term management of the problem of sediment in the river system. Soil conservation work may be taken up by land treatment through afforestation and cropland development supplemented by structural work for retarding the velocity of water over land and detaining silt. This may also include general afforestation, grazing control, terraced cultivation, gully plugging and contour bunding as found feasible in particular areas. These measures will be helpful in modifying minor and medium floods over small area. Priority areas for this have to be identified through preparation of priority delineation maps on the basis of reconaissance survey and taking help of aerial photographs and sattelite imagery.

[Para 8.3.4]

9.14 Systematic survey and investigation of the existing embankments on both banks of the river is required to be carried out every year after the flood season and encroachment, if any, in the free board in any portion should be made good by raising the height of the embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out, on the basis of the results of hydraulic model studies, to keep the flowing channel away from the embankment.

[Para 8.3.5]

9.15 In the portion where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or at least provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently under emergent situations.

[Para 8.3.5]

9.16 The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As major portion of flood prone area in the Sone basin is Protected by embankments, such zoning regulations should be introduced in the unprotected areas first and thereafter for the protected areas.

[Para 8.3.6.1]

9.17 It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour interval of 0.3 meter for implementation of Flood Plain Zoning measure. Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of floods such as 100 years, 50 years and 25 years. Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain corresponding to a 50 years and 25 years rainfall will also have to be prepared.

[Para 8.3.6.1]

9.18 At present there are two flood forecasting sites on the Sone river in Bihar namely Koelwar and Maner where daily forecasts are issued by the Central Water Commission during monsoon seasons, when the river stage is at or above the warning level which is generally about one metre below the danger level. It is considered desirable to have arrangements for inflow forecasting at, and making available the quantum of actual outflows from, the reservoirs like Bansagar, Rihand, Kutku and other proposed ones like-Kadhwan etc in the Sone river system. This would increase the lead time of the flood forecast for Koelwar and Maner sites considerably.

It is necessary to progressively refine and update the techniques of collection and processing of data and forecasting arrangements by way of improving communication systems and using telemetering devices according to the latest technology available so as to obtain increased warning time and reliable forecasts. Methods of observation of rainfall and runoff and their communication to the Control rooms should be improved with the use of latest available technology.

[Para 8.3.6.2]

9.19 On receipt of the forecast its dissemination to the local population in terms of likely depth of inundation and its duration in the area, by the Administrative authorities, is very important so that affected population, Cattle, movable properties etc are evacuated before the area gets submerged by flood waters which would cause damage. For this, a net-work of wireless stations and telephone system are necessary in the basin near critical/ vulnerable reaches of embankments and towns etc specially where other means of communication are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the location which could be considered safe for the level indicated in the flood forecast. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property. This training programme should become a regular feature before the flood season every year.

[Para 8.3.6.2]

9.20 The State Government should ensure that all routine exercises and necessary drills are carried out systematically before every flood season. Departmental instructions, manuals and rules in this regard should be widely circulated so as to make these available to all concerned. It is observed that disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year. Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the Officers and Staff of the Concerned Departments as also in the public and voluntary organisations to deal with flood emergency.

[Para 8.3.6.3].

9.21 It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. The training programmes including education and publicity should be got arranged by Civil Authorities with active participation of thc Officers-in charge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio (Akashwani), Doordarshan or transmitted through other channels and the effective follow up of such messages into appropriate actions should be taught to ali people in the flood prone areas.

[Para-8.3.6.3]

TOTAL NUMBER OF RAINGAUGE STATIONS IN AND AROUND SONE CATCHMENT REPORTED/MAINTAINED BY DIFFERENT AGENCIES

Sl No	Name of Tributary	NUMBER OF STATIONS MAINTAINED BY						Total of Rain Gauge stations
		IMD	MP Govt	UP Govt	BIHAR Govt	CWC GB WRD	Agency Unknown	
1	MAHANADI	17	9					26
2	JOHILLA	3	5					8
3	UPPER SONE	2	14			1		17
4	BANAS	1	6					7
5	GOPAD	1	7					8
6	RIHAND	6	12	6		1		25
7	KANHAR	6	4			1	3	14
8	GHAGHAR	1		1				2
9	NORTH KOEL	26				1	2	29
10	INTERVENING CATCHMENT	22	5		1	4		32
	TOTAL	85	62	7	1	8	5	168

[SOURCE: COMPREHENSIVE PLAN OF FLOOD MANAGEMENT FOR THE SONE RIVER SYSTEM PREPARED BY GFCC IN 1989]

Annex 2

NORMAL RAINFALL AND RAINY DAYS AT VARIOUS SITES IN A YEAR IN BIHAR PORTION OF THE SONE BASIN

(RAINFALL IN mm)

SL NO	RAINGAUGE STATIONS	LOCATION		NORMAL ANNUAL RAINFALL	NORMAL RAINYDAY IN A YEAR
		LAT	LONG		
1	BHANDARIA	23°43'	83°50'	1471.9'	69.1
2	RANKA	24°00'	83°50'	1337.7'	66.8
3	NAGARUNTARE	24°17'	83°30'	1166.4'	62.7
4	BALUMATH	23°50'	84°47'	1384.4'	68.7
5	BARWADIH	23°51'	84°07'	1334.3'	67.1
6	BISRAMPUR	24°15'	83°56'	1269.5'	59.8
7	BISHUNPUR	23°23'	84°20'	1447.6'	87.5
8	DALTONGANJ(OBSY)	24°03'	84°04'	1242.4'	63.9
9	GARU	23°40'	84°14'	1603.1'	73.9
10	GARHWA	24°10'	83°48'	1206.4'	62.2
11	LATEHAR	23°45'	84°30'	1322.7'	67.0
12	LESLIGANJ	24°03'	84°13'	1220.6'	59.8
13	MAHUADAUR	23°24'	84°08'	1412.6'	72.6
14	MANATU	24°14'	84°24'	1490.2'	65.3
15	NETARHAT	23°29'	84°16'	1817.4'	84.7
16	PANKI	24°03'	84°28'	1203.2'	62.4
17	CHATTARPUR	24°22'	84°12'	1242.4'	62.0
18	CHATRA	24°12'	84°52'	1344.2'	66.8
19	CHANDWA(CHANWA)	23°41'	84°44'	1470.7'	72.3
20	GUMLA	23°02'	84°33'	1471.0'	82.3
21	HUSAINABAD	24°32'	84°01'	1079.1'	51.3
22	BHAUNATHPUR	24°23'	83°35'	1173.8'	52.2
23	ARWAL	25°14'	84°41'	1065.9'	53.2
24	DAUDNAGAR	25°03'	84°24'	1311.0'	55.9
25	DEHRI(OBSY)	24°55'	84°11'	1122.6'	55.1
26	AGEAON	25°23'	84°36'	1189.6'	51.5
27	PALIGANJ	25°20'	84°50'	954.0'	44.2

[SOURCE: COMPREHENSIVE PLAN OF FLOOD MANAGEMENT FOR THE SONE RIVER SYSTEM PREPARED BY GFCC IN 1989]

MONTHLY RAINFALL AT VARIOUS SITES IN BIHAR OF THE SONE RIVER BASIN

RAINFALL IN mm

Sl No	Raingauge Stations	June	July	Aug	Sept	Oct	Total Monsoon	Nov	Dec	Jan	Feb	Mar	Apr	May	Total Non Monsoon	Annual
1	BHANDARIA	165.3	414.5	418.3	244.9	70.9	1313.9	25.9	7.4	30.2	43.4	22.1	10.7	18.3	158.0	1471.9
2	RANKA	160.0	374.4	382.5	216.7	57.9	1191.5	15.5	5.3	27.9	41.1	22.6	12.2	21.6	146.2	1337.7
3	NAGARUNTARE	129.8	342.7	344.7	184.9	49.5	1051.6	14.7	5.6	25.9	34.3	14.7	6.9	12.7	114.8	1166.4
4	BALUMATH	169.2	364.7	407.9	218.7	70.6	1231.1	17.5	5.8	22.9	40.9	22.3	11.9	32.0	153.3	1384.4
5	BARWADIH	177.8	389.1	372.4	193.5	68.6	1201.4	16.5	8.4	31.0	38.6	20.1	8.4	9.9	132.9	1334.3
6	BISRAMPUR	152.7	364.7	380.0	199.6	51.8	1148.8	17.8	6.1	27.2	33.8	15.5	7.4	12.9	120.7	1269.5
7	BISHUNPUR	198.9	364.0	390.9	239.0	79.5	1272.3	10.4	4.3	33.8	48.8	25.9	15.5	36.6	175.3	1447.6
8	DALTONGANJ(OBSY)	153.4	350.8	362.7	196.9	53.3	1117.1	14.2	4.6	26.9	33.8	20.1	10.2	15.2	125.0	1242.1
9	GARU	241.3	421.6	459.2	232.4	77.0	1431.5	19.8	6.3	31.0	43.9	29.2	17.8	23.6	171.6	1603.1
10	GARHWA	141.7	336.0	345.4	206.0	51.8	1080.9	15.2	4.8	29.0	33.8	18.0	6.9	17.8	125.5	1206.4
11	LATEHAR	176.5	358.4	368.5	209.0	71.1	1183.5	14.7	7.1	26.4	36.1	20.1	10.9	23.9	139.2	1322.7
12	LESLIGANJ	164.3	357.4	353.3	190.5	41.4	1106.9	17.0	5.3	22.1	34.8	16.5	8.9	9.1	113.7	1220.6
13	MAHUADAUR	189.1	380.2	388.9	208.8	82.8	1250.4	22.3	5.8	28.2	40.1	23.6	10.2	32.0	162.2	1412.6
14	MANATU	185.7	389.4	474.0	253.7	52.8	1355.6	16.0	6.1	33.5	35.1	17.5	11.2	15.2	134.6	1490.2
15	NETARHAT	243.8	504.2	511.6	251.2	108.7	1619.5	26.2	7.9	32.0	42.9	33.3	13.2	42.4	197.9	1817.4
16	PANKI	136.9	343.4	381.8	181.6	45.7	1089.4	15.5	3.8	24.9	29.2	16.0	7.9	16.5	113.8	1203.2
17	CHATTARPUR	156.5	319.3	385.8	222.0	48.8	1132.4	15.2	4.6	23.6	30.5	16.0	7.9	12.2	110.0	1242.4
18	CHATRA	173.2	360.9	385.1	229.1	61.0	1209.3	18.0	4.1	27.2	33.0	18.5	10.7	23.4	134.9	1344.2
19	CHANDWA(CHANWA)	186.7	381.0	409.2	232.9	104.9	1314.7	23.9	6.3	25.9	36.6	22.9	11.2	29.2	156.0	1470.7
20	GUMLA	215.9	385.1	374.9	210.8	94.0	1280.7	21.8	5.8	26.9	46.7	28.2	20.8	40.1	190.3	1471.0
21	HUSAINBAD	113.3	288.0	336.5	186.9	54.4	979.1	8.1	2.5	28.5	27.9	13.7	7.6	11.7	100.0	1079.1
22	BHAUNATHPUR	121.2	344.7	369.8	195.6	43.4	1074.7	10.4	3.3	24.4	30.5	12.9	7.4	10.2	99.1	1173.8
23	ARWAL	127.8	299.0	310.6	197.1	48.0	982.5	10.2	3.8	16.3	23.4	7.6	5.3	16.8	83.4	1065.9
24	DAUDNAGAR	142.5	364.5	411.0	230.9	55.6	1204.5	14.0	4.3	24.1	26.4	12.5	5.1	20.1	106.5	1311.0
25	DEHRI(OBSY)	128.5	282.2	360.9	214.9	44.2	1030.7	11.9	4.3	19.6	24.6	11.7	7.1	12.7	90.9	1121.6
26	AGEAON	141.2	314.5	346.5	225.8	65.3	1093.3	10.7	5.8	19.1	23.4	7.6	6.3	23.4	96.3	1189.6
27	PALIGANJ	97.0	251.2	293.5	200.7	88.6	886.0	6.3	2.0	16.3	15.0	4.8	5.1	18.5	68.0	954.0

[SOURCE :- Comprehensive Plan of Flood Management for the Sone River System prepared by GFCC in 1989.]

Annex 3

THE YEARLY MAXIMUM OBSERVED GAUGE, DISCHARGE AND DANGER LEVEL AT VARIOUS SITES DF THE SONE RIVER SYSTEM IN BIHAR

NAME OF SITE: JAPLA DANGER LEVEL (in m): 125.09

YEAR	PEAK GAUGE (in m)	DATE	PEAK DISCHARGE (in cumec)	DATE
1965	126.560	9.9.65	3212.06	8.9.65
1966	125.720	31.7.66	2984.25	10.8.66
1967	127.090	24.8.67	5353.55	23.8.67
1968	126.850	14.8.68	5993.59	14.8.68
1969	126.950	16.8.69	3861.59	7.8.69
1970	127.340	12.9.70	9020.14	2.9.70
1971	127.870	20.7.71	9297.80	31.9.71
1972	126.730	9.8.72	3341.09	14.8.72
1973	126.400	30.8.73	3871.20	10.9.73
1974	126.774	19.8.74	22602.45	17.8.74
1975	127.940	23.8.75	26131.63	20.7.75
1976	127.640	17.9.76	10730.08	17.9.76
1977	126.920	30.7.77	2202.21	20.7.77
1978	127.260	25.9.78	4530.19	7.9.78
1979	125.985	10.8.79	3127.16	10.8.79
1980	126.860	17.7.80	11691.61	21.9.80
1981	125.585	25.8.81	3404.12	25.8.81
1982	126.290	1.9.82	7027.81	1.9.82
1983	126.980	9.9.83	11273.97	9.9.83
1984	127.210	5.9.84	9980.72	1.9.84
1985	126.140	29.8.85	7003.96	29.8.85
1986	125.670	22.8.86	4398.00	22.8.86
1987	127.840	11.9.87	20011.36	11.9.87
1988	126.420	13.8.88	8650.46	13.8.88

Annex 3 (contd)

NAME DF SITE: NASRIGANJ Danger level (in m)

YEAR	PEAK GAUGE (in m)	DATE	PEAK DISCHARGE (in cumec)	DATE
1970	97.920	12.7.70	3345.40	16.7.70
1971	98.620	20.7.71	8402.9	18.8.71
1972	98.620	9.8.72	6616.08	1.9.72
1973	90.700	31.8.71	2778.41	3.10.73
1974	92.050	19.8.74	6645.52	20.8.74
1975	19.550	23.8.75	14172.47	19.7.75
1976	92.350	17.9.76	10835.36	16.8.76
1977	91.640	31.7.77	9040.99	9.8.77
1978	92.315	25.9.78	25495.90	25.9.78
1979	92.095	11.8.79	5275.69	11.8.79
1980	89.750	17.7.80	16994.06	17.7.80
1981	91.330	25.8.81	4660.24	28.8.81
1982	92.205	1.9.82	11636.42	1.9.82
1983	91.850	10.9.83	20366.82	10.9.83
1984	90.340	5.9.84	14241.22	5.9.84
1985	89.690	22.8.85	7150.59	22.8.85
1986	93.230	23.8.86	4489.78	23.8.86
1987	93.230	11.9.87	30745.30	11.9.87
1988	90.930	13.8.88	7819.78	13.8.88

NAME OF SITE :DALTENGANJ DANGER LEVEL (in m)209.00

YEAR	PEAK GAUGE (in m)	DATE	PEAK DISCHARGE (in cumec)	DATE
1970	N.A	857.32	12.9.70	
1971	208.848	30.8.71	959.41	7.9.71
1972	208.58	7.8.72	729.58	8.8.72
1973	208.8	29.9.73	657.78	20.8.73
1974	208.67	16.8.74	719.46	29.8.74
1975	209.62	18.7.75	849.46	16.7.75
1976	210.91	17.9.76	515.96	14.8.76
1977	209.0	10.9.77	558.98	8.9.77
1978	209.39	4.8.78	620.59	7.8.78
1979	207.84	18.8.79	308.48	17.8.79
1980	208.85	13.7.80	277.34	29.7.80
1981	208.33	14.7.81	1057.20	14.7.81
1982	208.28	5.9.82	1296.24	5.9.82
1983	207.75	7.9.83	397.47	27.7.83
1984	208.75	3.9.84	2013.31	3.9.84
1985	208.22	29.8.85	860.35	29.8.85
1986	206.67	13.7.86	956.08	13.7.86
1987	209.25	12.9.87	3165.59	13.9.87
1988	208.44	13.6.88	740.14	13.6.88

Annex 3 contd

NAME OF SITE : MOHAMADGANJ DANGER LEVEL : NA

YEAR	PEAK GAUGE (in m)	DATE	PEAK DISCHARGE (in cumec)	DATE
1956	144.100		NA	
1957	143.850		NA	
1958	143.630		NA	
1959	142.990		NA	
1960	144.210	1178.80		
1961	144.527	25.8.61	1430.30	8.8.61
1962	144.350	23.9.62	1044.30	3.8.62
1963	143.828	24.10.63	902.87	4.9.63
1964	143.720	9.9.64	1405.97	9.9.64
1965	144.813	29.7.65	4831.84	24.9.65
1966	143.803	5.8.66	1050.28	6.8.66
1967	144.778	24.8.67	1804.12	24.8.67
1968	143.958	13.8.68	1169.36	14.8.68
1969	144.038	8.8.69	1552.61	14.8.69
1970	145.378	11.9.70	2149.84	26.8.70
1971	144.678	9.8.71	2173.90	31.8.71
1972	144.428	14.7.72	1581.33	19.9.72
1973	143.598	20.8.73	1618.12	20.8.73
1974	143.928	17.8.74	2219.72	17.8.74
1975	144.578	18.7.75	3739.42	17.7.75
1976	146.658	17.9.76	939.52	30.7.76
1977	145.668	30.7.77	1370.51	5.8.77
1978	144.928	26.9.78	3188.88	28.9.78
1979	142.978	18.8.79	500.37	28.9.79
1980	143.178	8.9.80	894.50	8.9.80
1981	142.928	23.8.81	556.06	15.7.81
1982	143.878	31.8.82	1831.26	31.8.82
1983	142.648	29.7.83	6650.43	8.9.83
1984	143.738	19.8.84	1410.52	3.9.84
1985	143.473	7.8.85	1394.40	7.8.85
1986	143.285	28.7.86	1218.03	4.8.86
1987	145.578	11.9.87	3727.00	11.9.87
1988	142.548	12.8.88	1873.97	14.6.88

Annex 3 (contd)

NAME OF SITE :KOELWAR DANGER LEVEL (in m): 55.52

YEAR	PEAK GAUGE (in m)	DATE	PEAK DISCHARGE (in cumec)	DATE
1956	57.060		NA	
1957	56.570		NA	
1958	55.060		NA	
1959	54.490		NA	
1960	57.558	18.8.60	11551.00	18.8.60
1961	57.375	11.7.61	4259.00	7.8.61
1962	55.968	8.8.62	7050.42	8.8.62
1963	55.649	6.9.63	4316.00	6.9.63
1964	57.584	27.8.64	16333.04	27.8.64
1965	57.184	9.9.65	8423.11	10.9.65
1966	55.474	1.8.66	3889.04	3.8.66
1967	57.034	25.8.67	7085.18	21.9.67
1968	57.474	15.8.68	4250.81	18.8.68
1969	57.374	17.8.69	5245.72	16.8.69
1970	57.369	12.9.70	14844.86	12.9.70
1971	58.674	20.7.71	36818.64	20.7.71
1972	56.840	10.8.72	10560.45	10.8.72
1973	56.404	21.8.73	5203.96	4.9.73
1974	57.084	19.8.74	10614.40	19.8.74
1975	58.789	23.8.75	26441.93	22.8.75
1976	57.954	18.9.76	20595.30	18.9.76
1977	57.414	31.7.77	10317.03	9.8.77
1978	57.939	25.9.78	17856.01	25.9.78
1979	56.064	11.8.79	6452.25	11.8.79
1980	57.074	18.7.80	10908.06	22.9.80
1981	55.369	28.8.81	4323.40	26.8.81
1982	56.622	1.9.82	10699.75	2.9.82
1983	58.014	10.9.83	20450.05	10.9.83
1984	58.094	6.9.84	8737.70	31.8.84
1985	55.729	23.8.85	5795.38	23.8.85
1986	55.104	9.8.86	4280.13	9.8.86
1987	58.590	11/12.9.87	13260.58	16.9.87
1988	56.524	14.8.88	4512.77	6.8.88

EVER MAXIMUM OBSERVED GAUGE AND DISCHARGE IN RESPECT OF THE ABOVE MENTIDNED SITES OF THE RIVER SYSTEM ARE TABULATED BELOW

Sl No	Name of Sites	Name of River	Maximum Dbserved Gauge in metre	Date of Occurance	Maximum Observed Discharge (Cumec)	Date of Occurance
1	JAPLA	SONE	127.940	23.8.75	26131.63	20.7.75
2	NASRIGANJ	SONE	98.620	20.7.71	30745.30	11.9.87
3	DALTENGANJ	NORTHKOEL	210.910	17.9.76	3165.59	13.9.87
4	MOHAMADGANJ	NORTHKOEL	146.658	17.9.76	8727.00	11.9.87
5	KOELWER	SONE	58.789	23.8.75	36818.64	20.7.71

[SOURCE: COMPREHENSIVE PLAN OF FLOOD MANAGEMENT FDR THE SONE RIVER SYSTEM PREPARED BY GFCC IN 1989]

Annex 4

AVERAGE ANNUAL SILT DATA OF THE SONE RIVER SYSTEM AT DIFFERENT SITES IN BIHAR

RIVER SONE **SITE-JAPLA** UNIT- LAKH TONNES

SL.NO	YEAR	ANNUAL SILT LOAD	REMARKS
1	1978	241.67	
2	1979	284.82	
3	1980	199.53	
4	1981	164.02	
5	1982	475.97	
6	1983	159.16	
7	1984	376.81	
8	1985	150.22	
9	1986	91.31	

RIVER-NORTH KOEL **SITE-MOHAMADGANJ** UNIT-LAKH TONNES

SL.NO	YEAR	ANNUAL SILT LOAD	REMARKS
1	1981	7.93	
2	1982	5.55	
3	1983	15.31	
4	1984	95.40	
5	1985	56.33	
6	1986	33.00	

RIVER-SONE **SITE-KOELWAR** UNIT-LAKH TONNES

SL.NO	YEAR	ANNUAL SILT LOAD	REMARKS
1	1962	223.42	
2	1963	204.60	
3	1964	611.56	
4	1965	187.43	
5	1966	182.21	
6	1967	501.99	
7	1968	100.39	
8	1969	242.93	
9	1970	301.30	
10	1971	3380.67	
11	1972	119.07	
12	1973	265.89	
13	1974	147.24	
14	1975	1018.57	
15	1976	420.62	
16	1977	598.96	
17	1978	605.50	
18	1979	108.38	
19	1981	54.42	
20	1982	475.89	
21	1983	181.11	
22	1984	789.93	
23	1985	269.72	
24	1986	173.48	

[SOURCE: COMPREHENSIVE PLAN OF FLOOD MANAGEMENT FOR THE SONE RIVER SYSTEM PREPARED BY GFCC. IN 1989]

Annex 5

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING COMPUTED DISCHARGE AND OBSERVED DISCHARGE

SITE- JAPLA **RIVER-SONE**

Sl No	Year	Observed Annual Peak Gauge (m)	Corresponding Annual Peak Discharge (Cumecs)	Observed Peak Discharge (Cumecs)
1	1965	126.560	3291.58	3212.06
2	1966	125.750	2860.00	2984.25
3	1967	127.090	12276.57	5353.55
4	1968	126.850		5993.59
5	1969	126.980	5975.00	3861.59
6	1970	127.340	4180.00	9020.14
7	1971	127.870	15657.20	9297.80
8	1972	126.730	739.46	3341.09
9	1973	126.400	5215.00	3871.20
10	1974	126.740	14374.31	22602.45
11	1975	127.940	20385.12	26131.63
12	1976	127.640		10730.08
13	1977	126.920	4072.07	2202.21
14	1978	127.260	8200.00	4530.19
15	1979	125.985		3127.16
16	1980	126.860	7200.00	11691.61
17	1981	125.585		3404.12
18	1982	126.290		7027.81
19	1983	126.980		11223.97
20	1984	127.210	16895.60	9980.70
21	1985	126.140		7003.96
22	1986	125.670		4398.00
23	1987	127.840	N A	20011.36
24	1988	126.420	N A	8650.46

Annex 5 (contd)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING COMPUTED DISCHARGE AND OBSERVED DISCHARGE

Site – Nasriganj **River Sone**

Sl No	Year	Observed Annual Peak Gauge (m)	Corresponding Annual Peak Discharge (Cumecs)	Observed Peak Discharge
1	1970	97.920	9460.00	3345.40
2	1971	98.620		8402.90
3	1972	98.620	9490.00	6616.08
4	1973	90.700	4260.00	2778.41
5	1974	90.050	13629.32	6645.52
6	1975	93.550	2950.87	14172.47
7	1976	92.350	16299.94	10835.36
8	1977	91.640	4117.76	9040.99
9	1978	92.315		25495.90
10	1979	90.185		5275.69
11	1980	92.095		16994.06
12	1981	89.750	4112.22	4660.24
13	1982	91.330		11636.42
14	1983	92.205		20366.82
15	1984	91.850		14241.22
16	1985	90.340		7156.59
17	1986	89.690		4489.78
18	1987	93.230	NA	30745.30
19	1988	90.930	NA	7819.78

Annex 5 (contd)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING COMPUTED DISCHARGE AND OBSERVED DISCHARGE

Site Daltenganj **River North Koel**

Sl No	Year	Observed Annual Peak Gauge (m)	Corresponding Annual Peak Discharge (Cumecs)	Observed Peak Discharge
1	1970	NA	NA	857.32
2	1971	208.848	968.00	959.41
3	1972	208.580	836.27	729.58
4	1973	208.800	853.32	657.78
5	1974	208.670	400.73	719.46
6	1975	209.020	1322.29	849.46
7	1976	210.910	618.00	515.96
8	1977	209.000	2258.27	858.98
9	1978	209.390	1330.00	620.59
10	1979	209.840	439.08	308.48
11	1980	208.850	426.00	277.34
12	1981	208.330	1057.20	
13	1982	208.280	1296.24	
14	1983	207.750	288.33	397.47
15	1984	208.750	2013.31	2013.31
16	1985	208.220	860.35	
17	1986	208.670	958.08	
18	1987	208.250	–	3165.59
19	1988	208.440	–	740.14

Annex 5 (contd)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING COMPUTED DISCHARGE AND OBSERVED DISCHARGE

Site Mohammedganj **River North Koel**

Sl No	Year	Observed Annual Peak Gauge (m)	Corresponding Annual Peak Discharge (Cumecs)	Observed Peak Discharge
1	1961	144.527	846.20	1430.30
2	1962	144.350	1086.25	1044.30
3	1963	143.828	195.76	902.87
4	1964	143.720		1405.97
5	1965	144.813	2949.70	4831.34
6	1966	143.803	736.79	1050.28
7	1967	144.778		1804.12
8	1968	143.958	1540.00	1159.36
9	1969	144.038	1137.31	1552.61
10	1970	145.378	2987.93	2149.84
11	1971	144.678	3975.00	2173.90
12	1972	144.428	168.42	1581.33
13	1973	143.598		1618.12
14	1974	143.928		2219.72
15	1975	144.578		3739.42
16	1976	146.658	16358.94	939.52
17	1977	145.668	2783.59	1370.51
18	1978	144.928	4760.00	3188.88
19	1979	142.978	870.00	500.37
20	1980	143.178	894.50	894.50
21	1981	142.928	641.41	556.06
22	1982	143.878		1831.26
23	1983	142.648	602.28	650.43
24	1984	143.738	2030.00	1410.52
25	1985	143.473		1394.40
26	1986	143.283	1198.07	1218.03
27	1987	145.578	–	8727.00
28	1988	142.548	–	1873.97

Annex 5 (contd)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING COMPUTED DISCHARGE AND OBSERVED DISCHARGE

Site Koelwar **River Sone**

Sl No	Year	Observed Annual Peak Gauge (m)	Corresponding Annual Peak Discharge (Cumecs)	Observed Peak Discharge
1	1960	57.558	11551.00	
2	1961	57.375	6900.00	4259.00
3	1962	55.968	7050.42	
4	1963	55.649	4316.09	
5	1964	57.584	16333.04	
6	1965	57.184	5860.69	8423.11
7	1966	55.474	3606.99	3889.04
8	1967	57.340	7185.47	7085.18
9	1968	57.474	4924.15	4250.81
10	1969	57.374	9841.67	5245.72
11	1970	57.369	14844.86	
12	1971	58.674	36818.64	
13	1972	56.840	10560.45	
14	1973	56.404	6488.95	5203.96
15	1974	57.084	10614.40	10614.40
16	1975	58.789	32363.68	26441.93
17	1976	57.954	20595.30	
18	1977	57.414	16582.12	10317.03
19	1978	57.939	17859.00	
20	1979	56.064	6452.25	
21	1980	57.074	8499.11	10908.06
22	1981	55.369	4323.40	
23	1982	56.622	10699.75	
24	1983	58.014	20450.05	
25	1984	58.094	12660.11	8737.70
26	1985	55.729	5795.38	
27	1986	55.104	4280.13	
28	1987	58.590	NA	13260.58
29	1988	56.524	NA	4512.77
30	1989	54.890	–	–
31	1990	58.594	–	–

[Source: Comprehensive Plan of Flood Management for the SONE RIVER SYSTEM prepared by GFCC in 1989]

Annex 5 (contd)

MAXIMUM DISCHARGE DATA AT INDRAPURI

Year	Total river discharge at barrage site at Indrapuri (in cumec)
25.9.78	20432.60
10.8.79	8666.17
30.8.80	13658.43
16.7.81	4151.61
31.8.82	15262.76
9.9.83	18030.21
5.9.64	19569.68
29.8.85	7452.24
10.7.86	5998.75
12.9.87	19718.31
13.8.88	10541.47
16.8.89	4890.52
19.9.90	6259.20
1.9.91	13396.20

[SOURCE : State Hydrology cell of the Water Resource Department.]

Annex 6

HISTORY OF FLOODS

Records of floods in the Sone River System are available for different years since 1901. However, the major floods occuring in Bihar portion in different years are described below:-

1901 – In 1901, due to heavy rainfall in the Sone and adjoining areas and simultaneous rise of water level in the rivers Sone and Ganga, a vast area was inundated.

1923 – In 1923 also the flood in the river Sone was very high and inundated a vast areas near its confluence with the Ganga as a result the city of Patna was also inundated. This was due to heavy rainfall over the catchment during August.

1971 – In 1971,peak flood occured in the third week of July. The Ganga was already flowing above danger level and as a result of high flood in the river Sone, the flood situation in lower reaches became extremely critical.

1975 – In 1975, the upper Sone catchment experienced very heavy rainfall due to the passage of a deep depression in the 3rd week of August. The capital city "Patna" was innundated and 2 to 3 metres depth of water flowed through the city roads and streets. The Sone catchment experienced very heavy rains on 22nd August. The Patna Flood Enquiry committee constituted by the Govt. of Bihar,has described the 1975 flood as below:-

"Following heavy rainfall in the catchment of sone started rising from 19.8.75. At Indrapuri,it reached a level of 108.85m against the warning stage of 108.24m on 23.8.75 at 05.00 Hrs. The maximum level reached at koelwar was 58.81m on the same day between 10 to 14 Hrs. and this level was less than the level attained in 1971 ie 58.884m which is the maximum on record. However, at Japla it exceeded the level recorded in the year 1971 which was 127.89m. Simultaneously, the main trunck drain, Ganga was above warning stage of 48.6m at Patna since 22.8.75. It continued to rise further and reached a level of 49.988m at 18 Hrs. of 24.8.75 at Gandhighat. This level was 0.35m higher than the level recorded in 1971 and the highest on record so far. Its level at Digha surpassed the level of 52.15m at recorded in 1971 and reached the level of 52.52 m at 8 Hrs. on 24.8.75. However, this has not exceeded the level of 52.585m recorded in the year 1923. It would thus be seen that in 1975,there was syncronisation of flood peaks both in the Ganga and the Sone from 23rd to 24th August 1975.

As areas of the extremely high flood level at Digha the combined waters of Ganga and Sone overtopped the entire road from Digha to Maner, excepting high lands near villages to the extent of about 30 to 60 cm. and there was a sheet flow from Sone & Ganga towards the low lying areas in the countryside Patna and Digha. There were seven breaches on the road during this flood.The river Sone also spilled over the right bank between Koelwar and Maner, thereby causing 11 breaches in the Maner distributary. This water also entered the Patna-Danapur area. This combined waters entered Patna in the night of 24.8.75 resulting in the deluge of 1975.

1990 – The Sone was above danger level for 9 days in July, 7 days in August, 17 days in September at Japla gauge site. No flooding was reported.

1991 – The Sone flowed above danger level for 4 days in August only.

1992 – The water level was above danger level at Maner from 15.9.92 to 20.9.92 and at Koelwar from 14.9.92 to 15.9.92. No flood was reported.

1993 – The river did not witness any significant flood during this year.

ANNUAL FLOOD DAMAGE DATA FOR THE SONE RIVER
(Converted from the available figures for the districts in the basin)

Year	Area affected in Lakh Ha	Damage to crops			Damage to houses			Cattle lives lost Nos	Humon lives lost Nos.	Damage to public utilities in Lakh Rs		Total damage (in Rs Lakh)	
		Area affected in Lakh Ha	(Values in Rs Lakh) at then current Price	at the 1991 constant Price	Nos	(Value in Rs Lakh) at then current Price	at 1991 cunstt Price			At then current Price	at 1991 constt Price	At then current Price	at 1991 Constt Price
1969	0.3012	0.000001	0.0907	0.4500	1339	1.1978	5.910	5	1			1.2885	6.360
1970	0.0069	0.002400	2.6695	13.5600	107	0.0412	0.209					2.7107	13.768
1971	1.5035	0.310200	436.7605	2186.2764	24024	117.4832	588.055	36	7	8.6852	43.473	562.9289	2817.707
1972	–	–	–	–	–	–	–	–	–	–	–	–	–
1973	0.1487	0.014600	76.5146	289.1600	235	2.3842	9.057					78.8988	298.171
1974	0.0841	0.016600	16.3318	47.9200	6	0.0676	0.198					16.3994	48.122
1975	0.2276	0.129100	181.1774	547.1847	7411	140.6010	424.639	74	7			321.7791	971.825
1976	2.0140	0.681200	761.6350	2524.4500	53053	503.6781	1669.451	19	456			1265.3131	4193.905
1977	0.3371	0.118400	57.9222	165.3000	321	1.8388	5.248		1	0.2268	0.647	59.9878	171.195
1978	0.7512	0.258400	254.1559	732.3650	4280	6.9148	19.925	1	15			261.0707	751.103
1979	–	–	–	–	–	–	–	–	–	–	–	–	–
1980	0.4487	0.161700	129.8920	317.1960	97	1.6932	4.135	2	1			131.5852	321.331
1981	–	–	–	–	–	–	–	–	–	–	–	–	–
1982	0.2320	0.062000	186.0600	378.4680	923	10.0107	20.362	1		0.1127	0.229	196.1834	399.060
1983	0.2073	0.122300	25.8276	46.9450	40	0.4508	0.823	1				26.2804	47.768
1984	0.3962	0.378600	436.3250	721.6640	1160	204.2140	337.761		8	142.7958	236.178	783.3348	1295.604
1985	0.0882	0.063000	27.7200	44.6768	222	5.7733	9.305			2.5704	4.143	36.0637	58.123
1986	0.6397	0.345000	162.3187	248.9700	1779	8.3474	12.804		1	109.0824	167.314	279.7485	429.079
1987	0.6253	0.502500	1279.0633	1688.3600	32029	1637.4578	2161.444	88	29	41.1682	54.342	2957.6891	3904.150
1988	0.0960	0.013600	94.0250	124.1130					1		1.329	94.9250	125.301
1989	0.0700	0.020000	10.0000	12.3900	327	3.0000	3.717			1.0000	1.329	14.0000	17.436
1990	3.2500	1.200000	761.4800	865.7260	3533	53.3000	60.597	69	18	68.8100	78.230	883.5900	1004.436
1991	1.0800	0.360000	282.8900	282.8900	1523	5.9300	5.930	1	4	1.5000	1.500	290.3200	290.320
1992	0.4800	0.080000	34.0000	34.0000	6305							34.0000	34.000
1993	–	–	–	–	–	–	–	–	–	–	–	–	–
Av(1969-93)	0.52	0.206	450.88	213.560	12	23	23.49	687.93					

[Source: Comprehensive Plan of Flood Management for Sone River System prepard by G F C C in 1989 and Relief and Rehabilitation Deptt of Govternment of Bihar]

Annex 8

LIST OF FLOOD CONTROL SCHEMES IN THE CATCHMENT OF SONE RIVER SYSTEM (EMBANKMENTS RESERVOIRS TOWN/VILLAGE PROTECTION AND OTHER MEASURES ETC. (EXISTING ONGOING & PROPOSED)

	Name of scheme	Name of State	Estimated cost Rs.in Lakh	Area protected/ benefited in ha	Present status	Remarks
1	2	3	4	5	6	
FLOOD PROTECTION SCHEME						
A.	Embankment scheme					
1.	Buxar Koelwar Embankment scheme (sector A)	Bihar	1380.50	10000.00	Under Execution	Total for whole B.K. Embkt 99350ha is benefited area
(i)	Sone embankment (14.66 Km)					
(ii)	Ganga Embankment (9.08 Km)					
(iii)	East Gangi Right Embankment (19.05 Km) East Gangi Left Embankment (5.97 Km)					
(v)	Koelwar Ring Bund (2.38 Km)					
(vi)	Arrah Town Protecion Bundh (7.68 Km)					
2.	Sone Left Embankment Scheme					
(i)	Non-sagar Koelwar Embankment scheme (14.95 Km)	Bihar	769.00	30770.00	Under Execution	
(ii)	Raising & strengthning of existing Trikol Bundh from Nan Sagar to Sandesh (4.88 Km)					
(iii)	Raising & strengthning of Koelwar distributary from sandesh to Harpur lock (36.30 Km)					
3.	Sone Right Embankment Scheme	Bihar	431.69	16187.00		
(i)	Raising & stengthning of Amra distributary from Mair to amra (21.05 Km)					
(ii)	Construction of new Embankment from Amra to Baidrabad (9.15 Km)					
(iii)	Raising & strengthning of left bank of Patna Canal from Baidrabad to Rani Talab (16.78 Km)					
B	RESERVOIR SCHEMES		Live storage Capacity Mcum			
(1)	Rihand Multipurpose Project	Uttar Pradesh		8986.00	Completed	
(2)	Obra Reservoir Scheme	–do-		211.00	–do-	
(3)	Dhandhraul Reservoir Scheme (Ghaghar)	–do-	42.73	142.00	–do-	

Annex 8 (Contd)

1	2	3	4	5	6	
			In crores			
(4)	Bansagar Multipurpose Project	Madhya Pradesh	740.03 (Only of Unit I, Dam portion)	5419.00	Under Execution	
(5)	North Koel Project (Kutku Dam)	Bihar	439.03	758.00	-do-	
(6)	Kanhar Irrigation Project	Uttar Pradesh	107.44	128.00	-do-	
(7)	Kanhar Reservoir Schm. Bihar	350.00	524.00	Proposed		
(8)	Kadhwan Reservoir Scm.	-do-	373.00	2420.00	-do-	
(9)	Simdih Hydroelectric Project	Madhya Pradesh	67.07	330.00	-do-	
(10)	Churhat Hydroelectric Project	-do-	123.84	1075.00	-do-	
(11)	Nagunra Hydroelectric Project	-do-	8.25	360.00	-do-	
(12)	Gurdah Hydroelectric Project	Uttar Pradesh	164.70	2050.00	-do-	
(13)	Paral Hydroelectric Project	Madhya Pradesh	89.97	422.00	-do-	
(14)	Duniadih Hydroelectric Project	-do-	98.72	482.00	-do-	
(15)	Joka Hydroelectric Project	-do-	104.34	215.00	-do-	
(16)	Karmi Hydroelectric Project	Madhya Pradesh	94.94	11.00	-do-	
(17)	Kharauli Hydroelectric Project	-do-	81.40	587.00	-do-	
(18)	Diadol Hydroelectric Project	-do-	19.52	52.00	-do-	
(19)	Other Reservoir like Mahan, Amanet, Auranga etc.	-do-		936.00	-do-	
C.	TOWN/VILLAGE PROTECTION SCHEME		In Lakh	Area protected		
(1)	Patna Town Protection Scheme	Bihar	4850.00	0.753	Completed	Total protected area from Sone
(2)	Arrah Town Protection Scheme	-do-				Proposed Ganga & Punpun
(3)	Dehri Town Protection Scheme	-do-	-do-			
(4)	Dhandiha Ring Bund Scheme (Village Protection scheme)	-do-	83.90	10.00	-do-	
D.	OTHER MEASURES					
(1)	Anti Erosion Scheme					
(i)	Fuha Anti Erosion Scheme	Bihar	121.601		Under Execution	
(ii)	Mahadeva Anti erosion scheme	Bihar			Proposed	
(iii)	Nauhatta Anti Erosion Scheme	-do-			-do-	
2.	Soil Conservation			Area Tackled		
(i)	7 Nos head water dams 32 Nos detention dams 88 Nos farm Ponds etc.	Uttar Pradesh	2001.85	35500.00	Proposed	
(ii)	15 Nos head water dams 62 Nos detention dams	Bihar	4767.29	132.10	-do-	

Annex 8 (Contd)

1	2	3	4	5	6	
	262 Nos Farm Ponds etc					
3.	Irrigation Schemes					
(a)	Existing Schemes					
(i)	Sone Barrage Project	Bihar	14.43 (1967) Crores	7.68	Completed	Major Scheme
(ii)	Ghaghar Irrigation Project	Uttar Pradesh	42.73 (1917)	0.27	–do-	–do-
(iii)	Umrar Irrigation Scheme	Madhya Pradesh		2029.00	–do-	Medium Scheme
(iv)	Simar Irrigation scheme	–do-		3119.00	–do-	–do-
(v)	Budwa Irrigation Scheme	–do-		2200.00	–do-	–do-
(vi)	Kunwarpur Irrigation Scheme	–do-		4251.00	–do-	–do-
(vii)	Kanchan Irrigation Scheme	–do-		3845.00	–do-	–do-
(vii)	Chirka Reservoir Scheme	Bihar		1416.00	–do-	–do-
(ix)	Panderwa Irrigation Scheme	–do-		668.00	–do-	–do-
(x)	Chaco Irrigation Scheme	–do-		2307.00	–do-	–do-
(xi)	Jinjoy Irrigation Scheme	–do-		2428.00	–do-	–do-
(xii)	Butandup Irrigation Scheme	–do-		810.00	–do-	–do-
(xiii)	Chausan list Irrigation Scheme	–do-	376.00	6400.00	–do-	–do-
(xiv)	Anaraj Irrgation Scheme	–do-		4978.00	–do-	–do-
(xv)	Left Banki Irrigation Scheme	–do-		6070.00	–do-	–do-
(xvi)	Maley Irrigation scheme	–do-		8264.00	–do-	–do-
(xvii)	144 Nos Minor irrigation scheme	Madhya Pradesh	-	33658.00	–do-	Minor Schemes
(xviii)	27 Nos Minor Irrigation Scheme	Uttar Pradesh		3849.00	–do-	–do-
(xix)	15 Nos Minor irrigation Scheme	Bihar	2335.00	–do-	–do-	
(a)	ON GOING SCHEMES					
(i)	Sone Canal Modernisation scheme	Bihar		1194.72	(Inclusive of annual irrigation 7.68Lakh ha as mentioned under 3(a) (i) above) In crores	
(ii)	Bansagar Project	Madhya Pradesh	172.44 (1974)	8.49	Under Execution	Major scheme
(iii)	Bansagar Project	Uttar Pradesh	85.00	1.34	Under Execution	–do-
(iv)	Kanhar Irrigation Project	Uttar Pradesh	107.44 (1984)	0.33	–do-	–do-
(v)	Sone Pump Canal	–do-	0.65	–do-	–do-	
(vi)	North Koel (Kutku Dam)	Bihar	439.03	1.05	–do-	–do-
(vii)	Gopad list scheme	Madhya Pradesh		7800.00		Medium scheme
(vii)	Barchar Nala Tank	–do-		3139.00	–do-	

Annex 8 (Contd)

1	2	3	4	5	6	
(ix)	Banku Irrigation Scheme	–do-		3441.00		–do-
(x)	Barnoi Irrigation Scheme	-do-		2388.00		–do-
(xi)	Chunghutta	–do-		10960.00		–do-
(xii)	Kanjar	–do-		3036.00		–do-
(xiii)	236 Nos Minor Irrigation Scheme	Madhya Pradesh		0.51		–do-
(xiv)	16 Nos Minor Irrigation Project	Uttar Pradesh		2548.00		Minor Scheme
B.	Proposed/Identified Schemes					
(i)	Mahan	Madhya Pradesh	38.94 (1983)	19040.00	Proposed	Major Scheme
(ii)	Joka	–do-		26721.00	–do-	–do-
(iii)	Rehar	Madhya Pradesh		32750.00	–do-	–do-
(iv)	Baradih(DBC)	–do-		14280.00	–do-	–do-
(v)	Amanat	Bihar	55.51		–do-	–do-
(vi)	Kodhwan	–do-	373.00		–do-	–do-
(vii)	Baradih(Kanhar)	–do-	250.00	53960.00	–do-	–do-
(viii)	Auranga	–do-	198.72	61950.00	U/C	–do-
(ix)	Zamania Pump Canal Scheme	–do-	240.00 In Lakh		Proposed	–do-
(x)	Tahley	–do-	388.00	16657.00	–do-	–do-
(xi)	33 Nos Medium Project	Madhya Pradesh		1.877	–do-	Medium Scheme
(xii)	3 Medium Project	Bihar		0.1096	–do-	–do-
(xiii)	134 Nos Minor Projects	Madhya Pradesh		0.6115	–do-	Minor scheme

[Source :- Comprehensive Plan of Flood Management for the Sone River system prepared by GFCC in 1989]

Annex 9

SALIENT FEATURES OF NORTH KOEL RESERVOIR PROJECT

A.	DAM AND APPURTENANTS	
	Location	Latitude 23°40'30"N Longitude 83°59'00"E
	Name of river	North Koel
	Catchment area	2885 Sq Km.
	Average rainfall (annual)	147 cm.
	Design flood discharge (Routed) 0.19 Lac Mcum/sec.	
	Routed flood discharge over spillway	0.16 Lac Mcum/sec.
	Mean annual runoff	1.30 Lac. ham.
	Maximum Reservoir level	EL 368.50m.
	Full Reservoir level	EL 367.28m.
	Dead storage level	EL 330.1 m.
	Dead storage	0.21 Lakh ham.
	live storage	0.96 Lakh ham.
	Gross storage at F R L	1.17 lac ham.
	Reservoir area F W L	7120 Hectare.
	No. of spillways	9 Nos. of 15m. each
	Type of spillway buckets	Ski-Jump
	Top level of dam	EL 372.0 m.
	Height of dam from lowest river bed	67.86 m.
	Top width of dam	8.75 m.
	Total length	343 m.
	Instruments	190 Nos.
B	MOHAMMADGANJ BARRAGE AND APPURTENANTS	
	Location	Latitude 24° 24'20"N Longitude 83° 21'0"E
	Catchment area	10640 Sq Km.
	Average annual rainfall	122 cm.
	Maximum dishcharge observed	0.198 lac cum per second.
	Design discharge	0.24 lac Mcum/second.
	Length of barrage	819.6 m.
	No. of weir bays	836
	No. of undersluice bays	4
	Span of each bay	18.3m.
	Pond level on U/S of Barrage	148.17m.
	Maximum Flood Level	151.12m.
	Average River bed level	144.00m.
	Crest level of Barrage	144.32m.
	Crest level of undersluices	143.71m.
Power Generation		
	Installed capacity	2 Units of 12 M W each
	No. and type of turbines	2 Nos. of vertical Francis turbines

[Source: Comprehensive plan of flood management for the Sone River System prepared by GFCC in 1989]

Annex 9 (contd)

SALIENT FEATURE OF SONE BARRAGE PROJECT

State	Bihar
District	Rohtas
Cost of the Project	Rs. 14.43 Crores.
Catchment area	69.000 Sq Km.
Average annual rainfall	139.8 cm.
Observed Maximum discharge	0.341 Lakh cumecs.
Design discharge	0.413 Lakh cumecs.
Length of barrage	1410 m.
Crest level of weir sluice	104.0 m.
Crest level under sluice	103.4 m.
Average bed level	103.8 m.
Pond level	108.3 m.
Design HFL	110.0 m.
Observed HFL	111.3 m.

[Source: Comprehensive Plan of Flood Management for the Sone River system prepared by GFCC in 1989]

Annex 10

SALIENT FEATURES OF SONE, PROPOSED RESERVOIR PROJECT

KANHAR RESERVOIR PROJECT	
State	Bihar
District	Palamau
Latitude	23°53'20"N
Longitude	83°35'2"E
River	Kanhar
Situation	Near Baradih village, P S Ranka Sub-Division, Garhwa.
Catchment area upto Dam site	3028.5 Sq Km.
Maximum annual rainfall (1943-44)	218.80 cm.
Maximum Annual rainfall (1966-67)	70.80 cm.
Mean Annual Rainfall	133.17 cm.
Design flood descharge	15,9227 Cumecs.
Available 75 PC Dependable Runoff (Annual)	1.23 Lakh ham.
Available 75 PC Dependable Runoff (Monsoon)	1.15 Lakh ham.
Mean Annual Runoff	1.37 Lakh ham.
Mean Monsoon Runoff	1.275 Lakh ham.
Maximum Water Level(Top of gate)	414.33 m.
Full Reservoir Level	413.41 m.
Dead Storage Level	396.34 m.
Gross storage at MWL	60108 ham.
Storage at FRL	576.04 ham.
Dead storage Capacity	5205 ham.
Live Storage Capacity	52390 ham.
Reservoir areas at FRL	6342 ha.
Reservoir areas at MWL	7011 ha.
Type of Dam	Holled earth filed dam Non-homogeneous material combined with Masonry spillway.
Lowest bed level of river	374.69 m.
Type of spillway	Ogee type
Length of spillway	377.74 m.
Spans	16 Nos.
Total Cost of the Project	206.13 Crores.
Bihar's Share of Cost	184.80 Crores.
M P;s Share of Cost	21.33 Crores
Incidance of Cost	
Cost per Acre of GCA	Rs. 4750.00
Cost per Acres of CCA	Rs.11268.00
Benefit Cost Ratio	
On 5% Interest	3.27
On 10% Interest	1.89

[Source: Comprehensive Plan of Flood management for the Sone River System prepared by GFCC in 1989]

Annex-10 (contd)

KADWAN RESERVOIR SCHEME SALIENT FEATURES

Location of head works:	Near village Kadwan Dist. Palamau & Rohtas(Bihar)
Latitude	24°30'15"N
Longitude	83°37'50"E
River	Sone
Purpose	Irrigation & Hydro Power
Total catchment area	55636 Sq Km
Free catchment area	13150 Sq Km.
Mean annual funoff at dam site	11.8 MAF (1.456 Mham)
Average rainfall	1284.60 mm.
Designed flood discharge (Routed)	37.997 Cumecs.
maximum water level	175.00m
Full reservoir level	173.00m.
Dead storage level	142.50m.
Minimum Draw dawn level	152.00m
Average bed level of River	136.00m
Crest level of dam	178.00m.
Capacity at DSL	0.616 MAF (0.076Mham)
Capacity at FRL	4.05 MAF (0.5 Mham)
Submergence area at FRL	28.800Hect.
Type	Earth dam (Zoned typed)
Height of dam	45.0 m.
Length of dam	2730 m.
Type of spillway	Ogee shaped with ski jump bucket
Length of spillway	420 m.
Maximum discharge capacity of spillway	37,997 Cumecs.
Power Plant	
Installed capacity	126 M W
Generating Unit	3 x 42 M W
Discharge of Penstock	110 Cumecs, when Reservoir Level 173.00 m.
Abstract of Cost	
Earth dam & spillway	Rs 216.48 Crores.
Hydel power	Rs 156.32 Crores.
	Rs 372.80 Crores
B C Ratio	
At 10 per cent interest	2.299
At 5 per cent interest	5.65

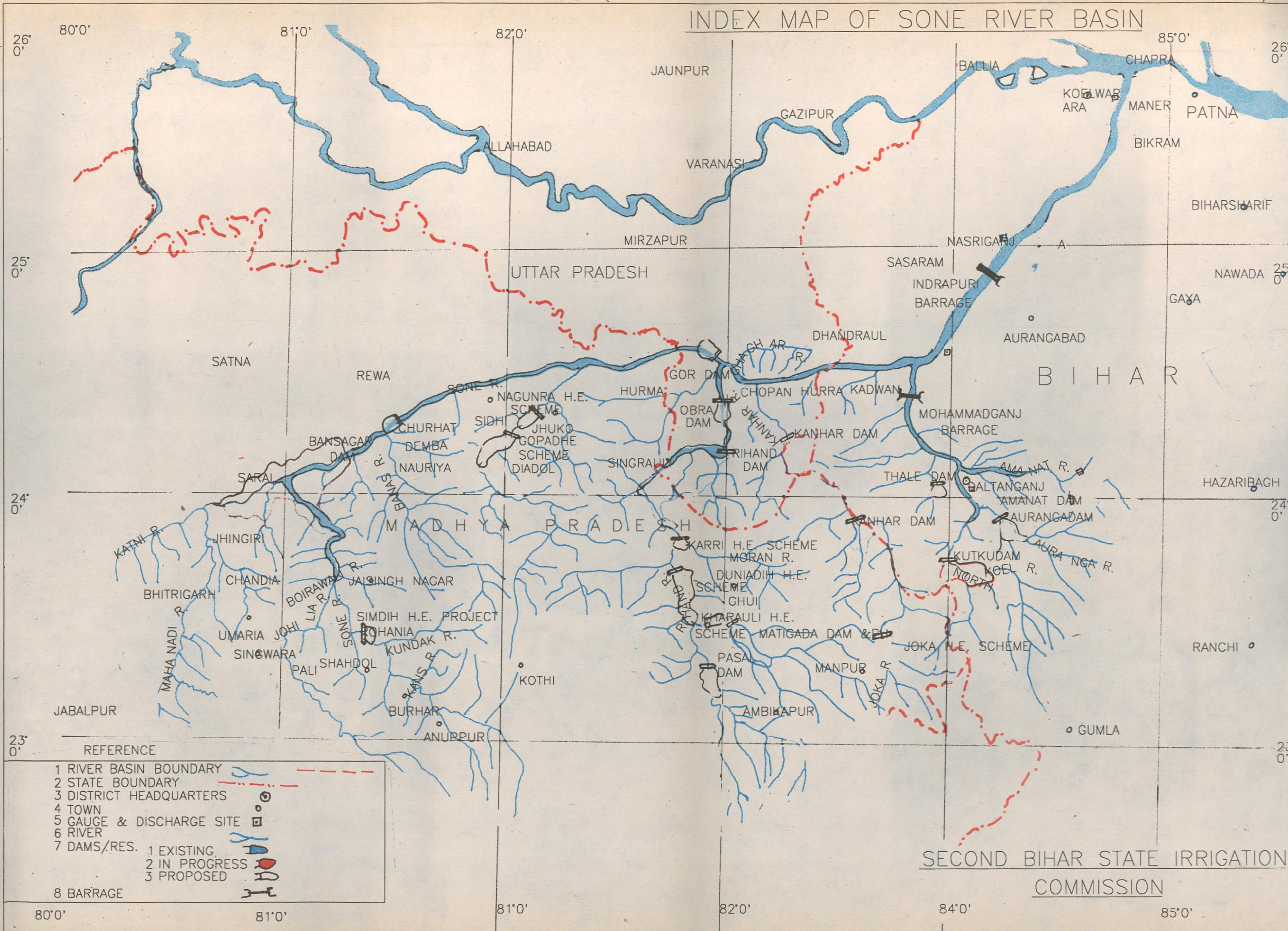
[Source: Comprehensive Plan & Flood Management for the Sone River system prepared by GFCC in 1989]

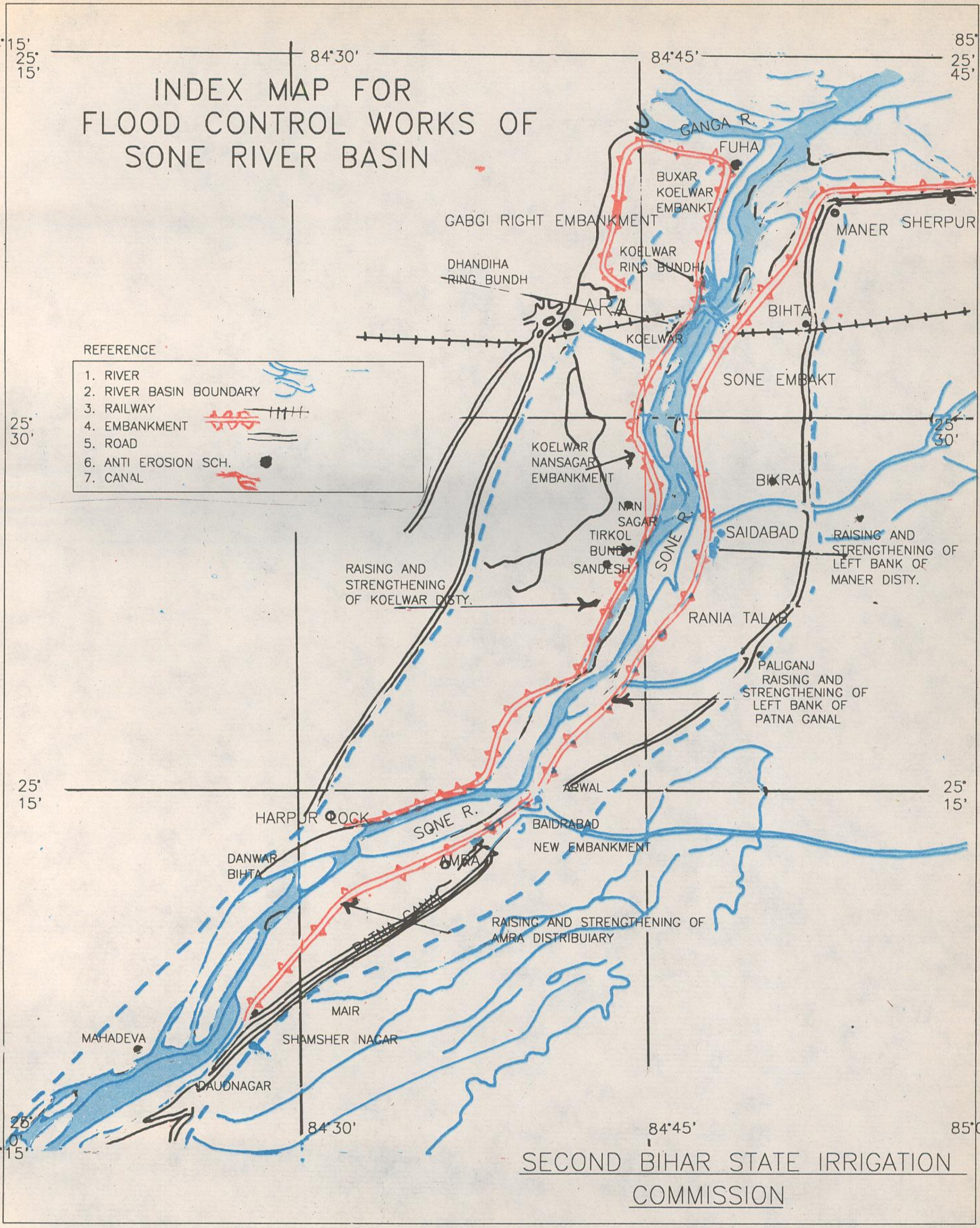
SALIENT FEATURES OF THE AURANGA RESERVOIR PROJECT

A DAM & RESERVOIR (UNIT 1)

State	Bihar		
District	Palamu		
Latitude	23° 57' N		
Longitude	84° 15' E		
River	Auranga		
Location	Near Palamu fort in Betla National Park		
Catchment area	1462 Sq Km		
Rainfall (1921-72)	a	Max annual rainfall (1930-31) 1918.0 mm	
	b	Min annual rainfall (1955-56) 792.5 mm	
	c	Mean annual rainfall(1921-72) 1326.0 mm	
Water yield at Dam site	a	52200 ham at 90% dependibility	
	b	64000 ham at 75% dependibility	
	c	72400 ham at 50% dependibility	
Storage level	a	Max water level at MWL	312.30 m
	b	Full reservoir level FRL	311.30 m
	c	Dead storage level DSL	294.10 m
Storage capacity	a	Dead storage capacity	9200 ham
	b	Live storage capacity	46000 ham
	c	Gross storage at MWL	60720 ham
	d	Gross storage at FRL	55200 ham
Submergence area	a	Reservoir area at DSL	1194.33 ham
	b	Reservoir area at FRL	4536.00 ha
	c	Reservoir area at MWL	4738.50 ha
Type of Dam	Rolled earth fill dam in the river section and chute spillway on the left flank		
Particulars of spillway	Type		chute spillway
	Length		128.70 m
	Crest level		298.80 m
	Design bed		12.80 m
	Design discharge		8495 Cumecs
	No of spans		8 spans of 15 m each
	Type of gate		Radial gate
Estimated cost	i	Cost of unit I (Dam & appurtenants)	Rs 99.22 Crore
	ii	Cost of unit II	Rs 193.96 Crore
	Total cost of project		Rs 293.18 Crore

DRG:-8/01


INDEX MAP OF SONE RIVER BASIN
80°0'
81°0'
82°0'
85°0'
26° 0'
25° 0'
24° 0'
23° 0'
84°0'
JAUNPUR
BALLIA
CHAPRA
KOELWAR
ARA
MANER
PATNA
GAZIPUR
ALLAHABAD
VARANASI
BIKRAM
BIHARSHARIF
MIRZAPUR
NASRIGANJ
SASARAM
NAWADA
UTTAR PRADESH
INDRAPURI BARRAGE
GAYA
AURANGABAD
DHANDRAUL
SATNA
REWA
SONE R.
GOR DAM
BIHAR
NAGUNRA H.E. SCHEME
HURMA
CHOPAN
HURRA
KADWAN
OBRA DAM
MOHAMMADGANJ BARRAGE
SIDHI
CHURHAT
JHUKO
GOPADHE SCHEME
KANHAR DAM
BANSAGAR DAM
DEMBA
RIHAND DAM
NAURIYA
DIADOL
SINGRAULI
AMANAT R.
SARAI
THALE DAM
BALTANGANJ
HAZARIBAGH
AMANAT DAM
AURANGADAM
KANHAR DAM
MADHYA PRADESH
KATNI R.
JHINGIRI
KARRI H.E. SCHEME
MORAN R.
KUTKUDAM
AURANGA R.
NORTH KOEL R.
CHANDIA
JAISINGH NAGAR
DUNIADIH H.E. SCHEME
BHITRIGARH
BOIRAWAH R.
GHUI
LIA R.
SIMDIH H.E. PROJECT
KHARAULI H.E. SCHEME
SONE R.
RIHAND R.
KANHAR R.
BANAS R.
BAIGA R.
GHANIA
MATIGADA DAM
JOKA H.E. SCHEME
RANCHI
UMARIA
JOHI
KUNDAK R.
SINGWARA
PASAL DAM
MAHA NADI R.
PALI
SHAHDOL
MANPUR
KANS R.
KOTHI
JOKA R.
JABALPUR
BURHAR
AMBIKAPUR
ANUPPUR
GUMLA
REFERENCE
1 RIVER BASIN BOUNDARY
2 STATE BOUNDARY
3 DISTRICT HEADQUARTERS
4 TOWN
5 GAUGE & DISCHARGE SITE
6 RIVER
7 DAMS/RES. 1 EXISTING
2 IN PROGRESS
3 PROPOSED
8 BARRAGE
SECOND BIHAR STATE IRRIGATION COMMISSION


INDEX MAP FOR
FLOOD CONTROL WORKS OF
SONE RIVER BASIN
REFERENCE
1. RIVER
2. RIVER BASIN BOUNDARY
3. RAILWAY
4. EMBANKMENT
5. ROAD
6. ANTI EROSION SCH.
7. CANAL
84°15'
25° 15'
84°30'
84°45'
85°0'
25' 45'
25° 30'
25° 15'
25° 0'
GANGA R.
FUHA
BUXAR KOELWAR EMBANKT.
GABGI RIGHT EMBANKMENT
MANER
SHERPUR
KOELWAR RING BUNDH
DHANDIHA RING BUNDH
ARA
BIHTA
KOELWAR
SONE EMBAKT
KOELWAR NANSAGAR EMBANKMENT
BIKRAM
NAN SAGAR
TIRKOL BUNDH
SANDESH
SONE R.
SAIDABAD
RAISING AND STRENGTHENING OF LEFT BANK OF MANER DISTY.
RAISING AND STRENGTHENING OF KOELWAR DISTY.
RANIA TALAB
PALIGANJ
RAISING AND STRENGTHENING OF LEFT BANK OF PATNA GANAL
ARWAL
HARPUR LOCK
SONE R.
BAIDRABAD
NEW EMBANKMENT
DANWAR BIHTA
AMRA
PATNA CANAL
RAISING AND STRENGTHENING OF AMRA DISTRIBUIARY
MAIR
MAHADEVA
SHAMSHER NAGAR
DAUDNAGAR
SECOND BIHAR STATE IRRIGATION COMMISSION

APPENDIX 9

PUNPUN BASIN

AT A GLANCE

PLAN FOR FLOOD MANAGEMENT IN THE PUNPUN RIVER BASIN (IN BIHAR)

I	Salient Features of the Basin.		
	1	Total Drainage Area	9026 Sq Km
	2	Drainage Area in Bihar	9026 Sq Km
	3	Population in Bihar	49.94 lakh
	4	Water Resources (Surface Water)	2253 MCM
	5	Average Annual Rainfall (in Bihar)	969 mm
	6	Total Length of Main River	235 Km
	7	Cropped Area in Bihar	5775 Sq Km
II	Flood Damage (Average for 26 years 1968-93)		
	1	Total Area Affected	0.570 Lha
	2	Cropped Area Affected	0.280 Lha
	3	Damage to Crops	Rs 810.00 lakh
	4	Total Damage	Rs 2109.19 lakh
	5	Human lives lost	11 Nos
	6	Cattle Heads Lost	79 Nos
	7	Average population Affected (average for 9 years 1984-92)	4.00 Lakh
III	Progress of Flood Protection Measures (1954-92)		
	1	Length of Embankments	40.60 Km
	2	Length of Drainage Channels	Partial work done
	3	Towns/Villages protected	2 (PTP and Sherghati)
	4	Areas Protected	0.26 Lha
	5	Total Expenditure (1954-92)	Rs 398.45 Lakh
IV	Eighth Plan Proposals (1992-97)		
	1	Length of Embankment	Total 98 Km in the State
	2	Additional Area to be benefited by flood Control Drainage and Anti Water logging measures	Total 1.00 lakh ha in the
	3	Total outlay for flood control measures in the state (1992-97)	Rs 35230 lakh.

AN APPROACH TO THE PROBLEMS OF FLOOD AND DRAINAGE CONGESTION & REMEDIAL MEASURES IN THE PUNPUN RIVER BASIN (IN BIHAR)

1.0 INTRODUCTION

1.1 The Ganga sub-basin is an important portion of the main Brahmputra-Meghna-Ganga river basin and is the largest river system extending over an area of 8.614 Lakh Sq Km within India. Flat terrain, high intensity of rainfall and poor drainage conditions combine to cause flooding and drainage congestions almost every year in a large part of this sub-basin, particularly in the portions lying in the Eastern Uttar Pradesh and Bihar. The flood damage in this sub-basin accounts for a major part of the total flood damage of this country.

1.2 Bihar is situated in the central part of the Ganga sub-basin. The portion lying on the northern side of the left bank is known as North Bihar and that lying on the southern side of the right bank is known as South Bihar. The lower part of northern region of this State is affected by serious flooding almost every year. A number of major rivers like the Mahananda, the Kosi, the Kamla-Balan, the Bagmati, the Burhi Gandak, the Gandak and the Ghaghra etc which originate from the Himalayas join the river Ganga on its left bank in this region. The Southern region is characterised by low hills and slopes in some parts and Gangetic plain in a narrow strip along the Ganges. Many rivers like the Karmnasa, the Sone, the Punpun, the Kiul-Harohar, the Badua-chandan,the Gumani etc which originate from hilly region of South Bihar join the river Ganga on its right bank.

1.3 The major rivers of North Bihar like the Ghaghara, the Gandak, the Bagmati, the Kosi, the Mahananda etc flow through a considerable length in Nepal and a substantial part of their catchment falls in the glacial region of the great Himalayas. As these rivers are snowfed, they are perennial in nature. The major rivers of South Bihar like the Karmnasa, the Sone, the Punpun, the Kiul-Harohar etc are rainfed and carry little discharge in non-monsoon months. The Punpun, one of the important right bank tributaries of the river Ganga, originates from Chotanagpur hills of Palamu district and joins the Ganga near Fatuha,about 25 Km down stream of Patna. It has a total catchment area of 9025.75 Sq Km. This river is considered important with respect to flood management because it forms the southern boundary of the State Capital (Patna) and often poses a threat to the safety of Patna town during heavy precipitation in its catchment.

1.4 Floods and droughts are regular features in the State of Bihar due to vagaries of climate and rainfall. While one part of the State is under the grip of severe floods due to excessive rainfall the other part suffers from drought due to scanty and untimely rainfall.

1.5 Floods have caused devastation and acute human suffering too frequently since the down of civilisation and the man has had to live with the flood since his existence. The impact of flood was not perhaps felt to the same extent in the past as is felt now. This was due to the fact that much smaller number of people were living and pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities.

The flood problem has been accentuated due to ever increasing encroachments on the flood plains by the growing population to meet its requirements of food and fibre. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements have also aggravated the flood situation. All these have resulted in an anomalous situation where, in spite of protection measures carried out so far in the state with an investment of Rs 611 crores (approx.) which has provided reasonable degree of protection to an area of about 28.25 lakh ha, the flood damages have gone on increasing instead of decreasing.

2.0 THE PUNPUN RIVER BASIN

2.1 The river basin consists of number of small tributaries like the Morhar, the Dardha, the Batane, the Madar, the Ramrekha, the Bakri, the Adri, the Neera, the Senane, the Begi, the Khudwa, the Mawaria, the Siroka and the Panchanawa etc which join the main river Punpun. The river Punpun originates from Chotanagpur hills in Hariharganj block of Palamu district in Bihar at an elevation of 442m and at latitude 24°11'N and longitude 84°9'E. The river system is bounded by the Sone river on the West, the Kiul-Harohar-Falgu on the east, the Ganga on the north and North Koel on the south. It flows for most of its portion in a north, north-eastern direction and falls into the Ganga near Fatuha, about 25 Km down stream of Patna. Its total length is about 235 Kms. The river receives a substantial portion of discharge from its right bank tributaries. As is the case with the main river, the tributaries are also rainfed and majority of them originate from the same range of hills in Palamu, Aurangabad and Gaya districts of Bihar.

2.2 The Punpun river system drains an area of about 9025.75 Sq Km which is approximately one percent of the total area of the Ganga sub-basin in the Country. The entire catchment lies within the State of Bihar and is spread over the districts of Patna,Gaya, Aurangabad, Hazaribagh, Palamu, Jahanabad and Nalanda. Four major tributaries namely, the Morhar having catchment area of 2585 Sq Km, the Dardha with 1001 Sq Km, the Madar with 1255 Sq Km and the Batane with 634 Sq Km join the river on its right bank. The Khudawa, the Begi, the Siroka, the Mawaria and the Panchanwa rivers having lengths of 16.44 Km, 10.12 Km, 30.36 Km, 24.08 Km and 6.32 Km respectively join the main river on its left bank. The catchment areas of these left bank tributaries are too small and their contribution to the flood flow in the basin is insignificant.

2.3 The Grand Trunk Road (NH-2), divides the catchment into two parts in such a way that almost all the hilly part of the catchment falls on its south and plain areas on its north. The upper catchment which lies in the districts of Palamu and Hazaribagh is characterised by low hills mostly covered under forest and slopes with depression and valleys. The lower part of the catchment are in the districts of Aurangabad, Gaya, Nalanda, Jahanabad and Patna is mostly plain or having some uniform mild slope and are being used for cultivation. The elevation of the Punpun river basin varies from 442 m near the origin of the river to about 50m near its outfall into the Ganga.

2.4 The Punpun river system is traversed by a number of small tributaries, some of which bifurcate and rejoin meeting each other a number of times during their course of flow. A statement showing length/catchment area of tributaries in the Punpun river basin is enclosed at Annex 1. The salient details of the main tributaries of the Punpun river basin are given below :

2.4.1 The Morhar

The river Morhar originates in the hills of Palamu district. At a place (Latitude 24°32' and Longitude 84°45') near Rashanganj, the river Morhar bifurcates in two channels. One of the channels is known as the Budh River and other as the Morhar. Further down, these two channels bifurcate and rejoin with each other a number of times to meet again near village Men (Latitude 25°1'N and Longitude 84°54'E)and finally separate into two channels in the name of the Morhar and the Dardha till both of them join the Punpun near Ramganj and Jamalpur respectively. The Morhar has another channel known as the Ghaghar. Owing to steep gradient and shallow depth the river keeps on changing courses. According to recent developments, the main river flow is concentrated along the Ghaghar which falls into the Punpun at about 145 Kms upstream of the confluence of the Punpun with the Ganga. It crosses the Patna-Gaya railway line between Nadwan and Pothahi railway stations. The river Morhar, along with the Dardha cause flood in the lower reaches of the river system. The catchment area of Morhar-Dardha is 2585 Sq Km and length 185 Kms. There is one possible reservoir site on the river Morhar which is in the district of Gaya near Chatra.

2.4.2 The Dardha

As stated earlier the river Morhar bifurcates near village Men (Latitude 25°2'N, Longitude 84°54'E) and the bifurcating channel is known as the Dardha. The Jamuna Nadi, which originates from a place south of G T Road (N H 2) near Sherghati, runs almost parallel to the Morhar and the Dardha and Joins the Dardha near Jahanabad. Subsequently the river flows in the name of the Dardha and outfalls into the Punpun near village Jamalpur near the confluence of the Punpun with the Ganga.

2.4.3 The Batane

This river also originates from the hills of Palamu district near Dalpatpur village at an elevation of about 225m. It joins the river Punpun at village Jamadra near crossing of the Punpun with Grand Chord Railway line of Eastern Railway. Its catchment area is 634 Sq Km and length is 78 Kms. A dam known as Batane dam has been constructed on this river for providing irrigation benefits in the area.

2.4.4 The Madar

Like the Morhar and the Dardha, this river has also got a big catchment. But shape of the catchment is fan shaped and not an elongated one like the Morhar and the Dardha . The river originates in the hills of Aurangabad districts, near village Barki and joins the Punpun near village Gagarh. Its length is about 56 Kms and catchment area 1255 sq Km. Its tributaries are the Tekari Nalla, the Jharahi Nalla, the Keshar Nalla, the Satnadia Nalla and the Dhawa Nalla etc. There is one reservoir site, namely, Jagnath dam on this river.

2.5 The Punpun river catchment lies within the State of Bihar and is spread over the districts of Patna, Gaya, Aurangabad, Hazaribagh, Jahanabad, Nalanda and Palamu. The districtwise break-up of the catchment area is given below in Table 1 and distribution of the catchment area in each of the above districts is in Table 2.

Table-1

Districtwise Break-up of catchment area

Sl No	Name of district	Catchment area in Sq Km lying in the district	Percentage of total catchment in the district	Remarks
1	Patna	1046.27	11.59	
2	Gaya	2598.17	28.78	
3	Aurangabad	2721.76	30.16	
4	Hazaribagh	677.95	7.51	
5	Palamu	780.41	8.65	
6	Jahanabad	1180.31	13.08	
7	Nalanda	20.90	0.23	
	Total	9025.75	100%	

Table-2

Distribution of catchment area in different districts

Sl No	Name of District	Total Geographical area of the district in Sq Km*	Catchment area lying in each district in Sq Km	Percentage of district in the catchment
1	Patna	3219.07	1046.27	32.51
2	Gaya	4940.85	2598.17	52.60
3	Aurangabad	3302.90	2721.76	82.41
4	Hazaribagh	11095.11	677.95	6.11
5	Palamau	12470.18	780.41	6.26
6	Jahanabad	1569.40	1180.31	75.20
7	Nalanda	2367.71	20.90	0.88

The important places falling in the drainage basin of the river Punpun are Patna, Gaya, Jahanabad and Aurangabad.

2.6 Details of different tributaries of the Punpun river are given below:-

Table-3

Sl No	River	Bank	Origin	Outfall	River condition
1	Batane	Right	Hills of Palamu district near village Dalpatpur at an elevation of about 225 m	In River Punpun at village Jamadra	Functions as drainage channel
2	Ramrekha	Right	Near village Kotila	In river Punpun near village Bairia	–do-
3	Barki	Right	Near village Badhadra	In river Punpun at village Nakain	–do-
4	Adri	Right	Near village Malgaria	In river Punpun near village Obra	–do-
5	Madar	Right	Hill of Aurangabad district near village Barki	In river Punpun near village Gagorh	–do-
6	Neera	Right	Near village Dewakali	In river Punpun near village Kurlka	–do-
7	Senane	Right	In village Jalalpur	In river Punpun near Kurtha	–do-
8	Morhar/Budh	Right	Hills of Palamu district	In river Punpun near village Alamganj	–do-
9	Dardha	Right	Morhar bifurcate near village Men	In river Punpun near village Jamalpur	–do-
10	Begi	Left	–	–	
11	Khudawa	Left	–	–	
12	Mawaria	Left	–	–	
13	Siroka	Left	Near village Chaukwa chatan	In upper Morhar near Imamganj.	
14	Panchanwa Nalla	Left	–	–	

2.7 Southern or upstream areas of the Punpun river basin lies in Hazaribagh plateau West of Koderma plateau and characterised by Granite Country rock and represents a typical rocky topography in which a number of isolated mounds can be seen. The hilly and mountaineous region ranges between 200m to 600m in height above MSL. Lower down gently undulating uplands are dissected by narrow valleys and depressions and interrupted by few scarred and isolated hillocks or mondrocks which represent the major part of the tract. The general elevation varies from RL 140m to Rl 200m.

Most of the valleys are confined along the main streams and their tributaries. The general elevation of the valley portion varies from RL 90m to RL 140m. Alluvial plains are recent and old types and situated below the plateau regions. These are situated along the main stream and their tributaries. The elevation varies from RL 60m to RL 90m.

The general direction of the drainage is from south west to north-east.

2.8 ECONOMICS

2.8.1 The total population of the basin as per 1991 census is 49.94 lakh, the density being 544 persons per Sq Km against the State average of 497 persons per Sq Km (1991 census). The total population is likely to cross 53.0 lakh mark by the end of 2000 AD. About 85% of the population live in rural areas and only 15% in the urban areas. Nearly 85% of the population constitute the work force engaged in Agriculture.

[Source – Directorate of Statistics and Evaluation, Govt of Bihar, Patna]

2.8.2 There are a good number of small scale industries located in this river basin. Small scale industries like Jute mill, flour mills, electrical goods, seed crushing, biscuit, leather, soft drinks factories are located at Patna and Fatuha and other few medium/small industries at Gaya.

2.8.3 The following important highways and railways run through this basin :-

High ways :-

1 Grand Trunk road (NH 2)-(Dobhi-Aurangabad)

2 NH 30 (Patna-Bhaktiyarpur)

3 Gaya- Panchananpur-Dighi-Daudnagar

4 Rafiganj-Obra-Jamhore

5 Aurangabad-Amba-Hariharganj-Daltenganj

6 Amba-Nabinagar-Dehri

7 Aurangabad-Obra-Arwal-Bikram-Maner-Patna

8 Rafiganj-Deo

9 Gaya-Makhadumpur-Masaurhi-Punpun-Patna

10 Gaya-Dobhi

11 Gaya-Sherghatti

12 Masaurhi-Dumra-Mandi-Patna

13 Jahanabad-Arwal

Railways :-

1	Patna-Jahanabad-Gaya	
2	Gaya-Rafiganj (Grand Chord line)	Eastern Railway
3	Bakhtiarpur to Patna (Main line)	

2.8.4 Two major and eighteen medium irrigation projects besides many open wells, State/ Private tube wells exist in the basin which provide irrigation facilities to approximately 3.27 lakh ha of culturable land. There are altogether 376 State tube-wells, 40969 open wells, many private tubewells and 7 minor reservoirs and diversion schemes in the basin.

2.8.5 Towns in the lower reaches of the catchment like Jahanabad, Gaya etc have water supply for domestic use from ground water and towns in the upper region of the catchment like Aurangabad, Hariharganj, Nabinagar etc have mixed drinking water supply both from surface water as well as from ground water.

2.9 The land use pattern in the Punpun river basin is indicated below in Table 4.

Table 4

Sl No	Category	Area in Sq Km	% of total
1	Forest Land	1214.22	13.45
2	Land under miscellaneous trees and groves	31.06	0.34
3	Current fallow	1105.75	12.25
4	Other Fallow	318.07	3.53
5	Culturable waste	66.10	0.73
6	Net area under cultivation	4668.94	51.73
7	Barren land and Permanent Pastures	506.41	5.61
8	Area under non agricultural use	1115.20	12.36
	Total	9025.75	100

It may be seen from the above Table that the net area under cultivation is 51.73 per cent of the total geographical area and if the current fallow is added to it, the total culturable area comes to about 63.98 per cent.

3.0 GEOLOGY

3.1 Broadly, the geology of the area varies from granite, gniess, charnokites in the hills to the recent alluvium in the plains. The broad soil groups are calcium and non-calcium, recent and old alluvial and brown forest soils, red soils, podzowe, lateritic soils with cover being very deep in plains and deep to shallow in hills. The colour of the soil is yellow to gray. The texture is medium heavy in uplands and medium to heavy in low lands. Clay content is high (30%-50%) which is responsible for medium to high water holding capacity. Low land soils are poorly drained which results in water logging specially in Tal areas having saucer shaped configuration. The permeability of the soil is medium to low. Surface soil on drying is hard and forms cracks (5 to 8 cm wide and 60 to 120 cm deep). Hard Pans are some times found below the plaugh layer. The soil swells on wetting and is very plastic causing poor aeration to plant roots.

Table 5

Soils type in the Punpun basin

Sl No	District	Type of soil
1	Patna	Alluvial
2	Gaya	Red, Yellow & Alluvial soil
3	Aurangabad	Red, Yellow & Alluvial soil
4	Hazaribagh	Red, Yellow & Alluvial
5	Palamu	Red, Yellow & Alluvial
6	Jehanabad	Red, Yellow & Alluvial
7	Nalanda	Alluvial

The geohydrological map of the Punpun River basin is enclosed at Annex 2.

4.0 HYDROLOGY

4.1 The Punpun river basin forms a part of the Gangetic plain and it is situated in the direct path of the tropical depression which forms in the Bay of Bengal during the monsoon season and travels in north-westerly direction. As such, most of the precipitation, about 85 per cent of the annual rainfall occurs during the monsoon months of June to October. The yearwise monsoon rainfall in mm from 1963 to 1990 inside the Punpun river basin and adjacent to it are given at Annex 3.0 and 3.1. Blockwise rainfall pattern of this Punpun river basin is enclosed at Annex 3.3.

4.2 According to norms laid down by the Bureau of Indian Standards (1S:4987), one raingauge for a drainage area up to 520 Sq Km is adequate for plains. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser, particularly in upstream region of the catchment. In not too elevated region with average elevation one Km above mean sea level, the required network density is one raingauge station for every 260 to 390 Sq Km area. The India Meteorological Department (IMD) have, however, prescribed at least one raingauge for every 500 Sq Km of the drainage area. It also specifies that at least 10% of such raingauge stations should be self recording [SRRG] . Rashtriya Barh Ayog [RBA] has recommended that 20% of the required raingauge stations should be self recording.

4.3 Density of Raingauge station as per the norms laid down by WMO

Table 6

Sl No	Type of Terrain	Density Required (One station for)	
		Ideal	Acceptable
1	Flat region of temperate mediterranean and tropical zone	600-900 Sq.Km	900-3000 Sq Km
2	Mountaneous region of temperate mediterranean and tropical zone	100-250 Sq.Km	250-1000 Sq Km
3	Arid and polar zone	1500-10000 Sq.Km	Depending upon the feasibility

10 per cent of the raingauge stations are required to be self recording to know the spatial and temporal distribution of rainfall in the area, which, however, has to be increased to 20 per cent in accordance with the recommendations of the RBA.

4.4 The raingauge stations in the State are installed and maintained by the (1) India Meteorological Department (IMD) (2) State Government and (3) Central Water Commission (CWC). List of raingauge stations inside the river system and adjacent to it with their location, average annual rainfall, and the period on the basis of which computation were made is enclosed at Annex 3.2.

There are 26 raingauge stations existing in the basin or in the adjacent basins out of which two are self recording stations. These SRRGs are located at Palmeraganj and Sripalpur. But, these two stations have been installed only a few years back and long term data for these stations are not available.

According to the norms of the IMD, 20 raingauge stations are considered necessary in the drainage area of the river Punpun out of which twelve such stations are required in the lower catchment and eight in the upper catchment of the basin. Against this requirement, there are 10 raingauge stations in the upper catchment and 16 raingauge stations in the lower catchment.

4.5 Self recording raingauges (SRRG) are also as per norms in plains. However, a few such raingauge stations are required in the hilly area in the upper catchment.

4.6 Out of 24 ordinary raingauge stations in the Punpun river basin and its adjacent areas rainfall data of about 13 stations maintained by the IMD are available for a period from 1901 onwards. These were collected and analysed by the GFCC while preparing a comprehensive plan of flood management of the Punpun river system in 1986.

The average annual rainfall over the entire river basin has been reported as 1181.8 mm by the GFCC in their comprehensive plan of Punpun river basin (1986). This was based on the rainfall data from 1901 to 1950. This has now been worked out in this Commission on the basis of further available data and it is found that the average annual rainfall and average monsoon rainfall for the period 1901 to 1987 are 969 and 932mm respectively.

4.7 GAUGE AND DISCHARGE

4.7.1 According to the norms prescribed by the WMO, Dne gauge-discharge site is required for every 300 Sq Km of the drainage area in hilly portion and for every 1000 Sq Km in the plains. Accordingly, 14 gauge-discharge sites are necessary in the basin. Against this 15 gauge-discharge sites and 4 gauge sites ie altogether 19 observation sites are located in the Punpun river basin. The location of Gauge & discharge sites are shown at Annex 4. The danger levels, maximum observed gauge, discharge etc are shown in the statement at Annex 5.

It would appear from the details at Annex 4 that out of 19 sites only five sites are maintained by CWC. These are at Palmeraganj, Kinjar, Shripalpur, Miachak and Kolachak. The first two (Palmerganj and Kinjar) are only gauge sites and the remaining three are gauge-discharge observation sites. In addition to the above, a few sites are maintained by the Water resources Department of the State Government. These sites are located at Hamidnagar on the Punpun, Kendui on the Ghaghar and Bari-Bigha on the Dardha. However, only gauges are observed at these sites and discharges are computed on the basis of empirical formula.

Maximum observed gauge, discharge, and duration of flood in days at Shripalpur site maintained by CWC for period from 1962 to 1992 are enclosed at annex 5.1

4.7.2 The maximum and minimum discharges observed at three existing sites on the Punpun river basin are as follows :

Table 7

Sl No	Location	Peak Discharge in Cumecs				Remarks
		Maximum	Year	Minimum	Year	
1	Shripalpur	1015.00	1987	121.80	1966	(1957-1992)
2	Miachak	188.20	1987	Nil	1966, 68, 70, 71, 75, 82, 83	(1962-1992)
3	Kolachak	429.22	1976	10.14	1966	(1960-1992)

4.7.3 As will appear from the list of gauge/gauge-discharge sites of State Government (Annex-3) 4 out of 13 sites are temporary and have not been maintained properly. Only One to three year data of 13 sites are available in water year book 1990,1991- Part 1 prepared by the State Hydrology Cell of the Water Resources Department. It is, therefore, suggested that all the existing sites of the State Government be converted to gauge and discharge sites and maintained according to the standards laid down by the WMO/ Bureau of Indian Standards and the data be observed in the prescribed manner, processed, analysed and recorded properly for use in future planning of water resources utilisation and flood management schemes in the basin.

4.8 RUN-OFF FACTOR

4.8.1 Finding out run-off factor of the catchment is essential to know the run-off likely to result from short duration heavy rains. In order to find out the total run-off during the monsoon period for planning of schemes for drainage of accumulated water, it is necessary to determine the run-off factor applicable for the monsoon period as a whole. In order to conduct such study and analysis rainfall data for the stations spread over the entire drainage area of the basin and run-off data at suitable locations on the river for a sufficiently longer period (at least 20 years or more) are considered necessary inputs.

4.8.2 The Ganga Flood Control Commission was able to get hold of rainfall data of 13 raingauge stations for the period 1901 onwards in the Punpun river basin and its adjacent basins. For the purpose of development of a rainfall run-off relationship, various events were identified and used by GFCC. The gauge hydrograph for the monsoon period for the year from 1976 to 1982 were plotted and duration of various storms causing considerable rise in the river stage were identified. The daily discharge during the period of the storm were computed by using the rating curve. With the help of this, the total annual run-off in mm in a particular storm was computed by GFCC. The values of the total average rainfall over the catchment and the amount of direct run-off in case of each of the storms are indicated in the statement at Annex 3.4.

4.9 SEDIMENT CHARACTERISTICS

4.9.1 The past history of the river Punpun indicates that river has no meandering tendency .As there is no silt observation site in the basin, the silt problem has not been quantified. It is, however, apparent that there is no such problem requiring attention in the basin.

5.0 FLOOD FREQUENCY ANALYSIS

5.1 Frequency analysis is carried out to interpret the past records of the hydrologic events like the precipitation, run-off, flood levels etc to predict the probabilities of such occurrences in future. For quantitative assessment of the magnitude of flood problem, it is essential to evaluate or estimate the frequencies of rainfall, flood etc. Such studies are necessary inputs for proper design and location of hydraulic structures as well as other related studies.

5.2 CRITERIA OF DESIGN FLODD

5.2.1 The Ministers' Committee on Floods and Flood Relief constituted by the Government of India in 1970 had recommended that,

"As most of the embankments have been constructed on inadequate and meagre hydrological data available, it is necessary that the existing embankments are reviewed to see that these are safe for a flood of 50 years frequency for major rivers and atleast 25 years frequency for small tributaries. Similarly all the future proposals of embankment should also be based on the above criteria".

5.2.2 The recommendations of the RBA constituted by the Govt of India in 1976 (which submitted its report in March, 1980) regarding the degree of protection by embankments are as follows

"The use of benefit- cost criterion would require (i) damage data with respect to different flood frequencies, (ii) expertise to carry out alternative benefit- cost and trade- off exercises. These are not available at present. Hence for the time being the Commission recommends, as a general guide, adoption of the following criteria based on flood frequencies :

(i) For predominantly agricultural areas : 25 years flood frequency, (in special cases where the damage potential justifies, a higher design flood/maximum observed flood, may be adopted),

(ii) For town protection works, important industrial complexes etc: 100 years flood frequency, (for larger cities like Delhi, the maximum observed flood, or even the maximum probable flood should be considered for adoption) meanwhile studies should be undertaken to review the basis of these flood frequencies and attempts made to collect the data and appoint the necessary personnel, so as to enable the application of benefit cost criterion in due course " (Para 13.5 of RBA report)

5.2.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guide lines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankments, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile necessary step may be taken for eventual application of benefit- cost criterion for fixing the design."

The summary of recommendations as accepted is as follows:

"In the case of embankment schemes, the height of the embankment and the corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 years frequency in the case of predominantly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of industrial and other vital organisations."

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of vital industrial establishments.

5.3 ANALYSIS OF AVAILABLE DATA

5.3.1 At present gauge discharge are being observed by the CWC at Shripalpur, Miachak and Kolachak. In addition, gauges are observed at Palmeraganj and Kinjar. The peak gauge and peak discharge data of the river Punpun at Shripalpur site,the river Morhar at Miachak site and the river Dardha at Kolachak site respectively are being observed since 1957 . In order to obtain a reasonably good estimate of future probability of occurrence of event, atleast 20 to 25 years of yearly peak value of gauge and discharge are required for frequency studies. The gauge discharge data for Shripalpur, Miachak and Kolachak sites which are available for more than 25 years, have been used in the study. The yearly peak gauge and peak discharge for Shripalpur, Miachak and Kolachak and gauge data for Palmerajanj and Kinjar are enclosed at Annex 5.

5.3.2 The frequency analysis of the above available data using Gumble method gave the following results.

Table 8

A Flood discharge in the river Punpun/Morhar/Dardha (By Gumbel Method)

Site	Year of data availability	Flood discharge in cumec corresponding to				
		5 yrs	10yrs	25 yrs	50 yrs	100 yrs
Shripalpur	1959-92	730.41	871.40	1049.13	1181.58	1312.76
Miachak	1962-92	144.37	182.91	231.65	267.78	303.72
Kolachak	1960-92	299.03	387.90	499.75	583.30	666.06

Table 9

B Flood levels in river Punpun/Morhar/Dardha

Site	Year of data availability	Flood levels in metres corresponding to				
		5 yrs	10yrs	25 yrs	50 yrs	100 yrs
Shripalpur	1957-92	53.004	53.809	54.824	55.580	56.330
Miachak	1962-92	52.529	53.446	54.601	55.545	56.311
Kolachak	1957-92	55.633	56.434	57.444	58.197	58.943

5.3.3 It is observed from the available data of the Shripalpur, Miachak and Kolachak site that the maximum recorded discharge of the three sites were not the same in the same year. The maximum discharge at Shripalpur & Miachak site occurred in the year 1987 where as at Kolachak the maximum discharge occured in 1976. Some times higher discharges have been observed at lower stages. The rise in river stages corresponding to a flood by Gumbel method of 25 years and that for 100 years are 2.67 per cent, 3.04 per cent and 2.54 per cent for Shripalpur, Miachak and Kolachak sites respectively, similarly the increase in flood discharge, for a flood corresponding to 25 years to a flood of 100 years for Shripalpur, Miachak and Kolachak sites are 20.08 per cent, 23.73 per cent, and 24.97 per cent respectively.

The frequency analysis of the available gauge/discharge data of different sites of Punpun river system have also been done by Log Pearson Type III method in this commission. The comparative study of this analysis with the analysis done by Gumbel Method is indicated in Table no 9A. It is evident from the comparative study that flood frequency for different return periods with respect to discharge gives marginally higher value in Log Pearson Type III method but the value of river stages are found to be lower in Log Pearson Type III method as compared to Gumbel's method.

Table 9A

Comparative study of Frequency analysis of Gauge/Discharge of the Punpun river basin

River	Site	Analysis	Return period			
			25 yrs	50 yrs	100 yrs	
Punpun	Shripalpur	Discharge in cumecs	1049.13 1082.18	1181.58 1213.95	1312.76 1343.69	By Gumbel method By log Pearson Type III From 1959-92
Morhar	Miachak	–Do–	231.65 234.80	267.78 277.46	303.72 320.70	By Gumbel method By log Pearson Type III From 1962-92
Dardha	Kolachak	–Do–	499.75 559.63	583.30 654.93	666.06 742.34	By Gumbel method By log Pearson Type III
Punpun	Shripalpur	Gauge	54.824 53.654	55.580 53.802	56.330 53.909	By Gumbel in method By log Pearson Type III
Morhar	Miachak	–Do–	54.601 53.444	55.545 53.728	56.311 53.964	By Gumbel method By log Pearson Type III
Dardha	Kolachak	–Do–	57.444 56.324	58.197 56.507	58.943 56.650	By Gumbel method By log Pearson Type III

5.4 UTILITY OF FLOOD FREQUENCY STUDIES

5.4.1 The result of flood frequency studies are useful in delineating the flood prone area on the contour map in order to create awareness in the local people regarding the extent and depth of submergence in the unprotected areas at different stages of the river during flood. To make these studies useful it is essential to have contour map (with 0.3 m contour interval) of the flood prone area, preferably in a scale of 1:15000. Another utility of these studies will be in the future formulation and planning of the Water resources utilisation and flood management projects in the basin.

5.5 AGGRADATION AND DEGRADATION OF THE RIVER BED

5.5.1 Rastriya Barh Ayog has indicated in Para 5.3.1 of its report that the aggradation of the river, caused due to the construction of an embankment, poses a threat to the safety of the embankment itself. In this connection, it has been pointed out in the report of comprehensive plan of Punpun river system (1986) prepared by GFCC that the aggrading/degrading behaviours of the Punpun, the Morhar, and the Dardha were studied in detail by three different methods and it was observed that all the three river/tributaries have degrading tendency. It is apparent from these studies that possibility of aggradation after the construction of proposed embankments in the Punpun river system is remote.

6.0 FLOOD AND DRAINAGE PROBLEM

6.1 FLOOD PROBLEM

6.1.1 Grand Trunk road (NH 2) divides the Punpun river basin into two parts, hilly and plain. The upper part of the river basin, constituting about 30% of the total area, lies in the south in Palamu, Hazaribagh and Aurangabad districts. Due to the hilly characteristics, these areas are not affected by floods. The lower part of the river basin north of G T Road, is generally gently sloping to almost plain in the tail reach near its outfall into the Ganga. Most of the areas are cultivated in this part of the river system. The Punpun river basin witnessed severe successive floods in 1967, 1969, 1971,1976,1987 and 1991. The highest flood ever recorded, till 1976 was of the year 1905. In 1976 a new record of flood level was reported to have been created which was higher by 1.05 m over the 1905 level at Punpun Railway bridge.

6.1.2 The river Punpun flows almost on the ridge in its lower reach. The bankful capacity of the river is inadequate due to which it is unable to contain the flood discharge and causing floods in the basin. An embankment was constructed in the year 1955-59 in a length of about 17.6 Km only on the left bank of the river to protect Patna town from the floods of the Punpun river. The right bank of Fatehpur distributary of Patna canal which runs on the left bank of the river Punpun was strengthened in the year 1967 to act as flood embankment. The construction of embankment on the left bank of the river has provided a reasonable degree of protection to the areas lying on the left bank of the river but the areas on the right bank continue to suffer year after year. The right bank spill of the river Punpun, not only causes problem in its own catchment but it also aggravate the problem of Fatuha and Bakhtiarpur Tals.

6.1.3 Rivers of Punpun basin are mostly in regime condition and are non-perennial in nature. Flooding in lower reaches takes place, due to spilling of their banks during monsoon season.

6.1.4 Experience of past several years show that low banks and inadequate channel capacities of the river and inadequacy of waterways in structures across it in the lower reaches are the main causes of heavy spilling, as a result of which a vast tract of land is inundated almost every year even during normal floods. Spilling is more acute on both the banks of the Punpun north of Jahanabad-Kinjer road. The spill of the Punpun, after traversing north-east wards meet the spill of the two tributaries, the Morhar and the Dardha. The Morhar spills north of Taregana-Bharatpur road, whereas, the Dardha spills north of Taregana-Dumri road. The spilling of the river Punpun on its left bank has ,however, been controlled a great extent after construction of left bank embankment under Patna town Protection Scheme.

6.2 DRAINAGE PROBLEM

6.2.1 The drainage problem in the Punpun river basin is confined to lower zone of the river system. As discussed earlier the spilling over the right bank aggravates the problems of Fatuha and Bakhtiarpur Tals (part of Mokama group of Tals). The main river flow passes through the railway and road bridges across the river near Fatuha and joins the river Ganga about 0.5 Km down stream of the bridge on Patna- Bakhtiarpur road. It has been reported that the waterways of these bridges are inadequate which result in flood congestion, thus increasing the flood height and duration of flooding on the upstream. When both the rivers Ganga and the Punpun are in high stages, the duration of flooding in the Punpun river system increases due to unhelpful outfall conditions.

6.2.2 It has also been observed that whenever the river Ganga is in high stages and the river Punpun in low flow condition, the back water of the Ganga enters the Punpun and Dardha rivers upto a distance of about 10-15 Kms from its confluence. It further travels into the Dhowa river and spills on the right side of these rivers resulting in further aggravation of the drainage congestion in the Mokama group of Tals.

6.2.3 The maximum depth of submergence on the right bank was recorded in the year 1987, the year in which the stage in the river Ganga was also higher.

6.2.4 Frequency And Extent of Submergence.

The flood problem in the river Punpun is acute in the area lying north of the Jahanabad- Kinjer road, where the frequency of flooding is once in three years or so and the frequency increases to once in a period of two years or so near the outfall of the Punpun into the Ganga. The frequency of flooding of its tributaries, the Morhar and the Dardha are also similar to that of the Punpun ie once in 2 years near outfall and once in three year or so in the middle reaches below Jahanabad-Kinjer road. However, these results are based on the analysis of data of a limited period of 35 years (during 1957-92) only.It is also reported that the flood causing considerable damage occurs almost every alternate year in the entire reach of the three tributaries on the downstream of Jahanabad-Kinjer road.

6.3 FLOOD DAMAGE

6.3.1 The damages caused by flood are classified broadly into the two following categories:-

a) Direct damages

(b) Indirect damages.

6.3.2 The Direct damages are those which are caused due to the direct physical contact with flood water. These include losses to (i) growing and preharvest crops (ii) houses and house-hold assets (iii) public utility works (iv) public buildings and (v) losses of human lives and live stocks.

6.3.3 The indirect losses are not susceptible to quantification. Therefore, approximate monetary evaluation can only be done for such damages. These generally include (i) loss of earning in agrobased industry and trade (ii)loss of revenue to the road and rail transport system due to disruption of services (iii) loss of revenue to small shopkeepers and other daily wage earners and (iv) loss of employment to the daily-wage earners in public and private sector.

6.3.4 The flood damage data are collected by the Revenue (Relief and Rehabilitation) Department of the State Government and passed on to the various concerned organisations of the State and Central Government. CWC is collecting and compiling such damage data of all flood prone States at national level. It is observed that the flood damage statistics, which is essentially required for the benefit-cost studies for any proposed flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The Commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river basin wise be carried out every year under the following three separately identified categories :

i Unprotected areas;

ii Protected areas due to failure of protection works;

iii Areas between the embankments and the river.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long-term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area. The Central Flood Control Board had decided that the Flood Control Department of the States should compile basinwise flood damage data with effect from 1960. This is not being followed in Bihar and the flood damage data still continues to be collected districtwise (not basinwise) by the Revenue (Relief and Rehabilitation) Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of immediate requirements of relief operations that becomes necessary on account of current damage caused by flood. As such the need for compiling the annual flood damage data, according to the administrative jurisdiction ie district and block wise category in the State can not be denied. On the other hand, the flood control measures are required to be planned basin and sub-basin wise. It is, therefore, suggested that such data be collected by the Revenue authorities with active co-operation of the concerned Staff of the Water Resources Department, Agriculture Department, Road Construction and Building Construction Departments and the data be compiled and processed both by the statistical organisation at district and State level, district wise as well as basin/sub-basin wise for future use of planning of relief measures and flood management respectively.

The flood damage data for the Punpun river basin converted from available district wise figures are enclosed at Annex 6. Time series of whole sale price index (1990-1991)is enclosed at Annex 6.1.

The block wise statement showing frequency of flooding in the Punpun river basin is enclosed at Annex 7.

6.3.6 From the persual of the data processed by the Revenue Department it is noticed that the damage to the property of the Central Government such as Railways, post & Telegraph etc, are not properly accounted for. On the other hand the cost of relief and rehabilitation measures, grant of loans, remission of land revenue etc, are added to the flood damage. This practice should be discouraged as it is contrary to the recommendations of the Rashtriya Barh Ayog (RBA). The suggested methodology of flood damage assessment is enclosed at Annex 8.

6.3.7 It would be evident from the available flood data (Annex 6) that average annual area affected by the flood and drainage congestion is 570 Sq Km (Maximum being 2360 Sq Km and the minimum being 20 Sq Km in the years 1987 & 1974 respectively). The average annual damage to the crop, houses, and public utility at 1991 prices works out to Rs 809.91 lakhs, Rs 456.49 lakhs and Rs 842.79 lakhs respectively. The river system had witnessed worstever flood during the year 1987 causing maximum damages. The value of damages to crops and houses during the year 1987 were Rs 3646.61 lakh and Rs 1951.61 lakh respectively at the then price level. The human and cattle lives lost were 43 nos and 57 nos respectively. The data reveals that high floods in the river are experienced almost once in three years. The comparative study of the flood damage data placed at Annex- 9 shows that the average annual damage (at the 1983 then current price level) in this basin was about 0.45% and 0.86% of the total annual average damages of the country (as a whole and Ganga sub-basin respectively where as the geographical area of the basin is 0.268% and 1.025% of the country and the Ganga sub-basin respectively. It means that the average damages for unit area in Punpun river basin is approximately equal to that of per unit area of the Ganga sub-basin (as a whole).

6.3.8 The trend of distribution of various components of damages, such as crop damage, damage to houses etc during different blocks of years is indicated below :-

Table 10

Sl No	Type of damage	Period						Average from 1966-93 on '91 constant price
		1966-70	1971-75	1976-80	1981-85	1986-90	1991-93	
1	Damage to crops	7.46%	73.17%	68.14%	26.28%	43.23%	90.42%	38.40%
2	Damage to houses (Private properties)	92.54%	21.91%	31.85%	29.47%	20.23%	7.64%	21.64%
3	Damage to public utility	NA	4.92%	0.01%	44.24%	36.54%	1.94%	39.96%

6.3.9 It is observed from the figures furnished above that the crop damage, damage to houses and damage to public utilities from 1966-93 at 1991 constant price level constitute 38.40 per cent, 21.64

per cent and 39.96 per cent of the total damages. The damage to the houses is maximum to the extent of 92.54 per cent during the block year 1966-70 and damage to public utilities is 44.24 per cent during the block year 1981-85. The damage to crops is maximum to the extent of 90.42 per cent during the block 1991-93. However, these figures do not indicate any specific trend of variation in any of the above areas i.e. the crops, damage to houses and damage to public utilities etc.

7.0 PAST APPROACH

The Punpun river system was affected by severe flooding during the years 1967, 1969, 1971, 1973, 1976, 1977, 1978, 1980, 1987 and 1991 in the recent past. Efforts were made in the past from time to time to find a solution to the problem of flooding and drainage in the basin. An embankment was constructed in the year 1955-59 in a length of about 17.6 Km on the left bank of the river to protect Patna town from the floods of the Punpun river. Besides this, right bank of Fatehpur distributary of Patna canal which runs on the left bank of the river Punpun was strengthened in the year 1967 to act as flood protection embankment.

Dr K L Rao, the then Union Minister of Irrigation & Power, during his inspection of the area in 1970 had suggested for construction of embankments along the river Punpun and its two tributaries, the Morhar and the Dardha to provide relief to the affected people. Accordingly, a comprehensive Punpun Embankment Scheme, estimated to cost Rs 976.60 lakh was prepared in 1972 by the State Government.The salient features of this scheme are given below:-

7.1 EMBANKMENT SCHEMES

7.1.1 The scheme envisaged the following works :-

(a)	Construction of new embankments		Km
	Punpun Right embankment		61.18
	Punpun Left embankment		52.90
	Morhar Right embankment		24.37
	Morhar Left embankment		24.47
	Dardha Right embankment		24.37
	Dardha Left embankment		21.33
		Total :	208.62
(b)	Strengthening of Existing embankments		
	Patna canal distributary		10.35 Km
	Patna Town protection		17.67 Km
(c)	Construction of Antiflood Waterway Sluices		Designed discharge
	Ganghar	30.48 m	99.05 cumec
	Dhowa	60.96 m	172.63 cumec
(d)	Construction of Drainage sluices -	132 Nos	
(e)	Extension of Railway & Road bridge at Fatuha (additional waterway)		190 metres (Rail bridge) 150 metres (Road bridges)
(f)	No of additional road bridges proposed on Patna-Fatuha PWD Road		5
(g)	Additional waterway in the Patna-Gaya Railway embankment		195 m

This scheme having BC ratio of 1.33 was expected to protect an area of about 0.50 Lha.

7.1.2 This scheme was reported to have been examined by the Central Water & Power Commission and Ministry of Finance. It was subsequently discussed in the second meeting of TAC of GFCC held on the 17th & 18th August, 1973. The TAC found it difficult to assess the quantity of Punpun flood water entering the Ganga at high flood stage and that spilling into the Mokamah Tal in addition to the Ganga back water also spilling simultaneously. The TAC, therefore, suggested construction in stages and recommended that the Ganga spill and Punpun spill into Mokamah Tal Area should be separated by constructing a flood embankment on the right bank of the Punpun from the railway bridge to a distance of about 10 to 13 Km u/s where the RL of the ground is 49.22m corresponding to the H F L of Ganga at Fatuha. The TAC also recommended that the top of bank should not exceed R L 51.51 m at junction with Railway embankment and be constructed to a suitable flood slope. The Committee also recommended for raising and strengthening of existing left bank embankment in view of the proposed right bank embankment. The left bank embankment has, since, been included as a part of Patna Town Protection scheme and has been proposed to be extended upto the Panchanwa Nalla, besides its raising and strengthening corresponding to the 1976 HFL, which is the highest flood level ever recorded in the Punpun river so far.-

7.1.3 Based on the above suggestions of the TAC of GFCC, a revised project report for phase I of Punpun embankment scheme, estimated to cost Rs 99.00 (Rs 77.00 + Rs 22.00) lakhs was prepared in two parts by the State Government. The first part comprised of an embankment on the right bank of the Punpun in a length of 10 km and along the Dardha in a length of 3.7 km .The scheme also provided for protection of upstream end of Dardha Embankment by 'Bullah' piling and stone pitching. The cost of the scheme was Rs 77.00 lakhs. This scheme was finally cleared by the Planning Commission in March, 1975.

7.1.4 The second part of the scheme envisaged construction of another embankment on the left bank costing Rs 22.00 lakhs to provide protection to about 1034 hectares of land. Clearance of GFCC for this scheme could not be obtained and in the meantime before the execution of the first part of the sanctioned scheme could be taken up, the river Punpun witnessed an unprecedented flood during the year 1976, breaking all previous records of HFL at various points by a high margin. This led to the setting up of a High Level Technical Committee by State Govt. under the Chairmanship of Shri R. Ghosh, the them Chairman, GFCC to devise and suggest measures to protect the areas from floods of the river Punpun.

7.1.5 The summary of recommendations of the High Level Committee (1976) is enclosed at Annex-10. The Committee recommended that the 1973 Ccmprehensive Punpun Embankment scheme costing Rs 976 lakhs should be reviewed in the light of 1976 floods. The same Committee also recommended that the execution of 13.6 Km long embankment on the right bank of the river Punpun, for which sanction already existed, be kept in abeyance. Meanwhile, GFCC laid stress on the desirability of taking up the construction of the 13.6 km long embankment on the right bank of the Punpun along with the proposed Mokamah Tal scheme. They also suggested that the embankment on right bank of the Punpun, can be incorporated in the Comprehensive Punpun scheme when finalised. Thus the scheme so prepared had to undergo modification and appraisal many time and finally a scheme amounting to Rs 195.50 lakhs was prepared for phase I construction by State Government which envisaged the following works:-

(a)	Construction of Embankment	
	(i) along Punpun Right Bank	12.33 Km
	(ii) along Dardha Right Bank	1.69 Km
(b)	Spacing between the two Punpun embankments	1100 m
(c)	Distance from the centre of Dardha river to the right Dardha embankment	215 m
(d)	Flood slope Punpun	1 in 10,000
	Dardha	1 in 3,000

This scheme has since been sanctioned and the work was taken up but due to one reason or the other the scheme could not be completed so far even after a lapse of more than a decade.

7.2 Drainage scheme

7.2.1 Rural drainage scheme

The Tripathi Committee constituted after the 1975 Patna floods while recommending remedial measures for the protection of Patna Town reviewed the problem of drainage congestion on the left bank of the river Punpun also and suggested that the entire drainage basins surrounded by the rivers Ganga, Sone and Punpun be segregated by compartmentalisation and the drainage be disposed of into the Ganga and the Punpun by gravity wherever possible and by pumping where drainage by gravity is not possible. The entire area between the Ganga, the Sone and the Punpun rivers has been segregated in 14-sectors. Out of 14 sectors, delineated by the committee, four sectors, namely sector I,XII, XIII, and XIV had been proposed to be drained into the river Punpun. Detailed survey and investigations have indicated that creation of independent sectors for the purpose of drainage is not possible in sectors XII, XIII and XIV. (An area of about 195 Sq Km in sectors I, XII, XIII and XIV remains submerged under various depths of water for four monsoon months practically every year).

The area lying on the south of Patna Bye-pass road from Anishabad to Didarganj and in the east of Patna-Gaya section of the Eastern Railway from Patna Jn to Punpun railway station is known as Jalla area and is completely submerged under water during the rainy season. The problem gets aggravated with disposal of sewerage into the Jalla area through the Pahari pumping station. The sewerage gets mixed with rain water and spreads for and wide, creating serious unhygenic conditions for the people. The inhabitants of Jalla area launched an agitation against the sewerage disposal through Pahari pumping station into the area. As a result the State Government decided to execute some additional works such as additional sluices in Punpun left embankment near Didarganj and Khanpur, separation of sewerage disposal of Pahari pumping station from Jalla area, revival of Patna city Mout and old nala between Didarganj and Terhi pool etc.

Accordingly a scheme costing Rs 549.0 lakh was prepared in the year 1978 for solution to the aforesaid problems. This scheme comprised of the following works:

i Improvement to Kothia-Sabalpur channel and other drainage channel leading to the Ganga.

ii Badshahi-khanpur drainage system.

iii Parsa-Baramutta drainage system.

iv Pahari-Didarganj sewer channel

v Revival of Patna city Mout

vi Construction of additional sluices.

Salient features of above four drainage schemes are enclosed at Annex 11.

Work was started in Kothia-Sabalpur, Badshahi-khanpur, Parsa-Baramutta and Pahari drainage channels. The work on Pahari drainage channel had to be stopped due to public objection on certain portion of its alignment. The scheme was revised in 1983 at an estimated cost of Rs 673.48 lakhs, out of which an amount of Rs 190 lakhs have already been spent so far.

7.2.2 The flood spills from the right bank of the river Punpun enter the Mokamah group of Tal area and aggravate its drainage problem further. The Mokamah Tal area suffers from acute drainage congestion during the monsoon months due to either or all of the following flood spills from the right bank of the Ganga during its higher stages through vents in Fatuha-Lakhisarai road, (b) through the spill in the Punpun right bank when the Ganga is high and (c) back flow through the river Harohar. In addition to the above, some south flowing rivers like the Falgu, the Paimar, The Panchane, the Mohane, the Sakri and the Nata etc also contribute to the submergence of the Tal areas due to blockage of the drainage into the Ganga when its stages are higher. The area covered under the Mokamah group of Tals falls in the Kiul-Horohar river basin. So far as the Punpun basin is concerned a scheme for construction of embankment along the right bank of the river Punpun from its confluence with the Dardha river to Didarganj and along the right bank of the Dardha upto Bir to prevent entry of water into the Tal areas through the Punpun river has already been taken up for execution and the work is in progress.

7.3 Reservoir/Dam scheme

The Batre and the Batane reservoirs having a catchment area of 81 Sq Km have already been constructed in the Punpun river basin. These reservoirs are meant for irrigation purposes only and do not provide for any storage space for flood cushion but some flood moderation is expected to be achieved with properly designed operation of the reservoir during monsoon season.

7.4 Soil Conservation Measures

Soil Conservation measures have to play significant role in a flood management or water resources development programmes. To achieve this, priority areas have to be identified through the methodology developed for the purpose.

A master plan for flood control in Bihar prepared by the erstwhile Irrigation (now Water Resources Department), of the State Government was prepared in the year 1974. An area of 458 Sq Km of the Punpun river basin has been identified for soil conservation measures in this master Plan at an estimated cost of Rs 343.00 lakhs. The present stage of this scheme is not known. Some measures had been taken up earlier in the catchment of this basin. Ever since the 2nd Five Year Plan upto the year 1982-83 , soil conservation measures were in operation in selected water sheds of the Sone, Punpun and Ajoy river basins as a Centrally sponsored scheme, and the work was integrated with the activities of the Soil Conservation Wing of the State Government. The extent of work done so far and the resultant benefits are possibly not being recorded properly in systematic and desired manner. These details could not be made available to this Commission inspite of best efforts.

8 Future Approach

Various alternatives that could be considered in future for management of the residual problems of floods and removal of drainage congestion are described in the following paragraphs :-

8.1.1 Reservoirs

According to various experts, properly operated flood control reservoir/(s) combined with efficient flood forecasting, offers the most dependable flood control. The National policy on flood of 1954 also recommended dams on tributaries as long term measures for flood control. Reservoirs in general, even without specific flood cushion have a beneficial effect on the flood problem of a basin. Because of their high cost, the reservoirs are not economically viable or justified exclusively for flood control purpose but a multipurpose reservoir to provide irrigation, power, domestic water supply, recreation and other benefits alongwith flood moderation would be economically viable.

Storage reservoirs, in general are no doubt effective in moderating flood but it mainly depends upon the storage capacity provided in the reservoir exclusively for flood cushion. Even without specific flood storage in the reservoir its proper operation in accordance with the exigencies of the situation is likely to provide flood moderation by lowering the peak. There are eight possible reservoir sites in the Punpun river basin. Out of which two have already been constructed.These are indicated below :-

Sl	Name of Dam site	Catchment area (in Sq Km)	Remarks
1	Batre	81.00	Already completed as irrigation project.
2	Batane		
3	Bhangiya	34.75	To be investigated in detail.
4	Bhutanda	37.50	
5	Chotki res	83.75	Schemes formulated and awaiting
6	Jagennath res	45.00	sanction for execution in detail.
7	Morhar res	256.00	
8	Jharhi		To be investigated in detail
	Total	538 Sq Km	

It would be thus seen that possible catchment area that can be intercepted through construction of storage reservoirs is only about 538 Sq Km which is only 6 per cent of 9026 Sq Km, the catchment of the whole river system. Naturally the effect of these reservoirs, even if all are built up will be insignificant. It is, however, considered desirable to review the design of the aforesaid proposed reservoirs in order to provide for maximum possible benefits of flood moderation in the lower Punpun basin. Installation of flood forecasting network in the existing and proposed reservoir should also be considered because reservoirs with a good forecasting system of inflow and well designed operation rule curve for outflow can help to reduce the flood damage considerably.

8.1.2 Embankments

The problem of flooding in the Punpun river basin is mainly due to spilling of banks. Due to lack of complete basic data, it has not been possible so far to know the extent of flood moderation with the help of the existing as well as the proposed reservoirs in the basin. It is also not certain as to when the proposed reservoirs will be taken up and completed. Keeping the above scenario in view, the embankments appear to be the immediate solution to the flood problem in the basin.

Accordingly, it is suggested that the continuing schemes should be completed without any further delay to avoid the damages that accrue every year as well as to prevent the cost over run of the schemes. The following embankment schemes should be considered for implementation on priority:

Along the river Punpun

a Left Punpun embankment exists from Didarganj to Shiekhpura and is further extended upto Khajuri escape channel. Its extension beyond Sheikhpura upto Jahanabad-Kinjar road needs to be taken up as the river spills over its bank in this portion and the river is reported to be flowing within its bankful capacity beyond this on the upstream.

b The Punpun right embankment from Fatuha to its confluence with the Dardha and further along the right bank of the Dardha is under execution at present under Phase I. This scheme is lingering since long without any valid justification. This needs to be looked into and the scheme be completed without any further delay as otherwise the investments made already are not serving any purpose.

c The Punpun right embankment scheme from its confluence with the Dardha river to Jahanabad-

Kinjer road and embankments on the left bank of the Dardha and both banks of the Morhar as proposed earlier to be taken up under Phase II needs further detailed investigations and review as discussed in the following paragraphs :-

Prior to under-taking any execution work on the Phase II portion of the scheme, it needs to be modified on the basis of further detailed investigations suggested earlier. It is observed that difference in the flood stages between the floods of 25 years return period and 100 years return period is less than 1 metre. This indicates the necessity of preparation of flood plain maps to a fairly large scale and with contour intervals of o.5 M to 1 M or even less if possible. In addition, the following studies need to be carried out to arrive at a suitable and proper solution which would be viable both technically and economically:

a Location of exact spilling points:-

The reaches in which the rivers of this basin spill over its bank causing flooding in the adjoining areas should be specifically located and past data of depth of spill along with depth of submergence every year during floods should be collected and be continued to be observed in future.

b Effect of embankment on countryside drainage:-

After the construction of embankment, the natural drainage from the protected areas into the river is bound to be affected. Drainage congestion for longer duration may adversely affect the crop production in the countryside in addition to causing several health hazard and other inconveniences to the people residing in the area. A study of the map of the Punpun river basin indicates that there are large number of roads and irrigation channels in the area lying between the Punpun and the Morhar river. These areas lying on the country side of the proposed embankments on the left bank of the Punpun, both banks of the Morhar and the right bank of the Dardha are apprehended to suffer from drainage congestion in case of heavy local precipitation when these rivers are in higher stages. This problem could not be identified specifically for want of the required historical data. It is, therefore, necessary that the effect of such adverse situations be studied carefully and suitable solution be worked out and executed alongwith the left Punpun embankment on the upstream of its confluence with the Dardha. Removal of such drainage congestions through sluices in the proposed embankments needs to be considered carefully and locations and waterways of such sluices be finalised accordingly to arrive at a satisfactory solution of the problem.

c Problem of Aggradation:-

The aggrading/degrading behaviours of the Punpun, the Morhar and the Dardha rivers have been studied in the past and it had been found that all these three rivers/tributaries had degrading tendency. It is, thus evident that there is practically little possibility of aggradation in these rivers in the Jacketted condition after completion of the proposed embankments.

8.1.3 Intermingling of Various Tributaries/Branches

There is considerable intermingling of flood waters of various tributaries of this basin and therefore it has been difficult to assess the correct flood discharge in any particular tributaries. Intermingling of flood flows of these rivers occurs due to their over bank spills which is primarily caused by human interference by way of construction of cross bunds for irrigation purposes, and encroachment in the khadir area of the river for cultivation resulting in reduction of their channel capacities. The possibility of activating of some of unimportant tributaries resulting in significant portion of run off being carried through those only can not be ruled out. Such tendency has been observed in case of the Ganghar which is reported to carry a major portion of the flood flow of the Morhar these days.

Development of such events after construction of flood embankments etc is likely to upset the whole programme unless due care of such possible event is taken at the time of planning itself. Resectioning and improvement of the channel sections may also have to be considered. The possibility of providing a sluice to restrict the flow in the Dardha, which is a branch of the river Morhar, during the flood season needs to be considered. If found feasible, it is, expected to regulate the discharges in the two rivers resulting in reduction of the intensity of flooding in the area.

"All the above and related aspects need to be carefully considered and settled before finalising the scheme for taking up actual execution for providing protection to the flood prone and removal of drannage congestion areas in the Punpun river basin.

8.1.4 Drainage Improvement

While discussing, the flood problem in the Punpun river system, it has been indicated that one of the possible cause of flood problem and drainage congestion is provision of inadequate waterways at Railway and Road bridges across the river Punpun. This problem is likely to be further aggravated under the jacketted condition when the spills to the Mokama Tal area will be checked and the entire quantity of river flow will be made to pass through the existing rail and road bridges. This problem was considered by the Road construction Department of the State at the time of construction of a new road bridge on the river Punpun downstream of the existing Railway bridge at Fatuha. As the HFL observed at the Railway bridge site and the discharge figure of the river Punpun at bridge site were under dispute, the matter was discussed in detail in a joint meeting of Senior Engineers on 29.4.81 and 4.5.81 in which high officials from Water Resources and Road Construction Departments of Bihar, Ganga Flood Control Commission, Ministry of Shipping and Transport, Government of India, participated. The main contention of the Water Resources Department was that in view of existence of a total clear water-way of 705.6 m (2315 ft.) in the Railway embankment from Patna Byepass Railway crossing near Deedargang to Fatuha , the provision of 49.9 m (163.75 ft) as total waterway in the road bridge on immediate downstream of the railway bridge was not adequate. Water Resources Department were of the view that the new bridge should have been designed for a discharge of 5600 cumecs (2,00,000 cusecs) instead of 2130 cumec (76,000 cusecs). After protracted discussions, it was finally decided that spill structures would be provided in the road in between Deedarganj and Fatuha to take care of additional discharge whatsoever is decided by the Water Resources Department in consultation with GFCC. In this connection the suggestion of Central Water Commission Communicated to State Government by GFCC vide their letter No.GFCC/ Tech/266/81/6726-23 dated 13th November '81 is reproduced below

"The State Government had carried out some studies relating to the design discharge for proposed embankments on Punpun in 1972. The subject was taken up with Director (Hydrology Dte-II),CWC. It was advised by him that the studies made in 1972 were based on inadequate data and the studies could not therefore be adopted. The CWC had suggested in 1972 that a good network of GD sites together with a few self recording raingauge station may be immediately set up in the catchment for collection of necessary data. They had also suggested that the effect of back-water due to blockage when river Ganga was also in floods was to be examined through hydraulic Model Studies".

It is, therefore, desirable that appropriate hydrological studies alongwith model studies as suggested by CWC/GFCC are carried out at the earliest and the design flood discharge under jacketted condition be finalised accordingly .

8.1.5 Interbasin Transfer

The diversion of Punpun flood waters to the Sone river basin on the West or to the Kiul-Harohar river basin on the east also needs to be investigated and studied in detail. Some part of the spill on the right bank of the Punpun flows to Dhowa river system and aggravates the flood situation in Mokamah Tal areas. While the transfer of flood water from the Punpun river basin to the Kiul-Harohar river basin is not considered desirable as it would further aggravate the drainage problems of Mokamah group of Tals. However, the feasibility of augmentation of the flow in the Falgu river by diverting part of Punpun Flood was considered as this area is a chronically drought affected area with very little irrigation facility at present . On examination this proposal was not found to be feasible as the topography of the area does not permit this diversion. The transfer of flood water from the Punpun river basin to the Sone river basin which is to the west of the former is another possibility. From the topography and other features of the two river basins, it appears that the diversion of water from the Punpun river can be done by constructing a diversion channel from Hamidnagar on the river Punpun to Arwal on the river Sone. The difference of elevation between these two places is about 5m Whereas the distance will be 20 to 25Km depending upon the alignment. Thus the slope of channel will be in between 1/4000 and 1/5000. The possibility of such a channel for diverting 1120 cumecs (40,000 cusecs) had been examined by the State Government as indicated in their Comprehensive Plan prepared in 1973. This proposal was dropped from any further consideration due to its high cost and land acquisition problems. It is, therefore, apparent that the possibility of inter basin transfer of flood waters from this basin to its adjacent basins on either side is remote.

8.1.6 Construction of Raised Platform

During the flood season, breaches sometimes occur in the embankments as a result of which protected areas get flooded. Submergence of the protected area is also caused due to heavy precipitation on the countryside coinciding simultaneously with high stages in the out fall channels. The affected persons take shelter on the embankments alongwith their livestock and properties in such situations. As a result, not only the embankments get damaged but the works like flood fighting and rehabilitation get hampered . Generally people do not go back to their original living places even after the flood subsides and continue to live on the embankments endangering its safety and hampering regular maintenance, it is therefore suggested that :-

i Occupation of embankments and the acquired lands should be got vacated effectively to avert any danger or risk to the flood management embankments and to the people living in the protected areas.

ii Raised platform above the highest flood level may be constructed in areas liable to inundation near villages on Governments or acquired lands. These could be also constructed on the countryside of the embankments abutting the same. Such platforms should preferably be connected with all weather roads and should also be provided with necessary facilities for ware housing, community living, sanitary and potable water supply installations, space for keeping cattles and storing fodder, telecommunication facilities etc in order to obviate likely inconveniences to the people residing on such platforms during floods. These should be handed over to Local Bodies/Panchayats for being utilised as community property and kept free from encroachment.

8.1.7 Soil Conservation and Water shed management

As is well known Soil conservation measures in the catchment areas of a river basin play an important part not only with respect to flood management but also in water resources development programmes. It is, therefore, suggested that the Soil conservation work done so far in this river system be properly evaluated and the remaining works required to be implemented for delivering the intended benefits should be formulated and completed on a time bound programme.

8.1.8 Non-Structural Measures

a Flood Plain Zoning

The question of introducing flood plain zoning measures has been under consideration for a long time.In view of the increasing pressure of population and consequential greater encroachment of flood plain zoning has assumed added significance. The continuing trend of rise in flood damage figures in recent years is primarily due to greater encroachment into flood plains.The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As a major portion of flood prone area in the Punpun basin is protected from flood since long,such zoning regulations should be introduced in the unprotected areas first and for developments in the protected areas hence forth.

It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour interval of 0.3 metre for implementation of this measure.Flood risk maps will be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of floods such as 100 years, 50 years and 25 years .Similar risk maps for the submergence caused due to drainage congestion as a result of water level likely to attain, corresponding to a 50 years and 25 years rainfall will also have to be prepared.

b Flood Forecasting and Flood Warning

At present there is only one forecasting site at Shripalpur on the river Punpun in this basin for which flood forecasts are issued by the local office of the Central Water Commission.The forecasts at Shripalpur are being issued on the basis of simultaneous hydrograph of Kinjer which has the following difficiencies-

i The lead time available for forecast is very short

ii The effect of rainfall in the lower reaches of the river basin gets ignored although it is quite significant.

There is,therefore,need for development of a suitable mathematical model for forecasting the flood on the basis of rainfall data.For this a good network of self recording raingauge stations need be designed and established .Extension of forecasting services for the Morhar and the Dardha should also be considered.

Flood forecasting and warning has proved to be a great help in issuing warning to the people in flood prone areas,organising flood fighting and safety measures for the engineering works, timely evacuation of people from affected areas and salvation of movable properties besides mobilising relief operations. Although there is wide application of the flood forecasting system and warnings issued by CWC, there is very little feed back on the procedures specified or evolved by the Civil Administration and the Engineering Organisation for undertaking relief/rescue/precautionary action on the basis of the forecasts.It is also not known as to how effectively the necessary advice is being given to the people.

On receipt of the forecast,its dissemination to the local population in terms of likely depth of inundation and its duration in the area by the Administrative Authorities is very important so that affected population, cattle, movable properties etc are evacuated before the area gets submerged by flood waters which would cause damage. For this, a network of wireless stations and telephone system are necessary in the basin near critical /vulnerable reaches of embankments and towns etc.specially where other means of communication are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the level indicated in the flood forecasts. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property.This training programme should become a regular feature before the flood season every year.

c Disaster Mitigation System and Preparedness

This is an important measure which directly influences the damage prevention,if managed efficiently,at all levels according to the prescribed procedures and guidelines.Improper management could also result directly in increased damage.The State Government should, therefore, ensure that all routine exercises and necessary drills are carried out systematically before every flood season and departmental instructions,manuals and rules in this regard should be widely circulated so as to make these available to all concerned.It is observed that disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year.Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the Officers and Staff of the concerned Departments as also in the public and voluntary organisations to deal with flood emergencies.

It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public.This will develop confidence amongst all concerned to manage any emergency situation. The training programmes,including education and publicity should be arranged by the Civil Authorities with active participation of the Officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio(Akashvani), Doordarshan or transmitted through other channels and the effective follow up of such messages into appropriate actions should be taught to all people in the flood prone areas.

8.2 A map of the Punpun river bain showing the completed, under execution and proposed flood management and drainage schemes is enclosed as Drawing No 9/01 and 9/02.

9.0 Summary of Recommendations

9.1 It is observed that hydrometeorological data of the river basin are not being observed, collected, analysed and documented in a systematic manner. A few self recording raingauge stations are required to be installed in the upper hilly catchment of the basin in accordance with the recommendations of the RBA. It has been reported that four out of 13 sites gauge/gauge- discharge sites maintained by the State Government are temporary and are not being maintained properly. It is, therefore, suggested that all the existing sites of the State Government be converted to gauge and discharge sites and maintained according to the standards laid down by the WMO/Bureau of Indian standards and the data be observed in the prescribed manner, processed, analysed and recorded properly for use in future planning of water resources utilisation and flood management schemes in the basin.

[Para 4.7.3]

9.2 In order to find out the total runoff during the monsoon period for planning of schemes for drainage of accumulated water, it is necessary to determine the runoff factor applicable for the monsoon period as a whole. In order to conduct such study and analysis rainfall data for the stations spread over the entire drainage area of the basin and runoff data at suitable locations on the river for a sufficiently longer period (at least 20 years or more) are considered necessary inputs.

[Para 4.8.1]

9.3 The relevant recommendations made by the Ministry of Irrigation, Government of India in the guidelines and instructions for implementation of the recommendations of RBA are reproduced below:

"In the case of embankment, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile necessary step may be taken for eventual application of benefit cost criterion for fixing the design."

The summary of recommendations as accepted is as follows:

"In the case of embankment schemes, the height of the embankment and corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio, taking into account the damage likely to occur for the relative flood frequencies. However, till such time as the details of all relevant parameters are available, embankment schemes might be prepared for a period of 25 years frequincy in the case of predominatly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of industrial and other vital organisations".

While endorsing the decisions of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the Commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of vital industrial establishments.

[Para 5.2.3]

9.4 It is observed that the flood damage statistics, which is essentially required for the benefit-cost studies for any proposed flood management measures are not being scientifically and rationally collected and compiled. The RBA had made many useful recommentations in this regard which do not seem to have been followed. The commission suggests that the recommandations of the RBA should be followed strictly and realistic evaluation of flood damage, river basinwise, be carried out every year under the following three identified categories separately :-

i Unprotected areas.

ii Protected areas due to failure of protection works.

iii Areas between the embankments and the river (on the river side)

The extent of drainage congestions in the protected and unprotected area should be indicated separately. The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency the flood damage data should be collectively reviewed by the conncrned Departments at the end of each year. Such reconciled long term basinwise data of flood damage may be used for damage fore-casting purpose as well as in economic viability study for any future flood protection management scheme in the area.

[Para 6.3]

9.5 There are eight possible resorvoir sites in the Punpun river basin,out of which two have already been constructed. It would be seen that the possible catchment area that can be intercepted through construction of storage reservoirs in only 6 per cent of the catchment of the whole river system. Naturally the effect of these reservoirs even if all are built up will be insignificant. It is, however, considered desirable to review the design of the aforesaid proposed reservoirs in order to provide for maximum possible benefits of flood moderation in the lower Punpun basin. Installation of flood forecasting network in the existing and proposed reservoir should also be considered because reservoirs with a good forecasting system of inflow and well designed operation rule curve for outflow can help to reduce the flood damage considerably.

[Para 8.1.1]

9.6 The problem of flooding in the Punpun river basin is mainly due to spilling of banks. Due to lack of complete basic data it has not been possible so far to know the extent of flood moderation with the help of the existing as well as the proposed reservoirs in the basin. It is also not certain as to when the proposed reservoirs will be taken up and completed keeping the above scenario in view, the embankments appear to be the immediate solution to the flood problem in the basin.

Accordingly, it is suggested that the continuing schemes should be completed without any further delay to avoid the damages that accrue every year as well as to prevent the cost over run of the schemes. The following embankment schemes should be considered for implementation on priority:-

i Left Punpun embankment exists from Didarganj to Sheikhpura and is further extended upto Khajuri escape channel. Its extension beyond Sheikhpura up to Jahanabad-Kinjer road needs to be taken up as the river spills over its bank in this portion and the river is reported to be flowing within its bankful capacity beyond this on the upstream.

ii The Punpun right embankment from Fatuha to its confluence with Dardha and Further along the right bank of the Dardha is under execution at present under phase I. This scheme is lingering since long without any valid justification. This needs to be looked into and the scheme be completed without any further delay.

iii The Punpun right embankment scheme from its confluence with Dardha river to Jahanabad-Kingar road and embankments on the left bank of the Dardha and both banks of the Morhar as proposed earlier to be taken up under Phase II needs further detailed investigations and review as suggested in the main report.

[Para 8.1.2]

9.7 There is considerable intermingling of flood waters of various tributaries of the Punpun basin and, therefore, it has been difficult to assess the correct flood discharge in any particular tributary. Intermingling of flood flows of these rivers occurs due to their over bank spills which is primarily caused by human interference by way of construction of cross bunds for irrigation purposes, and encroachment in the Khadir area of the river for cultivation, resulting in reduction of their channel capacities. The possibility of activating of some of unimportant tributaries resulting in significant portion of run off being carried through those only can not be ruled out. Development of such events after construction of flood embankment, is likely to upset the whole programme unless due care of such possible event is taken at the time of planning itself. Resectioning and improvement of the channel sections may also have to be considered. The possibility of providing a sluice to restrict the flow in the Dardha, which is a branch of the river Morhar, during the flood season needs to be considered. If found feasible, it is, expected to regulate the discharges in the two rivers resulting in reduction of the intensity of flooding in the area.

All the above and related aspects need to be carefully considered and settled before finalising the scheme for taking up actual execution for providing protection to the flood prone and removal of drainage congestion in the Punpun river basin.

[Para 8.1.3]

9.8 One of the possible cause of flood problem and drainage congestion is provision of inadequate waterways at Railway and Road bridges across the river Punpun. This problem is likely to be further aggravated under the jacketted condition when the spills to the Mokamah Tal area will be checked and the entire quantity of river flow will be made to pass through the existing rail and road bridges.

It is, therefore, desirable that appropriate hydrological studies alongwith model studies as suggested by CWC/GFCC are carried out at the earliest and the design flood discharge under jacketted condition be finalised accordingly.

[Para 8.1.4]

9.9 Occupation of embankment and acquired lands should be got vacated effectively to avert any danger or risk to the people liking in the protected area. Raised platforms above the highest flood level may be constructed, in areas liable to inundation, near villages on Government or acquired lands. These could also be constructed on the countryside of the embankment abutting the same. Such platforms should preferably be connected with all weather roads and should be provided with facilities to make living on them easy during floods. Such raised platforms should be handed over to local Bodies/Panchayats for being utilised as Community property and kept free from any encroachment.

[Para 8.1.6]

9.10 As is well known Soil conservation measures in the catchment areas of a river basin play an important part not only with respect to flood management but also in water resources development programmes. It is, therefore, suggested that the Soil conservation work done so far in this river system be properly evaluated and the remaining works required to be implemented for delivering the intended benifits should be formulated and completed on a time bound programme.

[Para 8.1.7]

9.11 Flood Plain Zoning measures will be useful in both protected and unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. Such zoning regulations should be introduced in the unprotected areas first and for developments in the protected areas hence forth.

Flood risk maps of the basin may be prepared showing the areas likely to be flooded for different frequencies of floods such as 100 years, 50 years and 25 years. Similar riskmaps for submersion caused due to drainage congestion corresponding to a 50 years and 25 years rainfall may also be prepared.

[Para 8.1.8(a)]

9.12 At present there is only one forecasting site at Sripalpur on the river Punpun in this basin for which flood forecasts are issued by the local office of the Central Water Commission. It is considered desirable to have more flood forecasting services for the rivers Dardha and Morhar also.There is also need for development of a suitable mathematical model for forecasting the flood on the basis of rainfall data. For this a good network of self recording raingauge stations need be designed and established.

On receipt of the flood forecast, it dissemination to the local population in terms of likely depth of innundation and its duration in the areas by the administrative authorities is very important so that necessary actions are taken before the area gets flooded so as to cause damage. For this, a network of modern communication system like telemetring device is necessary in the basin near critical/vulnerable reaches of embankments and towns etc, specially where other means of communications are not adequately dependable.

Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the levels indicated in the flood forecasts. Necessaroy training in this regard should be imparted to the officials concerned on a regular and continuous basis before the flood season every year.

[Para 8.1.8(b)]

9.13 The State Government should ensure that all routine exercises and necessary drills for disaster preparedness are carried out systematically before every flood season. Departmental instruction, manuals and rules in this regard should be widely circulated so as to make these available to all concerned.

It is essential that training programme and exercises are held regularly to improve the disaster preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. Such training programmes should be arranged by the civil authorities with active participation of the officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio (Akashvani), Doordarshan, or transmitted through other channels and the effective follow-up of such messages into appropriate actions should be taught to all people in the flood prone areas.

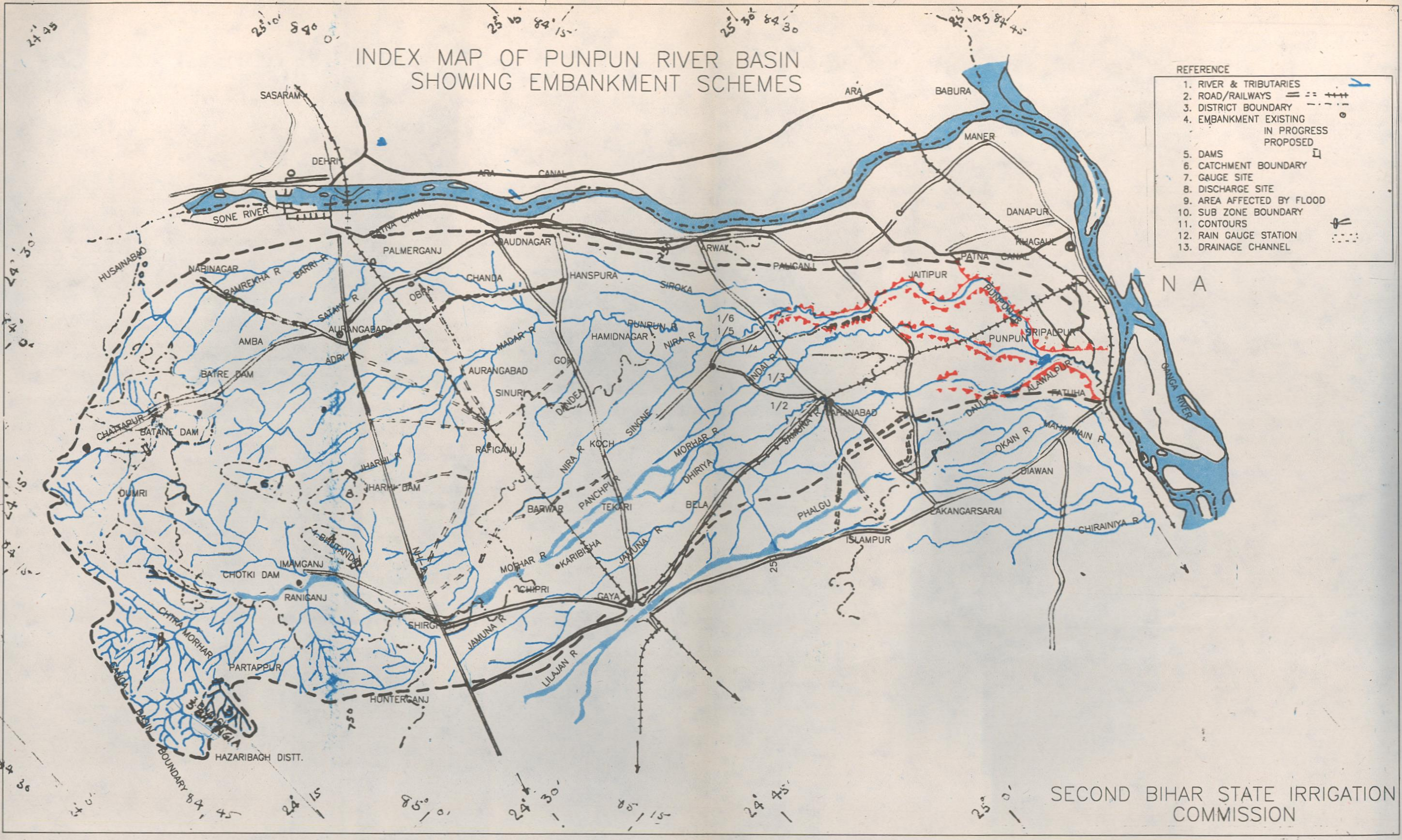
[Para 8.1.8(c)]

Annex 1

STATEMENT SHOWING LENGTH/CATCHMENT AREA OF THE TRIBUTARIES/ PART OF THE PUNPUN RIVER SYSTEM

Sl No	Name of Tributaries/ Sub-River System	Length in Km	Catchment Area in Sq Km	Remarks
1	RAMREKHA	36.37	104	R triburary
2	BARKI	21.25	111	R triburary
3	BATANE	78.43	634	R triburary
4	ADRI	40.00	336	R triburary
5	MADAR	56.25	1255	R triburary
6	BILARI	24.03	154	R triburary
7	NIRA	43.75	320	R triburary
8	SENANE	24.00	134	R triburary
9	MORHAR	185.00	2585	R triburary
10	DARDHA	122.50	1001	R triburary
11	KHUDAWA	16.44	–	L tributary
12	BEGI	10.12	–	L tributary
13	SIROKA	30.36	–	L tributary
14	MAWARIA	24.08	–	L tributary
15	PANCHANWA	6.32	–	L tributary
16	PUNPUN & L S TRIBUTARIES	–		
17	PUNPUN	234.60	1896	

DRG. 9/01



INDEX MAP OF PUNPUN RIVER BASIN
SHOWING EMBANKMENT SCHEMES
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1. RIVER & TRIBUTARIES
2. ROAD/RAILWAYS
3. DISTRICT BOUNDARY
4. EMBANKMENT EXISTING
IN PROGRESS
PROPOSED
5. DAMS
6. CATCHMENT BOUNDARY
7. GAUGE SITE
8. DISCHARGE SITE
9. AREA AFFECTED BY FLOOD
10. SUB ZONE BOUNDARY
11. CONTOURS
12. RAIN GAUGE STATION
13. DRAINAGE CHANNEL
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DEHRI
ARA
BABURA
MANER
ARA CANAL
SONE RIVER
PATNA CANAL
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PALMERGANJ
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ARWAL
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OKAIN R
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JHARHI R
JHARHI DAM
DUMRI
BARWAR
PANCHPUR
TEKARI
BELA
PHALGU
KAKANGARSARAI
ISLAMPUR
CHIRAINIYA R
BILTANDI
IMAMGANJ
CHOTKI DAM
RANIGANJ
MORHAR R
KARIBISHA
CHIPRI
GAYA
SHIRGHATI
JAMUNA R
LILAJAN R
CHITRA MORHAR
PARTAPPUR
HUNTERGANJ
HAZARIBAGH DISTT.
BOUNDARY
SECOND BIHAR STATE IRRIGATION
COMMISSION

YEARWISE MONSOON RAINFALL (in mm) INSIDE THE PUNPUN RIVER BASIN AND ADJACENT TO IT

		1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	OBRA	1148.4	1046.7	941.5	409.8	1143.2	1252.3	1208.6	801.0	1410.6	587.0	658.2	931.5	612.5	667.5	798.1	1477.6
2	RAFIGANJ	913.2	1042.6	687.3	740.8	1178.6	604.4	–	868.0	1489.7	414.4	581.3	495.5	435.0	1149.0	884.5	953.7
3	MADANPUR	–	–	–	–	–	–	–	–	–	–	–	–	768.1	1182.6	1326.0	1484.0
4	GURUA	–	–	–	–	–	–	–	–	–	–	–	–	–	1020.5	681.0	1114.6
5	KONCH	–	–	–	–	–	–	–	–	–	–	–	–	–	858.3	577.2	923.2
6	GOH	–	1334.6	607.4	488.0	779.0	529.0	808.8	421.5	1550.2	414.4	641.0	993.0	537.8	1014.5	1383.0	1083.0
7	HANSPURA	1053.5	1041.6	710.4	729.8	1161.2	–	1022.1	525.8	–	–	–	736.3	569.4	1028.4	1031.0	1092.6
8	TEKARI	944.6	885.7	875.0	610.0	1154.3	879.5	838.9	1030.7	1367.1	576.0	807.3	933.9	–	1554.0	883.7	825.6
9	KARPI	–	–	–	–	–	–	–	779.8	1235.5	476.0	816.0	747.0	–	744.7	1049.0	1091.9
10	KURTHA	1185.2	499.0	676.4	633.3	1092.6	703.9	871.1	986.7	1798.2	–	698.0	–	–	628.5	603.0	727.0
11	PALIGANJ	–	–	–	–	–	–	–	–	1142.0	661.5	995.7	598.0	781.0	1114.4	707.9	1060.5
12	PATNA	–	–	–	–	–	–	–	–	1333.5	686.5	1092.7	894.2	1262.9	1206.0	1357.0	1600.0
13	BIKRAM	–	–	–	–	–	–	–	–	1830.9	963.2	1186.4	847.8	872.7	1360.8	1142.0	1302.9
14	NAUBATPUR	–	–	–	–	–	–	–	–	1289.7	802.4	934.5	828.0	699.4	1070.9	1150.0	1128.7
15	PUNPUN	–	–	–	–	–	–	–	–	–	–	–	978.7	905.6	1046.9	1291.0	1600.7
16	PHULWARI	–	–	–	–	–	–	–	–	1269.6	632.7	1028.8	922.2	1075.5	1229.7	1657.0	1382.3
17	AURANGABAD	777.0	874.7	651.6	465.0	815.3	1156.8	999.7	823.8	1281.6	697.1	619.4	860.7	935.2	1259.5	1088.0	1291.2
18	BARUN	–	1040.9	766.6	471.8	1016.9	966.2	823.5	857.2	1819.7	–	–	835.7	963.8	1141.7	841.6	1060.4
19	DEO	890.4	984.8	764.5	282.8	726.2	–	1178.3	936.0	1335.3	459.4	833.3	762.4	584.8	1219.9	803.0	1324.1
20	KUTUMBA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	NABINAGAR	758.0	1115.0	954.0	546.0	955.4	492.6	784.6	671.0	1621.2	762.0	–	783.5	548.0	821.0	611.0	1273.0
22	HARIHARGANJ	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	CHHATARPUR	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	SHERGHATI	521.1	599.6	533.0	520.3	811.6	813.9	946.4	555.5	1171.8	811.5	797.9	683.6	658.0	1056.0	951.0	1177.0
25	JEHANABAD	995.3	824.6	763.8	267.7	1069.4	746.2	812.4	584.0	1460.5	624.3	962.1	692.7	656.1	1092.7	1045.0	1001.9
26	MANATEE	745.6	781.6	852.0	618.4	1038.7	806.8	966.4	993.3	–	–	–	–	–	–	–	–
27	HUNTERGANJ	–	–	–	364.9	885.0	772.8	952.0	1046.9	–	–	–	906.6	994.6	1544.4	1037.0	1542.3
28	IMAMGANJ	–	–	–	–	–	623.1	–	–	–	–	–	–	–	855.5	852.0	1230.0
29	FATUHA	–	–	–	–	–	–	–	–	1277.0	785.8	938.6	603.4	615.1	–	–	1055.9
30	MASAURHI	–	–	–	–	–	–	–	–	1316.8	788.9	1026.1	1159.0	776.8	1256.0	953.3	811.8
31	MAKHDAMPUR	845.5	878.2	646.4	436.4	1392.0	885.3	537.3	816.0	1705.6	419.4	854.8	773.3	–	1215.4	1020.6	1371.2
32	BODH GAYA	627.8	1202.6	713.0	571.0	992.9	992.7	1144.5	770.3	1392.1	831.5	787.6	848.8	–	967.8	1037.5	1379.4
33	PARAIYA	–	–	–	–	–	–	–	–	–	–	–	652.9	–	724.5	940.7	991.1
34	BELAGANJ	882.8	–	979.3	595.4	810.0	756.9	709.5	451.1	1360.0	643.5	460.2	528.5	–	519.7	455.8	1238.8
35	DHANRUA	–	–	–	–	–	–	–	–	1491.0	668.8	627.3	905.0	692.5	1124.0	919.5	945.8
36	AMAS	–	–	–	–	–	673.7	–	–	–	–	–	–	–	1102.0	766.0	1101.0
37	DUMARIA	–	–	–	–	–	–	–	–	–	–	–	–	–	613.0	530.2	1214.5
38	PRATAPPUR	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	966.9
	AVERAGE RAINFALL	877.74	943.49	757.76	603.02	1004.37	803.30	912.76	773.26	1432.59	652.71	824.63	803.93	759.28	1043.43	949.13	1171.33

Annex 3.1

YEARWISE MONSOON RAINFALL (in mm) INSIDE THE PUNPUN RIVER BASIN AND ADJACENT TO IT

		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	OBRA	463.3	755.3	782.5	697.6	781.7	935.5	982.1	1011.5	1321.5	820.1	704.3	-
2	RAFIGANJ	424.9	899.7	930.1	675.5	881.4	893.2	1148.5	895.4	1166.2	1015.0	806.0	-
3	MADANPUR	748.8	1018.8	723.7	988.0	1152.9	1364.8	1156.1	966.9	1187.6	623.8	1181.9	-
4	GURUA	-	844.0	737.1	493.1	557.6	866.7	1245.0	-	-	-	-	-
5	KONCH	478.3	483.4	-	-	-	762.2	1125.1	1117.5	1209.6	1162.4	-	-
6	GOH	672.3	901.2	1043.2	926.2	635.9	900.2	1147.5	1021.5	1334.6	1137.7	716.1	-
7	HANSPURA	623.3	1060.9	707.0	798.6	715.6	1016.2	917.6	962.0	1230.4	913.6	616.5	-
8	TEKARI	483.1	740.7	800.8	-	539.5	1206.0	706.4	980.1	1365.4	1070.3	-	-
9	KARPI	550.3	808.8	776.5	612.6	724.8	854.1	937.5	1701.2	1627.1	-	-	-
10	KURTHA	549.6	768.4	658.0	1087.5	601.5	1066.6	1019.7	925.4	1193.6	-	-	-
11	PALIGANJ	674.3	714.3	970.5	545.5	-	567.5	1137.1	899.5	1213.7	698.0	946.2	937.5
12	PATNA	800.7	932.5	1166.6	605.5	750.3	1112.5	1538.8	995.5	1530.3	1326.7	1045.2	1106.2
13	BIKRAM	927.6	1225.0	1580.6	571.1	763.0	1145.3	834.5	670.2	1702.4	893.2	804.3	984.0
14	NAUBATPUR	830.8	1228.7	1099.4	417.8	824.4	693.8	565.7	1057.9	1317.6	938.0	985.5	1222.9
15	PUNPUN	599.5	1037.2	1104.3	575.7	928.5	1022.2	1278.5	1215.0	1347.3	946.1	704.4	1086.8
16	PHULWARI	659.9	1143.3	1239.4	567.4	413.4	994.4	1618.2	882.9	1353.9	878.9	551.1	666.3
17	AURANGABAD	494.4	1076.5	671.3	949.4	674.6	1091.1	841.0	870.2	1150.4	964.3	943.0	-
18	BARUN	367.9	702.1	530.1	739.7	813.5	1165.9	1211.8	951.8	1586.6	805.2	778.1	-
19	DED	456.0	976.3	705.2	1090.6	812.7	962.8	1116.9	832.7	1091.6	701.0	807.7	-
20	KUTUMBA	-	-	1203.4	910.6	952.8	1094.5	1016.2	759.1	570.2	1137.7	1337.8	-
21	NABINAGAR	519.0	581.0	553.4	789.2	743.8	900.0	908.5	1044.5	1327.5	905.5	962.9	-
22	HARIHARGANJ	-	-	676.5	857.8	769.5	1051.0	993.0	772.4	1033.9	908.3	801.8	-
23	CHHATARPUR	-	-	776.5	525.5	1031.7	991.5	1265.5	757.0	1328.0	417.4	1107.4	-
24	SHERGHATI	1121.0	925.3	521.4	693.4	627.0	1124.5	951.3	1106.5	1277.3	939.8	-	-
25	JEHANABAD	554.0	520.5	685.2	489.3	875.7	1225.8	1090.9	890.3	1251.6	-	-	-
26	MANATEE	-	-	-	-	-	-	-	-	-	-	-	-
27	HUNTERGANJ	882.8	888.9	615.0	824.5	696.4	1161.7	1356.6	980.4	-	-	-	-
28	IMAMGANJ	-	536.6	761.8	799.8	575.8	878.8	981.6	919.0	1243.4	569.3	-	-
29	FATUHA	682.7	1177.0	1079.1	650.1	814.8	1229.2	1350.9	1339.3	1377.6	978.0	1001.6	-
30	MASAURHI	896.7	956.9	1131.0	754.3	931.1	949.0	1027.0	940.4	1455.2	896.8	353.6	-
31	MAKHDAMPUR	484.3	939.8	576.9	994.8	672.5	1369.1	1106.4	1100.2	1111.1	-	-	-
32	BODH GAYA	816.8	687.7	690.1	756.7	719.2	1301.0	1173.4	1098.6	1466.1	1033.0	-	-
33	PARAIYA	396.1	725.1	-	-	-	-	-	-	-	-	-	-
34	BELAGANJ	824.2	838.3	928.4	786.2	699.4	1126.6	1328.5	1082.7	1465.5	856.8	-	-
35	DHANRUA	618.5	997.0	711.0	357.1	454.5	561.1	772.7	433.2	707.5	526.2	431.9	-
36	AMAS	-	815.0	644.0	493.1	-	715.5	606.1	576.0	956.5	524.0	-	-
37	DUMARIA	-	-	-	344.0	843.0	914.9	946.1	590.0	1175.7	-	-	-
38	PRATAPPUR	864.8	840.9	801.0	920.0	1313.0	-	-	-		-	-	-
	AVERAGE RAINFALL	652.20	871.12	840.62	714.62	766.41	1005.97	1068.65	951.13	1275.07	885.07	837.50	
		19466.10	28747.10	28581.00	24288.20	25291.50	35215.20	37402.70	32346.80	41677.10	24787.10	17587.30	6003.70

[SOURCE: Chief Engineer, Master Planning, Water Resources Department, Govt. of Bihar.]

Annex 3.2

A LIST OF RAINGUAGE STATIONS INSIDE THE PUNPUN RIVER BASIN AND ADJACENT TO IT

Sl No	Name of Raingauge Station	District	Location		Average Annual Rainfall (mm) (1901-1950)
			Lat	Long	
1	BIKRAM	PATNA	25°27'	84°52'	1076.4
2	PALIGANJ	PATNA	25°20'	84°50'	954.0
3	SARMERA	PATNA	25°15'	85°48'	1107.6
4	ARWAL	GAYA	25°14'	84°41'	1065.9
5	DEO	AURANGABAD	24°39'	84°25'	1260.8
6	JAHANABAD	JAHANABAD	25°13'	85°00'	1090.8
7	KURTHA	GAYA	25°80'	84°48'	1093.5
8	RAFIGANJ	AURANGABAD	24°48'	84°38'	1215.8
9	NABINAGAR	AURANGABAD	24°37'	84°08'	1132.4
10	SHERGHATI	GAYA	24°33'	84°48'	1156.9
11	AURANGABAD	AURANGABAD	24°45'	84°23'	1263.4
12	RANCHI(OBSY)	RANCHI	23°23'	85°20'	1512.7
13	GUMLA	RANCHI	23°02'	84°33'	1471.0
14	CHHATARPUR	PALAMU	24°22'	84°12'	1242.4
15	MANATU	PALAMU	24°14'	84°24'	1490.2
16	PATAN	PALAMU	24°13'	84°11'	1279.4
17	LATEHAR	PALAMU	23°45'	84°13'	1322.7
18	NETARHAT	PALAMU	23°29'	84°16'	1817.4
19	HARIHARGANJ	PALAMU	24°33'	84°17'	1311.2
20	PATNA(OBSY)	PATNA	25°27'	85°10'	1166.4
21	HANTERGANJ (DBSY)	HAZARIBAGH	23°59'	85°22'	1338.7
22	CHATRA	HAZARIBAGH	24°02'	84°52'	1344.2
23	HANTERGANJ	HAZARIBAGH	24°27'	84°48'	1315.9
24	DALTENGANJ(OBSY)	DALTENGANJ	24°03'	84°04'	1242.1
25	PALMERGANJ (Self Recording Station)	DALTENGANJ	—	—	—
26	SRIPALPUR (Self Recording Station)	PATNA	25°30'	85°5'55"	—

[SOURCE : Comprehensive Plan of Flood Management for Punpun River System-1986]

Annex 3.3

BLOCKWISE RAINFALL PATTERN OF PUNPUN RIVER BASIN

SL NO	NAME OF BLOCKS	AVERAGE MONSOON RAINFALL in mm	75% PROBABLE MONSOON RAINFALL in mm	90% PROBABLE MONSOON RAINFALL in mm	RUN OFF in inch
1	2	3	4	5	6
1	PATNA	1117.21	903.77	692.80	11.25
2	PHULWARI	1015.35	661.50	569.70	6.20
3	FATUHA	998.00	734.25	612.90	7.50
4	MASAURHI	951.61	794.62	661.90	8.75
5	PUNPUN	1044.67	937.70	594.50	12.50
6	DHANRUA	727.70	534.92	432.03	4.00
7	NAUBATPUR	954.00	807.90	578.50	9.70
8	PALIGANJ	881.74	707.90	598.00	6.50
9	BIKRAM	1080.42	837.82	679.50	10.00
10	BODHGAYA	960.44	742.45	663.74	7.26
11	PARAIA	883.76	724.65	472.90	6.92
12	KONCH	869.74	553.72	478.79	3.62
13	TEKARI	919.11	755.72	557.75	7.52
14	BELAGANJ	847.25	607.02	458.00	4.55
15	MANPUR	987.45	773.38	608.20	7.88
16	SHERGHATI	841.95	618.58	521.31	4.78
17	AMAS	747.74	583.52	502.34	4.09
18	IMAMGANJ	832.82	599.45	549.74	4.40
19	DUMARIA	786.87	560.45	344.00	3.73
20	GURUA	925.46	695.00	512.47	6.38
21	JAHANABAD	847.28	640.20	508.82	5.20
22	MAKHDUMPUR	930.28	652.53	460.35	5.46
23	KURTHA	858.64	651.81	601.95	5.44
24	KARPI	919.27	735.90	535.44	7.13
25	AURANGABAD	900.12	697.10	594.20	6.63
26	DEO	872.78	722.42	458.38	6.92
27	KUTUMBA	1042.48	870.60	–	11.00
28	NABINAGAR	841.25	603.46	537.90	4.50
29	BARUN	927.45	763.72	500.95	7.90
30	OBRA	931.55	697.60	562.05	6.38
31	HANSPURA	893.68	710.40	588.19	6.66
32	GOH	870.86	603.78	668.05	4.47
33	RAFIGANJ	852.83	657.63	431.96	5.50
34	MADANPUR	1058.46	768.10	683.74	7.90
35	CHHATARPUR	823.10	511.74	204.00	3.10
36	HARIHARGANJ	863.48	770.25	685.80	7.83
37	MANATU	1046.77	839.54	753.68	10.00
38	HUNTERGANJ	966.27	796.47	589.80	8.75
	AVERAGE:-		760.50	665.16	

[Source : CE Master Planning, WRD Patna]

Annex 3.4

THE VALUE OF THE TOTAL AVERAGE RAINFALL OVER THE PUNPUN BASIN AND THE AMOUNT OF DIRECT RUNOFF IN CASE OF EACH OF THE STORM ARE TABULATED BELOW

Sl no	Period of Storm	Amount of rainfall (mm)	Amount of Run-off (mm)
1	10.9.76 to 14.10.76	519.98	173.71
2	25.6.78 to 9.7.78	237.83	43.98
3	22.7.78 to 22.9.78	422.24	289.65
4	1.9.78 to 29.9.78	110.57	35.08
5	18.9.78 to 23.10.78	217.5	173.04
6	17.7.79 to 5.8.79	149.45	41.92
7	25.7.79 to 5.8.79	54.29	8.67
8	17.8.79 to 31.8.79	43.18	23.98
9	24.8.80 to 3.9.80	90.92	60.06
10	3.9.80 to 25.9.80	165.57	110.71
11	2.7.81 to 14.7.81	91.78	8.99
12	14.7.81 to 7.8.81	234.18	61.31
13	31.7.81 to 16.8.81	80.91	21.21
14	19.8.81 to 4.9.81	85.22	25.66
15	5.6.82 to 18.6.82	109.53	14.56
16	29.8.82 to 16.9.82	93.01	26.85
17	10.9.82 to 23.9.82	61.93	29.64

[Source: Comprehensive plan of Punpun river system March 1986 propared by GFCC]

LIST OF GUAGE AND DISCHARGE SITE IN THE PUNPUN RIVER BASIN

Sl No	Name of site	STREAM	LOCATION LAT LONG	MAINTAINED BY DIVISION	ZERO GAUGE in m	CATCHMENT AREA in (Sq Km)	METHOD	DISTRICT
1	SIRIS	PUNPUN	24°49'N 84°16'E	WRD DIV 2 PATNA	94.61	990.00	FM	AURANGABAD
2	FATUHA	PUNPUN					FM	
3	HAMIDNAGAR	PUNPUN	25°3' N 84°40'E	WRD DIV 2 PATNA	71.43	3225.00	FM	AURANGABAD
4	SANTHUA	BARAHE	24°47'N 84°19'E	WRD DIV 2 PATNA	104.50	624.00	GS	AURANGABAD
5	BHARKHEL	TEKARI	24°54'N 84°33'E	WRD DIV 2 PATNA	78.08	910.00	FM	AURANGABAD
6	KENDAI	MORHAR						
7	NEIMA	"	25°0' N 85°0' E	WRD DIV 2 PATNA	54.30	2600.00	FM	
8	IMAMGANJ	"						
	(RAHARIA)	"	24°29'N 84°36'E	WRD DIV 2 PATNA	161.25	680.96	FM	GAYA
9	ROSHANGANJ	"	24°31'N 84°44'E	WRD DIV 2 PATNA	153.60	1528.32	FM	GAYA
10	PANCHANANPUR	"	24°53'N 84°52'E	WRD DIV 2 PATNA	90.86	2072.00	FM	GAYA
11	RAWJANI	JAMUNE	25°8' N 85°1' E	WRD DIV 2 PATNA	58.34	2072.00	FM	JAHANABAD
12	PATNA-MASHAUDHI ROAD	DARDHA	—					
13	FATUHA	GANGA	—					
14	PALMERAGANJ	PUNPUN	—	CWC DIV 5 PATNA		1280.00	GS	
15	KINJAR	"	—	CWC DIV 5 PATNA		3810.00	GS	
16	SRIPALPUR	"	25°30'N 85°5'55"E	CWC DIV 5 PATNA	—	5250.00	CMG/ GDWQ	
17	MIANCHAK	MORHAR	25°5'50"N 85°5'55"E	CWC DIV 5 PATNA	—	2302.00	CMG	
18	KOLCHAK	DARDHA	25°21'32"N 85°5'28"E	CWC DIV 5 PATNA	—	715.00	CMG	
19	KADIGANJ	SAKRI		CWC DIV 5 PATNA			CMG	

Abbreviations :

WRD – Water Resources Department, Govt of Bihar.
CWC – Central Water Commission.
FM – Discharge Data By Flood Method Gauging (GD site)
CMG – Discharge Data By Current Meter Gauging (GD site).
GS – Gauge Site.
GDWQ – Gauge, Discharge and Water Quality

YEARWISE PEAK VALUES DF GAUGE AND DISCHARGE DATA

	DL =50.60m HFL/YEAR = 53.91/1976		DL = 97.50M HFL/YEAR = 99.13/1976				DL = 65.00m HFL/YEAR = 67.95/1976					
YEAR	SRIPALPUR SITE RIVER : PUNPUN		MIACHAK SITE RIVER : MDRHAR		KOLACHAK SITE RIVER : DARDHA		PALMERGANJ SITE RIVER : PUNPUN		KINJER SITE RIVER : PUNPUN		KADIGANJ SITE RIVER : SAKRI	
	Peak Gauge in m	Peak Discharge in Cum	Peak Gauge in m	Peak Discharge in Cum	Peak Gauge in m	Peak Discharge in Cum	Peak Gauge in m	Peak Discharge in Cum	Peak Gauge in m	Peak Discharge in Cum	Peak Gauge in m	Peak Discharge in Cum
1957	52.270	-	-	-	55.933	-						
1958	51.020	-	-	-	55.838	-						
1959	-	469.00	-	-	52.649	-						
1960	52.365	465.30	-	-	55.663	249.30						
1961	53.125	628.00	-	-	55.461	207.70						
1962	52.661	641.17	52.218	93.65	55.501	255.15						
1963	50.890	341.09	51.097	23.09	55.252	136.62						
1964	52.685	621.90	52.007	43.61	54.932	137.54						
1965	49.675	217.75	50.707	51.13	54.228	36.48						
1966	48.769	121.80	48.367	-	51.922	10.14						
1967	52.825	576.47	53.067	82.25	55.627	247.20						
1968	51.830	457.80	48.962	-	54.432	104.16						
1969	52.205	568.50	50.657	22.99	54.914	174.41						
1970	51.845	526.43	50.192	-	53.992	37.94						
1971	52.930	697.65	52.401	134.60	55.572	322.36						
1972	49.593	213.34	50.012	-	54.082	75.80						
1973	52.475	630.39	51.807	51.03	55.612	366.11						
1974	50.683	290.71	51.487	41.24	53.437	65.09						
1975	49.863	223.66	49.537	-	52.057	17.07						
1976	53.910	828.79	53.517	160.00	55.872	429.22						
1977	52.410	611.95	51.647	48.49	55.638	321.17						
1978	52.850	621.55	52.657	153.82	55.672	268.93						
1979	51.785	381.12	52.197	71.00	54.982	96.00						
1980	53.013	828.37	52.232	97.27	53.557	82.68						
1981	51.347	424.75	51.300	45.50	54.640	57.84						
1982	51.347	424.75	49.357	-	53.737	66.49						
1983	51.773	507.36	49.637	-	52.412	13.68						
1984	53.167	770.30	52.567	186.50	55.722	324.28						
1985	52.327	580.09	52.627	29.80	54.592	108.00						
1986	52.670	876.08	52.477	155.90	55.602	366.78						
1987	53.485	1015.00	52.672	188.20	55.897	401.99						
1988	52.645	546.67	52.160	122.63	55.770	345.05						
1989	51.685	608.21	50.817	87.20	53.782	175.42						
1990	53.175	900.00	52.537	168.63	55.832	397.45						
1991	53.105	762.11	51.877	158.38	54.392	168.48	96.30	66.97				
1992	50.190	342.11	49.247	50.76	53.102	44.48	95.11	65.44				

Annex 5.1

MAXIMUM OBSERVED GAUGE AND DISCHARGE DATA

Station: Sripalpur

Danger level: 50.60 m

Year	No of times it crossed danger level	Duration of flood in Days	Max. gauge in metre (Date of occurance)	Max. discharge in cumec (Date of occurance)
1	2	3	4	5
1962	4	14	52.661 (28/9)	641.170 (27/9)
1963	1	2	50.890 (27/10)	370.500 (27/10)
1964	2	15	52.685 (20/7)	621.900 (20/7)
1965	-	-	49.675 (29/9)	439.200 (3/9)
1966	-	-	48.769 (24/8)	121.800 (24/8)
1967	3	30	52.825 (21/9)	582.440 (26/9)
1968	4	13	51.765 (15/8)	500.000 (15/8)
1969	2	21	52.317 (18/9)	642.830 (18/9)
1970	1	4	51.845 (14/9)	5526.430 (14/9)
1971	5	63	52.930 (8/8)	1138.450 (8/8)*
1972	-	-	49.593 (29/8)	213.340 (29/8)
1973	3	14	52.535 (17/10)	630.300 (17/10)
1974	1	2	50.683 (29/8)	290.710 (29/8)
1975	-	-	49.863 (21/7)	223.660 (21/7)
1976	1	15	53.910 (18/9)	829.290 (18/9)
1977	5	23	52.420 (2/8)	611.950 (1/8)
1978	4	53	52.890 (7/8)	682.980 (30/6)
1979	2	6	51.785 (21/7)	381.120 (20/8)
1980	4	21	53.013 (11/9)	828.370 (11/9)
1981	4	11	51.347 (22/7)	424.750 (23/7)
1982	-	NA	51.347	424.750
1983	3	NA	51.773	507.360
1984	-	36	53.167	770.300
1985	-	NA	52.327	580.090
1986	2	15	52.670	876.080
1987	3	25	53.485	1015.000
1988	4	NA	52.645	546.670
1989	-	NA	51.685	608.210
1990	2	-	53.175	900.000
1991	-	-	53.105	762.110
1992	-	-	50.690	342.110

* Some descrepancy in observation

FLOOD DAMAGE DATA OF THE PUNPUN RIVER BASIN
(Converted From The Available Figures For The Districts In The Basin)

Year	Area Affected in Lha	Damage to Crops			Damage to Houses			Cattle Lives Lost in nos	Human Lives Lost in nos	Damage to Publics Utilities in Rs Lakh		Total Damage in Rs Lakh	
		Crops area affected in Lha	At then current price Rs Lakh	At 1991 constant price Rs Lakh	in Nos	At then current price Rs Lakh	At 1991 constant price Rs Lakh			At then current price	At 1991 constant price	At then current price	At 1991 constant price
1966	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1968	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
1969	0.1700	NA	0.050	0.298	702.0	0.620	3.695	2	1	NA	NA	0.67	3.990
1970	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
1971	1.6200	0.4300	555.440	2999.380	2488.7	92.780	501.010	19	11	51.320	277.128	699.54	3777.520
1972	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA NA	NA	NA
1973	0.1000	0.0200	62.150	267.860	NA	0.550	2.370	NIL	NIL	NA	NA	62.70	270.230
1974	0.0200	0.0200	8.250	27.640	NIL	NIL	NIL	NIL	NIL	NA	NA	8.25	27.640
1975	0.1100	0.1100	137.980	445.670	5955.0	135.420	437.410	18	4	NA	NA	273.40	883.080
1976	2.3600	0.8500	986.130	3244.370	73111.0	621.840	2045.850	497	25	NA	NA	1607.97	5290.220
1977	0.1900	0.0600	53.000	162.180	55.0	0.940	2.870	NIL	NIL	0.220	0.670	54.16	165.720
1978	0.8100	0.2900	250.770	767.360	7068.0	8.650	26.470	7	7	NA	NA	259.42	793.830
1979	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
1980	0.4400	0.1500	64.800	148.130	74.0	1.790	4.092	NIL	NIL	NA	NA	66.59	152.220
1981	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
1982	0.1800	0.0500	162.000	322.060	319.0	4.120	8.191	NIL	NIL	NA	NA	166.12	330.250
1983	0.1400	0.0300	19.660	36.135	NIL	NIL	NIL	NIL	2	NA	NA	19.66	36.135
1984	0.6850	0.6620	552.670	938.430	3549.0	849.750	1442.880	NIL	28	1288.960	2188.650	2691.38	4569.960
1985	0.1060	0.0757	33.330	53.490	267.0	6.940	11.138	NIL	1	3.090	4.960	43.36	69.580
1986	0.9180	0.4545	195.260	297.560	12800.0	5.712	8.704	NIL	3	365.580	557.110	566.55	863.370
1987	2.1800	1.4400	3646.670	5225.680	54578.0	1951.610	2796.660	57	43	3149.980	4513.920	8748.26	12536.250
1988	0.1060	0.0150	113.118	149.750	-	-	-	NIL	2	-	-	113.18	149.750
1989	0.0212	0.0061	3.030	3.750	99.0	0.909	1.1263	NIL	NIL	0.303	0.375	4.24	5.250
1990	0.9800	0.5180	244.169	277.590	489.0	8.49	9.65	18	NIL	36.810	41.850	289.47	329.090
1991	0.2120	0.0818	20.949	20.949	462.0	1.77	1.77	14	2	0.454	0.454	23.17	23.170
1992	0.0720	0.0180	-	-	-	-	-	-	-	-	-	-	-
1993	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
UPTO 15-08-93													
TOTAL	11.420	5.2811	7109.426	15388.28	162016.	3691.891	7303.886	632	129	4896.717	7585.117	15698.09	30277.255
AVERAGE	0.57	0.28	374.18	809.91	12294.3	230.74	456.49	79	11	544.08	842.79	826.22	2109.19

SORURCE Comprehensive Plan Of Flood Control For The Punpun River System Prepared By GFCC in 1986 And From Relief And Rehabilitation Dept Govt of Bihar.

Annex 6.1

TIME SERIES OF WHOLSALE PRICE INDEX (1900 TO 1991)

(1970-71 = 100)

Average	Index	Average	Index
1900	10.4	1971	105.0 *
1905	9.8	1972	113.0
1910	10.9	1973	131.6
1915	13.6	1974	169.2
1920	25.1	1975	175.8
1925	20.3	1976	172.4
1930	15.3	1977	185.4
1935	11.3	1978	185.0
1940	13.2	1979	206.5
1945	27.6	.1980	248.1
1950	46.5	1981	278.4
1952	44.8	1982	285.3
1955	44.0	1983	308.5
1956	45.3	1984	334.0
1958	49.0	1985	3533.3
1960	54.2	1986	372.2
1962	57.5	1987	395.7
1964	65.8	1988	428.6
1966	79.7	1989	457.7
1968	91.3	1990	498.9
1970	99.0	1991	567.2

Note: Index numbers upto 1946 are on base 1970=100 and are derived; thereafter upto 1988. the official series on base 1970-71=100. Since then the base is changed to 1981-82, and figures from 1989 to 1991 are estimated conversions on 1970-71 base.
*Average for nine months.

Annex 7

The percentage area of differnt blocks falling in the basin in seven districts

SL NO	NAME OF BLOCKS	% AREA OF THE BLOCK FALLING IN THE BASIN	YEAR OF FLOOD	FREQUENCY DURING 1970-86
1	**Patna District**			
1	Paliganj	62.80%	1971,76,78,84, 86,87,88,90.	5
2	Bikram	26.00%	1971,75,76,78, 86,87,90.	5
3	Naubatpur	6.90%	1971,76,78,80, 85,86,87,88,90,91.	6
4	Punpun	94.40%	1971,76,78,80, 84,85,86,87,90.	7
5	Phulwari	32.08%	1971,76,78,86, 87,90.	4
6	Patna	12.93%	1971,73,75,76, 78,80,82,83,84,86,87,91.	10
7	Masaurhi	100.00%	1971,76,78,84, 85,86,87,90.	
8	Fatuha	66.30%	1971,76,78,80, 82,84,85,86,87,90,91,	
9	Dhanarua	100.00%	1971,76,78,80, 84,85,86,87,90.	
2	**Jehanabad district**			
1	Karpi	88.20%	87,90	
2	Ghosi	42.50%	87,90	
3	Makhdumpur	91.70%	87,90	
4	Jehanabad	100.00%	87,90	
5	Kurtha	100.00%	87,90	
6	Kako	100.00%	87,90	
3	**Gaya district**			
1	Tekari	100.00%	1971,76,78,84,87.	4
2	Konch	100.00%	1976,87.	1
3	Belaganj	68.00%	1976,87.	1
4	Gaya	100.00%	1976,78,87.	2
5	Manpur	15.20%	1987.	
6	Bodhgaya	68.50%	1976,87	1
7	Sherghati	100.00%	1978,87	1
8	Paraiya	100.00%	1976,78,87.	2
9	Gurua	100.00%	1987.	-
10	Amas	100.00%	1987.	-
11	Dumariya	100.00%	1971,87.	1
12	Imamganj	100.00%	1987.	-
13	Barachatti	6.80%	——	-

Annex 7

SL NO	NAME OF BLOCKS	% AREA OF THE BLOCK FALLING IN THE BASIN	YEAR OF FLOOD	FREQUENCY DURING 1970-86
4	**Aurangabad district**			
1	Nabinagar	47.00%	1978,87.	1
2	Barun	32.30%	1971,76,78,87.	3
3	Daudnagar	26.30%	1971.	1
4	Haspura	94.34%	1971,76,87.	2
5	Goh	100.00%	1976,87.	1
6	Rafiganj	100.00%	1971,76,87.	2
7	Obera	80.00%	1971,76,78,87.	3
8	Aurngabad	100.00%	1976,78,87.	2
9	Madanpur	100.00%	–	-
10	Kutumba	100.00%	1976,87.	1
11	Deo	100.00%	–	-
5	**Nalanda district**			
1	Hilsa	10.00%	1971,73,76,78 84,86,87,90.	6
6	**Palamu district**			
1	Chattarpur	63.10%		
2	Hariharganj	80.00%		
3	Manatu	35.00%		
4	Patan	5.40%		
7	**Hazaribagh district**			
1	Hunterganj	36.40%	1987	
2	Pratappur	73.20%		

[Source :- Flood draught statistical data book]

Appendix 9/47

Annex 8

RBA'S Recommendations - Methodology of Flood Damage Assessment

1. The final estimate of crop damage in areas where they are completely destroyed but resown/ replanted should be made in terms of loss of inputs.

2. Information on (i) stage of the crop at the time of flood and (ii) crop completely destroyed and (iii) crops damaged but replanted /resown should be collected.

3. Crop losses in terms of money should be estimated by using farm harvest prices.

4. Crop yield rates should be derived from crop cutting experiments.

5. The collection of crop damage statistics should be integrated with that of agricultural statistics.

6. Whenever possible, contour maps along with gauge data should be used by the Flood Control Deptt. to derive estimate of area flooded.

7. Remote sensing techniques operated through artificial satellite(s) may be used in selected areas to provide a sample check on the extent of area and cropped area affected by floods.

8. State Government should take measure for collection of data on damage to household goods. As a first step, they should aid and sponsor research and set up economic cells for conducting suitably designed economic surveys in this respect.

9. The monetary value of the cattle lost should be estimated. With regards to loss of human life, only that due to floods should be taken into account.

10. In the case of public utilities, double counting of unrepaired damages of earlier years should be avoided.

11. The estimate of damages to properties of the Central Government should also be included in the consolidated figures of damages at the State, national and other levels.

12. Department dealing with flood control at the Centre and in the State should arrange for exploratory studies and sample surveys for throwing more light on the significance of indirect damages due to floods and for indicating norms for including them in the future.

13. Flood damage report may be reported separately for the following three categories of are as :-

- i Unprotected areas,
- ii Protected areas, and
- iii Area situated between the embankments and the rivers.

14. The extent of area affected by drainage congestion should be compiled seperately for protected areas and unprotected areas.

15. Damage data should be compiled basin and sub-basin wise also.

16. The district statistical office should supervise the work of damage data collection at the village and block levels and prepare estimates.

17. At the state level the work of compilation and processing should be undertaken by the Directorate of economy and Statistics.

18. At the national level, damage data should be compiled by the Central Water Commission With an Economics unit added to it. It should publish data at the National level.

19. Time schedule for submission of reports at various levels should be specified and adhered to.

20. At the State and National levels, there should be a periodical review of the methodology of data collection, compilation and publication.

21. The Central Water Commission should aid and encourage research in the methodology of flood damage assessment.

Annex 9

COMPARATIVE STUDY DF AVERAGE ANNUAL FLOOD DAMAGE FIGURES WITH THAT OF COUNTRY AS A WHOLE AND GANGA SUB-BASIN

Sl No	Item		All India	Ganga sub-basin	Punpun river system
1	Total area affected (in Lha)		92.33	47.82	0.41
2	Total population affected (In Lakh numbers)		298.53	169.20	-
3	a	Total crop area affected (In Lha)	39.86	22.72	0.13
	b	Damage to crops	26132.30	16279.27	153.35
4	a	Number of houses damaged	1105705	638432	7478
	b	Damage to houses (In Rs lakh)	7067.68	3965.29	57.78
5	Damage to public utilities (In Rs lakh)		13633.30	4646.20	3.44
6	Number of human lives lost		1434	401	3
7	Number of cattle lives lost		105	11061	36
8	Total damages (In Rs lakh)		46831.10	24851.10	214.57
9	Total geographical area (In Sq Km)		32,90,000	8,61,000	9025.75
	i	Percentage of total damages of Punpun river system with that of India, as a whole	= 0.45%		
	ii	Percentage of total damage of Punpun river system with that of Ganga sub-basin (Area in India)	= 0.86%		
	iii	Percentage of geographical area of Punpun river system with that of India as a whole	= 0.286%		
	iv	Percentage of geographical area of Punpun river system with that of Ganga sub-basin (Area in India)	= 1.025%		

RECOMMENDATIONS OF THE HIGH LEVEL TECHNICAL COMMITTEE, 1976

Remedial measures proposed:-

After a study of the River Morphology, the existing flood protection works and the experience of floods of 1967, 71 and 76, the Committee recomends the following flood protection measures:-

a SHORT TERM MEASURES :

i As mentioned earlier, Punpun does not create appreciable flooding upto Jahanabad Kinjar road. It is the lower reaches in the vicinity of Patna where Punpun spills heavily on both the banks due to inadequate capacity and low banks. Backing up of Punpun water due to flood locking in river Ganga also enhances the problem.Spill on the left bank is controlled by right bank of Fatehpur distributay from Akbarpur to Patna-Gaya line and thereafter by Punpun left embankment. The High Level Experts Committee on Patna Floods, 1975, had recommended that the adequacy of this embankment should be throughly examined and if necessary further raising and strengthening should be done, so that the embankment is safe for a hundred year flood with a free board of 0.9 m.

ii River Punpun has surpassed in 1976 its previous recorded H.F.L. of 1905 by 1.05 m at Punpun Railway Bridge . Since the Railway Bridge was constructed well before 1905 and flood of that year was considered highest on record,the level recorded in 1976 can be safely assumed very nearly to 100 years frequency of flood. However, flood frequency study for water level at Sripalpur gauage site about 1 Km downstream of the Railway bridge has been made based on water levels available from the year 1957 to 1976. The study reveals that the HFL in 100 years flood frequency without taking into account the proposal of right embankment comes to 54.45 m against observed HFL of 53.91 m in 1976 which is 0.54 m higher. This difference will be covered in a free board of 1.8 m above HFL of 1976. Hence the Committee recommends that the HFL of 1976 will be taken as design HFL for raising and strengthening of the existing embankment and for the new embankment as recommended by the Tripathy Committee. There is no necessity of changing the alignment and the recommendation of Tripathy Committee should stand as it is except in respect of remodelling of the Khajuri Distributary to function as an escape-cum-navigation channel. This proposal has been thoroughly examined and investigated by the State Gvernment. It is found that Punpun is not a navigable river.In monsoon season, the river remains almost dry with a depth of water varying from 1 ft to 2 ft in most of its reaches, Secondly the full supply discharge of Patna canal above Naubatpur cross regulator is 1600 cusec and below it 600 cusec only. On the above backgrounds, it is recommended that the Khajuri distributary should be designed and constructed as an escape channel and not as an escape-cum-navigation channel. The full supply discharge of the distributary should be 500 cusec.From consideration of safety and economy, the proposed channel will be in cutting and as such minors on either bank from above the first fall will have to be provided for maintaining the existing irrigation facilities provided in 4000 acres by the Khajuri distributary.

iii Comprehensive Punpun Embankment Scheme prepared in 1973 costing Rs 976.00 lakh should be reviewed in the light of 1976 floods. Also, while deciding the spacing & alignment of proposed right embankment along river Punpun the effect of jacketting on the left Punpun embankment should be carefully considered in order to obviate any danger to the safety of left bank embankment which protects Patna town.

iv The sanctioned scheme amounting to Rs 77.00 lakh for construction of right embankment to check spill of Punpun on right bank and entering into Mokameh Tal may be kept in abeyance till the review of the comprehensive scheme suggested above.

v The design criteria for the embankments should conform to the design criteria recently approved by the Ganga Flood Control Commission.

vi A technical Committee on Drainage of Water trapped in between the Patna bye-pass (Phase-I) and Railway main line, constitued by the Government of Bihar has suggested that a scheme for drainage of Patnacity area (Old Patna) should be implemented as a part of Punpun Flood Protection Scheme. This scheme envisages remodelling of the City Mote nala which is very old and is the only trunk drain leading to Ganga for draining of storm water of Patnacity. This proposal has been considered by this Committee and it is felt that this scheme, how-so-ever urgent and important it might be, cannot form a part of Punpun Flood Protection Scheme and its cost should be borne from the funds other than flood sector since Punpun flood water will be checked by its left embankment.

b LONG TERM MEASURE :

RESERVOIRS The total catchment area of Punpun is 3425 sq miles upto its confluence with the Ganga at Fatuha. There is no site for construction of major dam on Punpun or its tributaries. Of course, there are 7 sites for comparatively smaller dams which will control a total catchment area of about 271 sq miles. These sites are indicated in the index map enclosed as annex IV. though these dams will be controlling smaller catchments the Committee feels that provision of some specific flood storage or provision of adequate carry-over storage over the irrigation requirements in these dams would help in flood moderation particulary because it is this part of the catchment which receives higher intensity of rainfall contributing to floods in Punpun river. As a matter of fact , these dams are already being contemplated for irrigation of lands in one of the worst drought regions of the State and, therefore, provision of some additional storage by way of carry-over storage should be done to help in flood moderation during emergency.

PATNA TOWN PROTECTION

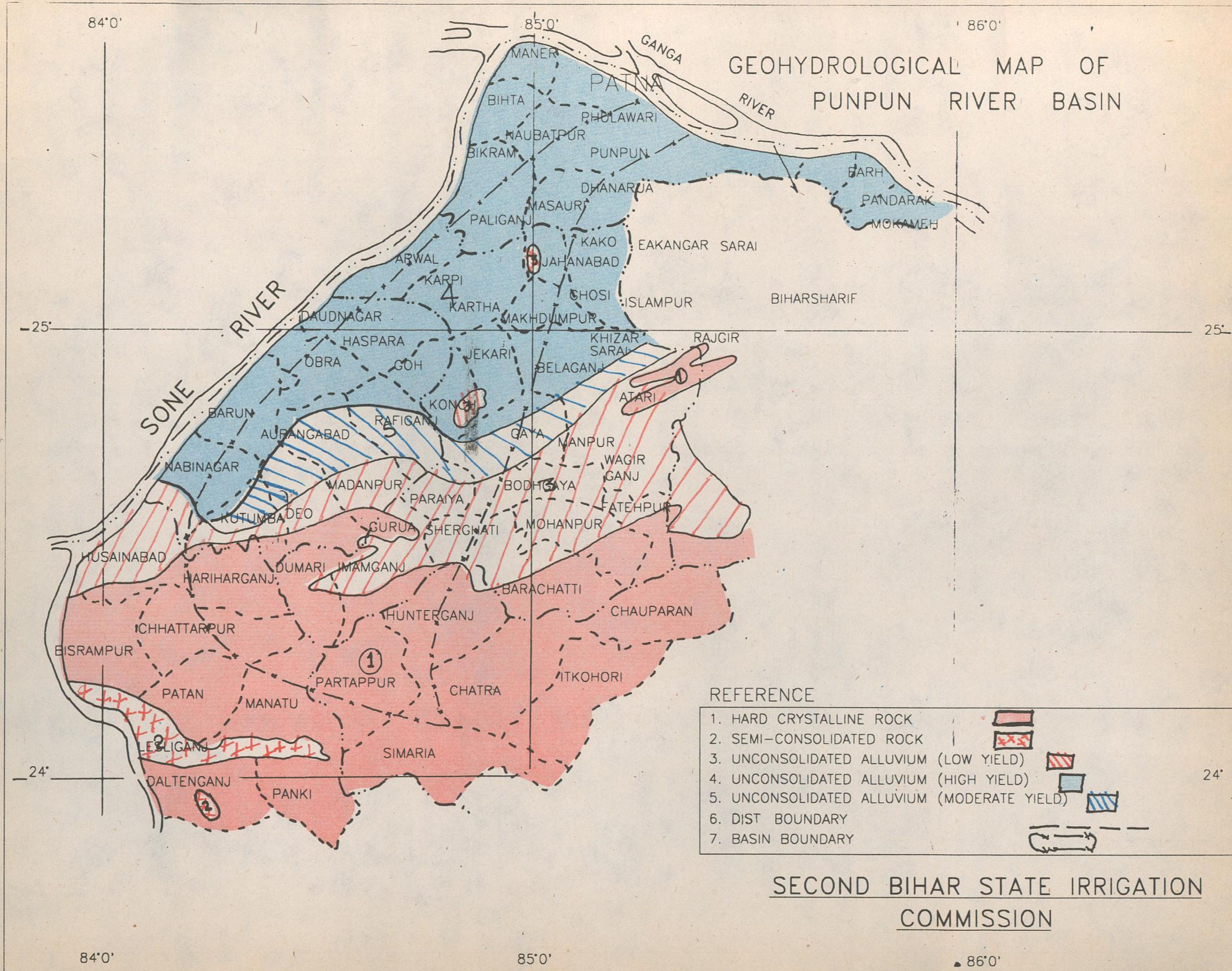
Rural Drainage (Punpun part)

Sl No	Name of the Drainage Channel	Total length (in Km)	Design discharge (in cumec)	Bed width (in m)	Bed slope	F.S. Depth (in m)	Side slope	Total E/W involved (in Lakh CUM)	Land to be required (in ha)	No. of Inlets (in Nos)	No. of bridges (in Nos)	Structures	Estimated cost (in Rs lakh)	Area to be drained (in sq km)
1	Kothia-Sabalpur	6.50	28.32	15.24	1 in 5000	2.13	1:1	2.92	25.9	10	15	one No. A.F. sluice at ch 8 of PLE*	133.37 (in 1983)	
2	Badshahi-Khanpur	31.00	19.46	11.58	-	1.83	1:1	6.81	-	42	SLR-18 FB-52 wooden Bridge - 10	one AF sluice at ch 123 of PLE	167.56 (in 1983)	72
3	Pahari	10.06	17.0	11.00	1 in 5000	-	1:1	cutting 1.538 filling 0.343	35.70	10	14	one Pumpiing station at Barmutta	136.0 (in 1983)	
4	Parsa-Barmutta	20.03	13.31	9.75	1 in 5000	1.68	1:1	8.76	-	-	-	-	68.88	109

[Source: From Punpun Flood Protection Division (Karbighiya) Patna.]

*PLE — Punpun left embankment.


DRG.NO.9/02
INDEX MAP OF PUNPUN RIVER BASIN
SHOWING DRAINAGE SCHEMES
REFERENCE
1. RIVER
2. ROAD
3. RAILWAY
4. DRAINAGE CHANNEL 1 2 3 4
5. EMBANKMENT COMPLETED
6. EMBANKMENT U/C
7. PHASE-II
SONCOTH NALA
SHERPUR
MAULANIPUR
SARNAPUR
RAMPUR
BALUA
REWA
DAUDPUR
SULTANPUR
LODIPUR
GANGES
BANKIPUR
PATNA
NANDLAPUR
MAHESPUR
SEWERAGE CH.
DIDARGNJ
KOTHIA CHL.
BANKAGHAT
BIGRAHPUR
FULWARI
BAHADURPUR
BADSHANI CHANNEL
CHILBILI
SECTOR-XIII
SECTOR-XIV
SRIPALPUR
SECTOR-XII
HASANPURA
SUATHA
CHATNA
BARUNA
BAHUARA
GOPALPUR
PUNPUN R.
CH 764
BELA
BAZIBPUR
MADARPUR
PARTH
LANSUNA
PAINAL
BHAGWANPUR
MAKHDUMPUR
SADISOPUR
RARTA
MANJHAULI
FARIDPUR
DIRANCHAK
DANAPUR
KHAGAUL
CHIRAURA
KORWAN
LODIPUR
NAUBATPUR
SECTOR-XI
KHAGURI ESCAPE CHANNEL
CH.O
CH 245.6
CH 192
BARKA
GOHILA
BARILA
ADAMPUR
PUNPUN
PUNPUN RIGHT EMB.
CH-336 PHASE-1
CH-336 TO 79 CH-642
CH-761
FATUHA
PHASE-II CH. 0 TO 336
CH-0
SECOND BIHAR STATE IRRIGATION COMMISSION


GEOHYDROLOGICAL MAP OF
PUNPUN RIVER BASIN
84°0'
85°0'
86°0'
25°
24°
GANGA
RIVER
SONE RIVER
PATNA
MANER
BIHTA
PHULAWARI
NAUBATPUR
BIKRAM
PUNPUN
BARH
PANDARAK
MOKAMEH
DHANARUA
MASAURI
PALIGANJ
KAKO
EAKANGAR SARAI
JAHANABAD
ARWAL
KARPI
GHOSI
ISLAMPUR
BIHARSHARIF
KARTHA
DAUDNAGAR
MAKHDUMPUR
HASPARA
KHIZAR SARAI
RAJGIR
OBRA
GOH
JEKARI
BELAGANJ
ATARI
KONCH
BARUN
RAFIGANJ
AURANGABAD
GAYA
MANPUR
WAGIR GANJ
NABINAGAR
MADANPUR
BODHGAYA
PARAIYA
FATEHPUR
KUTUMBA
DEO
GURUA
SHERGHATI
MOHANPUR
HUSAINABAD
DUMARI
IMAMGANJ
HARIHARGANJ
BARACHATTI
CHAUPARAN
HUNTERGANJ
CHHATTARPUR
BISRAMPUR
PARTAPPUR
ITKOHORI
PATAN
MANATU
CHATRA
LESLIGANJ
SIMARIA
DALTENGANJ
PANKI
1
2
3
4
5
REFERENCE
1. HARD CRYSTALLINE ROCK
2. SEMI-CONSOLIDATED ROCK
3. UNCONSOLIDATED ALLUVIUM (LOW YIELD)
4. UNCONSOLIDATED ALLUVIUM (HIGH YIELD)
5. UNCONSOLIDATED ALLUVIUM (MODERATE YIELD)
6. DIST BOUNDARY
7. BASIN BOUNDARY
SECOND BIHAR STATE IRRIGATION
COMMISSION

APPENDIX 10

KIUL-HAROHAR BASIN

AT A GLANCE
PLAN FOR FLOOD MANAGEMENT IN THE KIUL-HAROHAR RIVER BASIN (IN BIHAR)

I Salient Features of the Basin

1	Total Drainage Area	17,225 Sq Km
2	Drainage Area in Bihar	17,225 Sq Km
3	Population in Bihar	81.50 Lakh
4	Average Annual Rainfall	1104 mm
5	Cropped Area In Bihar	7,466 Sq Km

II Flood Damage (Average for 25 Years 1968 - 92)

1	Total Area Affected	1.57 Lha
2	Cropped Area Affected	0.65 Lha
3	Damage to Crops	Rs 1813.50 Lakh
4	Total Damage	Rs 2687.50 Lakh
5	Human Lives Lost	27 Nos
6	Cattle Heads Lost	85 Nos
7	Average population Affected	11.29 Lakh

III Progress of Flood Protection Measures (1954-92)

1	Length of Embankments (Zamindari embankment 186.5 Km)	7 Km
2	Towns/Villages protected	1 No

IV Eighth Plan Proposal (1992-97)

1	Length of Embankment	Total 98 km in the State
2	Additional Area to be benefited by Flood Control, Drainage and Anti Waterlogging Measures	Total 1.00 Lha in the State
3	Total Outlay for Flood Control Measures in the State (1992-97)	Rs 35230 Lakh

AN APPROACH TO THE PROBLEM OF FLOOD AND DRAINAGE CONGESTION & REMEDIAL MEASURES IN THE KIUL-HAROHAR RIVER BASIN

1 INTRODUCTION

1.1 The Ganga sub-basin which extends over an area of 8.614 Lakh Sq Km within India is the largest river basin in the country and is a part of the main Brahamputra-Meghna-Ganga river basin. Flat terrain, high intensity of rainfall and poor drainage congestion combine to cause flooding and drainage congestion almost every year in a large part of this sub-basin, particularly in the portions lying in the Eastern Utter Pradesh and Bihar. The flood damage in this basin accounts for major part of the total flood damage of the country.

1.2 The State of Bihar is situated in the central part of the Ganga sub-basin. The portion lying on the northern side on the left bank is known as North Bihar and that lying on the southern side on the right bank is known as South Bihar. The northern region has a very flat topography and is subject to serious flooding almost every year. A number of major tributaries like the rivers Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc which originate from Himalayas join the river Ganga in this region. The Southern region is characterised by low hills and slopes in some parts and Gangetic plain in the rest. Many rivers like Karmnasa, Sone, Punpun, Kiul-Harohar, Badua-Chandan, Gumani etc which originate from Hilly region of South Bihar join the river Ganga.

1.3 The major rivers of North Bihar like the Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc flow through a considerable length in Nepal and a large part of their catchment falls in the glacial region of the Great Himalayas. These rivers are snow fed and hence perennial in nature. The major rivers of South Bihar like the Karmnasa, Sone, Punpun, Kiul-Harohar etc. are rainfed and carry little discharge in non-monsoon months. The river Kiul which joins the river Harohar near Surajgarha in the district of Munger has a total catchment area of 17225 Sq Km.

1.4 Floods and droughts are regular features in the State of Bihar due to Vagaries of climate and rainfall. While one part of the State is under the grip of severe floods due to excessive rainfall the other part suffers from drought due to scanty and untimely rainfall.

1.5 Floods have caused devastation and acute human suffering too frequently since the dawn of civilisation and the man has had to live with the flood since his existance. The impact of flood was not perhaps felt to the same extent in the past as is felt now. This was due to the fact that much smaller number of people were living and pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem has been accentuated due to ever increasing encroachments on the flood plains by the growing population to meet its requirement of food and fibre. The destruction of forest land for reclaimation of areas and for fuel requirement have also caused changes in the river regime. All these have resulted in an anamolous situation where, inspite of the protective measures carried out so far in the State with an investment of Rs 611 crores and 28.34 lakhs hectare having been accorded reasonable degree of protection, flood damages have gone on increasing instead of decreasing.

2 THE KIUL-HAROHAR RIVER BASIN

2.1 The river basin consists of a number of small rivers like the Mohane, Dhanyan, Sukhnar, Barnar, Damar, Nagi, Nakti, Bajan, Ajan, Falgu etc besides the rivers Kiul and Harohar. The main river Kiul of the Kiul-Harohar system originates from an elevation of 605 m east of Khajuri in Chotanagpur plateau at a Latitude of 24° 23' N and Longitude of 86° 10' E and flows in east direction close to the southern base of Gidheswari Hills. After that it flows taking north-easterly direction towards Lakhisarai and joins the river Harohar near Surajgarha in the district of Munger. This river system is bounded by the Badua-Chandan system on the east, the Ganga on the North, the Chotanagpur plateau on the south and the Punpun river on the West.

2.2 The Kiul-Harohar river system drains an area of 17223 Sq Km. The upper catchment of the river system lies in Chotanagpur Plateau area which is characterised by low hills and slopes with depression and valleys. Hills of these areas form a number of ranges. Country's general area south of Gaya rises gradually to a height of 600m and ultimately there is a rise of 1260m known as Parasnath. Formation of these are of Archean quartzites and schists. Alluvial deposit of the Gangetic plain with maximum depth upto 1000m, forms the upper layer of the region beyond which lies the rocky basement. The deposits are clay either of sandy or calcareous grade of sand (1.25-0.125 mm), silt (0.06-0.0002 mm) and clay less than 0.0002 mm. Gravel and pebble deposits are found near the northern foot hills of the region.

2.3 The Kiul-Harohar river system consists of a number of small rivers which during the course of flow bifurcate and rejoin meeting each other a number of times making it difficult to ascertain their exact length. Riverwise description of this river system as available from the previous records is given below.

2.3.1 Lilajan and Mohane (Falgu) : The river Mohane rises in the hills of Chatra district at an altitude of 914m above MSL. After traversing through hills and forests for about 64 Km, it crosses N H-2 (Grand Trunk Road) and enters the plains of Gaya district. After travelling a length of 40 km it receives Lilajan, a major tributary which originates in the hills of Chatra district at Latitude 24° 11' N and Longitude 84° 45' E at an elevation of 534 m above MSL and after traversing a distance of 85 km through hills and forests, crosses N H-2 (Grand Trunk Road) near Dobhi and travels a distance of about 29 km before joining the river Mohane. The combined river is known as the Falgu after the confluence of the Lilajan and the Mohane and travels in north ward direction up to Khizirsarai where it again bifurcates into two channels. The right channel is again known as the Mohane and the left channel is known as the Falgu. This river Falgu runs in northward direction where it is known as the Mahatmain and the Lokain, ultimately as the Dhowa. Another right bifurcated channel from Ghosi is known by local names of the Jalwa and the Nona which again reunite with the Dhowa. The right branch of the Mohane river joins the Bagahi river near Islampur and is again known as the Mohane in the down stream. The left branch of the Mohane joins the Jalwa river taking off from Falgu. This right channel known as the Mohane flowing further down for about 51 km embraces the river Paimar, another important river of the basin, which originates from the foot hills of Hazaribagh near Paharpur Railway Station of Grand-Chord section of the Eastern Railway before it enters the Bakhtiyarpur Tal and the combined river meets the Dhowa near Bakhtiyarpur. After this point, the combined river is again known as the Mohane.

2.3.2 A number of small streams namely Mangur, Dhadhar, Tilaiya, Dhanarji and Khuri taking off from north of the Barakar valley in the micasive hills of Kodarma range in Giridih/ Hazaribagh district join together to form the Panchane. This Panchane river bifurcates into a number of channels a few km upstream of Biharsharif town known as the Goithawa, the Charsua and the old Panchane. The Charsua course again meets the old Panchane after flowing about 26 km below and joins the river Mohane in the middle reach.

The river Goithawa after flowing in the northward direction for about 29 km in a very flat country, takes a turn in eastern direction and meets the two branches (the Jirain and the Kumbhari) of the river Sakri and the combined river below village Chhatarpur is known as the Dhanayan. The river Dhanayan flowing in the east for about 16 km meets the river Mohane at Trimohani and the combined river is known as the river Harohar.

2.3.3 Sakri : The river Sakri originates from the hills of Hazaribagh district at an elevation of 365 m above MSL near village Tisri and after flowing for about 64 km in the thick forest and hilly tracts of Hazaribagh district, enters the plains of Gaya district near village Dumri. It crosses the Kiul-Gaya section of the Eastern Railway near village Paura which is about 9.6 km east of Nawada town. After flowing further down for about 19 km in the north, it branches off into the Jirain and the Kumbhari below village Dewaspur. As mentioned above, these two branches meet the river Goithawa and the combined river is known as Dhanayan.

2.3.4 Harohar: The Harohar is the biggest and the most important tributary of the Kiul which joins it on the left bank, downstream of Lakhisarai. Its formation has already been described above. In the tail reach, the river Harohar flowing for about 16 km below Trimohani in a serpentine course, is joined by the river Tati. The river Tati originates from near Marui just on the east of Sakri valley and traverses a distance of about 51 km before it meets the river Harohar. The rivers Kaurihari, Baghel and Nata, taking off from Kauakol hills meet each other and the combined river below east of Sirari Railway station of the Kiul-Gaya section of the Eastern Railway is known as the Same. It flows further down for about 11 km in the north and meets the river Harohar near village Rapura in the tail reach.

2.3.5 Kiul: The river Kiul, which is the main outfall channel of this basin, rises in the hills of Chhotanagpur Plateau at an elevation of 605 m at Latitude 24° 33' N and Longitude 86° 10' E. The river flows first in north westerly direction, then in easterly direction close to the southern face of the Gidheshwari Hills and then in a northerly direction. It then flows in north-westerly direction up to Lakhisarai. After Lakhisarai, it turns in north-easterly direction and joins the river Ganga near Surajgarha in the Munger district. Bunbuni, Sukhnar, Barnar, Doharo, Nagi, Nakti, Bajan, Ajan and Morwe are the important tributaries joining the river Kiul on the right bank. The Harohar is the biggest and the most important tributary joining its left bank on the down stream of Lakhisarai. Its formation has already been dealt with earlier. The areas drained by the main rivers of the system are given below :

Table 1

Sl No	Name of the river	Drainage Area (Sq Km)
1	Falgu	5,281
2	Paimar	1,122
3	Sakri	5,500
4	Harohar	2,393
5	Kiul	2,927
	Total	17,223

About 1062 Sq Km of the above area, lying in the lower zone of the system is saucer shaped and is commonly known as Mokama Group of Tals. It is a vast tract of low lying land below a level of 45.72 m and is having width varrying between 6.5 km to 17.6 km and is about 100 km long. The Mokama group of Tals comprises of seven well defined depressions namely Fatuha Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Singhaul Tal and Barahiya Tal having an area of 52 Sq Km, 168 Sq Km, 132 Sq Km, 215 Sq Km, 200 Sq Km, 124 Sq Km and 171 Sq Km respectively. Out of this 93 Sq Km area consists of high lands which are submerged only during high floods. 788 Sq Km area consists of very low lands where only Rabi crop is possible and in the remaining 181 Sq Km area it is possible to grow two crops.

2.4 The important places of Bihar falling in the drainage area of the Kiul-Harohar river system are Hazaribagh, Nawada, Nalanda, Rajgir, Gaya, Bodh Gaya, Barahiya, Mokama etc. The important commercial centres are Lakhisarai, Barh, Bakhtiarpur, Nawada, Hazaribagh, Gaya etc.

2.5 Details of the important rivers of the Kiul-Harohar river system are given below :

Table 2

Sl No	Name of river	Bank L (Left) R (Right)	Origin	Out-fall	River condition
1	HAROHAR	joins Kiul on Left Bank		In the river Kiul on down stream of Lakhisarai	Functions as drainage channel
2	KIUL	Right bank of the Ganga	East of Khajuri in Chotanagpur Plateau at Lat. 24°53'N & Long.85°39'E.	In the Ganga on the down stream of Surajgarha	-Do-
3	MOHANE		Hills of Hazaribagh district	Meets the river Paimar near Dihra village in Bakhtiarpur Tal	-Do-
4	FALGU		The rivers Lilajan & Mohane meet near Gaya to form the river Falgu	Known in lower reaches as the Dhowa, it ends in the Mokama Tal	-Do-
5	SAKRI		Near village Tesri from Chotanagpur Hills at Lat. 24°34'N & Long. 86° 8'E.	It branches into river Jirain & Kumbhari which again combine with the river Goithwa to form the river Dhanayan. The river outfalls in the river Mohane at Trimohani.	-Do-
6	PAIMAR		It originates at nearly 12 km South of Paharpur Rly. Station at Lat. N 24° 32' & Long. E 83° 13'.	It outfalls in the river Mohane.	-Do-

2.6 Upper zone of the Kiul-Harohar river basin lies in the Chotanagpur Plateau which is characterised by low Hills and slopes with depressions and valleys. In some areas the hills form a series of ranges with general level gradually rising to a height of 600 m. However, there are few rises like Parasnath which is at a level of 1260 m. The lower zone of the catchment lies in the Gangetic plains which has been built-up in the process of land formation. The alluvial formation represents one continuous and conformable series whose accumulation is still going on. The entire expanse of the terrain exhibit unvarying monotony of alluvial deposits of the rivers of the Gangetic system with alluvial deposits concealing the rocky basement and having thick mantle of maximum depth around 1000 m. Higher reaches of the region has steep slope where as lower reaches are having milder slope. As a result, water accumulates in the lower reaches causing drainage congestion.

2.7 ECONOMICS

2.7.1 Total population of the basin as per 1991 cencus is 81.50 Lakhs and intensity of population is 475 person per sq km. About 92 per cent of the population lives in villages and only 8 per cent of the population lives in towns.

2.7.2 Many major industries have been established in the region because of availability of raw materials like coal, mica and iron. Work shop of the Eastern Railway at Jamalpur is a major industry. In addition to this there are small workshops of iron utensils, teatrays, guns, pistols, toasting fork cutlery etc. located at different centres. Also there are factories of Mica products at Kodarma, tobacco at Munger, China clay at Jamui, sugar mills, textile mills and rice mills in Gaya.

However, there is still a good prospect of industries of large, medium and small scale in the region.

2.7.3 The important highways and railways of the basin are indicated below :

Highways

1 National Highway No 31
2 National Highway No 2
3 National Highway No 30
4 Patna Sheikhpura Raoad
5 Patna Gaya Road &
6 Fatuha-Biharsharif Road.

Railway lines

1 Main line (Patna Jn-Howrah) of Eastern Railway
2 Asansol- Mughal Sarai line (Grand Chord) of Eastern Rly.
3 Kiul- Gaya (K-G) line of Eastern Railway
4 Patna- Gaya (P-G) line of Eastern Railway
5 Bakhtiarpur- Rajgir line of Eastern Railway.

2.7.4 Many irrigation projects in the area have been completed providing good irrigation facilities. Some of the important schemes are Barnar Reservoir scheme, Sakri Lower valley stage-II, Lower Kiul project, Nagi Reservoir and Panchane Phase-II.

2.7.5 Towns in the lower reaches of the catchment like Barh, Bakhtiarpur, Mokama, Nawada etc, have water supply for domestic use from ground water and towns in the upper region of the catchment like Giridih, Hazaribagh etc have mixed drinking water supply both from surface water as well as from ground water.

2.8 The land use pattern in the Kiul- Harohar river basin is as below:

Table 3

Sl No	Particulars			Area in Sq Km	Percentage
i	Forest Land			4136.22	23.82
ii	Land under miscellaneous trees and groves			114.00	0.67
ii	a	Current fallow	1354.72	2409.15	14.05
	b	Other fallow	796.92		
	c	Culturable waste	257.51		
iv	Net area under cultivation			7466.37	43.53
v	Barren Land and permanent pastures			1070.82	6.24
vi	Area under Non-Agricultural use			1954.95	11.69

The principal crops of the region are paddy, maize, sugarcane, wheat, gram and other rabi crops.

3 GEOLOGY

The upper zone of the river system in the south is hilly lying in Chotanagpur plateau, the geological characteristics of which represent the geology of the upper catchment of the Kiul-Harohar river system. Similarly it's lower zone in the north lies in the Gangetic plains, geological characteristics of which represent the geology of the lower catchment. The entire Chotanagpur plateau area is characterised by low hills and slopes with depression and valleys. In some areas these hills form series of ranges. South of Gaya the general level of the country gradually rises until eventually a height of 600 m is obtained. However, on this gradually rising surface there are rises like parasnath rising to 1260 m and others rising to lesser heights. These are also formed of Archean quartzites and schists. On southern side, the Hazaribagh plateau is seperated from the Ranchi plateau by the east west running Damodar valley.

The alluvial deposits of the Gangetic plain represents one continuous and conformable series, whose accumulation is still in progress. It encompasses a vast alluvial plain. The entire expanse of the terrain, of pleistocene to recent origin less than a million year old, exhibit unvarying monotony of alluvial deposits of the rivers of the Gangetic system. The alluvial deposits have completely concealed the rocky basement beneath a thick mantle, maximum depth of which is around 1000 meters.

The basement at the bottom of the area is known to dip 1° to 2° towards the north. The alluvial deposits are fluviatial and sub-aerial origin, with massive beds of clay either sandy or calcereous corresponding to the grades, sand (1.25-0.125 mm), silt (0.06-0.0002 mm) and clay (less than 0.0002 mm) occuring as principal constituents. Gravel and pebble deposits found to occur in close proximity of northern foot hill zones and become scarce towards the south.

The characteristics of clayey beds, particularly of the older alluvium, generally occupy elevated terraces, is the abundant dissemination of impure calcareous concretious the 'Kankar' formed by the segregation of calcareous materials of the alluvial deposits into lumps or nodules. The clay silt and sand of the older alluvium are dark ash in colour in distinct contrast to the relatively light coloured, constituents of newer alluvium, occupying a lower level than the former. The newer alluvium contains particular beds of sand, gravel and peat and passes into the deltaic alluvium of recent origin. In the deltaic belt, the impure peat beds are mostly common.

ROCKS

In the upper catchment, there occurs a group un-Metamorphosed rocks like Conglomerates, sand stones, lime stones, shales banded- haematile quartzites, etc, which are underlain by undermetamorphic rocks. The un-metamorphosed group of rocks is associated with basic lavas. The whole sequence of rocks, is traversed by younger igneous bodies of ultra basic, basic and acidic composition. The older metamorphic rocks constitute a portion of iron-ore series and the conglomerates, sandstones, limestones and some of the shales of the above sequence, are younger in age than the iron-ore series. This is also called kolhan series. These metamorphic rocks appear to have been folded in the form of a geanticline and are intercalated with lava-flows and associated products of valcanicity of more or less equivalent age. The metamorphic rocks of northen catchment are known as iron-ore series and are associated with younger granites and gneisses known as the Chotanagpur granite gneiss. The chotanagpur granites and gneisses occur in Hazaribagh and adjacent areas.

MINERAL WEALTH

The important minerals found in the Kiul-Harohar river system are mica, coal, limestone & copper.

SOIL CHARACTERISTICS

The general data regarding the soil of the river system indicates that mainly alluvial, red and yellow, red sandy soils and deltaic alluvium occur in this river system. The principal soil type found in various districts lying in the river system are given below:-

SOILS IN THE KIUL HAROHAR RIVER SYSTEM

Table 4

Sl No	District	Type of Soil
1	Patna	Alluvial
2	Nalanda	Alluvial
3	Gaya	Red, yellows & alluvial soil
4	Jehanabad	Red, yellow & alluvial
5	Munger	Alluvial and calcareous alluvial
6	Jamui	Alluvial & calcareous alluvial
7	Giridih	Red, yellow & alluvial
8	Hazaribagh	Red, yellow and alluvial

The soil of the land in the Mokama group of Tals constitute a separate group of soil association. The land on the southern bank of the river Ganga lies in a saucer shaped area and generally this area suffers from drainage congestion for a period of two to four months. The soil of these Tals are grey to dark grey in colour, medium heavy to heavy in texture, slightly to moderately alkaline in reaction and of good fertility status. As these soils become bone dry during summer and remain inundated during rains, only one crop during rabi season is grown with very good yield.

The alluvium soil found in various districts of this river system can further be sub-grouped on the basis of colour and other properties. The grey and greyish yellow type which is found in the district of Patna, Gaya, Jehanabad, Nalanda, Munger, and Nawada remains greyish yellow to grey in colour, medium heavy in texture and neutral to slightly alkaline in reaction. These soils on drying crack heavily, the crack being 50 mm to 75 mm wide and 61 cm to 91 cm deep. The paddy and paira crops are annual rotation on these soils, where irrigation is available, crops like wheat, sugarcane, maize, onion etc are also grown.

Reddish yellow and yellow type soils are found in the district of Patna, Gaya, Jehanabad, Nalanda, Munger and Nawada. These somewhat poorly drained soils show a tendency to crack during dry months. The yellowish red and yellow type soil are found at the foots of the hills separating the alluvial plain from the plateau region. These excessively drained to moderately drained, shallow to medium deep soil over the bed rocks and pebble are strongly to moderately acidic and are of poor to moderate fertility. Aerable crop like maize, zowar, during kharif and kulthi and mustard during Rabi season are generally grown on this soil. Paddy cultivation is also done in patches.

The main characteristics of calcareous alluvium soil is the high content of calcium carbonate. These soils are light coloured and their texture varies from sandy loam to loam. The p_H value of the soil is on the alkaline side.

The portion of river system lying in Chotanagpur plateau has red, yellow, reddish yellow, greyish yellow type of soils. The yellow soils are medium textured, silty soil, having practically no gravels. This soil is strongly to moderately acidic of light coloured having medium to high fertility. The red and yellow type of soil are moderately well drained, having good fertility and are less acidic. The reddish yellow soil resemble the yellow soil and are light textured.

4 HYDROLOGY

4.1 The Kiul-Harohar river basin forms a part of the Gangetic plain and it is situated in the direct path of the tropical depression which forms in the Bay of Bengal during the monsoon season and travels in north-westerly direction. As such, most of the precipitation, about 85 per cent of the annual rainfall, occurs during the monsoon months of June to October.

4.2 According to norms laid down by the Bureau of Indian Standards (IS 4987), one raingauge for a drainage area up to 520 Sq Km is sufficient for plains. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser, particularly in upstream region of the catchment. In not too elevated region with average elevation one km above mean sea level, the required network density is one raingauge Station for every 260 to 390 Sq Km area. The India Meteorological Department (IMD) have, however, prescribed at least one raingauge for every 500 Sq Km of the drainage area. It also specifics that at least 10 per cent of such raingauge stations should be self recording (SRRG). This should be increased to 20 per cent as per recommendations of Rashtriya Barh Auog (RBA).

4.3 The norms recomended by the World Meteorological Organisation (WMO) are given in Table 5.3. Out of these given raingauge station, 10 per cent are recommended to be of self recording type for knowing the intensity of rainfall in the region.

TABLE 5.3

Density of Raingauge Station as per the norms laid down by WMO

Sl No	Type of Terrain	Density Required (One Station for)	
		Ideal	Acceptable
1	Flat region of temperate mediterranean and tropical zone	600-900 Sq Km	900-3000 Sq Km
2	Mountaneous region of temperate mediterranean and tropical zone	100-250 Sq Km	250-1000 Sq Km
3	Arid and Polar Zone	1500-10,000 Sq Km	Depending upon the feasibility

4.4 The India Meteorological Department (IMD) mainly installs and maintains raingauge stations but some raingauge stations are also maintained by the State Governments and other agencies. List of raingauge stations maintained in the Kiul-Harohar river basin and in adjacent basins are enclosed at Annex 1 and 2. Comparision between the number of stations existing and those required as per recommendation of the IMD & WMO are given below :

Sl No	Catchment area in sq km.	No of Rain-gauge station existing	Adopted Norm		Required as per Norm		Remarks
			Ideal	Accepted	Ideal	Accepted	
1	Plain area (14,330)	33	700 Sq Km	1500 Sq Km	20	10	Ideal
2	Hilly Area 2893	7	200 Sq Km	500 Sq Km	15	6	Inadequate but acceptable

4.5 Above table shows that number of raingauge stations in plain is adequate and in hilly region it is inadequate but acceptable. Similarly self recording raingauges (SRRG) are also as per norms ie 2 in plains (Patna and Gaya) and 1 in hilly area (Hazaribagh)

4.6 RAINFALL

4.6.1 From the IMD publication "Memoirs of IMD Volume XXXI Part III only monthly and annual normal of rainfall and rainy days in respect to stations mentioned by IMD could be collected which are based on the data available from the date of installation (1950). The details are enclosed at Annex 3 in a tabular form.

4.6.2 It would appear from details at Annex 3 that the annual normal rainfall varies between 775 mm to 1344 mm from station to station. It also transpires that the lower catchment receives lesser rainfall than upper catchment and generally all the raingauge stations receive 90 per cent of their annual rainfall during monsoon months from June to October.

Rainfall data from 1974 to 1989 of different Blocks are available. On the basis of these data, computation of average annual, average monsoon rainfall and 90 per cent dependable monsoon rainfall has been done which are as following :

i Average Annual Rainfall 1104 mm

ii	Average Monsoon Rainfall	1029 mm
iii	75% dependable Monsoon Rainfall	913 mm
iv	90% dependable Monsoon Rainfall	818 mm

4.7 GAUGE & DISCHARGE

4.7.1 According to the norms prescribed by WMO, one gauge discharge site is required for every 300 Sq Km of drainage area in hilly region and for 1000 Sq Km in plain region. Table below gives a comparison between number of gauge and discharge sites existing and required as per WMO norms :

Table 7

Sl No	Catchment area in Sq Km	No.of existing G&D sites	Adopted norms	Required per norms	Remarks
1	Plain area 14,330 Sq Km	4	@ 1500 Sq Km	10	
2	Hilly Area 2,893 Sq Km	NIL	@ 500 Sq Km	6	

The list of Gauge-Discharge sites maintained by the State Government and Central Government organisations on the main rivers and its tributaries are placed at Annex 4.

The data availability of seven gauge and discharge sites maintained by the CWC are given below:

Table 8

Sl No	Name of site	Name of river tributary (Sq Km)	Catchment area	Nature of data available	Period
1	Lakhisarai	Kiul	2619	Gauge & Discharge	1963 to 90
2	Mankatha	Harohar	14177	Gauge & Discharge	1962 to 91
3	Kadarganj	Sakri	1590	Gauge & Discharge	1962 to 91
4	Gaya	Falgu	3171	Gauge & Discharge	1960 to 90
5	Gorhi	Kiul	260	Gauge	1979 to 91
6	Sono	Barnar	440	Gauge	1979 to 91
7	Jamui	Kiul	1810	Gauge	1979 to 91

These available data have been utilised in the present study. The data of Lakhisarai, Mankatha, Kadarganj and Gaya have been taken & analysed to compute the floods of different return period.

Also with the help of observed annual peak discharge and observed gauges rating curve have been developed for different sites.

4.7.2 The observed Gauge and Discharge data with the equation of their rating curve are enclosed at Annex 5. The maximum and the minimum discharge observed at different sites in the Kiul Harohar river basin between year 1962 to 1986 are given below:

Table 9

Sl No	Location River	Discharge in cumecs			
		Maximum	Year	Minimum	Year
1	Lakhisarai Kiul	1678.04	1984	158.11	1970
2	Gaya Falgu	3751.46	1986	106.29	1981
3	Kadarganj Sakri	1998.39	1965	28.87	1982
4	Mankatha Harohar	1938.83	1984	223.30	1972

4.7.3 The number of existing discharge site in the drainage basin of the Kiul-Harohar river system is less than the actual requirement as per prescribed norm. For a fairly reliable assessment of water resources data for a reasonable longer period and greater number of gauging locations are essential. It is, therefore, suggested that network of gauge discharge sites should be expanded by opening more sites at suitable locations as soon as possible and the observation, collection, analysis and documentation of all hydrometeorological data of all sites be carried out on standard scientific lines so that the data could be of proper use in future planning of any water resources or flood control scheme in the basin.

4.8 RUNOFF FACTOR

4.8.I For planning drainage scheme it is essential to asses the total runoff during monsoon. And for determination of total runoff from the basin under consideration determination of run-off factor applicable for the monsoon period as a whole for the area is a must. Runoff factor can be determined from the analysis of rainfall data, spread over entire basin, and runoff data at suitable location in the basin. These data for sufficiently longer period (at least 20 years) are considered essential input. But reliable data for such period for the Kiul-Harohar river basin are not available. It is, therefore, recommended that reliable and authentic data for rainfall and runoff for longer period be collected and a precise rainfall-runoff relationship be established for desired locations.

4.8.2 Total runoff from the catchment areas of the rivers entering the Mokama group of Tals, has been worked-out on the basis of rainfall data of 65 blocks falling in the Kiul-Harohar basin from the year 1974 to 1989 (16 years). The maximum and minimum rainfall in the basin during the period from 1974 to 1989 has been recorded as 1541.7 mm and 783.3 mm in the years 1987 and 1982 respectively yielding total surface runoff from the catchment as 10.57 and 2.88 Lakh ha m calculated yearly monsoon run-off from 1974 to 1989 is given below :

CALCULATION OF YEAR-WISE MONSOON RUNOFF

Table 10

Sl No	Year	Monsoon rainfall (cm)	Runoff (in cm)	Runoff (in Lakh ham)
1	2	3	4	5
1	1974	95.47	33.25	4.49
2	1975	83.29	24.46	3.30
3	1976	93.12	31.42	4.24
4	1977	92.30	30.81	4.16
5	1978	111.94	47.09	6.36
6	1979	86.41	26.67	3.60

1	2	3	4	5
7	1980	109.66	45.06	6.08
8	1981	90.94	29.82	4.03
9	1982	78.33	21.34	2.88
10	1983	95.38	33.17	4.48
11	1984	133.99	65.02	8.76
12	1985	123.44	56.69	7.76
13	1986	116.40	51.33	6.93
14	1987	154.17	78.28	10.57
15	1988	96.86	34.34	4.64
16	1989	93.47	31.67	4.28

The average monsoon rainfall works out to 102.9 cms and the runoff calculated with the help of Strange Table comes to 39.12 cm. Average volume of surface runoff from the catchment comes to 6.59 Lakh ham. It is seen that out of 16 years the run-off is less than average in 10 years and above average in 6 years.

5 FLOOD FREQUENCY ANALYSIS

5.1 Frequency studies/analysis is carried out to interpret the past records of the hydrological events like the precipitation, the runoff, flood levels etc and to predict the probabilities of such occurances in future. For quantitative assessment of magnitude of flood problem it is essential to evaluate or estimate the frequencies of rainfall, flood etc. Such studies are necessary input for proper design and location of hydraulic structure and for other related studies.

5.2 CRITERIA OF DESIGN FLOOD

5.2.1 Ministers' Committee on Flood and Flood Relief Constituded by the Government of India in 1970 had recommended that:-

"As most of the flood embankments have been constructed on inadequate and meagre hydrological data, which were available, it is necessary that existing embankments are reviewed to see that these are safe for a flood of 50 years frequency for major rivers and atleast 25 years frequency for tributaries. Similarly all the future proposals for embankment should also be based on the above criteria."

5.2.2 Recommendation of Rashtriya Barh Ayog (RBA) constituted by the Government of India in 1974 which submitted it's report in March 1980 regarding the degree of protection by embankments are as follows:-

"The use of benefit-cost criteria would require (i) damage data with respect to different flood frequencies (ii) data on damage due to probable failure of embankment (iii) expertise to carry-out alternative benefit-cost and trade-off excercises. These are not available at present. Hence for the time being we recommend, as a general guide, adoption of following criteria based on flood frequencies:-

i For predominantly agricultural areas: 25 year flood frequency (in special case where damage potential justifies, a higher design flood/maximum observed flood may be adopted.

ii For town protection works, important industrial complexes etc : 100 year flood frequency (for larger cities like Delhi the maximum observed flood, or even the Probable Maximum Flood (PMF), can be considered for adoption.

Meanwhile studies should be undertaken to review the basis of these flood frequencies and attempt made to collect the data and appoint the necessary personnel, so as to enable the adoption of benefit-cost criteria in due course "(Para 13.5 of RBA report)

5.2.3 The relevant recommendation made by the Ministry of Irrigation, Government of India in the guidelines and instructions for implementation of the recommendations of RBA are reproduced below:-

"In case of embankment, the design of a project should be determined, for the time being, on flood frequencies suggested. Meanwhile necessary steps may be taken for eventual application of the benefit cost ratio criteria for fixing the design."

The summary of recommendation as accepted is as follows:-

"In case of embankment scheme the hight of the embankment and the corresponding cost be worked out for various flood frequencies and also the benefit cost ratio, taking into account the likely damage to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available embankment scheme might be prepared for a flood of 25 years frequency in the case of predominantly agricultural areas and for flood of 100 years freqency for works pertaining to town protection and protection of industrial and other vital organisation."

While endorsing the descision of the Ministry of Irrigation, Government of India on the recommendations of the RBA, the commission suggests that all embankments on important rivers should be designed for a flood of 50 years frequency in general and for floods of 100 years frequency for works pertaining to town protection of vital industrial establishments.

5.3 ANALYSIS OF AVAILABLE DATA

5.3.1 Data relating to flood events in the Kiul-Harohar river basin are available at four sites only namely Mankatha, Lakhisarai, Kadarganj and Gaya. The available data are observed annual peak discharge and corresponding gauge and observed annual peak gauge. Rating curve for these sites have been developed with the help of these data. Using the technique of regression analysis, equations for these rating curve have been developed by GFCC which are enclosed at Annex 5. Using the data of observed peak gauges, peak discharges have been calculated with the help of these rating curve equations and are enclosed at Annex 6.

5.3.2 Peak flood discharges of different return period have been obtained by analysing the annual peak discharges using Gumbel and Log pearson Type-III distribution. These are indicated below:-

Table 11

Return Period	Lakhisarai		Mankatha		Kadarganj		Gaya	
	Q1	Q2 (Cumec)	Q1	Q2 (Cumec)	Q1	Q2 (Cumec)	Q1	Q2 (Cumec)
5 Years	1758	1246	1745	1380	1281	895	2248	1182
10 Years	2274	2009	2164	2040	1672	1588	3095	2581
25 Years	2926	2578	2693	2508	2165	2087	4143	4217
50 Years	3404	3004	3086	2803	2531	2449	4926	5844
100 Years	3889	3425	3475	3180	2895	2798	5707	7890

Note: Q1 and Q2 are the values of floods obtained by Gumbel and Log Pearson Type III distribution respectively.

5.4 UTILITY OF FLOOD FREQUENCY STUDIES

5.4.1 The result of flood frequency studies are useful in delineating the flood prone area on the contour map in order to be aware of the situation in unprotected areas at different stages of the river during flood. To make these studies useful it is essential to have contour map (with 0.3 m contour interval) of the flood prone area, preferably in a scale of 1:15000. Another utility of these studies will be in the future formulation and planning of the flood control projects in the basin.

6 FLOOD AND DRAINAGE CDNGESTION

6.1 FLOOD PRDBLEM

6.1.1 Flood problem of Kiul-Harohar basin are not of very serious nature like those of the river basins of North Bihar. However, flash floods have been occuring during period of heavy rains in the catchment. As recorded in the district Gazetteers the river Sakri experienced heavy flooding in 1896 and the river kiul also experienced comparatively bigger flood in 1961. Besides this moderate flooding have been noticed in the year 1962, 1963, 1967, 1969, 1971 and in 1976, in the river kiul. The river Falgu caused flooding in the year 1971 during which several breaches occured in the Uderasthan canal system. Also in the year 1986 severe flooding was caused by this river due to heavy rainfall in its catchment. Details of area flooded and damages caused in each river at specific locations could not be made available to the commission.

6.1.2 Rivers like the Kiul, the Harohar, the Punpun etc are flowing almost on the ridges in their lower reaches. The bankful capacity of these rivers are inadequate due to which they are unable to contain the flood discharges and as a result spilling takes place over their bank causing floods in the basin. At places such spills causing floods in the basin are prevented by Zamindari Embankments which are generally of inadequate section and incapable of withstanding even medium flood conditions.

6.1.3 Rivers of Kiul-Harohar basin are mostly in regime condition and are non perennial in nature. Flooding in lower reaches takes place occasionally, due to spilling during monsoon season. Flood problem of the basin as identified so far are indicated below :-

1 The Kiul spills over its bank in the lower reaches near Lakhisarai, flooding the nearby areas.

2 The Sakri river which flows into the Harohar river is a shallow river and it carries a lot of silt. Also it creates flood problem, occasionally, due to occurence of flash floods in the river. Some local Zamindari embankments are existing on this river below Sakri Weir in which there are number of gaps and the flood waters spills through these gaps.

3 The river Falgu also creates flood problem sometimes due to occurence of flash flood.

4 The river Panchane also causes flooding sometimes due to inadequate capacity of its several bifurcated channels.

The flood problems described above are not so serious also as to cause severe damages in the flood prone area. This is further corroborated by the fact that neither any flood control scheme has been investigated nor any flood control scheme executed by the Water Resources Department in the basin.

6.2 DRAINAGE PROBLEM

6.2.1 The drainage problem in the Kul-Harohar basin is confined to lower zone of the river system commonly known as Mokama group of Tals which consists of seven tals covering an area of 1062 Sq Km extending in a length of about 100 km from Fatuha in the West to the vicinity of Lakhisarai in the East. The width of the Tal varies from 6 km to 17 km. Though the Tal is continuous, it is differently named in its different reaches from west to east as Fatuha Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and Singhaul Tal. The river Harohar is the master drain of the Tal areas. Though the main drainage slope of the Tal area is from west to east, it has got cross slope also from south to north up to the river Harohar. The strip of Tal on the north of Harohar cross drains from north to south. The topography indicates that the river Harohar flows in the valley of Tal areas. Several rivers that rise in the hills of South Bihar flow in the north-ward direction and join the river Harohar which is the master drain of the Tal.

6.2.2 During monsoon months, the Tal gets filled up with water due to inflow of rivers entering the Tal and due to obstruction in drainage due to back water of the Ganga entering the Tal through the Kiul and Harohar rivers. Due to non-completion of the right bank Punpun embankment, spill water of the river Punpun and the back water of the river Ganga through the river Punpun also enters the Tal from Fatuha end.

6.2.3 The maximum depth of submergence in the recent past was recorded in the year 1987 which varied from 3.86 m in Fatuha Tal to 5.76 m in More and Mokama Tals. The eastern most Tals namely Barahiya and Singhaul suffered maximum submergence of about 4.5 m.

6.2.4 Due to monsoon submergence of the Tal area, optimum utilisation of its land resources is hampered particularly during kharif season. When the accumulated water of the Tal gets drained out by its natural drainage through the Harohar and the Kiul into the Ganga, by 15th October, a bumper Rabi crop is grown almost in the entire Tal area, depending upon the availability of the residual moisture in the soil.

Tal area do not get fully submerged every year. Kharif irrigation is practised in peripherial areas of the Tal where depth of submergence is small. In fact, in some areas where irrigation facility has been created, even double crop, during both Kharif and Rabi season are being grown. Similarly, in a very limited area hot weather crop is also grown. The existing cropping pattern (on an average) for the entire Tal is given below :

Kharif	30.30 %
Rabi	65.54 %
Hot Weather	4.16 %
Total	100.00 %

6.2.5 More than 50% of Kharif area is reported to grow a second crop of Rabi also. Hot Weather crop is being grown in a very small area (4.16%). The cultivation of Kharif crop, second crop of Rabi in the Kharif area and the Hot Weather crops are dependent on rains, light submergence by the waters of the Tal and partially supported by State and Private tubewells. Rabi crop is grown in 65.54% of the Tal area on an average after its submergence is cleared by the 15th of October.

6.2.6 Due to continued submergence of most of the Tal areas, from July to September, it is not possible to grow any kharif crop in a vast area. Rabi cultivation is based on the residual moisture of the soil freed from submergence. If some how drainage of the Tal is delayed beyond the 15th of Dctober, the Rabi sowing is delayed and crop suffers due to loss of soil moisture when it approaches the stage of maturity, because the required facility is not available at that time for irrigating the crops. This seems to be the main problem of the Tal. The above information of cropping pattern are based on the data obtained from Agriculture Department through the Chief Engineer, Master Planning Organisation of the Water Resources Department.

6.2.7 The area of Tals, ground elevation and range of highest water levels as observed between 1972 and 1991 are given below :

Table 12

Sl No	Name of the Tal	Area in Sq Km.	Ground Elevation in m	Highest Water levels as observed between 1972-91
1	Fatuha Tal	52.00	46.94 to 47.25	59.80
2	Bakhtiyarpur Tal	168.00	43.58 to 47.24	48.67
3	Barh Tal	132.00	42.06 to 46.02	47.30
4	More Tal	215.00	39.32 to 44.20	45.07
5	Mokama Tal	200.00	38.40 to 41.75	44.16
6	Barahiya Tal	171.00	38.70 to 41.65	43.10
7	Sighaul Tal	124.00	38.40 to 39.62	43.10
	Total	1062.00		

6.2.8 The difference in the lowest ground level of the Tals from west to east is 8.54 m. Similarly, the difference in highest ground levels is 7.63 m and difference in highest water levels is 7.70 m. Thus land and water slopes are nearly the same.

6.2.9 CAPACITY OF THE TALS

The total combined capacity of the various Tals at HFL, which varies from RL 50.80 m in Fatuha Tals to RL 43.10 m in Barahiya Tal (Average level of Tal during highest flood is about 46.025 m) is approximately 4.37 Lha m. Capacity of each Tal separately is noted below :

Table 13

Sl No	Name of Tal	Capacity in ham at highest water level
1	Fatuha Tal	6562
2	Bakhtiyarpur Tal	7968
3	Barh Tal	22030
4	More Tal	85777
5	Mokama Tal	104994
6	Barahiya Tal	112025
7	Singhaul Tal	97495
	Total	436851 Say 4.37 Lham

6.2.10 FREQUENCY AND EXTENT OF SUBMERGENCE

The frequency and extent of submergence in different Tals are furnished below. It also shows the number of years (out of 20 years) in which various Tals got submerged beyond 50 per cent, beyond 75 per cent up to 100 per cent.

Table 14

Sl No	Name of Tal	Area in hectare	Years in which more then 50% submerged	Years in which 75% was submerged	Year in which 100% was submerged
1	Fatuha Tal	5180	1972,73,76, 78,88,89 = 6 years	1972,73,76,78, 89 = 5 years	1973,76, 78,89, = 4 years
2	Bakhtiyarpur Tal	16835	1976,78,83, 86,87 = 5 years	1976,78 = 2 years	
3	Barh Tal	13209	1973,76,78, 87,90 = 5 Yr.	1976,78 = 2 years	
4	More Tal	21497	1973,74,76, 78,80,87, 89,90 = 8 yr.	1973,74,76,78, 80 = 5 years	
5	Mokama Tal	19943	1973,76,78, 80,82,83,84, 85,87,,89, 90 = 11 Yrs.	1973,76,78,80 82,83,84,87, 90= 9 years	1973,76, 80,82,87, 90= 7 yr.
6	Barahiya Tal	12432	1973,74,75, 76,78,80,82, 83,84,85,86, 87,88,89,90, 91= 16 years	1973,74,75,76, 78,80,82,83,84, 87,90= 11 Yrs.	1987= 1 year
7	Singhaul Tal	17094	1973,74,75, 76,77,78,79, 80,82,83,84, 85,87,89,90, = 15 years	1973,74,75,76, 78,80,82,83, 84,85,87 = 11 years	1983,84, 85,87 = 4 years

It is seen from the table that submergence over 50 per cent and upto 75 per cent in case of Fatuha, Bakhtiyarpur, Barh and More tal has occured only in 5 to 8 years in a period of 20 years while in lower Tals of Mokama, Barahiya and Singhaul the frequency is 11 to 16 in 20 years.

For successful rabi crop in major portion of the Tal which remains submerged in monsoon period (Kharif), drainage of Tal by 15th of October is very crucial. If drainage is delayed, then Rabi crop suffers irrepairably. The following Table indicates the years in which different Tals were free from submergence by 15th of October in last 20 years.

Table 15

Sl No	Name of Tal	Area in Sq Km	Ground elevation in metre	Years in which Tal was free of flood free of flood water on 15th of October
1	Fatuha Tal	52.00	46.96 to 47.25	1972,74,75,76,77,79, 80,81,83,84,85,86,87, 88,90,91= 17 years
2	Bakhtiyarpur Tal	168.00	43.58 to 47.24	1972,74,75,76,79,80, 81,82,83,84,85,86,87, 88,89,90,91= 17 years
3	Barh Tal	132.00	42.06 to 46.02	1972,74,75,76,77,79, 80,81,82,83,84,85,86, 87,88,89,91= 17 years
4	More Tal	215.00	39.32 to 44.20	1972,74,75,76,77,78, 79,80,81,82,83,84,85, 91= 13 years
5	Mokama Tal	200.00	38.04 to 41.75	1972,74,75,76,77,79,80 81,82,83,84,91= 11 yr
6	Barahiya Tal	171.00	33.70 to 41.65	1972,74,75,76,77,78,79 80,81,82,83,91= 12 yrs
7	Singhaul Tal	124.00	38.40 to 39.62	1972,74,75,76,77,78,79 80,81,82,83,84,85,86, 91= 15 years
		1062.00		

Note:- The Second Bihar State Irrigation commission has already submitted its report " Suggestion for priorities for detailed planning and execution of Tal areas schemes " to the State Government on 3rd December 1992.

6.3 FLOOD DAMAGE

6.3.1 The damages caused by flood are classified broadly into the two following categories:

a Direct damages

b Indirect damages

6.3.2 Direct damage:- The direct damges are those which are caused due to the direct physical contant with flood water. These include losses to (i) growing and preharvest crops (ii) houses and house-hold assets (iii) Public utility works (iv) Public buildings and (v) Losses of human lives and live stocks.

6.3.3 Indirect damage:- The indirect losses are not susceptible to quantification. Therefore, approximate monetary evaluation can only be done for such damages. These generally include (i) loss of earning in agrobased industry and trade (ii) loss of revenue to the road and rail transport system due to disruption of services (iii) loss of revenue to small shopkeeper and other daily wage earners and (iv) loss of employment to the daily wage earners in public and private sectors.

6.3.4 The flood damage data are collected by the Revenue (Relief and Rehabilitation) Department of State Government and passed on to the various concerned organisation of the State and Central Government. Central Water Commission is collecting and compiling such data of all flood prone States at National level.It is observed that the flood damage statistics, which is essentially for benefit-cost study for any flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The recommendation of the RBA should be followed strictly and realistic evaluation of flood damage river basinwise should be carried out every year under the following three separately identified categories :-

i Unprotected areas

ii Protected areas due to failure of protection work

iii Areas between the embankments and the rivers.

The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long term data of flood damage is to be used in economic viability study for any future flood protection/ management scheme in the area.

The Central Flood Control Board had decided that Flood Control Department of the State should compile the flood damage data basin wise with effect from 1960. This is not being done in Bihar and flood damage data still continues to be collected district wise (not basin wise) by Revenue (Relief and Rehabilitation) Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of immediate requirement of relief operation. As such the need for compiling the annual flood damage data, according to the administrative jurisdiction in district and blockwise category in the State can not be denied. On the other hand, the flood control measures are required to be planned basin and sub-basin wise. It is, therefore, suggested that such data be collected by the Revenue authorities with active co-operation of the concerned staff of the Water Resources Department, Agriculture Department, Road construction and Building construction Departments and the data be compliled and processed both by the Statistical organisation at district and State level, district wise as well as basin/sub-basin wise for future use for planning of relief measures and flood management respectively.

The flood damage data for the Kiul-Harohar basin converted from available districtwise figures are enclosed at Annex 7.

6.3.6 From the perusual of the data processed by the Revenue Department it is noticed that the damage to the property of the Central Government such as Railways, Post & Telegraph etc, are not properly accounted for. On the other hand the cost of relief and rehabilitation measures, grants of loans, remission of land revenue etc, are added to the flood damage. This does not appear to be proper and it should be discontinued.

6.3.7 It would be evident from the available flood data (Annex 7) that average annual area affected by the flood and drainage congestion is 1567.7 Sq Km (Maximum being 4361 Sq Km and the minimum being 70 Sq Km). The average annual damage to the crop, houses, and public utility on the 1991 prices works out to be Rs 1813.49 Lakhs, Rs 686.40 Lakhs and Rs 187.53 Lakhs respectively. The same values at 1968 constant price level are 292.63 Lakhs, 110.55 Lakhs and 30.20 Lakhs respectively. The river system has witnessed worstever flood during the year 1987 causing the maximum damage so far. The value of damage to crops and houses during the year 1987 were Rs 6990.81 Lakh and Rs 8694.09 Lakh respectively at the then price level. The human and cattle lives lost were 424 and 88 respectively.

The data also reveals that high floods in the river are experienced almost once in three years. The comparative study of the flood damage data placed at Annex 7 shows that the average annual damage in this basin is about 1.64 and 3.09 per cent of the total annual average damages of the country (as a whole) and Ganga sub basin respectively whereas the geographical area of the basin is 0.504 per cent and 1.925 per cent of the country and Ganga sub-basin respectively.

6.3.8 The trend of distribution of various components of damages, such as crops damage, damage to houses etc during various blocks of years is indicated below:-

Table 16

Sl No	Type of damage	Damage in percentage during the period				
		1968-72	1973-77	1978-82	1983-91	1968-91
1	Damage to crop	78.15	73.75	84.89	52.77	67.47
2	Damage to houses (Private properties)	17.74	25.37	1.94	36.91	25.55
3	Damage to public utilities	4.11	0.88	13.17	10.32	6.98

6.3.9 It is observed from the figures furnished above that the crop damage, damage to houses and damage to public utilities roughly constitute 76 per cent, 13 per cent and 11 per cent of the total damages except damage to the houses during the block year 1978-82 and damage to public utilities during the block year 1968-72 and 1973-77.

7 PAST APPROACH

Although the flood problem in the Kiul-Harohar basin is not so acute as in the North Bihar river basin, flash flood occur in different rivers/ tributaries of the basin causing problems of flooding and drainage congestion in the areas mostly covered by the Mokama group of Tals. Efforts were made in the past from time to time to find a solution to the problem of flooding and drainage in the basin. A Master Plan for Flood Control Works in State of Bihar was prepared in 1974 in which a number of schemes in this basin were formulated and a few out of them were constructed also subsequently. These schemes can be broadly classified as embankment schemes, drainage schemes, reservoirs, river training works, soil conservation etc. A list of flood control schemes executed, under construction and proposed in the basin is given in Annex 8. These schemes have also been shown in drawing enclosed.

7.1 EMBANKMENT SCHEMES

The important embankment schemes either planned or executed in this river system are the following:

- a Sakri Embankment scheme
- b Kiul Embankment scheme
- c Panchane Embankment scheme
- d Barahiya Tal ring bund scheme
- e Flood protection works in Falgu basin from Khizirsarai to Daniawan.

In addition to these there are large number of Zamindari Embankments in some reaches of Kiul, Sakri and Falgu rivers. Some of these embankments were found quite useful, whereas others were constructed purely on local considerations without providing adequate section and were aligned too close to the river edge for protection of as much area as possible. Without caring for their safety. In order to ascertain the usefulness or therewise of the existing Zamindari Embankments in the State, the Government of Bihar had constituted a committee under the Chairmanship of Shri K N Lal, the then Chief Engineer, in the year 1987. The Committee categorised the Zamindari Embankments into the following three categories.

1 Zamindari Embankments which were found to be suitable for taking over by the Irrigation Department (now Water Resources Department) under overall flood management plan in the basin. The list of such embankments in the basin is placed at Annex 9.1.

2 Zamindari Embankments which were found to be useful in overall flood management plan of the basin but were recommended to be taken over by the Irrigation Department after investigation by the Advanced Planning Wing. The list of such Zamindari Embankments in this basin are placed at Annex 9.2.

3 Zamindari Embankment which did not fit into the overall flood management plan of the basin under the control of the Irrigation Department (Water Resources Department) but were found to be of local use were recommended to be maintained by the district administration. List of such embankments in this basin are shown in Annex 9.3. No further action appears to have been taken by the Water Resources Department on the reports of this committee.

7.2 DRAINAGE SCHEME

Drainage congestion due to blockage of incoming water from upper catchment of the basin by high stages of the Ganga, resulting in vast pool of water known as Tal area, is the most serious problem of this basin which has been baffaling the mind of the people of the area as well as the State Government authorities.

The Government of Bihar invited suggestions from expert for improvement in the utilisation of land and water resources of the Tal and also constituted a committee, known as Mokama Tal Technical-cum-Development Committee, to suggest measures for improved utilisation of land and water resources of the Tal areas. The Bihar Legislative Council constituted a committee of the Council to suggest ways and means for overall development of the Tal area. Recommendation of Dr K L Rao, the then Union Minister for Irrigation and Power, is placed at Annex 7.4 and that of High Level Technical Committee headed by Shri C C Patel, the then Secretary, Department of Irrigation Government of India at Annex 11. The recommendations of two Committee named above are enclosed as Annex 12 and 13.

WRD of the GOB accepted some of the recommendations pertaining to development of the land and water resources of the Tal area and decided to execute them in a phased manner. In the first phase it was decided to drain out the low lying pockets by cutting and renovatiing 16 nos of existing channels connecting local depressions in Tal areas with the main out-let channels ie the Harohar and providing bed bars with Karri regulation at the junction to achieve the twin objectives of accelerating drainage during the kharif season and storing water specially during winter rains in December and January for Rabi irrigation. These works were taken up for execution in 1967 and were completed in 1969. However, the wooden Kurries were subsequently lost and at present a scheme has been taken up to provide mannualy operated vertical lift shutters of steel. During their visit to the Tal area, some of the Members of the Commission got an opportunity to see one of the channels and the regulator on it in which steel shutters were lowered in the process of their installations. Primafacie it appeared that this regulator as well as other like this would not be able to fulfill the objectives of storing any water for use in Rabi due to following reasons :-

1 The regulator will remain submerged in the Tal water during the monsoon except the top of the abutments and piers and will not be approachable except by boats. Therefore, operation of gates will be possible only after draining of the Tal which will not serve the purpose of holding back even a small quantity of the Tal water for subsequnt use.

2 As the whole Tal is a low lying area and gets submerged there is no high ground which could be tied with the abutment. It is, therefore, apparent that at the time of draining of the Tal, water will flow down by the side of abutment also outflanking them.

3 Capacity of the channel appeared to small to store any tangible quantity of water within its flank and behind the gates.

4 In such out of way places it will be difficult to maintain the water-tightness of the gates as a result of which even the little quantity of water collected behind the gates may leak out in course of a few days.

5 Rains, during Rabi period, are so scanty that the channels and the gates are not expected to collect any useable quantity of water from rainfall in the Rabi season.

6 It was observed during the visit that the top of gates were kept above the bank of the channel. The accompanying local officers were not able to justify provision of such high gates.

It is, therefore, suggested that the State Government may like to get the utility of these gates reexamined separately in each case before incurring further expenditure on such works.

In the second phase, out of many schemes proposed, only Punpun Right Embankment, in a length of 14 km, was approved by the Government and its construction was duly started. 60 per cent of the work is reported to have been completed and remaining work is reported to be held up due to public objection in the earlier years and possibly due to paucity of funds in the recent years. This embankment, when completed, is expected to prevent the spill of the Punpun river and the back water of the Ganga through the Punpun from entering into the Tal area from Fatuha end. This embankment will certainly provide much relief to Fatuha and Bakhtiyarpur Tals. It is, therefore, suggested that the execution of this embankment which is lingering since last so many years should be completed on a priority basis, in a time bound programme.

The third phase envisaged provision of storage dams in the hilly catchment of the north flowing rivers into the tals. The Tal areas get filled up primarily due to inflow of the rivers joining the river Harohar which flows from west to east in the middle of the Tal. The Commission feels that it is of paramount importance to hold up as much inflow as possible in reservoirs, weirs, ahars, tanks, pynes and canal etc. in the catchment above the Tal in the south which alone is expected to provide real relief from deep and long submergence of the Tal area.

7.3 RESERVOIR/ DAM SCHEME

Many reservoir/ irrigation schemes have been constructed or are under various stages of construction which are expected to prevent considerable amount of water from entering into the Tal area. Schemes so far constructed detain around 1.04 Lham of water and then subsequently divert them into the command through canal in case of reservoir or by direct diversion in canal in case of diversion weirs. Some of the important reservoir schemes in the river system are the following :-

a Upper Kiul Reservoir Scheme

b Barnar Reservoir Scheme

c Nagi Reservoir Scheme

d Nakti Reservoir Scheme

In addition to these there are a number of small reservoir/ weir schemes. A list of all these schemes is enclosed as Annex 7.8.

7.4 OTHER MEASURES

a No serious erosion problem has been reported at any place in the basin. some anti-erosion works at the extreme northern end of the basin on the right bank of the Ganga were taken up for protection of Barahiya town and Khutaha village.

b Soil Conservation Measures:

No concrete measure has been taken up in the catchment of this basin. However, a scheme for intensive soil conservation measures in the upper hilly catchment of the Sakri and the Kiul rivers, covering an area of 828 Sq Km at a cost of 414 Lakhs was included in the Master Plan for Flood Control in Bihar State prepared in 1974. The fate of this scheme is not known to the existing concerned officers of the Water Resources Department.

c Raising of Villages:

A proposal to raise 250 villages being affected by flood in the catchment of this river system involving an expenditure of Rs 25.00 lakhs was indicated in the Master Plan for Flood Control Works in Bihar prepared in 1974 but no action has been reported to have been taken so far.

8 FUTURE APPROACH

8.1 In accordance with the National Water Policy, a comprehensive plan for optimum use of remaining available water resource of the basin for multipurpose uses is required to be prepared at the earliest. Priorities for execution of different components of the comprehensive plan be fixed in accordance with availability of resources and schemes implemented accordingly. As the preparation of such comprehensive plan is likely to take longer time, planning for flood control and removal of drainage congestion in the basin is to be attempted on top priority in order to prevent recurring damage that are taking place due to flood and damage congestion in the basin. This plan for flood management and drainage congestion may be dovetailed into the comprehensive plan for optimum use of water resources in the basin.

8.2 Inspite of the efforts made so far to mitigate the flood and drainage problem of the basin, the drainage problem is still dominant problem in addition there are minor flood problem here and there. These are summarised as follows :

a Flooding and drainage problem in Mokama group of Tals

b Flooding in lower reaches near Lakhisarai due to spill from the river Kiul

c Innundation of areas in the vicinity of Sakri bank due to spilling of the river through the gaps in the embankment and also through the unembanked portions.

d Flooding by the river Falgu

e Flodding by the river Panchane.

8.3 In order to mitigate the flood and the drainage problem of this basin following measures are suggested to be taken up in future.

8.3.1 Reservoir:- A properly operated flood reservoir combined with effective flood forecasting, offer the most dependable flood control. The National Policy on Flood of 1954 also recommended dams on tributaries as a long term measure of flood control. Reservoir, in general, even without flood cushion have a beneficial effect on the flood problem of a basin. Effectiveness of a reservoir in moderating flood would depend upon the capacity available for absorbing flood runoff. Because of high cost the reservoirs are not economically viable for flood moderation purpose only. This is also in keeping with the recommendation of the Expert Committee on Mokama Tal as described in para 7.2.

It has been indicated in the report of this Commission on "detail Planning of Tal Area Schemes" submitted to the State Government on 3rd December 1992 that the capacity of the Tal as obtained in 1987 is 4.37 Lham. It has been further indicated that the maximum annual inflow into the Tal from the rivers coming from South is 10.57 Lham which occured during the monsoon period of 1987. Out of 16 years of records monsoon inflows, are almost equal to or more than the capacity of the Tal for 15 years. Had there been no such tremendous inflow into the Tal entering into it from several points, it would have been easier to contain the back water of the Ganga between the two banks of the Harohar by constructing embankments on its both sides. It is, therefore, important to investigate and construct schemes for the utilisation of runoff for storage/ utilisation in the upper catchment to the largest possible extent. The storage reservoirs, barrages, weirs and minor irrigation schemes constructed so far can store/utilise maximum up to 1.04 Lham only. Efforts in this direction has to be vigorously pursued which will provide substantial relief to the Tals apart from providing irrigation benefit to upper catchment in the areas lying south of the Tal. The commission, therefore, recommends that the following reservoir schemes be taken up on priority:-

1 Barnar Reservoir Scheme

2 Upper Kiul Reservoir Scheme

3 Tilaiya Diversion Scheme

4 Kundghat Irrigation Scheme

5 Sakri Reservoir Scheme

6 Mohane Reservoir Scheme

7 Lilajan Reservoir Scheme

A properly operated reservoir combined with efficient flood forecasting offers the most dependable flood control. The effectiveness of such reservoirs, however, is mainly dependent upon the capacity ofthe reservoir for absorbing flood runoff and its distance from the area of damage. It is, therefore, felt that suitable flood cushion may be provided in these reservoirs as far as practicable depending upon the catchment area intercepted by each of these. Prima facie these reservoir does not apear to have the capacity so as to absorb the flood water to eliminate flooding and damage congestion in the basin. Careful and planned operation of these reservoirs is expected to help in moderating flood to a large extent. This aspect may be looked into.

8.3.2 Embankments:- Master Plan For Flood Control Works in Bihar State, prepared in 1974 had suggested following embankment schemes in this basin to take care of occasional floods that occur in down-stream reaches of the rivers :-

a Sakri embankment scheme

b Kiul embankment scheme

c Panchane embankment scheme

d Barahiya Tal Ring Bund scheme

e Flood protection works in Falgu basin from Khizirsarai to Daniawan.

It appears that the aforesaid schemes have not been investigated in detail for preparation of schemes for obtaining sanction and their implementation. It is, therefore, felt that the necessity for these schemes may be reviewed in the present circumstances and if necessary detailed schemes should be prepared on the basis of proper and adequate investigations and past historical data for obtaining sanction and implementation if found economically viable.

8.3.2.1 In addition to these there are many zamindari bunds existing in the basin. These bunds were reviwed by K N Lal Committee as discussed in paragraph 7.3 in the past approach. The categorywise details of such existing Zamindari embankments are enclosed at Annex 9.1, 9.2 & 9.3. First category consist of such embankments which were considered suitable to be taken over by the Water Resources Department under its overall flood management plan in the basin. Second category of the Zamindari Bunds were those which were to be taken over by the Water Resources Department only after those were found suitable after detailed and proper investigation by the Advance Planning Wing of the Department. And third category of the Zamindari Bunds were those which were not found useful in overall flood management programme of the Department in the basin but were of local use. These were recommended by the Committee to be maintained by the respective District Collectors.

So far no action appears to have been taken on the report of K N Lal Committee. The Commission feels that follow up action may be taken on the recommendation of K N Lal Committee so far as this basin is concerned without any further delay by the State Government.

8.3.2.2 Construction of right bank Punpun embankment is expected to prevent the spill of the Punpun river and the back water of the Ganga through the Punpun from entering the Tal area from the Fatuha end. It is therefore suggested that the execution of this embankment, which is lingering since last so many years should be completed on priority basis in a time bound programme.

8.3.2.3 Dowel/Embankment in isolated length to prevent entry of the Ganga spill into the Tal area through the low lying lengths of road may be constructed.

8.3.3 Drainage Congestion:- For removal of drainage congestion many proposals have been put forward by the committees constituted by the State Government in the past. These proposals have been studied and view of this commission have already been expressed in the report on " Suggestions for priorities for detailed planning and execution of Tal area schemes " submitted to the State Government on December 3, 1992. The same recommendations are not being reproduced here to avoid repetition.

8.3.4 Channel improvement

8.3.4.1 The river Panchane is reported to create flooding in its sub-basin due to inadequacy of its several existing channels sections similar floods are being caused in the bifurcated channels of the river Falgu also. All these channels are in such a silted up condition that even during flow of small quantity of discharge these spill over their bank causing flooding in the adjacent areas flooding depending upon the quantity and stage of flow. These spills intermingle with each other and large part of the Nalanda district and parts of Munger and Patna district gets submerged during the monsoon season.

8.3.4.2 This calls for detailed planning and execution of channel improvement works in all such channels in the basin in order to make them capable of carrying the flood discharges within their banks. Before embanking on such works main and subsidiary channels be identified and then benefits be evaluated carefully taking the cost of maintenance into account.

8.3.5 Soil Conservation:- Under an Integrated Action Plan for flood management in the Indo Gangetic plains, watershed treatment and soil conservation measures were taken up in a few flood prone basins. These measures are still limited to experimental application. Their effectiveness in reducing the peak flood during monsoon is yet to be established. However soil conservation and watershed management measures are likely to have beneficial effect by way of reducing the quantities of silt flowing into the rivers.

Flash flood, which occur in the rivers like the Falgu, can be reduced by adopting proper soil conservation measures in their catchment. Basin bereft of green covers responds quickly to the input precipitation giving rise to flash floods. The Kiul-Harohar system drains the Chotanagpur plateau. There is a proposal under consideration of government of Bihar to take up soil conservation measures in the upper hilly catchments of the rivers Sakri and Kiul covering an area of 828 Sq Km at cost of 414.00 Lakhs. These schemes should be updated on the basis of experience gained so far and implemented at the earliest.

8.3.6 FLOOD PLAIN ZONING

8.3.6.1 The basic concept of flood plain zoning involves regulating the land use in the flood plains to restrict the damage caused by floods which are bound to occur from time to time as a natural phenomena. It, therefore, aims at contour surveys and production of maps for determining the location and extent of areas likely to be affected by floods of differnt magnitude/ frequencies and the likely depths of submergence with a view to develop these areas in such a fashion that the resulting damage is reduced to the minimum. Flood plain zoning is thus useful in both protected and unprotected area. While it can prevent indiscriminate growth in unprotected areas, it helps in regulating the development in protected area. The different flood zones can be regulated on the following pattern :-

Priority I

Defence installations, industries, public utilities like hospitals, electric and water supply installations, telephone exchange, aerodromes, railway stations, commercial centres etc. could be created in such a fashion that these are above the level corresponding to 1 in 100 years flood or the maximum observed flood level till date. These would also be above the level corresponding to 50 years return period rainfall and likely submergence due to drainage congestion.

Priority II

Public Institution, Government Offices, Libraries and residential areas should be safe for a 25 years flood or a 10 years rainfall.

Priority III

Play grounds and parks can however be located in areas vulnerable to frequent floods.

8.3.6.2 This Commission has considered the aspect of Flood Plain Zoning so far as the State of Bihar is concerned and has submitted a report on "Flood Plain Zoning " to the State Government on December 3, 1992. The commission has felt that strict regulation of land use in flood zones and drainage channels are very essential to reduce the flood damages in real terms and accordingly recommended that flood plain management measures should be strictly enforced.

8.3.6.3 Although detailed survey maps showing contour of 0.3 to 0.5 m interval would be required to demarcate different zones of the flood plain and to draw up proposals for the management and regulation, the work can be strarted even on the basis of available data on the frequency and extent of flooding in the past. To start with this works should be taken up on priority, in first phase, for the areas which are not protected from floods and drainage congestions at present. Subsequently the detailed data may be procured and Flood Risk Maps prepared for enforcing Flood Plain Zoning in the basin.

8.7 FLOOD FORECASTING AND WARNING:-

Flood forecasting has proved to be of great help in issuing warning to the people in flood prone areas, organising flood fighting and safety measures for engineering works, timely evacuation of people from affected areas and salvation of moveable properties besides mobilising relief operations.

The CWC has four discharge observation sites, one each on Kiul, Harohar, Sakri and Falgu and maintains three guage sites at Sono, Garhi and Jamui in the basin. However, at present no flood forecast and warning in being issued from any of these sites.

The rivers Sakri, Kiul and Falgu are prone to flash flood which has some times caused severe damage to property as well as to the human and cattle life. Prima facie it appears that prior flood forecast in these rivers will certainly help in minimising the flood damages so caused. The State Government may take further necessary steps for providing flood forecasting and warning facilities in the flashy rivers of the Kiul-Harohar system.

9 SUMMARY OF RECOMMENDATIONS

9.1 It is observed that hydrometeorological data of the river basin is not being observed, collected, analysed and documented in a systematic manner. There is no need for establishing more raingauge stations in the Kiul Harohar basin. However, the network of Gauge-Discharge sites should be expanded by opening more sites at suitable locations as quickly as possible. The area liable to floods and drainage congestionin the various reaches of the basin along with area actually flooded with crop details are not being observed and properly recorded. The area flooded by over bank spills should be marked separately from those which gets submerged due to drainage congestion on account of heavy precipitation coinciding with the high stages in the outfall channels. Systematic observation, collection analysis and maintenance of such data should be retrieved/procured from concerned sources, studied, analysed and documented for future use. The State Government may consider allotment of sufficient fund under the plan head for establishing data collection units with the primary objective of collection of data/ information on a continuous basis, so that it is useful for the future planner.

(Para 4.7.3, 4.8.1)

9.2 The summary of recommendation made by RBA and accepted by Ministry of Irrigation, Government of India is as follows:-

"In case of embankment, the design of a project should be determined, for the time being, on flood frequencies suggested. Meanwhile necessary steps may be taken for eventual application of the benefit cost ratio criteria for fixing the design."

"In case of embankment scheme the height of the embankment and the corresponding cost be worked out for various flood frequencies and also the benefit cost ratio, taking into account the likely damage to occur for the relative flood frequencies. However, till much times as the details of all relevant parameters are available embankment scheme might be prepared for a flood of 25 years frequency in the case of predominantly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of industrial and other vital organisation."

While endorsing the decisions of the Ministry of irrigation, GOI, on the recommendations of the RBA, the Commission suggests that all the embankments on important rivers should be designed for a flood of 50 years frequency in general and for flood of 100 years frequency for works pertaining to town protection of of vital industrial establishments.

We also endorse RBA recommendations for adoptionin embankment design in our State.

(Para 5.2.3)

9.3 It is observed that the flood damage statistics, which is essentially for benefit-cost study for any flood management measures, are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. The recommendations of the RBA should be followed strictly and realistic evaluation of flood damage river basinwise should be carried out every year under the following three separately identified categories:

i Unprotected areas

ii Protected areas due to failure of protection work

iii Areas between the embankments and the rivers.

The extent of drainage congestion in the protected and unprotected area should be indicated separately. The Water Resources Department dealing with flood management should be associated with collection and compilation of flood damage data. In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned Departments at the end of each year. Such reconciled long term data of flood damage is to be used in economic viability study for any future flood protection/management scheme in the area.

(Para 6.3..4)

9.4 The flood damage data are presently collected by Revenue Department and communicated to other concerned Departments. In view of requirement of these data to district administration & Revenue Department it is suggested that, the collection of these data may be continued by Revenue Department with active cooperation of staff of Water Resources, Agriculture and Roads & Building Construction Departments and the data should be processed and compiled both districtwise as well as basin/sub-basinwise by the statistical organisation at district and State level for future use for planning of relief measurs & flood management respectively.

(Para 6.3.5)

9.5 Irrigation schemes like Barnar Reservoir, Upper Kiul Reservoir and Tilaiya Diversion schemes, which are under various stages of construction are recommended to be completed at the earliest.

(Para 8.3.1)

9.5.1 Investigation of further likely reservoirs and irrigation schemes as well as construction of Reservoirs/Irrigation schemes like the Kundghat, Sakri, Mohane and Lilajan Reservoir schemes which have been planned in the basin are recommended to be taken up and implemented as soon as possible.

(Para 8.3.1)

9.5.2 It is felt that suitable flood cushion may be provided in the reservoirs as far as practicable depending upon the catchment area intercepted by each of these. Careful and planned operation of these reservoirs is expected to help in moderating flood to a large extent. This aspect may be looked into.

(Para 8.3.1)

9.6 Embankment schemes suggested in "Master Plan for Flood Control Works in Bihar State", prepared in 1974, has so far not been taken up for construction. It appears that the aforesaid schemes have not been investigated in detail for preparation of schemes for obtaining sanction and their implementation. It is felt that the necessity for these schemes may be reviewed in the present circumstances and if necessary detailed scheme should be prepared on the basis of proper and adequate investigation and past historical data for obtaining sanction and implementation, if found economically viable.

[Para 8.3.2]

9.7 To ascertain the usefulness of Zamindari Embankments in the State, Bihar Government constituted a committee under the chairmanship of Shri K N Lal, the then Chief Engineer in the year 1987. The Commission feels that follow up action on the reports of this Committee with respect to this basin may be taken without any further delay by the State Government.

(Para 8.3.2.1)

9.8 Construction of right bank Punpun embankment is expected to prevent the spill of the Punpun river and back water of the Ganga from entering the Tal area from Punpun end. It is, therefore, recommended that execution of this embankment, which is lingering since many years, should be completed on priority basis on a time bound programme.

(Para 8.3.2.2)

9.9 Dowel/ Embankment in isolated length to prevent entry of the Ganga spill into the Tal area through the low lying lengths of roads may be constructed.

[Para 8.3.2.3]

9.10 The river Panchane as well as the bifurcated channels of the Falgu are reported to create flooding due to inadequacy of carrying capacity of their several existing channels as a result of heavy siltation. This calls for detailed planning and execution of channel improvement works in all such channels in the basin in order to make them capable of carrying the flood discharges within their banks. Before embanking on such works main and subsidiary channels be identified and then benifits be evaluated carefully taking the cost of maintenance into account.

(Para 8.3.4.1, 8.3.4.2)

9.10.1 Watershed treatment and soil conservation measures are likely to have beneficial effect by way of reducing the silt inflow into the river. Soil conservation measures may prove very effective in the Falgu which experiences flash flood. There is already a proposal under consideration of the Government of Bihar to take up soil conservation measures in the Upper hilly catchment of the river Sakri and Kiul, covering an area of 828 Sq Km at a cost of 414 Lakhs.

Suitable schemes may be formulated & implemented at the earliest.

(Para 8.3.5)

9.11 Soil conservation and watershed treatment are likely to have beneficial impact by way of reduction in quick runoff response of the basin. It will reduce intensity of flash flood in the rivers like Falgu etc. Therefore, afforestation on a large scale should be taken up in the basin.

(Para 8.3.5)

9.12 Flood plain zoning measures will be helpful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected area and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of protection measures. Flood risk map of the basin on a contour map of scale 1:15000 and contour interval of 0.3 metre should be prepared showing the areas likely to be flooded by the floods of different frequencies such as 100 year, 50 year and 25 year flood. Similar flood risk maps showing submersion caused due to drainage congestion corresponding to a 50 year and 25 year rainfall should be prepared and flood plain zoning be enforced. To start with, this work should be taken up on priority, in first phase, for the areas which are not protected from floods and drainage congestions at present. Subsequently the detailed data may be procured and Flood Risk Maps prepared for the remaining flood prone areas in the basin for enforcing flood plain zoning.

(Para 8.3.6)

9.13 Flash floods occur in rivers like the Sakri, the Kiul and the Falgu which sometimes cause extensive damage to the human and cattle life as well as to the property in their flood zone. CWC has four gauge discharge sites and three gauge sites on these rivers but at present no facility of flood forecasting and warning is available. The State Government may consider and take necessary steps for providing flood forecasting and warning facilities in flashy rivers of the Kiul-Harohar system.

(Para 8.7)

Annex 1

RAIN-GAUGE STATION IN KIUL HAROHAR BASIN

Sl No	Name of rain-gauge station	Location		District	Maintained by	Self recording or ordinary
		Lat	Long			
1	Chatra	24°12' 0"	84°52' 0"	Hazaribagh	IMD	Ordinary
2	Hunterganj	24°27' 0"	84°48' 0"	do	IMD	do
3	Gujhandi	24°28' 0"	85°30' 0"	do	State	do
4	Barachati	24°30' 0"	85°02' 0"	Gaya	IMD	do
5	Tisri	24°25' 0"	86°04' 0"	Giridih	State	do
6	Bamdah	24°35' 0"	86°24' 0"	Munger	do	do
7	Rajauli	24°39' 0"	85°30' 0"	Nawadah	IMD	do
8	Satgawan	24°45' 0"	85°47' 0"	Hazaribagh	do	do
9	Gaya (obsy)	24°45' 0"	84°57' 0"	Gaya	do	Self recording
10	Nawada	24°53' 0"	85°33' 0"	Nawada	do	Drdinary
11	Gidhaur	24°52' 0"	86°19' 0"	Munger	do	do
12	Jhajha	24°47' 0"	86°23' 0"	do	do	do
13	Jamui	24°56' 0"	86°13' 0"	do	do	do
14	Sikndra	24°48' 0"	86°02' 0"	do	State	do
15	Pakribaraman	24°57' 0"	85°44' 0"	Nawadah	IMD	do
16	Silao	25°05' 0"	85°25' 0"	Nalanda	do	do
17	Nalanda	25°08' 0"	85°28' 0"	do	do	do
18	Jahri	25°05' 0"	86°00' 0"	Munger	State	do
19	Shekhpura	25°09' 0"	85°51' 0"	do	IMD	do
20	Islampur	25°09' 0"	85°13' 0"	Nalanda	do	do
21	Ekangersarai	25°13' 0"	85°14' 0"	do	do	do
22	Bihar	25°11' 0"	85°33' 0"	do	do	do
23	Asthawan	25°13' 0"	85°37' 0"	do	do	do
24	Sarmera	25°15' 0"	85°48' 0"	Patna	do	do
25	Chandi	25°15' 0"	85°20' 0"	Nalanda	do	do
26	Hilsa	25°19' 0"	85°17' 0"	do	do	do
27	Badalpur (Khagole)	25°20' 0"	86°05' 0"	Patna	do	do

Annex 2

RAIN-GAUGE STATIONS IN THE CATCHMENTS ADJACENTS TO THE KIUL HAROHAR BASIN

Sl No	Name of rain-gauge station	Location		District	Maintained by	Self recording or ordinary
		Lat	Long			
1	Hazaribagh	23°59' 0"	85°22' 0"	Hazaribagh	IMD	Self recording
2	Barhi	24°18' 0"	85°25' 0"	do	do Ordinary	
3	Dhanwar	24°25' 0"	85°59' 0"	Giridih	do	do
4	Chakaiband	24° 0' 0"	86°24' 0"	Munger	do	do
5	Sherghati	24°33' 0"	84°48' 0"	Gaya	do	do
6	Jahanabad	24°13' 0"	85°00' 0"	Jahanabad	do	do
7	Munger	25°23' 0"	86°28' 0"	Munger	do	do
8	Mokama	25°25' 0"	85°43' 0"	Patna	State	do
9	Kodarma	24°17' 0"	85°32' 0"	Hazaribagh	IMD	do
10	Begusarai	25°26' 0"	86°09' 0"	Begusarai	do	do
11	Bakhtiarpur	25°27' 0"	85°32' 0"	Patna	do	do
12	Barh	25°29' 0"	85°43' 0"	do	do	do
13	Patna	25°37' 0"	85°10'10"	do	do	Self recording

Annex 3

MONTHLY AND ANNUAL NORMAL OF RAINFALL AT RAINGAUGE STATIONS IN KIUL HAROHAR AND ITS ADJACENT BASIN MAINTAINED BY IMD

Normal rainfall in mm

Sl No	Name of raing-auge station	June	July	August	Sept.	Oct.	Total (monsoon)
1	Patna (Obsy)	158.0	276.1	340.4	237.7	54.6	1066.8
2	Bihar	138.2	283.0	305.8	185.7	42.9	955.6
3	Barh	140.2	238.8	265.4	185.4	43.9	873.7
4	Hilsa	120.1	248.4	310.6	188.5	37.1	904.7
5	Islampur	128.0	285.2	293.6	193.8	32.3	932.9
6	Asthanwan	129.3	249.2	236.8	179.8	43.7	888.8
7	Ekangersarai	85.1	221.2	214.9	157.0	32.0	710.2
8	Bakhtiarpur	125.7	294.6	351.8	224.3	49.3	1045.7
9	Sarmera	135.9	289.6	319.3	204.5	60.5	1009.8
10	Badalpur (Khagole)	75.7	206.8	249.4	160.0	31.5	723.4
11	Silao	108.2	268.5	266.2	167.6	38.9	849.4
12	Chandi	122.7	305.1	302.0	204.0	44.5	978.3
13	Gaya (Obsy)	140.5	331.0	366.5	197.1	48.8	1083.9
14	Nawada	123.7	267.7	308.6	176.8	47.2	924.0
15	Jehanabad	130.8	283.0	325.9	213.6	38.9	992.2
16	Sherghati	128.3	297.4	362.5	213.1	52.8	1054.1
17	Rajauli	139.9	308.1	350.8	213.1	55.4	1067.3
18	Pukribarawan	117.3	227.3	279.7	176.3	48.5	849.4
19	Baradwati	121.4	324.6	377.9	209.0	50.5	1083.4
20	Bagusarai	178.1	271.3	324.9	243.8	57.1	1075.2
21	Munger	174.0	263.4	324.9	212.3	55.4	1030.0
22	Jamui	160.0	292.6	292.9	216.4	59.4	1021.3
23	Sheikhpura	165.3	277.1	312.2	199.4	51.6	1005.6
24	Chakaibanda	193.3	300.2	305.1	227.6	87.6	1113.8
25	Gidhaur	200.1	327.1	317.1	233.4	85.9	1164.2
26	Hazaribagh	194.3	321.8	349.0	219.7	79.5	1164.3
27	Barhi	183.4	334.5	365.8	201.2	80.3	1165.2
28	Chatra	73.2	360.9	385.1	229.1	61.0	1209.3
29	Kodarma	175.5	305.6	342.7	210.3	70.6	1104.7
30	Hunterganj	151.4	380.7	388.6	231.9	60.2	1212.8
31	Satgawan	113.0	288.5	325.6	186.4	49.3	962.8
32	Dhanwar	166.4	326.4	303.5	197.9	82.5	1076.7

Annex 4

STATEMENT SHOWING THE GAUGE AND DISCHARGE SITES IN KIUL HAROHAR RIVER BASIN

Sl No	Name of the site	River/ tributary	Location		Nature of site	Maintained by CWC/ State Govt.	Year of starting
			Lat.	Long.			
1	Lakhisarai	Kiul	25°10"33	86°6'4"	G & D	CWC	1959
2	Gaya	Falgu	24°47'42"	85°0'57"	G & D	CWC	1959
3	Kadarganj	Sakri	24°54'33"	85°35'52"	G & D	CWC	1960
4	Mankatha	Harohar	25°10'33"	86°4'0"	G & D	CWC	1962
5	Garhi	Kiul	25°5'0"	86°0'0"	Gauge	CWC	1979
6	Sono	Barnar	24°40'0"	86°20'0"	Gauge	CWC	1979
7	Jamui	Kiul	24°55'0"	86°14'0"	Gauge	CWC	1979
8	Bhaluachatti	Mohana			G & D	State Govt	1953
9	Gobindpur	Sakri			G & D	State Govt	1958
10	Garhi	Kiul			G & D	State Govt	1964
11	Akbarpur	Khuri			G & D	State Govt	
12	Jamui road crossing	Kiul			G & D	State Govt	
13	Fatwa	Dhowa			G & D	State Govt	1970
14	Ramchandarpur	Harohar			G & D	State Govt	
15	Hunterganj Chatra road crossing	Lilajan			Gauge	State Govt	
16	Phulbaria	Tilaiya			Gauge	State Govt	
17	Khunta	Sakri			Gauge	State Govt	
18	Dinarganj	Panchane			Gauge	State Govt	
19	Dhadhar	Sohjana			Gauge	State Govt	
20	Tetarhat	Kiul			Gauge	State Govt	
21	Hasanchak	Kiul	25°14'0"	87°30'0"	Gauge	State Govt	1979
22	Near Surajgarha	Garka			Gauge	State Govt	1979
23	Headwork of the Kiul Irrigation Scheme	Kiul			Gauge & Discharge	State Govt	1959
24	Nagi Dam Site	Nagi			,,	,,	1959
25	Kulti	Jirain			,,	,,	1958
26	Tati Headwork	Tati			,,	,,	1958
27	Kaithwan Weir	Kauribari			,,	,,	1958
28	Near Chandi	Mohane			,,	,,	1970
29	Malisar	Paimar			,,	,,	1967
30	Pauna	Sakri			,,	,,	1948
31	Sahajana	Dhadhar			,,	,,	1967
32	Giriak	Panchane			,,	,,	1969
33	Goswari	Mohane			,,	,,	1970

Annex 5

DBSERVED GAUGE AND DISCHARGE DATA OF KIUL-HARDHAR RIVER BASIN
NAME OF SITE : LAKHISARAI

Sl No	Year	Annual peak discharge (cumec)	Corresponding gauge (metre)	Equation of rating curve (as found out on computer)
1	2	3	4	5
1	1963	798.55	42.643	$Q = 101.163 (G-39.7)^{2.08907}$
2	1964	383.92	41.778	for $G<43.00m$
3	1965	508.32	42.233	
4	1966	243.97	41.378	$= 280.12 (G-410)^{2.12547}$
5	1967	383.65	42.048	for $G>43.00m$
6	1968	458.14	41.648	
7	1969	1304.79	42.348	
8	1970	158.11	40.906	
9	1971	1071.00	42.613	
10	1972	1050.52	42.873	
11	1973	561.20	41.766	
12	1974	589.90	43.328	
13	1975	329.86	41.748	
14	1976	334.00	41.083	
15	1977	373.62	41.948	
16	1978	313.26	41.178	
17	1979	212.86	41.203	
18	1980	1243.74	43.018	
19	1981	520.80	41.863	
20	1982	177.45	40.513	
21	1983	817.04	42.283	
22	1984	1678.06	43.328	
23	1985	1073.32	42.118	
24	1986	495.75	41.483	

Annex 5 (Contd)

OBSERVED GAUGE AND DISCHARGE DATA OF KIUL-HAROHAR RIVER BASIN
NAME OF SITE GAYA

Sl No	Year	Annual peak discharge (cumec)	Corresponding gauge (metre)	Equation of rating curve (as found out on computer)
1	2	3	4	5
1	1960	572.00	105.909	$Q = 202.257(G-107.1)^{1.98975}$ for G<110.1m; $= 567.57(G-108.4)^{2.20116}$ for G> 110.1m
2	1961	347.24	105.841	
3	1962	1190.65	106.543	
4	1963	451.41	108.792	
5	1964	352.29	108.642	
6	1965	532.91	108.727	
7	1966	121.69	108.087	
8	1967	494.43	108.922	
9	1968	608.53	108.887	
10	1969	841.84	109.417	
11	1970	1521.16	109.792	
12	1971	1077.05	109.332	
13	1972	1103.39	109.262	
14	1973	450.11	108.659	
15	1974	537.36	108.829	
16	1975	396.94	108.927	
17	1976	382.17	108.715	
18	1977	278.53	108.892	
19	1978	736.06	109.227	
20	1979	191.59	108.417	
21	1980	258.04	108.342	
22	1981	106.29	108.082	
23	1982	136.83	108.307	
24	1983	126.95	108.112	
25	1984	2543.86	110.452	
26	1985	1006.32	108.952	
27	1986	3751.46	110.692	

Annex 5 (Contd)

OBSERVED GAUGE AND DISCHARGE DATA OF KIUL-HAROHAR RIVER BASIN
NAME OF SITE KADARGANJ

Sl No	Year	Annual peak discharge (cumec)	Corresponding gauge (metre)	Equation of rating curve (as found out on computer)
1	2	3	4	5
1	1962	1334.47	85.520	2.85448
2	1963	1062.08	85.770	Q+103.337(G-83.2)
3	1964	208.51	84.488	
4	1965	1998.39	85.346	
5	1966	48.92	83.960	
6	1967	209.90	84.396	
7	1968	400.85	84.870	
8	1969	614.74	85.085	
9	1970	144.30	84.240	
10	1971	344.86	85.090	
11	1972	102.32	84.388	
12	1973	337.24	84.865	
13	1974	586.50	84.825	
14	1975	580.59	84.835	
15	1976	183.37	84.265	
16	1977	579.52	84.840	
17	1978	358.44	84.490	
18	1979	165.47	84.645	
19	1980	2635.48	86.327	
20	1981	209.51	84.445	
21	1982	28.87	84.090	
22	1983	217.19	84.710	
23	1984	302.03	85.005	
24	1985	370.64	84.890	
25	1986	1115.18	85.345	

Annex 5 (Contd)

OBSERVED GAUGE AND DISCHARGE DATA OF KIUL-HAROHAR RIVER BASIN
NAME OF SITE MANKATHA

Sl No	Year	Annual peak discharge (cumec)	Corresponding gauge (metre)	Equation of rating curve (as found out on computer)
1	2	3	4	5
1	1962	883.74	40.237	
2	1963	872.48	39.666	$Q = 14.9957 (G-34.8)^{2.36783}$
3	1964	373.10	38.320	for G <40.5m
4	1965	329.766	38.201	
5	1966	168.81	37.026	$= 16.7032(G-36.0)^{2.65779}$
6	1967	1045.46	39.836	for G>40.5m.
7	1968	530.91	38.958	
8	1969	1819.95	41.541	
9	1970	402.35	39.320	
10	1971	1840.06	42.906	
11	1972	223.30	38.161	
12	1973	1914.29	39.986	
13	1974	769.09	40.096	
14	1975	752.83	40.491	
15	1976	657.39	40.924	
16	1977	838.66	40.789	
17	1978	1462.43	41.744	
18	1979	948.63	41.211	
19	1980	1650.66	40.654	
20	1981	840.46	39.611	
21	1982	1109.75	40.496	
22	1983	677.85	39.871	
23	1984	1938.83	41.614	
24	1985	917.02	40.526	
25	1986	1217.48	41.071	

Annex 6 (a)

OBSERVED ANNUAL PEAK GAUGE AND CDRRESPONDING DISCHARGE
NAME OF SITE - LAKHISARAI ON RIVER BASIN

Sl No	Year	Annual peak gauge (m)	Computed peak discharge Cumec	Remark
1	1963	43.208	1508.40	
2	1964	42.458	842.30	
3	1965	42.458	842.30	
4	1966	41.918	524.30	
5	1967	42.858	1117.70	
6	1968	41.898	524.30	
7	1969	42.453	839.10	
8	1970	40.973	167.50	
9	1971	42.613	944.20	
10	1972	43.018	1245.80	
11	1973	42.058	607.10	
12	1974	43.328	1688.00	
13	1975	41.748	452.30	
14	1976	43.538	2028.10	
15	1977	42.208	690.60	
16	1978	43.018	1245.80	
17	1979	43.020	1245.40	
18	1980	43.018	1245.80	
19	1981	41.563	507.00	
20	1982	41.538	360.80	
21	1983	42.283	734.50	
22	1984	43.328	1688.00	
23	1985	44.408	3794.60	
24	1986	43.078	1325.60	
25	1987	44.130	3166.80	
26	1988	41.680	421.40	
27	1989	41.580	378.23	
28	1990	41.450	325.65	

Annex 6 (b)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING DISCHARGE
NAME OF SITE - GAYA ON RIVER FALGU

Sl No	Year	Annual peak gauge (m)	Computed peak discharge Cumec	Remark
1	1960	105.659	-	
2	1961	105.878	-	Not considered
3	1962	106.077	-	
4	1963	108.907	656.40	
5	1964	109.617	1269.30	
6	1965	109.927	1599.30	
7	1966	108.492	390.60	
8	1967	108.417	349.80	
9	1968	108.792	575.90	
10	1969	109.567	1219.60	
11	1970	109.547	1200.00	
12	1971	109.692	1345.70	
13	1972	109.907	1576.90	
14	1973	108.947	685.70	
15	1974	108.877	634.90	
16	1975	108.007	166.60	
17	1976	108.877	734.90	
18	1977	110.007	1690.60	
19	1978	110.877	4179.40	
20	1979	108.417	349.80	
21	1980	108.342	311.30	
22	1981	108.082	195.10	
23	1982	108.307	294.10	
24	1983	108.112	207.10	
25	1984	110.452	2761.70	
26	1985	108.977	708.00	
27	1986	111.057	4877.20	
28	1987	110.080	1778.12	
29	1988	108.780	567.82	
30	1989	108.940	680.50	
31	1990	109.460	1116.62	

Annex 6 (c)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING DISCHARGE
NAME OF SITE - KADARGANJ ON RIVER SAKARI

Sl No	Year	Annual peak gauge (m)	Computed peak discharge Cumec	Remark
1	1962	85.520	1141.70	
2	1963	85.770	1529.00	
3	1964	84.488	194.50	
4	1965	85.590	1242.80	
5	1966	85.320	882.60	
6	1967	84.450	195.40	
7	1968	84.900	470.00	
8	1969	85.085	631.10	
9	1970	84.307	138.10	
10	1971	86.210	2400.60	
11	1972	84.990	544.50	
12	1973	84.865	442.90	
13	1974	84.825	413.20	
14	1975	84.835	420.50	
15	1976	85.310	870.80	
16	1977	84.850	431.60	
17	1978	85.130	675.10	
18	1979	84.880	454.40	
19	1980	86.327	1676.60	
20	1981	85.490	1100.00	
21	1982	84.090	74.10	
22	1983	84.710	335.10	
23	1984	85.005	557.70	
24	1985	85.500	1113.80	
25	1986	85.740	1478.60	
26	1987	85.640	1118.42	
27	1988	84.630	286.85	
28	1989	84.590	264.54	
29	1990	85.290	877.44	
30	1991	84.710	335.07	

Annex 6 (d)

OBSERVED ANNUAL PEAK GAUGE AND CORRESPONDING DISCHARGE
NAME OF SITE - MANKATHA ON RIVER HAROHAR

Sl No	Year	Annual peak gauge (m)	Computed peak discharge Cumec	Remark
1	1962	40.237	826.40	
2	1963	40.146	794.00	
3	1964	39.703	646.90	
4	1965	40.981	1191.60	
5	1966	39.006	450.00	
6	1967	40.501	910.20	
7	1968	38.966	439.90	
8	1969	41.706	1709.00	
9	1970	39.987	939.20	
10	1971	42.376	2296.80	
11	1972	38.536	339.90	
12	1973	40.516	918.30	
13	1974	40.626	979.00	
14	1975	41.496	1547.70	
15	1976	42.882	2813.60	
16	1977	40.896	1138.30	
17	1978	42.296	2183.70	
18	1979	41.211	1343.50	
19	1980	41.451	1521.30	
20	1981	39.701	646.30	
21	1982	41.441	1506.90	
22	1983	40.701	1021.70	
23	1984	41.651	1666.40	
24	1985	40.986	1194.80	
25	1986	41.106	1272.70	
26	1987	42.700	2620.19	
27	1988	40.340	863.88	
28	1989	38.930	430.93	
29	1990	41.380	1298.27	
30	1991	40.480	916.46	

STATEMENT OF FLOOD DAMAGE FOR KIUL HAROHAR BASIN (AT THEN CURRENT PRICE AND 1991 PRICE LEVEL

Year	Area affected (Lha)	Population affected	Damage to crops: Area (Lha)	Damage to crops: Value in Lakh Rs At then current price	Damage to crops: Value in Lakh Rs At 1991 price level	Damage to Houses (Number)	Damage to Houses: Value in Lakh Rs At then current price	Damage to Houses: Value in Lakh Rs At 1991 price level	Cattle lost (in No)	Human life lost (in No)	Damage to public utility in L Rs: At then current price	Damage to public utility in L Rs: At 1991 price level	Total damage (to crops houses and public utility) in L Rs: At then Current Price	Total damage: At 1991 price level
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1968	0.198	0.737	0.018	25.07	155.74	911	0.85	5.28			25.92	161.02	51.84	321.93
1969	1.094	12.044	269.000	100.27	598.58	19501	17.64	105.30	23	10	10.01	59.76	127.92	763.64
1970	0.268	820.000	0.138	80.28	459.92	2165	2.37	13.58					82.65	473.50
1971	6.339	23.559	1.830	1892.93	10224.35	131558	457.68	2472.34	105	38	70.55	381.10	2421.16	13078.88
1972												125.84		
1973	0.925	3.828	0.206	293.50	1473.21	2323	23.38	117.36	9	10	25.07		341.95	1716.40
1974	0.639	2.325	0.345	316.78	1365.33	7543	24.73	106.59	18	5			341.51	1471.92
1975	0.719	5.485	0.342	358.74	1202.58	13975	183.67	615.71	24	8			542.41	1818.29
1976	4.767	20.708	1.640	1802.66	5930.75	112123	852.43	2804.50	1525	40			2655.09	8735.25
1977	1.675	3.024	0.468	210.16	642.88	487	2.38	7.28	62		0.29	0.89	212.83	651.05
1978	2.607	9.175	0.969	749.15	2296.90	18522	25.24	77.38		15			774.39	2374.23
1979	0.203	0.760	0.032	27.13	74.53								27.13	74.53
1980	1.432	8.207	1.006	970.29	2218.08	3263	23.60	53.94	5	4	419.21	958.31	1413.10	3230.34
1981	0.291	1.081	0.169											
1982	0.447	2.298	0.274	822.03	1634.20	427	5.27	10.48					827.30	1644.74
1983	0.868	1.766	0.644	34.03	62.57	472	5.34	9.82		3	1.27	2.33	40.64	74.72
1984	1.723	102.572	1.419	1305.71	2217.36	1841	250.60	425.57		25	125.56	213.23	1682.80	2857.74
1985	0.339	2.472	0.263	46.87	75.25	1742	22.31	35.82		9	28.34	45.50	97.52	156.56
1986	2.583	13.882	0.632	1646.75	2509.50	27740	90.12	137.33		4	460.88	702.34	2198.32	3350.05
1987	4.361	35.740	3.050	4877.05	6990.81	122903	6065.32	8694.09	88	424	1083.45	1533.03	12026.15	17238.39
1988	0.380	2.914	0.094	360.54	477.13	479	17.58	23.26		13	4.70	6.22	382.82	506.62
1989	0.070	0.188	0.019	9.40	11.65	307	2.82	3.50			0.94	1.16	13.16	16.31
1990	3.010	13.850	1.160	871.72	991.06	1482	26.00	29.56	55	5	88.83	101.00	986.54	1121.60
1991	1.120	4.250	0.630	97.90	97.90	1596	38.39	38.39	41	4	1.50	1.50	137.68	137.68
Average	1.568	11.290	0.653	734.74	1813.49	20493	353.81	686.40	85	27	102.02	187.53	1190.65	2687.48

Annex 8

LIST OF FLOOD CONTROL SCHEMES IN KIUL HAROHAR RIVER SYSTEM

Sl No	Name of Scheme	Estimated cost Rs Lakh	Status
	EMBANKMENT SCHEME		
1	New Sakri Embankment Scheme	185.0	Proposed
2	Kiul Embankment Scheme	180.0	Proposed
3	Panchane Embankment Scheme	90.0	Proposed
4	Barahiya Tal ring band Scheme	296.10	Proposed
5	Scheme for road dowel from Lakhisarai to Sahebganj	500.00	
6	Repair of existing Sakri Embankment	30.00	Completed
7	Flood protection work in Falgu basin from Khizirsarai to Daniawan	2774.84	Proposed
	DRAINAGE SCHEME		
1	Mokama Tal Drainage Phase-I	64.53	Proposed
2	Mokama Tal drainage Phase-II	272.95	Proposed
3	Mokama Tal drainage Phase-III	496.21	Proposed
	RESERVOIR SCHEME		
1	Upper Kiul Reservoir Scheme	4130.00	Under construction
2	Barnar Reservoir Scheme	6293.00	Under construction
3	Nagi Reservoir Scheme	-	Completed
4	Makti Reservoir Scheme	-	Completed
5	Amriti Reservoir Scheme	11.17	Completed
6	Srikhand reservoir Scheme	14.84	Completed
7	Tarakol Reservoir Scheme	32.68	Completed
8	Kailashghati Reservoir Scheme	97.17	Completed
9	Morway Reservoir Scheme	-	Completed
10	Phulwaria Reservoir Scheme	2345.00	Completed
11	Lilajan Reservoir Scheme	3372.00	Proposed
12	Mohane Reservoir Scheme	12700.00	Proposed
13	Sakri Reservoir Scheme	13623.00	Completed
14	Job Reservoir Scheme	-	Completed
	ANTI EROSION SCHEME		
1	Barahiya Protection Scheme	1532.80	Proposed
2	Bhalui Anti erosion Scheme	16.90	Proposed
3	Patauna Village Protection Scheme	25.00	Proposed
4	Malipur Ramchandrapur flood protection scheme	99.17	Proposed
5	Harni flood protection Scheme	2.66	Completed
6	Khutaha protection work for 1981 floods	91.84	Completed
	OTHER SCHEME		
1	Channel Improvement	550.00	Proposed
2	Soil conservation measures	620.00	Proposed
3	Raising of villages	37.00	Proposed

Annex 9.1

EXISTING ZAMINDARI EMBANKMENTS SUITABLE TO BE TAKEN OVER BY WATER RESOURCES DEPARTMENT

Sl No	Dristrict	River	Location	Length	Remark
1	Nawada	Sakri	Left Embankment	About 4 Km	Kalyugwa Enbankment
2	Jehanabad	Falgu	Right Embankment	About 25 Km	Left embankment of Bharthu branch canal of Uderasthan Irrigation Scheme, in length of 25 Km to be resectioned for use as embankment.
3	Munger	Kiul	Right Embankment	6 Km	From Bhalui to Malya.

Annex 9.2

EXISTING ZAMINDARI EMBANKMENTS WHICH CAN BE TAKEN OVER BY WATER RESOURCES DEPARTMENT IF FOUND SUITABLE AFTER INVESTIGATION BY ADVANCED PLANNING.

Sl No	District	River	Location	Length	Remark
1	Patna/ Nalanda	Dhanahiya	Right Embankment	12 Km	From Malawa to Gopal bed and from Misiawa to Sarmera Mokama pitch road.
2	-do-	Mohane	Right & Left both Embankment	2x10 Km	From Shrinama Weir to Panshar-Hasanpur

Annex 9.3

EXISTING ZAMINDARI EMBANKMENTS WHICH ARE TD BE PRDPERLY MAINTAINED BY THE DISTRICT CDLLECTDRS

Sl No	District and Circle	River	Location	Length Km	Remark
1	Nawada	Sakri	Left embankment	4	From Barnawa Bhadai
2	Nawada	Sakri	-do-	6	From Hemdi to Hebatpur and Gopalpur
3	Nawada	Sakri	Right embankment	4	From Dariapur to Pangari Katauna
4	Nawada	Bhosaddi	Right embankment	4.5	From Palikhai to Thalikai Budhwara
5	Nawada	Tillaiya	-do-	1.5	From Sakri to Deora
6	Nawada	Dhanajay	Left embankment	1.5	From Saudapur to Panaul
7	Nawada	Dhanajay	Right embankment	2	From Tundichak to Latawar
8	Nalanda	Goithwa (west)	-do-	8	From Berote to Ammaidiya Sarai
9	Nalanda	Goithwa (west)	Left embankment	8	From Fateh Haldi to Havelli
10	Nalanda	Goithwa (west)	-do-	5	From Kumardih to Spacedih
11	Nalanda	Githwa (west)	Right embankment	14	From Chistpur to Bandi
12	Nalanda	Goithwa (east)	-do-	5	From Manoharbigha to Harganwa
13	Nalanda	Goithwa (east)	Left embankment	5	From Hargawa to Mustafapur
14	Nalanda	Goithwa (east)	Right embankment	4	From Shrichandpur to Panchetan
15	Nalanda	Jirain	-do-	-	From Manpur to Paroha
16	Nalanda	Vain	-do-	6	From Nawadin to Kottaribigha
17	Nalanda	Kumarhi	-do-	18	From Kaiwa to Dhanhiya Kirneshwar
18	Nalanda	Kumarhi	Left embankment	13	From Bahidin didhdha to Bind
19	Nalanda	Goithwa	Right embankment	10	From Damsiya to Vankita
20	Nalanda	Goithwa	Left embankment	5	from Kumardih to Sosandi

OBSERVATIONS MADE BY DR K L RAO, UNION MINISTER OF IRRIGATION AND POWER DURING HIS VISIT TO VARIOUS IRRIGATION AND POWER PROJECTS IN BIHAR FROM 8TH TO 12TH JULY, 1972.

Tal areas

14 The problem of the Tal areas stretches from Patna to Munger and no scheme has so far been finalized for this area. It is high time that we should have concentrated studies and start implementation of the projects in these areas. The following problems are connected with the Tal areas.

i The water in the Tals must be drained out for cultivation by October 15 every year.

ii Irrigation water must be made available in the Tal area after October 15 to end of June.

iii Nigar water-The drainage water of the fields in the higher lands which flow into the Tals,destroy the newly sown rabi crops after the Kharif season. Therefore, this water must be prevented from flooding the low area of the Tals.

iv The problem is aggravated by the fact that the catchment of the streams which flow into this area is more than 5,000 sq miles (1249.95 sq km) and due to inadequate outlets,the drain gets delayed which affects rabi cultivation.

The following measures suggested earlier, are repeated:

i Investigations are to be done for cutting down the amount of water that flows into the Tals. This is to be done by the constructions of storage reservoirs in the various, streams that flow into the Tals and also by the construction of embankments on the right side of the Punpun so that its water does not flow into the Tals.

ii Providing of outlet sluices on the major streams that join the Ganga like Harohar,Jirain Nalla, etc

iii These sluices will enable water to be drained from the lower areas of the Tals into the Ganga and prevent the water of Ganga at a ; igher level to flow into the same.

iv Embankments on the Harohar river on both sides will contain the river. These embankments should be provided with outlet sluices for taking water for irrigation purposes whenever so required. Thus the last three works together with some complementary drainage channels will assist reducing the inflow in the Tals and it will also be possible to drain out the water by 2nd or 3rd week of October. This can be considered as Stage I programme and should be undertaken for implementation immediately.

15 A hydraulic model has to be prepared at Patna. The Director, Poona Research Station, should send his concerned officers to help the construction of this model. It is also suggested that Prof.P Prasad of the Patna University and Prof. Chaturvedi of IIT, Delhi, may also be associated to develop the mathematical and system analysis technique for the model in order to get the proper solution. The hydraulic model should stretch from Patna to Munger and it is intended for studying flood control in the Tals.

16 For irrigation, may have suggested a canal along the Harohar river and the water always

present in the Harohar river can be utilised for this purpose. Some small belt of the Ganga Basin of the South of Ganga is highly fertile and this has to be saved from inundation and that is why in the past evidently no attention has been paid for development of this area. The problem may be studied in batches as the area streches from Patna to Bhagalpur. The area further is in a stretch of about 60 miles(96.56 km). Irrigation in this area may be studied. Irrigation may be provided by a net work of tubewells or pumping from some streams like Harohar, Dakra Nalla or from Ganga itself. The best and most economical and suitable type of irrigation programme must be drawn up for this area. It is not necessary to take up irrigation programme for the entire area mentioned above. It may be taken up in batches. One reach may be from Patna to Harohar, other from Harohar to Munger and the third from Munger to Sultanganj,and so on. All these areas must be provided with adequate drainage as the soil is sandy and water is bound to perpetuate. There are some area in the Gangetic plain which will not have so much of alluvial soil. It may contain under-lain hard rock like the middle plateau of India. These lands are still cultivable as in Palamau district, and Irrigation for these lands must be planned out. Such of the area as can be given irrigation by construction of local dams, should be planned out. But I feel there will still be quite a large extent of area which will still be not covered by command of any of the small projects. These areas must be investigated later as a part of the National Water Grid. The life required for commanding these lands is much less and the water is required for rabi season. The idle pumps will come in very handly for pumping water from the Ganga system in these areas.

17 I visited Kharagpur lake which has got about 70 sq miles (181.299 sq km) catchment area with an yield of about 80,000 acre ft (9867.84 ha m) .But the actual dam constructed can hold only 8,000 acre ft (9867.84 ha m) at the moment. Irrigation is provided in only 10,000 acres (4046.86 ha) for Kharif and 1500 acres (607.029 ha) for Rabi. The yield of the river being much more, it will be possible to irrigate many more lands. There is an excellent opportunity of doing this. The river comes out of a gorge and if it is plugged out by constructing a dam of 70 to 80 ft(21.336 to 24.384 m) high, it will be possible to further irrigate about 30,000 acres (12140.58 ha). The hydrology of this project must be studied and the levels finalized and Bihar engineers asked to send designs and estimates for construction of the storage dam. This being a very easy and economical proposition, it can be taken for construction almost immediately.

RECOMMENDATIONS DF SRI C C PATEL, SECRETARY GOI (1976)

A High level technical committee headed by Sri C C Patel,Secretary, GOI who was studying the problems of Mokama Tal inspected the site on 5th February 1976.

This Committee suggested the following measures:

Long term measures

i Construction of reservoir in the upper catchment in the river which enters the Tal area proposed to intercept 25 per cent of total catchment area

ii On the southern periphery of Tal area, a drainage channel should be constructed at higher contour so that it may collect all the inflow of rivers, coming into the Tal and drain into Ganga river

iii Soil conservation measures and contour bounding in the hills on the south of Tal area so that inflow in the Tal may be reduced

Short terms measures

i To stop inflow of Punpun river into the Tal area

ii To stop entry of Ganga water in the Tal area and early depletion of Tal the following measures suggested:

a Construction of dowel bundh between Barh and Dariyapur in the Patna-Munger Road where Ganga water overtops the roads

b To stop the flow of Ganga water through the bridges and culverts in Patna-Munger Road and construction of sluices therein

c Construction of marginal bundh from Indupur village to the confluence of Kiul-Harohar-Ganga

d Construction of anti-flood sluice in the river Harohar alongwith construction of afflux bundh. Sill level of this sluice should be such that some water can be retained in the Tal area for irrigation in the Rabi season

e Construction of 13.00 Km long embankment on the right side of Punpun river to stop back water of Ganga from entering Tal through Punpun river

f Construction of a channel on the upstream of the Kiul-Harohar confluence for discharging the flow of Harohar into Ganga directly

g 'S' loop between Balgudarghat should be made straight.

h For alround development of Tal area, Tal Development Committee should be formed.

RECOMMENDATIONS OF MOKAMA TAL TECHNICAL-CUM-DEVELOPMENT COMMITTEE HEADED BY ER N SANYAL (March, 1988)

SUMMARY OF RECOMMENDATIONS

Terms of reference no 1	To recommend on the possible schemes to mitigate the water logging problems in the Mokama Tal area.
Reference of paragraph of the report	
Para 8.2	Inundation caused by the Ganga by back flow through the Punpun as discussed in 2 (b), can be prevented by the embankment along the right bank of the Punpun and the Morhar from the rail bridge approach embankment near Fatuha to a few Km upstream upto the reach influenced by the back water of the Ganga. This right bank embankment of the Punpun and Morhar is a sanctioned project and is under execution. This back water inundation will cease, on completion of the project under execution, and hence,should be expeditiously completed.
Para 8.3	It has been noted by the committee that Road Construction Department has some reservation about the desirability of road side dowel. In case, road dowel,which should be cheaper than a separate embankment, is not found acceptable to the Road Construction Department, embankment in isolated lengths to prevent entry of the Ganga spill in the Tal area through the low lying length of the Road could be constructed.
Para 8.5	The inundation caused by the Ganga back flow through the Balgudarghat bridge over the Harohar can be eliminated by having a suitable antiflood sluice. As the drainage of the Tal occurs entirely through the Harohar caution is needed in finalising the dimensions of the water-way of the antiflood sluice,so that there is no vertical or horizontal construction of the available water-way. This sluice could be located immediately upstream of the road bridge as the bed of the river Harohar has some lengths of deepened bed immediately downstream of the road bridge. The sluice should be a barrage like structure, with a crest almost flush with the river bed and on account of high head, the gate may have to be two tiered or radial.
Para 8.7	The committe noted that some of the experts in their earlier reports had suggested that the ingress of water of these north flowing rivers could be prevented by having a West-East excavated channel, that is an artificial or man made river which shall intercept all these north flowing rivers before they enter the Tal and carry the water of these intercepted rivers directly to the river kiul at a higher level, where the Kiul shall not be flood-locked by the back water of the Ganga. The West-East dug channel shall have to be aligned along contours of higher elevation and the length of the channel shall be approximately 50 miles or 80 kms. Such a channel shall be costly but the benefits will also be enormous. Once the dug-channel is completed, alongwith the recommendation of para 8.3,8.4 & 8.5, the Tal area shall be reasonably free from inun-dation, and the only problem to be tackled would be the disposal of the rainfall in the Tal area itself, which at times may be more than the requirement of Kharif cultivation. This would mean that almost the entire Tal area of more than one lakh ha can be available for kharif cultivation as well, where as the present kharif cultivation is rather a chance crop.

Thus,the Tal area development as a kharif growing area may be a major-through in the effort of the State to expand the kharif production.

Para 8.8 and 8.10 Keeping in view the recommendations made in the Master Plan of the Ganga Flood Control Commission, the committee reviewed the possibility of using the Tal as a flood detention basin to moderate the peak flood of the Ganga. The cutting off of the flood plain storage accentuates the peak flow in the Ganga,which needs to be remedied by suitably located flood moderation detention basins. Mokamah Tal, already a chronically inundated area can be effectively used as a flood moderation detention basin. In case the scheme materialises, the cultivators in the Tal area shall have to be given prior warning of a dependable nature before such deliberate inundation and they shall have to be paid compensation for the damage due to the deliberate inundation. The modality of such compensation, that is whether it will be paid by the centre or the State and whether this can be covered by crop insurance scheme is an issue which has not gone into detail by the committee.

Para 7.6 The issue of expediting the drainage of Mokamah group of Tals by having cuts at various possible alternative sites be reviewed after the data of dependable nature be collected for some 7 to 10 years,to adjudge the technical and economic viability of each of the possible cut sites.

Para 8.13 The committee noted the availability of a fairly large range of water resistent varieties of kharif crop and the rapid pace in which new varieties are being introduced and felt that the Tal area should be classified in different zones with relative degree of proneness and magnitude of inundation so that the specific variety which would be most suited to the specific characteristics of a particular zone could be introduced there through demonstration plots and other extension services.

Terms of reference no 2 To recommend about irrigation schemes to provide irrigation facilities in the Mokama Tal area.

Reference of Paragraph of the report

Para 5.10 State tube-wells are considerably under utilised,possibly due to the reason,that most of these tube wells are unenergised or are idle due to theft of transformers and inadequate power supply. However few tube wells show significantly good results having encouraging figures of irrigation during different crop seasons to indicate the existence of suitable acquifer underneath, pointing the possibility of formulation of further programme of irrigation in this area. To solve the difficulties in unsatisfactory functioning of those tubewells, greater attention to maintainance and provision of dedicated power line seem to be necessary.

Para 5.12 So far as private tubewells are concerned,their availability will depend on the socio-economic condition of the farmers and their performance will vary with respect to its capacity etc. Their use will depend on the likely return from the crop besides the operating costs etc. However,private tubewells are largely in vogue in this area as shown in Table 8.1. The few private tubewell that were surveyed and data put up to the committee show that they have got a very encouraging performance in the area and hence, it must from a part of future planning. Other sources of irrigation like river pumps. etc have got very encouraging performance in the area and hence, it must from a part of future planning. Other sources of irrigation like river pumps. etc have got very limited areas of operation and hence, it may not be of much significance for the planning for the whole area.

Para 10.5 The area of the Tal north of the Harohar can also be irrigated by lift irrigation from the Ganga,and such lift irrigation scheme could irrigate the high land between the Ganga and the Tal in the first reach and then the low lands of the Tal sloping down to the Harohar in the lower reaches. The channel system in the Tal for such Ganga lift irrigation schemes shall have to be judiciously planned, so as to cause least surface drainage obstruction during the wet season. The west east dug channel, if it ever materialises, can also be exploited in a similar manner for irrigation the land south of the Harohar.

Para 10.6 The committee, after careful consideration, came to the conclusion that with ground water and Ganga water being available for irrigation water would not be a constraint in development of irrigated agriculture in the Tal area. The need for power and the cost of the erection of the infrastructure would however be considerable, and depending on availability of state resources,irrigation in Tal can be developed in stages over a reasonably spread out period.

Para 10.8 Keeping in view all these factors, the Committee did not favour any sluice across the Harohar for irrigation purposes and felt that the recommended antiflood sluice near Balgudarghat should not be misused for retaining water in Tal, which may bring in conflicting interest of cultivators of lower land and cultivators of upper land and adversely affect the regime of the river Harohar.

Terms of reference no 8 Development aspects in Mokama Tal Area

Reference of Paragraph of the report

Para 11.2 A doubt was raised as to whether prevention of ingress of the Ganga spill would not reduce the fertility of the Tal,as it would be deprived of the silt brought by the Ganga. In this context the committee noted that after centuries of ingress of the Ganga water and so called deposit of silt on the low land of Tal,the Tal still continues to be a depressed land,indicating that the deposition of fertilising silt must be microscopic in nature as otherwise the Tal should have been filled up as a level land by now. Possibly the effect of silt deposit is confined to the fringe area where the incoming silt gets deposited. The fertilising benefit of this small quantity of silt that might be there shall have to be compensated by natural and artificial fertiliser, like any other inundated area which is made flood free for better agriculture.

Para 11.3 Some apprehension was expressed before the Committee that reduced inundation may enhance the problems of insects and pests in the Rabi season, adversely affecting the crop. This aspect need further expert study to evaluate the validity of such apprehension,but it was felt that this problem can be suitably tackled with judicious agricultural practice,proper selection of type of crop and use of appropriate doses of insecticides and pesticides

Para 11.4 If the development of intensive irrigated Rabi and Hot weather agriculture is to be achieved after the engineering measures provide the necessary infrastructure, it will be necessary to bring in equitable distribution of land by (1) strict impostion of land ceiling rules and (b) by vacating unauthorised encroachment of Govt land by the influential people and (c) distributing the surplus land thus available to landless labourers in economically viable plot sizes.

Para 11.5 a Better communication system in the Tal area should be developed, but at the same time, care should be taken that new roads are provided with adequate waterways to permit free passage of Tal water during wet season.

b The mobility of the local officers and their functioning can be improved upon by suitable telecommunication or fast moving vehicles so that social and economic exploitation of the weaker section of the people is effectively guarded against.

Para 11.6 As these villages are likely to be marooned almost every year, suitable deep tubewell drinking arrangement, permanent grain storage arrangement and stock of essential medicines have to be planned as in disaster prone areas. The Tal administration should have low draft stable power boats for patrolling and relief during as a flood detention basin, as suggested elsewhere in the report, the village must have dependable flood warning facility.

Para 11.7 As the agriculture development in the Tal would depend on extension services, marketing and storage facility and growth of agro-based industries, a Tal development authority has to be developed, to do the function of the Command Area Development Authorities in a more meaningful manner.

Para 11.8 As the measures suggested for the Tal would bring in basic improvement in the productivity of land and quality of life and would be needing considerable investment, some sort of betterment levy can be imposed in the Tal apart from the irrigation charge, so that some part of the investment may be realised from the beneficiaries.

Para 11.9 If future studies indicate that vertical draining of the Tal to the lower acquifer shall benefit the neighbouring acquifer in a tangible manner,then this could be taken up as a programme of charging the acquifer, for subsequent ground water exploitation,and any benefit that thus would be occurring to the Mokama Tal being of a secondary nature.

Annex - 13

बिहार विधान परिषद की टाल क्षेत्र विकास समिति का प्रतिवेदन
(1988-89) दिनांक 27 जुलाई, 1988

अनुशंसायें

1 परिशिष्ट - 2, 3 एवं 4 के लिए आठवीं पंचवर्षीय योजना में प्रावधान करना एवं उसे युद्ध स्तर पर कार्यान्वित करना।

उपर्युक्त योजनाओं के कार्यान्वयन के लिए केन्द्र सरकार एवं विश्व बैंक से नकद लेना।

2 पूरे टाल क्षेत्र के सर्वांगीण विकास की योजनायें बनाना तथा उसे कार्यान्वित करने के लिये टाल विकास प्राधिकरण का गठन करना।

3 पूरे टाल क्षेत्र को सामाजिक एवं शैक्षक दृष्टि में पिछड़ा घोषित कर संविधान के अनुच्छेद 15 (4) के अन्तर्गत उनके पिछड़ेपन के निवारण के लिये विशेष उपबंध करना।

4 17 स्लूइस गेटों की मरम्मति युद्ध स्तर पर करायी जाय एवं इस कार्य के लिये विभाग के द्वारा आवंटित राशि को जिस पदाधिकारी ने दूसरे मद में खर्च किया, उस पर अविलम्ब कार्रवाई की जाय।

5 पूरे टाल क्षेत्र की कई हिस्सों में विभक्त कर एक–एक हिस्से को एक बार पूर्णतः सिंचित करने की व्यवस्था की जाय।

6 टाल क्षेत्र के किसानों को निजी नलकूप लगाने के लिए शत–प्रतिशत सबसिडी का प्रावधान किया जाय।

7 41 उद्वह सिंचाई परियोजनाओं को अविलम्ब चालू करना एवं उन परियोजनाओं को अपूर्ण छोड़नेवाले पदाधिकारियों पर कार्रवाई की जाय।

8 सरमेरा मोकामा पथ का अविलम्ब पुर्ननिर्माण एवं तकनिकी दृष्टि से दोषपूर्ण पथ निर्माण करनेवाले पदाधिकारियों के ऊपर शख्त कार्रवाई अपेक्षित है।

9 पाली टाल के पास हरोहर नदी पर पुल का निर्माण करना।

10 परिशिष्ट (1) के अकार्यान्वित अनुशंसाओं को अविलम्ब कार्यान्वित करना।

रमेश प्रसाद सिंह 15.7.91
लक्ष्मी देवी, स०वि०स०
विभूति कवि
स्टेनशीला हेम्ब्रम
ब्रजकिशोर सिंह, स०वि०स०

(परिशिष्ट - 1)

अनुशंसायें

जल संसाधन विभाग, लघु सिंचाई विभाग, लोक–निर्माण विभाग, कृषि विभाग एवं ग्रामीण अभियंत्रण संगठन विभाग के पदाधिकारियों, जिलाधिकारियों तथा टाल क्षेत्र के प्रमुख किसानों से विचार विमर्श के पश्चात् जो तथ्य सामने आये, उनके आलोक में समिति निम्नलिखित अनुशंसायें करती है :–

1 सिंचाई के लिये दीर्घकालीन योजना बनाना।

2 केन्द्र सरकार, विश्व बैंक एवं नवार्ड की मदद से राज्य सरकार पूरे क्षेत्र के सर्वांगीण विकास की कार्रवाई करे।

3 सिंचाई के लिये अल्पकालीन योजनायें बनाकर किसानों को तुरंत सिंचाई के लिये जल उपलब्ध कराया जाय ताकि गरमा फसल की पैदावार की सुविधा उन्हें प्राप्त हो सेक। जैसे उद्‌वह सिंचाई योजना के अन्तर्गत गंगा नदी का पानी सिंचाई के लिये उपलब्ध कराया जा सकता है। साथ ही साथ हरोहर नदी एवं अन्य सहायक नदियों पर उद्‌वह सिंचाई योजना के अन्तर्गत डिजल एवं विद्युतचालित पम्पिंग सेट बैठाकर किसानों को सिंचाई की सुविधा प्राप्त की जाय।

4 41 उद्‌वह सिंचाई परियोजनायें जो अभी तक चालू नहीं है, उन्हें अविलम्ब मरम्मती कर चालू करना।

5 तटबंध का निर्माण करना, जिससे सड़क के रूप में भी इस्तेमाल कर लाभ उठाया जा सकता है।

6 भारी संख्या में स्लुईस गेट का निर्माण करना। क्षतिग्रस्त स्लुईस गेट की पुनः मरम्मती एवं पुनिर्माण कर उन्हें चालू करना। साथ ही साथ सभी स्लुईस गेटों में लोहे के फाटक का इस्तेमाल करना।

7 रिंग बांध का निर्माण कर भू–खंडों को खरीफ फसल के खेती के योग्य बनाना।

8 हरोहर नदी की मिट्टी को काटकर उसे गहरा करना एवं उसके पाट को चौड़ा करना।

9 पैन एवं नदियों की सफाई।

10 अलंग एवं बांध पर मिट्टी देने का कार्य करना।

11 राजकीय नलकूपों का जाल बिछाकर किसानों को सिंचाई की सुविधा उपलब्ध कराना।

12 निजी नलकूपों के लिये किसानों को प्रोत्साहित करना तथा निजी नलकूप लगाने के लिये किसानो को सुलभ दर पर ऋण उपलब्ध कराना एवं उपर्युक्त सबसिडी देना।

13 नबार्ड की मदद से किसानों को ऋण उपलब्ध कराना।

14 भागलपुर, साहेबगंज एवं भोजपुर स्थित टाल क्षेत्र के विकास के लिये छोटी–छोटी योजनायें बनाना।

कृषि विकास के सम्बन्ध में अनुशंसायें –

1 टाल क्षेत्र में कीड़ों से फसल की सुरक्षा हेतु कीटनाशक दवाओं के हवाई छिड़काव की व्यवस्था करना।

2 उन्नत किस्म के बीज, खाद एवं कीटनाशक दवाओं को समय पर उपलब्ध कराना एवं उसके कार्यों के लिये सहकारिता बैंक एवं अन्य राष्ट्रीयकृत बैंकों के द्वारा सुलभ दर पर ऋण उपलब्ध कराना।

3 भूमि सुधार संबंधी कानूनों की सख्ती से लागू करना।

4 कृषि विभाग के लिये बजार, भंडारण की सुविधा प्रदान करना एवं कृषि पर आधारित उद्योग का निर्माण करना।

5 तरह–तरह के विकास की योजनायें चलाकर मजदूरों को रोजगार देना।

कुछ फौरी कर्त्तव्य –

1 सरमेरा–मोकामा पथ को अविलम्ब मरम्मती एवं उसे चालू करना।

2 क्यूल नदी का मुंह भर जाने से टाल क्षेत्र के जल निस्तार में कठिनाई हो रही है। उसकी अविलम्ब सफाई।

3 हेमजा डुमरा के पास सड़क पर बने पुल को बन्द कर दिया गया है, जिसके कारण पानी के निस्तार में कठिनाई हो रही है। इसलिए उसमें स्लुईस गेट लगवाने की दिशा में शीर्घ कार्रवाई।

4 जलालपुर एवं पंचमहला गांव के पास टाल क्षेत्र में पानी की निकासी के लिये ह्यूम पाईप पुलिया बनाया गया था, परन्तु वह क्षतिग्रस्त हो गया। इसकी मरम्मती के लिये अविलम्ब कार्रवाई।

5 बढ़हिया–मोकामा पथ के 59 वें मील में 20 फीट के तीन रपैन वाले लघु पुल को भरकर मकान बना लिया गया है। इसलिये उस अतिक्रमण को यथाशीघ्र हटाकर पुनः पुल के निर्माण की कार्रवाई। इसी तरह शेरपुर एवं मरांची गांव में भी पुल है इसे भी अतिक्रमण करके मकान बना लिया गया है। अतिक्रमण को हटाकर इसे भी चालू करना आवश्यक है।

6 समयागढ़ के अपूर्ण रिंग बांध को चारों तरफ से मिट्टी देकर अविलम्ब पूर्ण करना।

पर्यावरण एवं वानिकी

1 पर्यावरण एवं वानिकी की आवश्यकता को महसूस करते हुए तुरंत वृक्षारोपण की कार्रवाई करना तथा सुलभ शौचालय का निर्माण करना।

जांच एवं कार्रवाई –

1 जो स्लुईस गेट 1967 के बाद बनाये गये थे, उन्हें अभी तक चालू नहीं किया गया है। इस संबंध में सरकार को विभागीय जांच कर जिम्मेवारी निश्चित करनी चाहिये कि उसके लिये दोषी पदाधिकारी कौन हैं और उन दोषी पदाधिकारियों के विरूद्ध उचित कार्रवाई अपेक्षित है।

2 उद्वह सिंचाई योजना निमित पम्पिंग सेट्स जो आज तक चालू नहीं हुए हैं वह भी विभागीय शिथिलता का द्योतक है। इस संबंध में भी जबावदेही निश्चित कर कार्रवाई अपेक्षित है।

3 उपर्युक्त संख्या में अस्पतालों का निर्माण करना एवं कार्यरत अस्पतालों में चिकित्सकों की सेवा का सही उपयोग करना तथा जीवनदायी दवाओं को उपलब्ध कराना।

4 फसल रक्षा के लिये पुलिस की गश्ती की व्यवस्था, थाना एवं चौकियों का निर्माण करना।

5 चापाकल एवं गहरे ट्यूबवेल लगाकर पेयजल की सुविधा उपलब्ध करना।

6 आवश्यकतानुसार नाव की सुविधा उपलब्ध करना।

7 उपर्युक्त सभी अनुशंसाओं को लागू कराने के लिये टाल विकास प्राधिकरण का गठन करना आवश्यक प्रतीत होता है ताकि उपरोक्त क्षेत्र का सर्वांगीण विकास हो सके।

दिनांक 24 जून, 1988

(ह०) रमेश सिंह, स०वि०स०
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Annex 14

LIST OF RESERVOIR/IRRIGATION SCHEMES IN KIUL-HAROHAR BASIN
(A) LIST OF COMPLETED (FULLY OR PARTIALLY POTENTIAL CREATED) SCHEMES

Sl No	Basin No	Name of Basin	Name of Scheme	C E thousand ha	CCA	Potential Envisaged thousand ha	Potential Created thousand ha
1	2	3	4	5	6	7	8
1	10	KIUL HARO	Phulwaria	Patna	9.55	6.60	6.60
2	,,	-HAR,	Panchanne Weir	,,	10.00	16.45	16.45
3	,,	,,	Bharthunandan Weir	,,	4.80	2.83	2.83
4	,,	,,	Goithwa Weir	,,	15.00	-	-
5	,,	,,	Sansi Weir	,,	0.23	0.42	0.42
6	,,	,,	Paimar Barrage	,,	9.00	8.00	8.00
7	,,	,,	Ghora Katotra Reservoir	,,	0.58	-	-
8	,,	,,	Gulsakri Weir	,,	0.40	0.72	0.72
9	,,	,,	Kulti Weir	,,	2.80	3.35	3.35
10	,,	,,	Gokhula Scheme	,,	1.40	1.42	1.42
11	,,	,,	Baglati Scheme	,,	0.60	0.28	0.28
12	,,	,,	Mahabodhi Weir	,,	2.40	2.55	2.55
13	,,	,,	Nitane Weir	,,	0.60	1.60	1.60
14	,,	,,	Kadhar Weir	,,	0.80	1.13	1.13
15	,,	,,	Mahugain Weir	,,	1.20	1.78	1.78
16	,,	,,	Purain Weir	,,	-	0.17	0.17
17	,,	,,	Sakari Weir	,,	33.00	25.20	25.50
18	,,	,,	Job reservoir	,,	-	3.24	3.24
19	,,	,,	Kol Mahadeo Reservoir	,,	-	0.72	0.72
20	,,	,,	Sirnawa Weir	,,	-	2.63	2.63
21	,,	,,	Mahmudda Weir	,,	1.44	1.71	1.71
22	,,	,,	Upper Kiul Reservoir	Deoghar	14.00	14.80	12.00
23	,,	,,	Kailashghati Reservoir	,,	1.14	1.20	1.20
24	,,	,,	Tarakol Reservoir	,,	0.26	0.25	0.25
25	,,	,,	Lower Kiul Reservoir	,,	31.30	25.91	25.91
26	,,	,,	Bajan Reservoir	,,	-	0.97	0.97
27	,,	,,	AmritiReservoir	,,	0.80	0.43	0.43
28	,,	,,	Shrikhand Weir	,,	0.52	0.77	0.77
29	,,	,,	Gidheshwar Pyne	,,	-	6.47	6.47
30	,,	,,	Kaurihari Weir	,,	4.04	11.65	11.65
31	,,	,,	Nakti Reservoir	,,	2.83	2.83	2.83
32	,,	,,	Nagi Weir	,,	1.20	5.02	5.02
33	,,	,,	Kundghat Weir	,,	n a	1.61	1.61
34	,,	,,	Morwe Reservoir	Deoghar/ Bhagalpur	4.60	4.89	4.89
35	,,	,,	Baskund Reservoir	,,	-	1.00	1.00
36	,,	,,	Uderasthan Weir Patna	-	24.89	24.89	

Annex 14 contd.

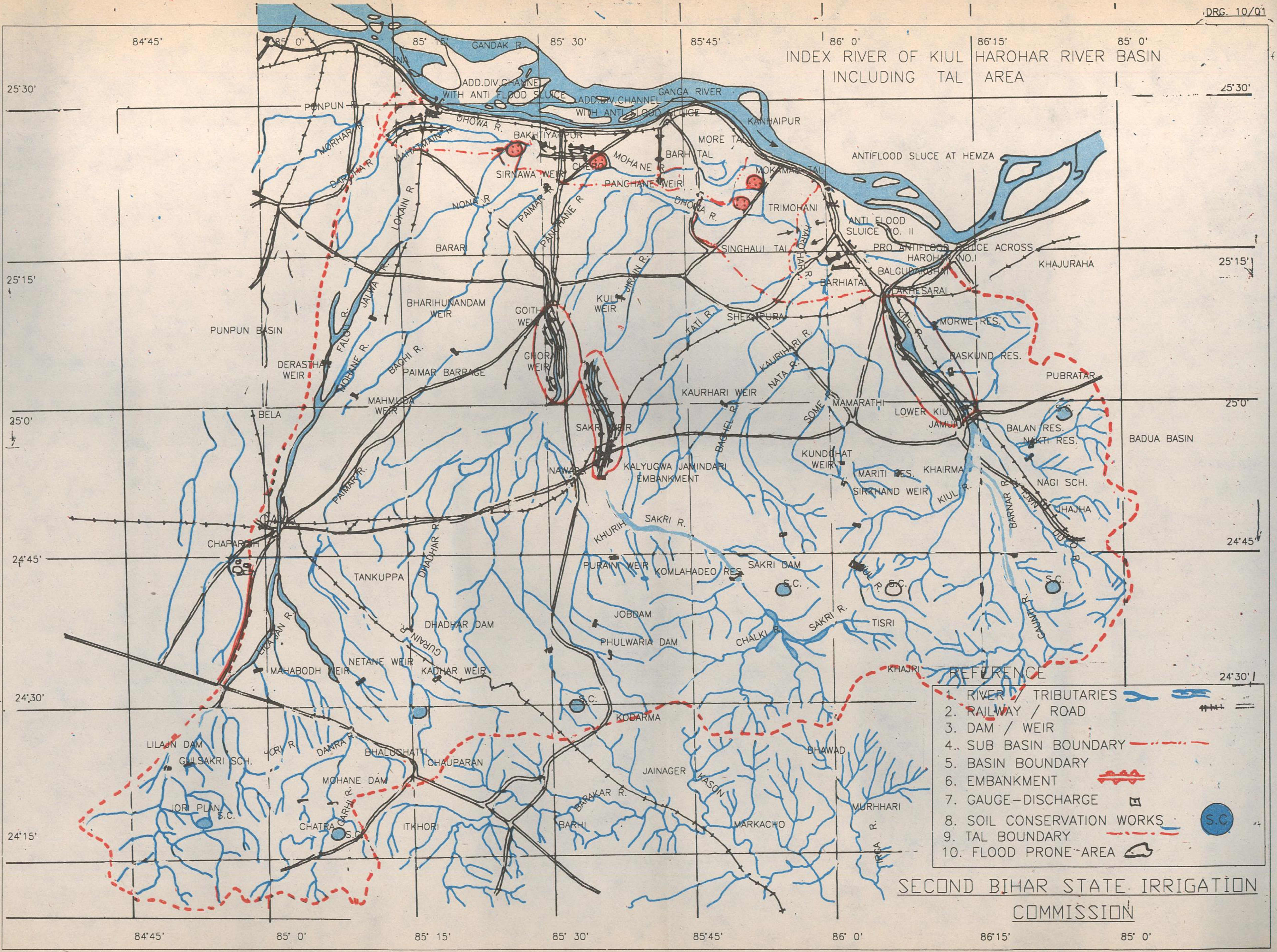
LIST OF RESERVOIR/IRRIGATION SCHEME UNDER EXECUTION IN KIUL-HAROHAR BASIN

Sl no	Name of Basin	Name of Scheme	Chief Engineer	C C A in 1000 ha	Potential Envisaged in 1000ha
1	2	3	4	5	6
1	Kiul-Harohar Basin	Barnar Reservoir	Deoghar	20.89	19.20
2	-do-	Upper Kiul Reservoir	Deoghar	16.18	14.80
3	-do-	Tilaiya Diversion	Patna	35.22	48.60

Annex 14 (cond)

PROPOSED RESERVOIR/IRRIGATION SCHEME IN KIUL HAROHAR BASIN FOR VIIITH PLAN

Sl No	Name of Basin	Name of Scheme	Chief Engineer	Potential Envisaged in thousand Hactare
1	2	3	4	5
1	Kiul-Harohar	Upper Sakri Reservoir	Patna	77.67
2	Kiul-Harohar	Kundghat	Deoghar	2.05
3	Kiul-Harohar	Mohane Reservoir	Patna	76.23


DRG. 10/01
INDEX RIVER OF KIUL HAROHAR RIVER BASIN
INCLUDING TAL AREA
GANDAK R.
GANGA RIVER
ADD.DIV.CHANNEL WITH ANTI FLOOD SLUICE
ADD.DIV.CHANNEL WITH ANTI FLOOD SLUICE
KANHAIPUR
PATNA
PUNPUN R.
MORHAR R.
DHOWA R.
BAKHTIYARPUR
MORE TAL
BARH TAL
MOHANE R.
ANTIFLOOD SLUICE AT HEMZA
MOKAMAH TAL
SIRNAWA WEIR
CHERO
PANCHANE WEIR
TRIMOHANI
ANTI FLOOD SLUICE NO. II
DARDHA R.
LOKAIN R.
NONA R.
PAIMAR R.
PANCHANE R.
DHOWA R.
SINGHAUL TAL
HAROHAR R.
PRO ANTIFLOOD SLUICE ACROSS HAROHAR NO.I
BALGUDAR
KHAJURAHA
BARAR
BARHIATA
LAKHISARAI
JALWA R.
BHARIHUNANDAM WEIR
KUL WEIR
GOITHA WEIR
PUNPUN BASIN
FALGU R.
TATI R.
SHEKHPURA
KIUL R.
MORWE RES.
BACHI R.
GHORA WEIR
KAURIHARI R.
BASKUND RES.
DERASTHAN WEIR
MOHANE R.
PAIMAR BARRAGE
NATA R.
PUBRATAR
MAHMUDA WEIR
KAURHARI WEIR
SOME R.
MAMARATHI
LOWER KIUL
JAMUI
S.C.
BELA
SAKRI WEIR
BALAN RES.
NAKTI RES.
BADUA BASIN
BACHEL R.
KUNDGHAT WEIR
NAWADA
KALYUGWA JAMINDARI EMBANKMENT
MARITI RES.
KHAIRMA
PAIMAR R.
SIRKHAND WEIR
KIUL R.
NAGI SCH.
BARNAR R.
JHAJHA
SAKRI R.
KHURIH
CHAPARGIH
DHADHAR R.
PURAIN WEIR
KOMLAHADEO RES.
SAKRI DAM
S.C.
KIUL R.
S.C.
S.C.
TANKUPPA
JOBDAM
GAUNTI R.
CHALKI R.
SAKRI R.
TISRI
DHADHAR DAM
GURAIN R.
PHULWARIA DAM
LILAJAN R.
MAHABODH WEIR
NETANE WEIR
KADHAR WEIR
KHAJRI
S.C.
KODARMA
LILAJN DAM
JORI R.
DANRA R.
BHALUGHATTI
BHAWAD
GULSAKRI SCH.
CHAUPARAN
JAINAGER
MASON
MOHANE DAM
BARAKAR R.
MURHHARI
JORI PLAN
S.C.
GARHI R.
CHATRA
S.C.
ITKHORI
BARHI
MARKACHO
IRGA R.
REFERENCE
1. RIVER / TRIBUTARIES
2. RAILWAY / ROAD
3. DAM / WEIR
4. SUB BASIN BOUNDARY
5. BASIN BOUNDARY
6. EMBANKMENT
7. GAUGE-DISCHARGE
8. SOIL CONSERVATION WORKS
S.C
9. TAL BOUNDARY
10. FLOOD PRONE AREA
84°45'
85° 0'
85° 15'
85° 30'
85°45'
86° 0'
86°15'
85° 0'
25°30'
25°15'
25°0'
24°45'
24°30'
24°15'
SECOND BIHAR STATE IRRIGATION
COMMISSION

APPENDIX 11

GANGA MAIN STEM

AT A GLANCE

PLAN FOR FLOOD MANAGEMENT IN THE MAIN GANGA STEM RIVER BASIN (IN BIHAR)

I	**Salient Features of the Basin**		
	1	Total Drainage Area	1,36,970 Sq Km
	2	Drainage Area in Bihar	16,900 Sq Km
	3	Population in Bihar	137.44 Lakh
	4	Water Resources -(Surface water)	5544 MCM
	5	Average Annual Rainfall (in Bihar)	1152 mm
	6	Total Length of Main River	2,525 Km
	6	Total Length of Main River (in Bihar)	445 Km
	7	Cropped Area In Bihar	10,333 Sq Km
II	**Flood Damage (Average for 25 Years 1968-92)**		
	1	Total Area Affected	2.94 Lha
	2	Cropped Area Affected	1.14 Lha
	3	Damage to Crops	Rs 4044.00 Lakh
	4	Total Damage	Rs 5084.97 Lakh
	5	Human Lives Lost	15 Nos
	6	Cattle Heads Lost	183 Nos
	7	Average population Affected (Average of 1980-92)	14.466 Lakh
III	**Progress of Flood Protection Measures (1954-92)**		
	1	Length of Embankments	612.23 Km
	2	Towns/Villages Protected	4/2 Nos
	3	Areas Protected	4.30 Lha
	4	Total Expenditure (1954-92)	Rs 10,937 Lakh
IV	**Eighth Plan Proposal (1992-97)**		
	1	Length of Embankment	98 km in the State
	2	Additional Area to be benefited by Flood Control, Drainage and Anti Waterlogging Measures	1.00 Lha in the State
	3	Total Outlay for Flood Control Measures in the State	Rs 35,230 Lakh

AN APPROACH TO PROBLEMS OF FLOOD AND DRAINAGE CONGESTION AND REMEDIAL MEASURES IN THE MAIN GANGA STEM RIVER BASIN (IN BIHAR)

1 INTRODUCTION

1.1 The Ganga Sub-basin which extends over an area of 8.614 lakh Sq Km within India is the largest river basin in the country and is a part of the main Brahmputra-Meghna/Ganga river basin. Flat terrain, high intensity of rainfall and poor drainage conditions combine to cause flooding and drainage congestions almost every year in a large part of this sub-basin,particularly in the portions lying in the Eastern Uttar Pradesh and Bihar. The flood damage in this sub-basin accounts for a major part of the total flood damage of the country.

1.2 The State of Bihar is situated in the central portion of the Ganga sub-basin. The portion lying on the northern side on the left bank is known as North Bihar and that lying on the Southern side lying on the right bank is known as South Bihar. The northern region and some portion, adjacent to the river Ganga, have very flat topography and are subject to serious flooding almost every year. A number of major tributaries like the rivers Ghaghra, Gandak, Bagmati, Kosi, Mahananda etc, which originate from the Himalayas join the river Ganga on the left bank and the rivers Karmnasa, Sone, Punpun, Kiul-Harohar Badua, Chandan etc which originate from plateau region join it on the right bank.

1.3 The major left bank tributaries like the Ghaghra, the Gandak, the Bagmati, the Kosi, the Mahananda etc flow through a considerable length in Nepal and a large part of their catchment falls in the glacial regions of the great Himalayas. These are snowfed and hence perennial. The major right bank tributaries like Karmnasa, Sone, Punpun, Kiul Harohar etc are rainfed rivers and are not perennial They carry heavy discharge during rainy season.

1.4 Floods and droughts are regular features in the State of Bihar due to vagaries of climate and rainfall. While one part of the state is under the grip of severe floods due to excessive rainfall, the other part suffers drought due to poor rainfall.

1.5 Floods have caused devastations and acute human sufferings too frequently since the down of civilisation and the man has had to live with floods since his existence. The impact of floods was not perhaps felt to the same extent in the past as is felt now. This was due to the fact that much smaller number of people were living and pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem has been accentuated due to ever increasing encroachments on the flood plains by the growing population to meet its requirements of food and fibre. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements have also caused changes in river regime. All these have resulted in an anomalous situation where, inspite of the protection measures carried out so far in the State with an investment of Rs 611 crore (approx) and 28.34 lakh ha having been afforded reasonable degree of protection, the flood damages have gone on increasing instead of decreasing.

2.0 THE MAIN GANGA STEM BASIN

2.1 The Ganga – It may be a revealation to many that the Ganga is not known by this name either at its source or its mouth. In its initial stage, up to Devprayag, the river is known as Bhagirathi. At Devaprayag, another hilly stream the Alaknanda joins it; from this point, the combined stream is known as the Ganga. Bhagirathi rises at the Gangotri glaciers in the Uttar Kashi district of Uttar Pradesh at an elevation of 7016 m. After flowing nearly 250 km through hilly terrain, it debouches into the plains at Rishikesh which is about 30 Km upstream of Hardwar, an important and renowned religious centre. Beyond Hardwar, the river flows over the fertile plains of Uttar Pradesh and receives the Ramganga on its left bank before touching Allahabad. At Allahabad, it is joined by the Yamuna on its right bank. The Chambal, the Betwa and the Ken are the principal streams flowing into the Yamuna and they drain considerable areas of Madhya Pradesh and Rajasthan. After Allahabad, the river travels for another 245 Km to Varanasi, a well known pilgrim centre during which course, it receives the Tons from the south. The Gomti joins it immediately downstream of Varanasi on the left side. The Ganga thereafter, flows in almost eastern on direction. A right bank tributary, the Karmnasa joins the Ganga near Chausa from right side. From Chausa to the confluence of Ghaghra, the river Ganga forms the boundary between the States of Bihar and Uttar Pradesh. A small tributary namely Kao joins the Ganga near Buxar on the right side. Between Buxar and Ara two small tributaries namely the Dharmawati and the Gangi join the Ganga on right side. A major tributary, the Ghaghra, joins the Ganga near Chapra on the left side. The river Sone joins it near Koelwar on right side. Another small tributary, the Mahi, joins the Ganga upstream of Sonepur on left side. The river Gandak, joins the Ganga near Hajipur on left side. Below this, the river Punpun joins the Ganga near Fatuha on right side and another small tributary, the Baya joins the Ganga near Bachhwara from left side . The river Ganga travels from west to east almost in full length in Bihar and joind by the river Kiul-Harohar below Surajgarha on right side and Burhi Gandak near Khagaria on left side. A small tributary, the Belharna joins the Ganga from right side near Bariarpur in Munger district. The river Kosi joins the Ganga on left side near Kursela. The river Chandan, a right bank tributary, joins the Ganga near Nathnagar in Bhagalpur. Then a small tributary, the Chir joins the Ganga on right side downstream of Bhagalpur. Two small tributaries, the Bhena and the Koa, join the Ganga near Kahalgaon on the right side.

As the Ganga approaches West Bengal, it swings round the Rajmahal hills opposite Maniharighat and starts flowing almost to wards south. The river Gumani joins the river Ganga near sahebganj on the right side The right arm of the river Mahananda known as the phulhar branch joins the river Ganga on the left bank near Maniharighat. The delta of the Ganga can be said to start from Farakka in West Bengal. The river bifurcates into two parts about 40 Km below Farakka. The left arm, called the Padma, flows eastward into Bangladesh. The right arm, called the Bhagirathi, continues to flow in West Bengal and is known as the Hooghly in lower reach. The left arm of the river Mahananda joins the river Padma on left bank in Bangladesh. The river flowing as the Bhagirathi and then the Hooghly (below its confluence with Jalangi)in West Bengal outfalls into Bay of Bengal opposite Haldia port.

The total length of the Ganga river from its origin to outfall into the Bay of Bengal measured along the Bhagirathi and the Hooghly is 2,525 Km, out of which 1,450 Km lies in Uttar Pradesh, 110 Km along the Uttar Pradesh Bihar border, 445 Km in Bihar and 520 Km in West Bengal.

The main Ganga stem basin in Bihar includes the Kao river, the Dharmawati river, the Gangi river, the Mahi river, the Baya river, the Bhena river, the Koa river the areas on both sides of the river. These small tributaries directly join the main Ganga river and they do not have any significant flood problem of their own. Only a portion of the areas of the districts of East Champaran, Muzaffarpur, Vaishali, Gopalganj, Siwan, Saran, Samastipur, Begusarai, Khagaria, Buxar, Bhojpur, Patna, Munger, Bhagalpur, Godda, Sahebganj and Katihar fall into the main Ganga stem basin in Bihar. The main Ganga stem basin, therefore, comprises of the smaller catchment running along the length of the main Ganga river within the territory of State which is not included in any of the recognised river basins in the State. In addition, the following four sub-basins draining directly into the river Ganga through different smaller streams are also included in the Main Ganga Stem basin:

1 THE KOA-DHARMAWATI SUB-BASIN

This sub-basin is bounded by the Sone basin in the east, the Karmnasa basin in the West and south and the Ganga in the north.The catchment area of this sub-basin is 4,128.77 Sq Km. It drains through the Kao-Thora, the Dharmawati, the Chher, the West Gangi and the East Gangi rivers.

2 The Mahi sub-basin.

The catchment area of this sub-basin is 2507.75 Sq Km and is bounded by the Gandak basin in north and east, the Ghaghra basin in the West and the Ganga river in the south. It drains through the Mahi, the Ghoghari and the Gandaki rivers.

3 The Baya sub-basin.

The catchment area of this sub basin is 2775.68 Sq Km and Canal is bounded by the Gandak basin in the West, the Burhi Gandak basin in North and east and the river Ganga in the south. It drains through the Baya and the Ghaghra rivers.

4 The Kao-Bhena sub-basin.

The catchment area of this sub basin is 2,014.18 Sq Km. and is bounded by Rajmahal hills in the east and south, the Chir river basin in the west and the river Ganga in the north. It drains through the river Koa and the river Bhena.

The tributaries/nalas included in the aforesaid sub-basins are described briefly in the following paragraphs:-

2.1.1 The Kao-Thora River

2.1.1.1 The river Kao is a rainfed river and originates from Dhuan Kund in Kaimur hill range in Rohtas district of Bihar at Latitude 24°50'N and longitude 84°0'E. Nearly 8 Km down stream of Dhuan Kund the river splits into two branches namely the Kao and the Kudra. The major discharge of the Kao flows through the Kudra river (left channel) which ultimately joins the Durgawati river, so it has not been included in the Ganga stem. The river Kao with its little residual discharge flows down the bifurcation point and the actual catchment of the river Kao practically lies below this bifurcation. After branching, the river Kao flows in north-easterly direction and crosses the Western Main Sone Canal,about 10 Km north of Dehri, then further travelling in the same direction it crosses Sasaram-Ara highway near Bikramganj and then travels in north direction. Earlier the river Kao used to join river Ganga but with the passage of time the river bed silted up near village Sikraul which resulted in shifting of the river in westerly direction.After crossing Bhojpur distributary of the Sone Canal System and Bikramganj-Dumraon road it enters the Bhojpur district and flowing further towards west, crosses Buxar Canal near Sikraul and joins the river Thora on right bank. The catchment area of the river Kao at its confluence point with the river Thora is 518.90 Sq Km.

2.1.1.2 The river Thora originates in Bikramganj block and flowing in the north-west direction, it receives its first major tributary,the Kao on the right bank flowing further in the same direction, it receives.the Kochan on its left side. The Kochaun originates from a place south of Nokha and flowing in a length of 45 Km, drains a catchment area of 306.25 Sq Km. Thereafter it flows in the north-west direction and receives another left side tributary the Noni near Itarhi. This river Noni has a catchment area of 168.75 Sq Km and its length is 15 Km. After its confluence with the Noni the river Thora crosses the Moghalsarai Patna section of the Eastern Railway and joins the right bank of the Ganga river near Kumarpur quite close to Buxar. This river serves as escape channel for the Sone Canal System. The catchment of the river Thora included in the main Ganga stem is 1393.9 Sq Km.

2.1.2 Dharmawati River

As stated in para 2.1.1, initially the river Kao used to join the Ganga, but with lapse of time, due to siltation near Sikraul, The main course of Kao now joins the river Thora. Below Sikraul, towards the

Ganga the dead course of the river Kao is known as the old Kao and flows parallel to Dumraon branch canal and draining local catchment it crosses Buxar-Ara section of Eastern Railway and Ara-Buxar highway near Dumraon. Below this point the river Chandra, which starts from village Nenua with a name of river Bhaisaha and is fed by numerous small drains from the command area of Buxar canal and Sikraul distributary joins this river on its left bank below their confluence, the combined river is known as the Dharmawati and flows towards east . At the tail end, it is known as the Dehra river and joins the Ganga on the right bank. Total length of this river is 64 Km. The reach below Ara-Buxar road is largely affected by the floods of the river Ganga, which has resulted in silting up of its bed. The river flows almost parallel to the Ganga in major portion of its length before ultimately joining it. The catchment area of this sub basin included in the main Ganga stem in the Main Ganga Stem basin is 68.1 Sq Km.

2.1.3 Chher River

The Chher river drains the area bounded by Dumraon branch canal, Bihiya branch Canal, Raghunathpur distributary and Korath distributary . Starting near Bikramganj and running almost south to north, it crosses Ara-Buxar section of Eastern Railway near Raghunathpur and then takes a turn to east. After travelling about 10 Km, it turns to north again and crosses Ara-Buxar road. Flowing in the same direction, it outfalls into the Gaura-Bhagar Nadi of the Ganga just downstream of the confluence of the Dehra. The length of the river is 80 Km and it drains a catchment area of 681 sq Km besides functioning as escape channel for the Sone Canal system.

2.1.4 The Gangi (West) river

The river Gangi drains an area of 258 Sq Km bounded by the Bihia branch canal and Kateya distributary. It originates from Piro block and flows in almost north direction. It crosses Ara-Buxar section of Eastern Railway east of Bihiya and then after trevelling 5 Km towards east. It crosses Ara-Buxar road and again turns to north. Further flowing in this direction, it outfalls in the Gaura Bhagar Nadi of the Ganga near Salempur. The total length of this river is 41 Km. It also functions as escape channel for the Sone canal system.

2.1.5 The Banas River (East Gangi)

2.1.5.1 This river originates from Nasriganj block of Rohtas district and flows in north east direction. It drains the area lying between Ara canal and Dumraon branch canal in up stream and Ara canal and Katea distributary in the down stream. Flowing in north west direction it crosses Sasaram-Ara road near Garhani and after traversing a distance of about 4 Km it takes a turn towards north-east and crosses the Ara-Buxar section of Eastern Railway near Chandwa, West of Ara and then crosses the Ara-Buxar Road. It flows just north of Ara town and then it receives its tributary, the Kumhari on the right side.

2.1.5.2 The river Kumhari originates near village Baghi in Bhojpur district and flows in north-east direction. It crosses the Ara-Patna section of Eastern Railway and Ara-Patna road on East of Ara and joins the river Banas on north of Ara. The length of the Kumhari river is 48 Km and it drains the area lying between Ara canal and the Sone river.

After the confluence of the Kumhari and Banas, the combined river is known as the East Gangi river. Thereafter, the river flows in almost north direction and joins the Ganga on the right bank near village Ekauna. This also functions as an escape channel for the Sone Canal System. The drainage area of the river is 856.25 Sq Km and its length is 100 Km.

2.1.6 The Mahi River

2.1.6.1 The river Mahi rises from the plain field about 10 Km north east of Masrakh and about 10 Km west of river Gandak in the Saran district of Bihar. It flows in south-east direction for a length of about 10 Km and then runs in a zig-zag way close to Saran Embankment along the river Gandak upto Sangrampur, where it crosses Taraiya-Amnaur road. From here, it flows in South-West direction for some distance and then again towards south-east direction. It crosses Amnaur-Marhowrah road near Amnaur and chapra-Rewaghat road near Bheldi and is joined by the river Ghoghari near Derni Bazar.After its confluence with the Ghoghari, it turns to south and receives the river Gandaki on the right side at Sunarpatti near Shitalpur. Then it crosses Chapra-Hazipur road and Chapra-Sonepur section of N.E.Railway and turns towards east. Finally it outfalls into the river Ganga near Chitupokhar in Saran district. Its total length is 91 Km and it drains an area of 255.8 Sq Km (excluding the drainage areas of the Ghoghri and the Gandaki.) This also functions as an escape channel of the Gandak Canal System.

2.1.6.2 The river Ghoghari originates from Agarhara Karmai chaur near village Ajabinagar and flowing in south east direction it crosses Malmalia-Salempur ghat road Norhowrah branch canal, Masrakh-Sattarghat state Highway, Chhapra-Masrakh section of N.E. railway, Masrakh-Taraiya state Highway, Chhapra-Morhaurah and chapra Rewaghat State Highways before finally joining the river Mahi near Derni Bazar. The total length of the river is 95 Km and it drains an area of 932.8 Sq Km in the districts of Gopalganj, Siwan and Saran.

2.1.6.3 The river Gandaki was originally a spill channel of the river Gandak, but after construction of Saran Embankment spilling has been checked and now it drains the local catchment lying on the country side of the Saran embankment. At present it takes off near village Herapakar in 87th mile of the Saran Embankment (on the right bank of the river Gandak) and flowing towards south it crosses N H 28, Thawe-Chapra section of N E Railway, Saran Main canal, Siwan-Barauli road, and Siwan-Malmalia State Highway after which it flows in south-east direction and crosses Chapra-Malmalia road near Baniapur and is then joined by the river Dhamti on its left near village Piarauta. It flows further in south east direction and crosses Chapra-Masrakh State Highway near Negra, Chapra-Masrakh section of NE Railway Chapra-Marhowrah State Highway near Paterhi, Chapra-Rewaghat State Highway and finally outfalls into the river Mahi at Sunarpatti near Sitalpur. Its total length is 163 km and it drains an area of 568 Sq Km in the districts of Gopalganj, Siwan and Saran.

2.1.6.4 It appears that the river Dhamati was also originally a spill channel of the river Gandak as it is originating from a place quite close to Saran Embankment (on the river Gandak) near village Dewapur in Gopalganj district. Flowing towards south it crosses Gopalganj-Dumariaghat NH 28, Gopalganj-Chapra section of NE Railway near Ratan Sarai, Saran Main Canal, Siwan-Malmalia road near Basantpur and finally outfalls into the river Gandaki near village Pirauta, about 8 Km from Baniapur. The total length of this river is 71 Km and it drains an area of 212 Sq Km in the districts of Gopalganj, Siwan and Saran.

2.1.7 The Baya River

It is said that Baya river is an abandoned course of Gandak but the present structure of the river is that of a drainage channel as described below. Four numbers of small rivers off take from the four different groups of chaurs of East Champaran district. They are the Tilawe nala, the Govindganj nala, the Bengahi nala and the Nekhwa nala. The Tilawe nala joins the Govindganj nala near Rengwa chaur and after their confluence, it is known as the Dhangarha river which tails in the Sarotar chaur. The Bengahi nala also falls in Sarotar chaur. The river Raghua offtakes from the Sarotar chaur and meets the Mekhwa river near village Murmala, just before entering Muzaffarpur district beyond which it is known as the upper Baya river. It travels further in South east direction and flowing near Deosar Anti-flood sluice of the Tirhut embankment on the river Gandak it crosses the Vaishali branch canal of the Gandak canal system beyond which it is known as the lower Baya river. The length of the upper Baya is 22.8 Km. After flowing about 25 Km, it is joined by the river Jhajha near Fatehabad in Paru block of Muzaffarpur district on its left bank.It travels further in south east direction and enters Vaishali district near Saraiya village and then crosses the Haziipur-Muzaffarpur road and Hazipur-Muzaffarpur section of N E Railway between Bhagwanpur and Goraul in Vaishali district. Flowing further in the same direction,it enters into Samastipur district near ShahpurPatori at its 142rd Km and crosses the Hazipur-Bachhwara-Barauni section of NE Railway Before entering Begusarai district near Bachhwara it is joined by the river Ghaghra on its right bank after which it turns to south and joins the left bank of the river Ganga near Semariaghat. The total length of the lower Baya is 211 Km. It also functions as an escape channel for the Gandak canal system.

2.1.8 The Bhena River

About four small streams rise from the western part of Rajmahal hills near Mahagama in Godda district of Bihar and they flow in north west direction. They join each other near Dighi, near border of Godda and Bhagalpur districts and form the Bhena river after which the Bhena river flows in north westerly direction up to Ekchari and crosses the Bhagalpur -Sahebganj section of the Eastern Railway before outfalling into the river Ganga on its right bank.

2.1.9 The Koa River

About fifteen small streams rise from Rajmahal hills between Sahebganj and Mahagama in Sahebganj and Godda districts of Bihar. The streams offtaking from southern part of Rajmahal hills flow in north west and west direction and form the Dhulia river, in the Godda district which flows in north-west direction. Other streams offtaking from northern part of Rajmahal hills in Sahebganj district flow in south-West and west direction and form the Lohra river in Godda district which also flows in North-West direction. It bifurcates into two parts before entering into Bhagalpur district. The left part meets the Dhulia river at the border of Godda and Bhagalpur district and the right part meets the Dhulia river immediately after entering into Bhagalpur district. The combined river there after is called the Koa river which flows in north-west direction in Bhagalpur district. It crosses the Bhagalpur-Sahebganj section of the Eastern Railway near Kahalgaon before outfalling into the river Ganga on its right bank.

2.1.10 Origin and outfall of different tributaries included into the Main Ganga stem basin in Bihar are shown in the Table below:-

Table 1

Sl No	River	Bank L/R	Origin	Outfall	Remarks
1	Kao-Thora River	R	From the hills (south of Sasaram)	Into ganga near Kumarpur	
2	Dharmawati	R	Plain field of Bhojpur district	Into Ganga near Balua	
3	West Gangi	R	Piro Block	Into Ganga near Salempur	
4	East Gangi	R	Near Nasriganj in Rohtas district	Into Ganga near Ekouna	
5	Mahi	L	Near Masrakh in Saran district	Into Ganga near Nayagaon	
6	Baya	L	Confluence of Mekhwa and Raghwa River in East-Champaran district	Into Ganga near Simariaghat in Begusari district	
7	Bhena	R	Western part of Rajmahal hills in Godda district	Into Ganga near Ekchari	
8	Koa	R	Rajmahal hills in Sahebganj and Godda districts	Into Ganga near Kahalgaon	

L. Left side bank
R. Right side bank.

2.2 The main Ganga stem drains a total area of 1,36,970 Sq Km (13.697 million ha). Out of this, 91,631 Sq Km lies in Uttar Pradesh, 29,057 Sq Km lies in West Bengal and 16,900 Sq Km lies in Bihar. In Bihar, the Main Ganga stem covers the independent drainage areas of the Kao, the Dharmawati,the Gangi, the Mahi, the Baya, the Bhena and the Koa rivers, which directly join the Ganga and they do not have any significant problem of their own. The upper part of the sub-basin up to Hardwar and some areas in Varanasi, Munger and Santhal Pargana districts are hilly and the rest of the area lies in plains. Most of the left bank tributaries of the Ganga have their origin in the great Himalayas. They are snowfed and perennial.

2.3 The main Ganga stem basin in Bihar is bounded by the Ghaghra basin, the Gandak basin, the Burhi-Gandak basin, the Kosi basin and the Mahananda basin on the north, by the Karmnasa basin, the Sone basin, the Punpun Basin,the Kiul-Harohar basin the Belharna basin and the Gumani basin on the south, by the Uttar Pradesh portion of Ganga Ghaghra and Karmnasa basins on the west and by the Mahananda and Ganga(Bhagirathi/Hooghly) basins of West Bengal on the east.

The entire 2,525 km course of the river Ganga from source to out fall can be divided into five major sections. These sections alongwith river slopes in different stretches are indicated below:

Table 2

Sl No	Reach	Type	Length (Km)	Average slope
1	Source to Rishikesh	Mountainous	310	1 in 67
2	Rishikesh to Allahabad	Upper Plain	796	1 in 3,196
3	Allahabad to Farakka	Middle Plain	957	1 in 15,795
4	Farakka to Nabadwip	Deltaic non-tidal Plain	230	1 in 23,000
5	Nabadwip to outfall	Deltaic tidal Plain	232	1 in 24,000

The river Ganga flows in a meandering pattern in plains. The extent of meandering is shown in the following table.

Table 3

Sl No	Reach	Direct length (Km)	Length along the channel (Km)	% age of meandering
1	Balwalli to Garhmukteshwar	104	117	12
2	Garhmukteshwar to Rajghat	59	67	14
3	Rajghat to Kanpur	280	312	11
4	Kanpur to Allahabad	176	216	23
5	Allahabad to Varanasi	136	208	51
6	Varanasi to Sara	680	864	27
7	Sara to the Bay of Bengal	296	320	8

The meandering is maximum between Allahabad and Varanasi and minimum between Sara and the Bay of Bengal.

2.4 The important places of Bihar falling in the drainage area of the Main Ganga Stem basin are Buxar, Ara, Patna,Sonepur, Mokama, Barauni, Begusarai, Munger,Bhagalpur,Kahalgaon and Sahebganj.

2.5 The Gangetic Plain in India, in which the Ganga is the main river, has been built up in the process of land formation. The rivers originating from the Himalayas have played major role in such land formation process. Almost all the rivers of the Gangetic plain, which originate from the Himalayas, join the river Ganga, and bring enormous sediment with them. The sediment brought by them formed in land deltas which resulted in the meandering and braiding tendencies in the rivers leading to shifting of courses. There are many big inland deltas in the main Ganga Stem basin, known as diaras in Bihar. In Bihar, the Ganga flows almost in the plain except at some places in Munger, Bhagalpur and Sahebganj districts, which are hilly.

2.6 ECONOMICS

2.6.1 The total population of the Main Ganga Stem basin in Bihar, as per 1991 census, is 137.44 lakh which is expected to cross 170 lakh by the end of the year 2000 AD @ 23.49 per cent increase per decade. The density of population in the basin in Bihar is 813 persons per Sq Km against 497 persons for whole of Bihar. About 84.4 per cent of the population live in rural areas and 15.6 per cent in the urban areas.

(Computed on the basis of Census Report of 1991)

2.6.2 In the Main Ganga Stem basin in Bihar agriculture is the predominant occupation of the people. The Bhojpur district is famous for rice production. Patna, the capital of Bihar is situated in this basin where a good number of small scale industries are located. The Golghar, the famous store for grains, is located at Patna.

A distillery, a leather industry and Bharat Wagon Factory are located at Mokama.

An oil refinery, fertilizer plant and thermal power plant are located at Barauni and a big railway workshop and Indian Tobacco Industry are running at Jamalpur and Munger. Bhagalpur is famous for Silk, Handloom and Powerloom industries.

A 840 Megawatt Thermal Power Plant is under construction at Kahalgaon.

In addition to many multi-disciplinary educational institutions under Patna and Bhagalpur Universities, there are Engineering and Medical Colleges at Patna and Bhagalpur and Agriculture College at Sabour.

2.6.3 The following are the important highways and railways of this basin in Bihar:-

Highways

i	NH 30	Mohania- Ara- Patna- Bakhtiyarpur
ii	NH 31	Bakhtiyarpur- Mokama- Purnea- Assam
		This N.H. crosses the Ganga river at Mokama through the famous Rajendra Bridge and passes through Barauni.
iii		Patna-Hajipur-Muzaffarpur road.
		The famous Mahatma Gandhi Road Bridge over the Ganga is situated on this road.
iv		Mokama- Munger- Bhagalpur- Kahalgaon Road.

v	Buxar- Patna- Bakhtiarpur road,
vi	Buxar- Bhojpur- Babhnoul- Bikramganj Road.
vii	Bhagalpur- Dumka Road.
viii	Hajipur- Chhapra Road.
ix	Patna- Gaya Road.

Railways

i	Mugalsarai- Buxar- Ara- Patna- Mokama section (Eastern Railway Main line)
ii	Kiul-Bhagalpur- Sahebganj- Burdwan section (Eastern Railway Loop line)
iii	Mokama-Hathidah- Barauni- Samastipur section It crosses the Ganga at Hathidah through the famous Rajendra Bridge.
iv	Patna- Gaya section.
v	Bakhtiyarpur- Rajgir Section
vi	Barauni- Bachhwara- Hajipur section (Metre Gauge)
vii	Sonepur- Chapra- Gorakhpur Section (Both Metre Gauge and Broad Gauge)
viii	Sonepur- Muzaffarpur- Samastipur Section (Broad Gauge)
ix	Barauni- Khagaria- Katihar section (Broad Gauge)

Navigation

The river Ganga is navigable in Bihar. At many places ferry services exist for connecting either banks. The river is navigable upto its outfall and many small and medium sized crafts ply on the river.

Air Route

There is an aerodrome at Patna which connects Patna with Delhi, Calcutta, Lucknow, Ranchi by air traffic.

2.6.4 Prior to independence, there was no arrangement for irrigation from the river Ganga in Bihar. But at present, Chausa, Surajgarha and Dakranala pump canal schemes are providing lift irrigation facilities from the Ganga through pumps and Zamania, Bateshwarsthan and Sakarigali pump canal schemes providing lift irrigation from Ganga are in indifferent stages of Construction.

Besides these, some portion of the Main Ganga Stem basin in Bihar is irrigated by the existing Sone Canal System and Gandak Canal System.

2.6.5 Almost all the cities and towns located in the Main Ganga Stem basin in Bihar namely Buxar, Ara, Patna, Sonepur, Hajipur, Mokama, Barauni, Begusarai, Munger, Bhagalpur, Kahalgaon, Sahebganj etc. get their domestic water supply requirements from the ground water potential of the basin. Munger and Sultanganj use Ganga water also for industrial and domestic use.

2.6.6 The land use pattern in the Main Ganga Stem basin is as follows:

Table 4

Sl No	Category	Area in Sq Km	Percentage
i	Forest land	810.24	4.78 %
ii	Land under miscellaneous trees and groves	313.03	1.85 %
iii	Current fallow, other fallow and culturable waste	1909.90	11.29 %
iv	Net area under cultivation	10332.79	61.06 %
v	Barren land and permanent pastures	1103.48	6.52 %
vi	Area under non-agricultural use	2435.21	14.50 %
	Total	16904.65	100 %

Paddy, wheat, Maize, Gram, Sugarcane etc, are major crops of the basin.

3.0 GEOLOGY

3.1 The rivers of the main Ganga have their origin in the Himalayas. The mountains are said to be the cradles of their streams and rivers, which are nourished by the rains and snowmelts from the slopes and summits of the mountain range. The mountains considerably influence the nature of the climate and the pattern of the rainfall. The characteristics of a mountain system ie its mean elevation, its trend, slope and geology have dominant influence on the hydrology of the rivers which originate from it. The great mountain system of Himalayas, which towers over the great plains of India in the north, is one of the mightiest. The mountains in the Himalayan system stretch in a virtually unbroken chain as a series of more or less parallel, though sometimes converging, ranges from the Indus in the West to the Brahmaputra in the east.

The origin of the Himalayas and its geographical relation have significant bearing on the problem of flood in the main Ganga river. According to the geological concepts, it is believed that the Indian plateau moved north against Eurasia and pushed up the thick pile of geo-synclinal sediments in the Tethys, which is the name given to the long seaway between Eurasia and Indo- Africa bordered by various geo-syncline. This process of pushing up which started in Miocene times ended in Pleistocene after time interval of some 20 million years.

Physiographically, the Himalayas can be divided into four well marked orographic units, almost parallel to each other as follows:

i The Sub-Himalayas or the outer Himalayas or the Siwalik range (average height from 900 to 1,200 metre and width from 10 to 50 Km).

ii The Lesser or the Middle Himalayas (average height 2,000 to 3,000 metre and the width from 60 to 80 Km),

iii The great or Inner Himalayas (average height about 6,000 metres),

iv The Tibetan Himalayas or the Trans- Himalayas (average height between 3,000 and 4,000 metre)

The origin of the main Ganga Stem is from the Great Himalayas zone. This zone shows both sedimentary and metamorphosed rocks which have been intruded by large masses of granite, probably of different ages. It consists of a lower alpine zone up to 4,900 metre and an upper snow bound zone usually above 5,000 metre. The alpine zone contains rhododendron trees with crooked and twisted stems, thick shrubs with a variety of beautiful flowers and grass land.

Geologically, the main Ganga river system represents a monumental assemblage of land pieces, varying in age from pre-cambrians to the most recent, the Himalayas. The peninsular mass is the core around and upon which different acts of geological drama were staged and all have left their imprint in some form or other.

The basin, according to lithological sedimentational and tectonic history, can be divided into the following three regions:-

i The Peninsular block in the south,

ii The Young folded mountain belt in the north

iii The Ganga trough in between.

The Himalayan rivers originate from the mountains which are still young and friable. The frequency of earth-quakes due to the geological conditions of the region and relatively heavy rains in the Himalayan catchments due to the elevation and the general direction of the mountain range compared to the prevailing direction of the monsoon wind, causes frequent land slides and soil erosion. The extreme temperature variation and the friable nature of the rock in the Himalayan catchment further enhance the silt contribution from the Himalayan catchment. All these result in comparatively higher silt charge in the Himalayan rivers.

The drainage system of the Himalayas reflects its geological history. Instead of originating from the great Himalayas, as could be normally expected, the main drainages originate either in the northern plateau of Tibetan Himalayas or from the southern fans of the lesser or great Himalayas. According to the theory of " Antecedent drainage", rivers of the Ganga system were flowing, before the Himalayas in the present shape were born. Simultaneous to the mountain building process in the Himalayas, these river valleys are said to have upheaved and rejuvenated again and again. It is thus explained as per the concept of "Antecedent drainage", how some of the great rivers of this region drain not only the southern slopes of the mountains but also their northern slopes, the valley limit being much further north than the main axis of the great Himalayan range. It also explains the configuration and the enormous depth of the river Ganga, since the uplifting of the mountains and the erosion of the uplifted valleys occurred simultaneously. The theory of "river piracy" however, attributes the peculiar phenomenon of the drainage system of the Himalayas to the active headward erosion of the south flowing rivers, which eventually captured the basins of the north flowing rivers, on the other side of the main axis of the great Himalayan range. Whatever be the reason of the specific drainage system of the Himalayas, the Himalayan rivers are subject to frequent change of their course and alternations in their bed gradients which are not only caused by the differential erosion, capture of one river by another, land slips, glaciation etc but also from the earth-quakes along the belt of faulting which characterises the southern flank of the Himalayas.

3.2 The main Ganga stem basin in Bihar has mainly three types of soils such as (i) Alluvial soil (ii) calcareous alluvial soil (iii) Laterite, alluvial and red and yellow.

3.2.1 Alluvial Soil:- These soils represent the vast tracts of riverine alluvium of the Gangetic plain. Major area of the main Ganga stem has alluvial soils which is characterised by a level topography, with a general gradient of about 0.10 per cent from north-west to the south-east. The depth of alluvium is great and may extend many hundred metres. The colour of the soil ranges from pale gray, yellow to yellow brown and dark gray. The texture is generally silty loam or silty clay loam. These soils respond well to manuring and need some drainage facilities. The alluvial soils in the plains are very fertile and fit for cultivation of most of the crops.

3.2.2 Calcareous alluvial Soil:- These are alluvial soils which occur in Vaishali and Munger districts of Bihar. The main characteristic of the soil is the high content of $CaCO_3$. These soils are light coloured and their texture varies from sandy loam to loam. The p_H value of the soil is on the Alkaline side.

3.2.3 Laterite, Alluvial and Red and Yellow

These types of soils are present in the Godda and Sahebganj districts of Bihar. These are hilly regions. The colour are red and yellow and texture are loam.

4.0 HYDROLOGY

4.1 Hydrology deals with behavioural study of the waters on earth, their occurrence, circulation and distribution, their chemical and physical properties and their reaction with the environment including their reaction to living things. Engineering hydrology includes this segment of field pertaining to water management and design and operation of engineering projects for the control and use of waters.

During the monsoon, a low pressure area is normally observed in the weather map of India extending from west to east in upper half of the country, in which the gangetic plain lies. Abnormally heavy rainfall spells are generally associated with depressions or cyclonic storms moving across the various parts of India during the south west monsoon and tropical depressions which form in the Bay of Bengal during the monsoon season and travel in a north westerly direction. The western part of the catchment of the Ganga is dominated by south west monsoon season from June to September. As we advance towards the east, the period of monsoon is extended to six months ie from May to October due to inclusion of south-east monsoon from the Bay of Bengal. As such, most of the precipitation occurs in the monsoon period of May to October when about 85 per cent of the annual rainfall occurs. The intensity decreases from east to west and from north to south.

4.2 According to the norms laid down by Bureau of Indian Standards (IS-4987), one raingauge for a drainage area up to 520 Sq Km is sufficient for plains. However, if the catchment lies in the path of low pressure systems which cause precipitation in the area during their movements, the network should be denser, particularly in the upstream. In not too elevated region with average elevation one kilometre above sea level, the required network density is one raingauge station for every 260 to 390 Sq Km area. The India Meteorological Department have, however, prescribed at least one raingauge station for every 500 Sq Km of the drainage area. It also specifies that at least ten percent of such raingauge stations should be self recording in order to know the intensities of rainfall in the area. The Rashtriya Barh Ayog (RBA) has suggested this percentage to be atleast twenty per cent.

4.3 According to the norms laid down by the World Meteorological Organisation (WMO), the following densities for raingauge stations are required:

Sl No	Type of terrain	Density Required (one station For)	
		Ideal	Acceptable
1	Flat regions of temperate, mediterranean and tropical zones	600-900 Sq Km	900-3,000 Sq Km
2	Mountainous regions of temperate, mediterranean and tropical zones	100-250 Sq Km	250-1,000 Sq Km
3	Arid and polar zones	1,500-10,000 Sq Km	Depending on the feasibility

4.4 According to the norms laid down by Bureau of Indian Standerds (IS-4987),there should be 32 raingauge stations in the catchment area (16,905 Sq Km) of the Main Ganga Stem basin in Bihar. Against this, there are 30 raingauge stations maintained by IMD Data for 18 such stations are available for reasonable period. The Water Resources Department of the State Government are proposing to install more raingauge stations having sufficient number of self-recording stations.

4.5 Rainfall data of the aforesaid raingauge stations maintained by IMD were collected and analysed by the Ganga Flood Control Commission while preparing a Comprehensive Plan of Flood Control for the Main Ganga Stem basin in 1990.

Rainfall normals (1901-1950) for various raingauge stations maintained by IMD are enclosed at Annex I and average annual and monsoon rainfalls of different districts lying in the basin in Bihar are shown in the statement at Annex 2.

4.6 The maximum average annual rainfall of the order of 1370.3mm occurs in Godda and Sahebganj districts and minimum annual average of the order of 1068.9mm occurs in Bhojpur district in the drainage basin of the Main Ganga Stem in Bihar.

4.7 Gauge and Discharge

4.7.1 The recommendation of the world meteorological organisation for the minimum and tolerable densities of hydrological observation stations for various geographical regions is as below:-

Table 5

Sl No	Region	Minimum Density (Sq Km/stn)	Tolerable density under different condition (SqKm/stn)
1	Flat region of temperate mediterranean & tropical zone	1,000-2,500	3,000-10,000
2	Mountainous region of temperate, mediterronean & tropical zones	300-1,000	1,000- 5,000
3	Arid and polar zones	5,000-20,000	

The existing number of hydrological observation sites in the Ganga Main Stem its tributaries (included in the Main Ganga Stem) in Bihar are indicated below:-

Table 6

Gauge-Discharge/Gauge Sites (GD/G)

Sl No	River or Tributary	Catchment area in Sq Km	No of sites required	GD/G sites maintained by		Remarks
				CWC	State Govt	
1	Main Ganga river	4,855	2-5	4/8	0/24	Sufficient
2	Dharmawati, Kao	4,129	2-4	Nil	5/0	Sufficient
3	Mahi	2,563	1-3	Nil	Nil	Insufficient
4	Baya	2,816	2-3	1/0	1/1	Sufficient
5	Bhena, Koa	2,046	1-2	Nil	0/1	Insufficient

It is apparent from the above table, that there are sufficient Gauge-Discharge sites in the Main

Ganga river, the Dharmawati and the Baya rivers in Bihar. However, atleast one Gauge-Discharge site each in the Mahi and the Bhena rivers is required to be installed for having records of historical data for use of their water potential in future.

The mode of measurment, recording of data, its analysis and study are required to be updated in order to improve the reliability of such data. A list of existing sites of the CWC and the State Government showing type and years of data availability is enclosed at Annex 3.

4.7.2 The maximum discharges, highest flood levels, danger levels etc. observed at four existing sites maintained by the CWC on the river Ganga in Bihar are given below:-

Table 7

Sl No	Location	Danger Level	H.F.L. in metre Year	Peak discharge observed in cumecs			Period of availability of Discharge Data
				Maximum Year	Minimum Year	Average	
1	Buxar	60.32	62.09 1948	59,755 1986	16,530 1979	31,835	1960-87
2	Patna (Gandhi Ghat)	48.60	50.12 1987	66,800 1978	22,088 1979	43,744	1965-86
3	Hathidah	41.76	43.15 1971	73,530 1969	33,310 1979	50,258	1948-84
4	Azmabad		32.396 1971	83,047 1971	22,781 1957	50,845	1957-87

4.7.3 The above table indicates that the years of occurence of the highest recorded flood discharges of these four sites on the main Ganga in Bihar are not the same. At Buxar, it is in 1986, at Patna in 1978, at Hathidah in 1969 and at Azmabad in 1971. This variation in the years of maximum recorded discharge in different reaches of the main Ganga river indicate that:

a The record flood at particular sites were caused by one or more flood producing tributaries above the particular sites,

b There was wide spread intense rainfall in individual years over a particular reach of the river catchment causing peak run-off in a reach, but synchronisation of peak run-offs from individual catchments, constituting the major river system had been rare.

So far other small tributaries such as kao, Dharmawati, Mahi, Baya, Bhena etc. are concerned, some gauge/ gauge-discharge sites are being maintained by State Government as indicated at Annex-3. Systematic and properly recorded data of the sites maintained by the State Government are not available. Attempts are now being made to collect and compile such data in "Water Year Book."Lot of initiative and concerted action is still required to be taken to compile such historical records in proper manner on continuous basis (instead of compiting hap ha zard and scattered data) for future use of these data. In order to satisfy the accuracy of such observations, it is suggested that in future all the sites be maintained according to the standards laid down by the WMO/ Bureau of Indian Standards and the data be observed in the prescribed manner, processed, analysed and recorded properly on continuous basis for use in the planning of water conservation and utilization schemes in the basin. The data observation procedure and method should be frequently checked by Superior inspecting officer in order to insure its accuracy.

4.8 SEDIMENT CHARACTERISTICS

4.8.1 The river Ganga functions as the master drainage channel for the plains of Bihar. Almost all the rivers of North Bihar and some of South Bihar outfall into the Ganga. The rivers of North Bihar have their origin in the hills of Nepal. During rains, these rivers carry discharges much in excess oftheir channel capacity along with huge quantities of debris and sediments from the erodible slopes of the Himalayas. On emerging from the hills, their slopes remain fairly steep which tand to become gradually flatter lower down in the plains. These in turn are associated with decrease in velocities and consequent deposition of more silt and sediments, causing aggradation of river bed, low bankful capacity resulting in frequent spills and formation of inland delta. The heavy sediment deposition on the river beds particularly in the flatter reaches reduces, the capacity of the river to carry , the flood discharge and results in flood water spilling over the banks inundating the adjoining areas. Sometimes the rivers erode their banks and destroy a large chunk of agriculture lands and villages situated on their banks.

The silt load carried by the main Ganga is the result of large contribution of silt by these lateral rivers joining it on either side of its course.

4.8.2 The CWC is maintaining four sediment observation sites on the main Ganga river in Bihar situated at Buxar, Patna, Hathidah and Azmabad. However, no such site for silt observation on this river is at present being maintained by the State Govt. The data for above four sites for the period of 1971-1987 have been analysed by GFCC. The analysis is enclosed at Annex 4.

The trend of silt recorded at these four sites in Bihar on the basis of available data for the years 1971-87 is indicated below:-

Table 8

Sl No	Month	Monthly Sediment load in million tonnes			
		Buxar	Patna	Hathidah	Azmabad
1	June	0.84	8.77	17.49	26.92
2	July	154.31	283.48	427.27	430.69
3	August	1,132.74	1,066.82	1,341.05	1,447.51
4	September	840.72	982.53	1,452.60	1,215.80
5	October	190.57	231.40	540.86	670.26
	Total	2,319.18	2,573.00	3,779.27	3,791.18

The aforesaid analysis shows that the main Ganga carries a very heavy amount of silt during monsoon months at all the above sites. It is also found that on the average, total sediment load during the monsoon months is generally increasing as we go downwards from Buxar to Azmabad. The reason behind this increase can be attributed to the huge silt carried by the lateral tributaries joining the main Ganga river between Buxar and Azmabad such as the Ghaghra, the Gandak, the Kosi, the Mahananda etc. The silt load carried by the Gandak, the Bagmati , the Kosi and others is very heavy. At Buxar site, during the monsoon months, on the average the fine, medium and coarse silts account for 91.33 per cent, 7.32 per cent and 1.35 per cent of the total silt load respectively and the major amount of the total silt load is being carried away during the monsoon months August and September.

At Patna site, during the monsoon months on an average the fine, the medium and the coarse silts account for 83.58 per cent, 12.98 per cent, and 3.44 per cent of the total silt load respectively and major amount of the total silt load is being carried during the monsoon months August and september. At Hathidah site, during the monsoon months on an average the fine, the medium and the coarse silts account for 67.91 per cent, 23.45 per cent, and 8.64 per cent of the total silt load respectively and the major amount of the silt load is being carried during the monsoon months August and September.

At Azmabad site, during the monsoon months on an average fine, medium and coarse silts account for 84.96 per cent, 9.22 per cent and 5.82 per cent of the total silt load respectively and the major amount of the total silt load is being carried during the monsoon months August and September. Another point worthnoting in grading of silt is that while from Buxar to Hathidah, the percentage of fine silt has been decreasing and those of medium and coarse silt increasing, the same at Azmabad shows different trend and in zone below Hathidah to Azmabad, the percentage of fine silt has increased from 67.91 per cent to 84.96 per cent, whereas those of medium and coarse silt have reduced from 23.65 per cent to 9.22 per cent and from 8.64 per cent to 5.82 per cent respectively. This is perhaps due to transportation of considerable amount of fine silt in the Ganga by the rivers of north Bihar which join between these two locations and also due to deposition of coarser silt on the way due to flatter slope of this river in the reach. This, however,needs to be further investigated in detail and studied to arrive at some definite conclusion.

5.0 FLOOD FREQUENCY ANALYSIS

5.1 Frequency analysis is carried out to interpret the past records of the hydrologic events like the precipitation, run-off, flood level etc. to predict the probabilities of such occurrences in future. For quantitative assessment of the magnitude of flood problem, it is essential to evaluate or estimate the frequencies of rainfall, floods etc. Such studies are necessary inputs for proper design and locations of hydraulic structures as well as other related studies.

5.2 CRITERIA OF DESIGN FLOOD

5.2.1. Ministers Committee on floods and flood relief constituted by the Govt. of India in 1970 had recommended that:-

"As most of the embankments have been constructed on the inadequate and meagre hydrological data which were available, it is necessary that the existing embankments are reviewed to see that these are safe for a period of 50 years frequency for major rivers and at least 25 years frequency for small tributaries. Similarly all the future proposals of embankments should also be based on the above criteria".

5.2.2 The recommendation of the Rashtriya Barh Ayog (RBA), constituted by the Govt. of India in 1976 (which submitted its report in March 1980), regarding the degree of protection by embankments are as follows:-

The use of benefit-cost criterion would require (i) damage data with respect to different flood frequencies (ii) data on damages due to probable failure of embankments and (iii) expertise to carry out alternative benefit-cost and trade-off exercises. These are not available at present. Hence for time being we recommend, as a general guide, adoption of the following criteria based on flood frequencies:-

(i) For predominantly agricultural areas:- 25 years flood frequency. In special cases, where the damage potential justifies a higher design flood, maximum observed flood may be adopted.

(ii) For town protection works, important industrial complexes etc:- 100 years flood frequency (for larger cities like Delhi, the maximum observed flood or even the maximum probable flood should be considered for adoption).

Meanwhile studies should be under taken to review the basis of these flood frequencies and attempts made to collect. the data and appoint the necessary personnel, so as to enable the application of benefit-cost criterion in due course" (para 13.5 of R.B.A. Report).

5.2.3 The relevant recommendation made by the erstwhile Ministry of Irrigation, Govt. of India in the "Guidelines and instructions for implementation of the recommendations of RBA" are reproduced below:-

"In the case of embankment, the design of a project should be determined for the time being on flood frequencies suggested. Meanwhile necessary step may be taken for eventual application of benefit-cost criterion for fixing the design".

The summary of recommendations as accepted is as follows:-

"In the case of embankment schemes, the height of the embankments and the corresponding cost be worked out for various flood frequencies and also the benefit-cost ratio taking into account the damage likely to occur for the relative flood frequencies. However, till such times as the details of all relevant parameters are available, embankment schemes might be prepared for a flood of 25 years frequency in the case of predominantly agricultural areas and for flood of 100 years frequency for works pertaining to town protection and protection of industrial and other vital organisations".

5.3 ANALYSIS OF AVAILABLE DATA

5.3.1 At present gauge, discharge and sediment data are being observed by the CWC at four sites on the main Ganga river in Bihar namely Buxar, Patna, Hathidah and Azmabad. In order to obtain a resonably good estimate of future probability of occurence of the events, at least 20 to 25 years of yearly peak value of gauge and discharge are required for frequency studies. In case of the river Ganga, more than 25 years records for all the above four sites are available . The yearly peak gauge and discharge data for the above four sites namely Buxar, Patna, Hathidah and Azmabad are enclosed at Annex-5.

5.3.2 The frequency analysis of the above available data carried out by the GFCC,by using Log Pearson Type-III method and Gumbel method gave the following results:-

Table 9

FLOOD DISCHARGE IN THE RIVER GANGA

Unit: Cumecs

Sl No	Site	Years of data availability	Corresponding to Log pearson Type-III Method		
			25 years	50 years	100 years
1	Buxar	1960-87	51188	56170	61258
2	Patna (Gandhi ghat)	1965-86	72494	78293	83757
3	Hathidah 1945-84	72262	76875	81332	
4	Azmabad	1957-87	79911	84641	88813

Table 9 (contd)

Sl No	Site	Years of data availability	Corresponding to Gumbel Method			Highest observed/ computer discharge Year of Occurrence
			25 yrs	50 yrs	100 yrs	
1	Buxar	1960-87	54592	60600	66564	59755/1986
2	Patna (Gandhi ghat)	1965-86	79042	88335	97560	66800/1978
3	Hathidah	1945-84	76500	83400	90248	73530/1969
4	Azmabad	1957-87	87925	97724	107452	83047/1971

5.3.3 It is observed from the available data that the increase in the discharges for Buxar, Patna, Hathidah and Azmabad sites for 25 years return period to a flood of 100 years return period as per Log Pearson Type III method are 19.67 per cent, 15.53 per cent 12.55 per cent and 11.14 per cent respectively and as per Gumbels method are 21.92 per cent, 23.42 per cent,17.97 per cent and 22.20 per cent respectively. The above analysis leads to the following conclusions so far as flood frequency on the main river Ganga is concerned.

i The flood for a 100 years frequency is approximately 20 per cent more than the flood corresponding to 25 years frequency. The embankments on the main river Ganga may, therefore, be designed for a flood of 100 years frequency even for protecting predominantly agricultural land , if the same is found economically viable and is considered as only alternative method for flood management in the area. For the present, however,the criteria recommended by the R.B.A. to adopt a design flood of 25 years frequency for protection of predominantly agricultural areas may be adhered to.

ii There is a nominal decrease in the flood level, even with a substantial moderation of flood peak from 100 years frequency to 25 years frequency . It follows that if flooding has to be controlled by flood moderation (through reservoirs or detention-basins),the degree of moderation has to be quite large so as to bring down the depth of spilling over the bank to safe limit.

5.3.4 It can be seen from the above Table that the discharges for 25 yrs, 50 years and 100 years at Patna are more than that obtained at Hathidah site. This is contrary to the situation as is generally expected theoretically that the discharge in the lower reach should increase on account of addition of more drainage area. The following facts might be the likely causes of such deviation on unexpected pattern either singly or in combination:-

i Differences in mode of measurement /computations of the peak discharges,

ii Large scale infiltration and ground water recharge,

iii Large subterranean flows across the sub-basin boundaries

iv The river Gandak joining immediately below the G & D sites at Patna creating afflux,

v Large scale spilling of the banks in the reach and temporary detention of considerable discharge in the Mokama Group of Tals.

vi Large cross slopes in the width of the river affecting the observations at G/D sites.

vii River reach being affected by the meander of the river and

viii The availability of reliable data for analysis and computation of maximum discharge at the two sites.

5.4 UTILITY OF FLOOD FREQUENCY STUDIES

The results of flood frequency studies are useful in delineating the flood prone area on the contour map in order to be aware of the situation in the unprotected area at different stages of the river during floods. To make the studies useful, it is essential to have the contour map (with contour at suitable interval) of the area prone to floods preferably in a scale of 1:15,000. The next utility of these studies will be in formulation and planning of the flood protection/management projects in the basin. The contour maps for the areas of the Ganga stem basin could not be made available and hence flood prone area map of the basin for different frequencies of floods could not be prepared. The Commission suggests that the contour maps of these areas prepared earlier by the Survey of India may be procured and flood prone map of the basin for different frequencies of floods be prepared for the unprotected areas on priority basis and, thereafter, for the protected areas also so as to issue warning for shifting of people, cattle, movable properties etc. during possible breach in the embankments.

5.5 ANNUAL PEAK GUAGE DISCHARGE RELATIONSHIP (APGDR)

5.5.1 The Ganga Flood Control Commission have drawn the Gauge-discharge rating curves for the existing four sites of the CWC on the main Ganga rivers in Bihar at Buxar, Patna, Hathidah and Azmabad on the basis of the available historical data. The relationship between the two parameters, the stage and the discharge at the higher range of the river is of greater importance than the same at the lower range for the flood management purpose. The gauge-discharge relationship curve is formulated by the method of least square with the help of computer. The results of the four sites as computed by the GFCC are indicated below:

Table 10

River-Ganga

Sl No	Site	Equation of Gauge and discharge curve
1	Buxar	$Q = 263.808(z-51)^{2.13568}$
2	Patna	$Q = 365.960(z-41.1)^{2.26534}$
3	Hathidah	$Q = 100.075(z-32.2)^{2.6159}$
4	Azmabad	$Q = 238.284(z-22.8)^{2.42725}$

Where Q = Discharge in Cumecs z = Gauge in Metres

Due to the erodible nature of the bed of the river Ganga in this reach, these relationships need to be updated at frequent intervals on the basis of further data availability.

6.0 FLOOD AND DRAINAGE PROBLEM

6.1 FLOOD PROBLEM

6.1.1 The river Ganga is a source of frequent devastating floods in the plains of Uttar Pradesh, Bihar and West Bengal. The alluvial plains of the Ganga stretch for Kilometres together with a flat and fertile terrain in contrast with widely varying topographical and climatic features that influence the behaviour of the rivers traversing the various parts of the country. Consequently, the Himalayan rivers have entirely different problems, which are quite complex compared to non-Himalayan rivers.

6.1.2 In the upper catchment of the Ganga, in parts of the districts in Uttar Pradesh, namely Uttar-Kashi, Chamoli, Pauri, Tehri, Dehradun and Almora, soil erosion and gully formation are common due to steep slope, deforestation and faulty agricultural activities accompanied by frequent land slides. Bank erosion is active near Badrinath.

The Ganga causes damage by spilling over its banks at several places. The major problem of flooding along the Ganga occurs below its confluence with the Yamuna at Allahabad beyond which considerable damage is caused by spilling of flood waters over its banks during higher stages. It also erodes its banks near Mirzapur, Varanasi, Balia, Patna,.Begusarai, Barahiya(Khutaha), Munger, Khagaria (Mansi), Narayanpur and Karhagola etc. where important Anti Erosion Schemes have been executed in past to hold the river.

6.1.3 It has been observed in Bihar that, when the river Ganga is flowing at higher stages, the discharges from the tributaries get locked and cause wide spread flooding in the river systems and near their confluence points. The condition worsens when the floods in the Ganga and its tributaries synchronise. Therefore, the water level of the Ganga at any particular time during monsoon controls the intensity and duration of the flood in the catchment of its tributaries also. Flooding is quite wide spread in Khadir i.e. the meander belt of the river. The villages situated on the Diara land are the victims of the floods almost every year. The low lying areas are also affected due to drainage congestion for longer period even during normal floods. For instance, the area covered under Mokama Groups of Tals starting from Fatuha to Lakhisarai as well as Dakras & Bariarpur-Sultanganj tal area poses serious drainage problem due to flood of the Ganga river. This type of problem due to similar topography aslo exists on the left bank between Chapra and Bazitpur and between Narayanpur and Kursela. The problem of bank erosion on the Ganga is primarily due to changing pattern of its meandering tendency.

6.1.4 The slope of the river Ganga is very flat in Bihar portion and also in West Bengal i.e. 1:15,705 (.06m/km) to 1:24,000(0.04m/km) up to confluence with the Sea, thereby causing sluggishness in the drainage of flood water. The tributaries of this river, which join it in Bihar such as the Ghaghra, the Gandak, the Bagmati and Adhwara Group of rivers, the Kosi, the Mahananda etc. also bring enormous amount of silt from the Himalayas. The silt load is deposited in the bed due to flatter slope and causes the river to spill its banks. Such excessive deposition of silt has resulted in reducing the capacity of the river channel gradually and consequent formation of shoals and islands in the bed of the river. All these reduce the capacity of the river and enhances its meandering tendency, due to which the water spills over the banks into the countryside and cause flood.

6.1.5 According to the district gazetteer of Patna, the floods of 1901, 1913, 1923, 1936, 1948, and 1967 in Patna were severe in this century and there after there were very heavy floods in Patna in 1971 and 1975. The years of occurrence of floods since 1971 in different districts of Bihar caused by the main Ganga river is indicated below:-

Table 11

District	Years of occurrence of flood
Patna	1971,73, 74,75, 76, 78, 80, 82, 83, 84, 85, 86,87,88.
Rohtas	1971,75, 76, 84.
Bhojpur.	1071,73, 74, 75, 76, 78, 80, 82, 83, 85, 86, 87, 88
Saran	1971, 73, 74, 75, 76, 78. 80, 82, 83, 84, 86, 87, 88
Vaishali	1970, 71, 73, 74, 75, 76, 78, 80, 81, 82, 83, 85, 88
Samastipur	1970, 71, 73, 74, 75, 76, 78, 85, 86, 87, 88
Begusarai	1070, 71, 73, 74, 75, 76, 78, 80, 81, to 88
Bhagalpur	——do——
Munger	1971, 73, 75, 76, 78, 80, 82, 83, 84, 87, 88
Sahibganj	1971, 73, 74, 75, 76,78, 80, 81, 82, 83, 84, 87, 88

History of past floods as available from the records of the Irrigation and Revenue Departments from 1901 to 1992 are placed at Annex 6

6.2 DRAINAGE PROBLEM

6.2.1 As stated earlier the Main Ganga Stem basin in Bihar is inclusive of the Kao-Thora-Dharmawati river sub-basin, the Mahi sub-basin, the Baya sub basin and the Koa-Bhena sub-basin in addition to the small width of catchment along the coarse of the Ganga along its full length in Bihar draining directly into it. There is no significant drainage problem in the Kao-Thora-Dharmawati basin and the Koa-Bhena basin because these rivers are running in steep slope with adequate discharging capacity and the topography of the sub basin also allows efficient chainge. But the Mahi and the Baya sub-basins have considerable drainage problem which are described below:-

6.2.2 The Mahi and the Baya sub-basins suffer from acute drainage congestion due to existence of numerous depressions known as "Mauns" and "Chaurs". The mauns are the leftover old courses of the river. The topography of North Bihar had been thoroughly disturbed during the major earth quake of 1934, causing upheaval and depressions which disturbed the gradient of the rivers and aggravated the problem of flooding and drainage congestion. The capacities of the rivers have been reduced considerably due to siltation of the bed, weed growth and flattening of the hydraulic gradient. Their waterways have mostly been encroached upon for cultivation and are blocked at some locations by means of artificial barriers for fishing. All these factors lead to drainage congestion in the basin particularly in non-monsoon months. Heavy precipitation in the drainage basin coupled with high stages in the outfall channel further aggravate the drainage problem during the monsoon months.

Apart from the problems of congestion in the trund drains, the absence of subsidiary trunk drains connecting the depressions with the trunk drains and drainage congestion in the subsidiary trunk drains also accentuate the problem. The area which are water logged in an average year in Bihar portion of this Main Ganga Stem workout to about 1.30 Lha during kharif and 0.68 Lha during Rabi season. This area is mainly located in Mahi and Baya sub-basins of the Main Ganga Stem.

6.2.3 It appears that area suffering from surface drainage congestion in the basin is not being systematically surveyed and recorded every year in order to know the magnitude of the problem. It has also not been possible to delineate the areas affected by flood spills from those affected by drainage congestion as such details are not being observed. Efforts should be made to observe and keep separate records for the two afforsaid categories without any further delay. In the absence of these figures, it is not possible at this stage to make an analysis and relate the extent of drainage congestion or flooding with the magnitude and duration of floods experienced in the river in different years.

6.2.4 Sub-surface drainage condition in the basin is also a likely factor which contributes to the problem of drainage congestion. No systematic observation of ground water contour in the basin appears to have been or being carried out from year to year. However, the available records indicate that the ground water level varies between depths of 1.5 to 10 metre, depending upon the zone and season. A sizeable area suffering from drainage congestion is distributed throughout the Mahi and the Baya sub-basins and it has not been possible so far to identify any local zone which is suffering from such problem due to defficiencies of sub-surface drainage. The investigation carried out so far do not provide sufficient details to pin-point these zones. It is, therefore, necessary to carry out systematic field investigations regularly so as to pin-point such water drainage congested zones which are suffering due to lack of proper sub-surface drainage.

6.2.5 It appears that post facto evaluation study of any completed drainage scheme either in the basin or in any other basin in North Bihar has not been under taken so far. Such evaluation studies for a few completed drainage schemes in the basin need to be undertaken quickly so that future planning for removal of drainage congestion in basin is done after knowing their usefulness and efficiency.

6.2.6 A number of sluices have been provided in the embankments at suitable location in order to provide drainage of the area lying on the country-side of the embankment when the river stage is low after floods. It is necessary to carry out review of the adequacy of such sluices in the embankments in the basin and to take further necessary action on the basis of such review. It is, however, observed that even where sluices have been provided, they have become inopertive due to one or more of the following reasons:-

a high stages prevailing in the river,

b choking of the leading channel of the sluices due to siltation or encroachment,

c non-operation of gates due to mechanical faults and

d Shifting of the river channel away from the embankment and heavy siltation near the sluice on the river side.

6.2.7 It is common saying that the problem of drainage congestion and water logging increases with the introduction of irrigation. While this may be true in some cases but it can not be applicable universally as there are many areas in the basin which suffer from drainage congestion and water-logging where irrigation facility is not available so far. Some of the water logged area in the Mahi and Baya sub-basins were existing even before introduction of irrigation in the basin and virtually, there has been no change in their extent. A study has been made by Water and Power Consultancy Services (India) Limited, New Delhi on this phenomenon in the command area of the old Sone Canal System in course of preparation of Feasibility Report of Sone Canal Modernisation Project in March 1987,which covers the sub-basin of Kao-Thora and it was found that there has been no change in sub-soil water levels after the introduction of irrigation in the year 1876. The ground water levvel measurement along Sone canal was reportedly started as early as in the year 1886. As the ground water level adjoining the canals did not show any rise, the measurment was discontinued in the year 1942. The data clearly show that no water logging problem cropped up in the area even after running of canals for over half a century. The records of Baya and Mahi sub-basins available so far also do not indicate any appreciable rise in sub-surface water level. These records are not available for longer duration and those available are also not continuous. It is, therefor, recommended that ground water structures of the Baya and Mahi sub-basins be systematically and regularly observed to ascertain the fluctuations in sub-soil water table and records maintained for future planning of remedial measures.

6.3 FLOOD DAMAGES

6.3.1 The damages caused by floods and drainage congestions are classified broadly into the following two catagories (a) Direct damage and (b) Indirect damage.

6.3.2 The direct damages are those which are caused due to direct physical contact with flood water. These include losses to (a) growing and pre-harvest crops (b) houses and house hold assets (c) public utility works (d) public building and (e) loss of human lives and livestocks.

6.3.3 The indirect damages are not susceptible to quantification. Therefore, approximate monetary evaluation can only be done for such damages. These generally include:-

a Loss of earning in agrobased industry and trade,

b loss of revenue to the road and rail transport system due to disruption of services, c loss of earnings to small shopkeepers and other daily wage earners and

d loss of employment to the daily wage earners in the public and private sectors.

6.3.4 The flood damage data are collected by the Revenue (Relief and Rehabilitation) Department of the State Government and passed on to the various concerned organisations of the State and Central Governments. The Central Water Commission (C.W.C.) is collecting and compiling such damage data of all flood prone States at national level. The Central Flood Control Board had decided that Flood Control Department o1 the States should compile basinwise flood damage data with effect from 1960. This is not being followed in Bihar and the flood damage data still continues to be collected districtwise (not basinwise) by the Revenue (Relief and Rehabilitation) Department.

6.3.5 Flood damage data are required every year during the flood season for the purpose of immediate requirements of relief operations that becomes necessary on account of current damage caused by floods. As such, the need for compiling the annual flood damage data, according to the administrative jurisdiction in district and blockwise category in the State cannot be denied. On the other hand, planning of the flood management measures are to be on a basin and sub-basin wise manner. It is, therefore, necessary that such data are collected by the Revenue Authorities with active co-operation of the staffs of Water Resources, Agriculture, Road construction and Building Construction Departments, and the data are processed and compiled both district wise as well as basin/sub-basinwise by the statistical organisations at district and State level for further use for planning of relief measures and flood management respectively.

The flood damage data for the Main Ganga Stem basin in Bihar converted from the available districtwise figures are enclosed at Annex 7.

Proportionate damage in accordance with area has been accounted for in case of such districts of which only a part lie in the Main Ganga Stem river basin in Bihar.

6.3.6 From the perusal of the data processed by the Revenue Department, it is noticed that damage to property of Central Government such as Railways, Post and Telegraphs etc. are not properly accounted for. On the other hand, the cost of relief and rehabilitation measures, grant of loan, remission of land revenue etc is added to flood damage. This does not appear to be proper.

6.3.7 It is observed that the flood damage statistics,which is essentially required for the benefit-cost studies for any proposed flood management measures,are not being scientifically and rationally collected and compiled.The RBA had made many useful recommendations in this regard which do not seem to have been followed.This Commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage district/river basinwise be carried out every year under the following three separately identified categories:-

i Unprotected areas.

ii Protected areas due to failure of protection works,

iii Areas between the embankments and the river.

The extent of drainage congestion in the protected and unprotected area should be indicated separately.The WRD dealing with flood management should be associated with collection and compilation of flood damage data.In order to eliminate any inconsistency,the flood damage data should be collectively reviewed by the concerned departments at the end of each year.Such reconciled long term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area.

6.3.8 It would be evident from the available flood damage data of the basin (Annex-7) that average annual area affected by flood is 2.94 Lha. The average annual damages to the crop, houses and public utilities at 1991 constant prices work-out to Rs. 4044.70 lakh, Rs 702.74 lakh and Rs 337.53 lakh respectively, totaling to Rs 5084.97 lakh.

7.0 PAST APPROACH AND ACHIEVEMENT

7.1 In the early days embankments were constructed to prevent the spill of river causing damage to the agricultural lands, properties and inhabitated area which were constructed in scattered length according to the local requirements. Such embankments were not constructed in continuous length in systematic manner and were mostly not strong enough to withstand pressure of waters during high floods. However, such local embankments or zamindari embankments had not been constructed on the Main Ganga river because of its being a large river whose spills could not be controlled by small marginal embankments. It is seen that before independence, no major flood control work was taken up in the Main Ganga Stem basin though this basin had witnessed many high floods. The damages caused to life and properties and hardship suffered by the people during the successive floods of 1952, 1953 and 1954 coming in a row forced the authorities to consider providing a reasonable degree of protection to the flood prone areas of this basin.

7.2 After the worst and most devastating flood of 1954 the Government of India announced a national policy on flood control and launched a national programme of flood control in the year 1954. This policy stressed the need for collection of data and formulation of plans, implementation of short term measures like embankments and channel improvements and long term measures like construction of storage reservoirs on tributaries in conjunction with embankments, all under an outline of time bound programme. No long range plan could, however, be immediately formulated for want of survey and investigations as well as historical data, but emergent schemes were prepared and executed to provide a reasonable degree of protection from the ravages of floods to the areas concerned. These schemes have served their desired purposes.

7.3 The Central and State Governments appointed Several Committees to go into the problem of floods and suggest remedial measures. The Committees appointed are broadly of the following catagories:-

A Appointed by the Government of India to deal with general flood problem in the country.

B Appointed by the Government of India to deal with the specific problems.

C Appointed by the concerned State Government to deal with particular problem in the state.

D Reports/Observations of various experts/expert organisations.

The recommendations of such Committees relating to the Main Ganga Stem basin are described in the following paragraphs:-

7.3.1 High Level Committee on Floods (1957)

This Committee was setup in April, 1957 to make an assessment of the flood problem in the country and advise on the measures that should be taken to tackle it. The Committee consisted of senior engineers and a forest officer. The terms of reference of the Committee were:-

a To analyse the factors responsible for a succession of heavy floods in the Ganga and the

Brahmaputra basins and to indicate, in a general way, after an examination of the hydrological and other relevant data available, the lines on which the flood problems of various areas should be tackled.

b To review the measures undertaken to combat floods and to indicate the lines on which work should proceed in future, both in regard to the construction of flood protection works and in regard to the collection of data for the formulation of long term flood control measures.

c To lay down principles for the fixation of priorities in the construction of flood protection works.

d To examine specific flood problems of an acute character from states and to indicate the lines on which they should be tackled.

e To report on the circumstances in which embankments can be considered as a suitable method of flood protection .

f Any other recommendations bearing on the control of flood and mitigation of damage by floods.

The Committee submitted volume I of its report dealing with the general assessment and principles and policies in December,1957 and volume-II discussing flood control in various basins in November,1958.In its report,the Committee made a comprehensive assessment of the flood problems in various river basins,reviewed the measures undertaken till 1957 and suggested lines for further measures and collection of data.

7.3.2 Ministers' Committee on Flood Control(1964)

This Committee was setup in February,1964 by the Government of India and consisted of Ministers incharge of Flood Control in various States and representatives of Central Water and Power Commission,Ministry of Irrigation and Power,Ministry of Finance and the Planning Commission.The terms of reference of the Committee were:-

a To review and assess the action taken by the Central and State Governments in respect of the National Flood Control Policy outlined in 1954 with a view to indicate the extent of the various flood control measures have been effective and what further remains to be done in different States in the fourth,fifth and subsequent plans.

b To suggest ways and means for financing flood control schemes.

c To examine the existing pattern and suggest modifications and improvements to flood control organisations in the States and at the centre and inter-states levels like the River Commission.

d To examine and recommend policy in respect of flood warning and forecasting,flood plain zoning and flood insurance.

e To make recommendations on any other subjects relating to the above.

The Committee submitted its report in December 1964.In its report,the committee stressed the need for preperation of long range plans for flood control,co-ordination of flood control with other uses and improvement in the present system of collection of flood damage statistics.It did not favour the levy of flood cess as it would be an additional burden on the poor cultivators in the protected reach.It recommended change in the pattern of assistance to the State Governments for flood control works from 100 per cent loans to 50 per cent grant or subsidy.

7.3.3 Ministers' Committee on Floods and Flood Relief(1972)

This Committee was headed by the Union Deputy Minister of Irrigation and Power and consisted of Ministers incharge of Flood Control of flood prone States and representatives of the IMD and Central Water and Power Commission.The terms of reference of the Committee were:-

a To enquire into heavy loss of lives and property from floods and heavy rainfall.

b To examine and draw up suitable proposals for avoidance of such heavy loss of lives etc in future.

c To study the question of co-ordinated action by various agencies in organising flood relief measures.

The Committee submitted its report in March,1972.The important recommendations were as follows:-

1 Flood forecasting centres should be established in all flood prone river basins.Field meteorological Office should be established by the IMD to work in close co-operation with the flood forecasting centres.

2 Arrangements for dissemination of flood warnings should be made and the public should be educated about the significance of such warnings.

3 Each State Government should prepare a manual for flood operations including flood fighting,and should setup necessary organisations for the purpose.

4 Long range and comprehensive plans of flood control should be prepared expeditiously by the States by engaging special staff,if necessary.

5 Suitable legislation should be enacted by the States to prevent enchroachment on the rivers and natural drainage channels.

7.3.4 Working Group on Flood Control, 1978

The Central Flood Control Board, in its 16th meeting held at Delhi in November, 1977 decided that since irrigation, flood control and drainage aspects could not be dealt with in isolation and since in almost all States, the Ministers incharge of Irrigation were also incharge of Flood Control, the subject of flood control could be discussed in the State Irrigation Minister's conference, with which the Central Flood Control Board might be amalgamated. After the above decision of the Board, the next Irrigation State Minister's conference, that is the fourth conference held in February, 1979, at Thiruvananthapuram (Trivandrum) passed a resolution noting and endorsing the major policies and strategies recommended by the Working Group on Flood Control, set up by the Union Ministry of Irrigation. The final report of the Working Group, as brought out in November, 1978 by the Ministry of Agriculture & Irrigation recommended the following important points with regard to the strategy for flood protection:

i State Governments should critically examine all major existing works and put up proposals for stabilising existing benefits.

ii The work of flood forecasting should be extended to other inter-state rivers and should be continued with added emphasis on modernisation of the systems.

iii Flood affected States should prepare basinwise plans in close co-ordination with Irrigation and other Departments. The outline of Master Plan should be finalised by each flood affected States by March, 1980. Detailed Master Plans should be finalised by March 1982.

iv In connection with Flood Plain Regulation and Management, the basic work of detailed surveys and preparation of contour maps should be carried out in the central sector. The State Government should demarcate areas liable to floods of different frequencies and intensities both on maps as well as on ground and enforce necessary land use regulation.

v While embankments constructed so far have by and large given the desired protection to large areas at comparatively low costs, their consequent long term effects on river regime are yet to be evaluated. New embankment schemes should be taken up with caution after carrying out detailed studies.

vi Anti erosion works should normally be taken up for protection of town and a group of thickly populated village abadis, railway lines and roads where relocation is not feasible on techno-economic ground and for protection of portions of embankments benefitting large areas where retirement is not possible.

vii All storage reservoir projects in the catchment of flood prone rivers should be given priority. All such projects planned for irrigation/power should be reviewed in detail to examine the possibility of providing specific flood storage. Operation schedules should be drawn up so as to provide flood moderation to the extent possible.

viii Studies with regard to likely benefits of flood moderation by the proposed reservoir projects in Nepal should be immediately carried out.

ix Soil conservation programme would be complimentary to the engineering programme of flood control and should be taken up simultaneously. However, economic justification of this programme will have to come largely from other inherent benefits of such a programme. Experiences of other countries indicate that while these measures do have beneficial effects on reduction of flood peaks of small floods on small catchments, these may not have any significant effect in the reduction of flood peaks in the large damage producing floods. These measures help in reduction of silt in the river."

7.3.5 Fourth Conference of State Ministers of Irrigation, 1979 (Constituted by the Government of India)

The conference held in February 1979, passed several resolutions on Floods and Flood Protection. Those relating to important Flood Control strategy are summarised below:-

i The work of preparation of Master Plans for flood control and drainage within the framework of the overall development of water resources should be completed within next four years.

ii Preparation of detailed contour maps in respect of flood prone areas be expedited by taking up the work in the Central Sector. Steps whould be taken to demarcate flood zones corresponding to various flood frequencies and intensities.

iii Necessary administrative and legal steps be taken immediately by the concerned authotities to regulate further development activity in the flood plain.

iv New embankment schemes should be taken up with caution and detailed studies regarding their effect on the river regime and behaviour made while assessing the costs and benefits.

v Anti-erosion works should normally be taken up for protection of towns, industrial areas and a group of thickly populated village abadis, railway lines and roads where relocation is not possible on techno-economic grounds, and for protection of portions of embankments benefitting large areas where retirement is not feasible.

7.3.6 Committee on Scientific Flood Forecasting in the Country (1963)

This committee was setup by the Government of India in 1963 to review the system of flood warning existing in the country and procedure for undertaking effective system of flood forecasting. This Committee has representatives of the India Mateorological Department and the Central Water & Power Commission. In its report submitted in 1965, the Committee recommended setting up of flood forecasting centres and subcentres all over the country and setting up of a flood forecasting organisation to guide and co-ordinate flood forecasting programme.

7.3.7 Study of Scientific Assessment of Flood Damage (1964)

Since the assessment of flood damage made by the States was not on a uniform basis and the need for laying down a uniform procedure for having accurate and reliable statistical data of flood damage from all the States was keenly felt, the work of evolving a standard scientific procedure for the assessment of flood damage was entrusted to the National Council of Applied Economic Research in 1964. In its report, in addition to outlining the procedure of computing damage, the setting up of statistical cells attached to Chief Engineers of Flood Control at State head-quarters, designation of the District Collectors as the authority to co-ordinate all reports of damage data sent by the officials in the district, training of village officers in the observation and preparation of reports of the damage caused by floods and the nomination of Flood Control Department in the states as the overall agency for the collection of and dissemination of flood damage data was emphasised.

7.3.8 High Level Committee on Patna Floods (1975)

This Committee was set up by the Government of Bihar after the severe floods of 1975 in the rivers Ganga and the Sone which submerged large areas of the city of Patna and caused large scale damages in the Capital city as well as Danapur Cantonment area. The Committee consisted of Member (Floods) of the Central Water Commission as chairman, two members of Bihar Legislature, Chairman of the Ganga Flood Control Commission and the Chief Engineer of the Bihar Government as members. The term of reference of this Committee, inter alia, included investigation of the causes of floods and to suggest measures for future protection against similar catastrophy.

The Committee in its report, recommended execution of Schemes for protection of Patna and its surrounding areas in two phases in accordance with the following priority.

Priority-I

i (a) Construction of an embankment cum masonry wall on the south bank of the Ganga from Digha to Maner along with revetment at vulnerable places.

(b) Construction of sluices in the proposed embankment wherever the embankment will be crossing the drainage openings.

ii Construction of an earthen embankment cum-masonry dowel on the south bank of Ganga from Digha to the tail end of earthen embankment of the Punpun on left bank in conjunction with existing masonry dowel wall/embankment wherever necessary.

iii Construction of new earthen embankment from Maner to Saidabad along right bank of Sone.

iv Construction of an escape channel from Patna Canal upstream of Naubatpur through Khajuri Distributary and Panchahua nala with ancillery works.

v Closure of the lock gate on the Patna Canal and provision of a gate with proper seals at the junction of Patna Canal with the Ganga.

vi Restoration of Patna Canal and Maner distributary to its original section with a free board of 0.9 metre above 1975 HFL in the left bank of Maner distributary.

vii Raising and strengthening of Danapur distributary and construction of new embankment in its tail reach to prevent the entry of drainage water from rural areas lying on the west towards Patna.

viii River training works for preventing erosion at vulnerable places along the right bank of the Ganga.

ix Improving and/or remodelling the existing urban drainage in Patna and construction of sluices with gates on the drainage channels proposed for augmenting the capacity of the existing ones as per new proposals.

Priority-II

i Remodelling the drainage system in the rural areas by excavating new channels, remodelling of the existing channels and raising of the roads/distributaries wherever and to the extent necessary for segregating drainage of different sectors.

ii Raising and strengthening of the left embankment of the Punpun as well as construction of new embankment in its upstream reaches up to the escape channel.

7.3.9 In complience of recommendations of different committees formed since 1954, the State Government executed several embankment and town protection schemes in the Main Ganga Stem basin which have been listed and placed at Annex 8.

7.4 RESERVOIRS

It is an established fact that a properly operated flood control reservoir, combined with efficient flood forecasting, offers the most dependable flood control. The Ganga sub basin has a very large catchment in hilly areas in India and Nepal having a number of tributaries such as Yamuna, Ramganga, Gomti, Sone, Ghaghra, Gandak, Kosi, Mahananda etc. A number of reservoirs on these tributaries have already either been built, or are under construction and proposed for being taken up in future in Uttar Pradesh, Madhya Pradesh and in Nepal. But, these dams are mostly for power generation and irrigation purposes and they do not provide for specific storage space for flood cushion. Rough calculations indicate that if the entire river above Tehri is intercepted by Tehri dam and no water flows down, the reduction in flood gauge at Kanpur could be as small as 4 cm even on such an extreme assumption. Hence, the effect of peak flows in the reaches down stream of Allahabad and in Bihar would be almost insignificant so far as the main Ganga river is concerned. Therefore, by and large, the dams on the Ganga in its hilly catchment will not play any important role in respect of flood control or moderation in Bihar. Suitable dam sites are not available in Bihar where the river flows in plains through alluvial soil.

7.5 EMBANKMENT SCHEMES

7.5.1 Construction of embankment which is generally the quickest and cheapest measure for flood protection has been adopted in the past . Many embankment schemes have already been constructed on the main Ganga river and its tributaries (included in this report) to provide protection to flood prone areas and a few schemes are still under execution. Salient features of major embankment schemes, completed already, are given below:-

Table 12

Sl No	River	Name of Scheme	District	Length Km	Protected area (in ha)
1	Ganga	Kasba-Roopnagar Embankment	Patna	18.00	2500
2	Ganga	Gupta bund	Begusarai	13.2	3250
3	Ganga	Gupta-Lakhminia embankment and chak ring bundh	Begusarai	25	4200
4	Ganga	Old Gogari embankment	Khagaria	8	2700
5	Ganga	Gogari-Narayanpur embankment	Khagaria	44.2	14400
6	Ganga	Azampur-Karhagola embankment and Sankar embankment	Katihar	27.2	19430
7	Ganga	Karhagola-Jaunia second retired line	Katihar	5.7	910
8	Baya	Bajidpur Embankment	Samastipur	28	4400
9	Mahi	Mahi left Mahi Right	Saran	20.8 19.2	10500

These completed embankments are not in continuation, but are constructed in the reaches where flooding due to the river spills were severe in the past. They are situated mostly between Begusarai and Katihar on the left bank of the Ganga and at the confluences of the Mahi and the Baya with the Ganga.

Besides these completed schemes, two embankment schemes, Buxar-Koilwar embankment scheme on right bank of the Ganga (downstream of Buxar) and Hajipur-Bajidpur embankment on the left bank of the Ganga(downstream of Hajipur) are under execution since long. These schemes are described in the following paragraphs:-

7.5.2 Buxar-Koilwar Embankment Scheme

This embankment scheme was approved in the year 1974. It envisaged construction of embankments on right bank of the river Ganga from Buxar to Koilwar including embankments on left and right banks of the east and west Gangi rivers and on the left bank of the river Sone from its confluence with Ganga upto Koilwar to Protect the area lying between the Ganga and the Koilwar-Buxar section of the Eastern Railway including, Arrah and Buxar towns from floods of these rivers. This scheme consisted of three sectors, A,B and C. Sector A consist of the following works:-

i	Sone left bank Embankment (from Koilwar to confluence with the Ganga)	14.66 km
ii	Koilwar Ring bundh	2.38 km
iii	Ganga right bank Embankment (from Samaria Pararia to Bishunpur)	9.08 km
iv	East Gangi right embankment (from zamira to Samaria Pararia)	19.05 km
v	East Gangi left embankment (from zamira to Gyanpur)	5.79 km
vi	Arrah Town protection scheme	7.68 km
	Sector 'B' consists of the following works:	
i	East Gangi left embankment (from Masarha to Sempur)	22.64 km
ii	Ganga right bank embankment(from Salempur to Sempur)	71.23 km
iii	West Gangi right embankment (from south of Bihiya to Salempur)	14.48 km
	Sector 'C' consists of the following works:-	
i	West Gangi left embankment (from south of Bihiya to Barza)	15.78 km
ii	Main Ganga right embankment (from Buxar to Barza)	66.35 km

The original estimated cost of the scheme was Rs 1010.50 lakhs (1974). The work was started in 1973-74. The estimate was revised in the year 1982 and sanctioned for Rs 2628 lakhs. The expenditure on this scheme up to March 1992 was Rs 4728.58 lakhs. The total length of embankment to be constructed was 218.37 Km and area to be protected was 1,35,860 ha out of which 187.05 km length of embankment in reported to have been completed upto the year 1991-92 which provides reasonable degree of protection to an area of 35000ha from floods.

It has been reported that the second revised estimate amounting to Rs 10,031.96 lakhs was prepared in July 1992 by the State Government and sent to GFCC for clearance by the planning commission.

7.5.3 Hajipur-Bazidpur Embankment

This embankment scheme was proposed in 1981 to protect the area between the Ganga river and the Baya river on the left bank of the Ganga in Vaishali and Samastipur districts . It envisages construction of an earthen embankment from Hajipur to Bajidpur on the left bank of the Ganga, from Shahpur Patori to Bajidpur on the right bank of the Baya and from Shahpur Patori to a place located 10 km downstream on the left bank of the river Baya to connect it with the existing 28 km left bank embankment on the Baya which was providing reasonable degree of protection to an area of 4,400 ha from floods.

The original estimated cost of the Hajipur-Bajidpur embankment scheme in 1981 was Rs 1,147.00 lakhs. This was revised in 1991 to Rs 1,681.00 lakhs and sent to GFCC for clearance by the Planning Commission. The scheme envisages construction of 93 km length of embankment to provide reasonable degree of protection to an area of 80,300 ha from flood . The total expenditure incurred up to 1991-92 was Rs 458.72 lakhs, involving construction of only 9 km length of embankment providing protection to area of 7,780 ha only.

7.6 TOWN PROTECTION SCHEMES

The river Ganga is a major river which flows through almost middle of Bihar from west to east. Many important towns such as Buxar, Arrah, Patna Chapra, Hazipur, Mokama, Barahia, Barauni, Begusarai, Munger, Khagaria, Sultanganj, Bhagalpur, Katihar, Sahebganj are situated on its either bank. These towns and cities are always danger threatened by the spills of the river Ganga. In order to protect these important towns from floods, various town protection schemes, as indicated below, have been executed in the past:-

7.6.1 The Patna Town Protection Scheme.

Before 1975 floods, Patna town was protected from Gandhi Maidan up to Digha by a masonry wall the top of which was kept above the HFL of the Ganga. There was,however, no protection to Danapur contonment and the villages along southern bank of the Ganga from Digha to Maner. This masonry wall was constructed by the Public Works Department during the advent of initial five year plans after 1954. In this portion, a highway (NH-30) runs parallel to the Ganga. The Patna township had been threatened many times in the past by floods of the river Sone, the Ganga and the Punpun but fortunately the peak floods of these rivers had never synchronised earlier. Patna was seriously threatened with flood in the year 1971 and it was only with great effort that the Patna town could be saved from the ravages of floods that year. But shortly again, after a lapse of four years, Patna town and the adjoining areas experienced unprecedented flood in the year 1975 resulting in the inundation of large areas of town complex on the western sector to a depth varying from two to four metres.

Considering the seriousness of the situation, the State Government constituted a Committee known as Tripathi Committee to prepare an outline programme of a scheme for protection of Patna town from floods as well as to prevent recurrence of such flooding in future. A series of measures were recommended by the Committee as enumerated in Para 7.3.8 and accordingly schemes were formulated and executed under Patna'Town Protection Scheme. The estimated cost of the original scheme was Rs 1068 lakhs in 1975 which was revised to Rs 2,713.00 lakhs in 1981. 143.96 km length of embankment including masonry wall has already been constructed as a part of this scheme which is reported to provide a reasonable degree of protection to an area of 81,800 ha from flood. As indicated in the Administrative Report of water Resources Deptt. 1991-92, an amount of Rs 4065.52 lakhs has already been spent on this scheme. An estimate amounting to Rs 1723.77 lakhs has been prepared by the State Government for completion of the uncompleted residual portion of the Patna Town Protection Scheme work alongwith additional works which are considered fairly contingent to the main Scheme. This scheme is named as Patna Town Protection Scheme (Phase III).

7.6.2 Mansi-Mungerghat Protection Scheme

This scheme had been executed to provide protection to NH.31, Khagaria-Katihar section of the North Eastern Railway, oil pipe line, Khagaria town and adjoining villages and cultivable land which were threatened to be engulfed in the river Ganga due to severe erosive action on its left bank. The scheme was taken up for execution in the year 1973-74 and was completed in the year 1982-83 at a cost of Rs 368.922 lakhs. This scheme served its purpose as the relocation of aforesaid Railway, Pipe line, National highway was avoided by holding the river bank almost to its existing position away from these structures.

7.6.3 Barahiya Town Protection Scheme.

It was observed that the river Ganga started attacking its right bank after the construction of the Rail-cum-Road bridge at Mokama (Rajendra Pul) at a distance of about 8 km downstream of the bridge as a result of which a considerable chunk of fertile lands of Barahiya, Indupur and Jaitpur were eroded by the river Ganga every year. These villages have a population of about sixty thousand. Accordingly, antierosion schemes to prevent erosion of the right bank of the river Ganga near Barahiya town were taken up in the year 1974 and still continuing on year to year basis. An expenditure of about Rs 700 lakhs have already been incurred upto March, 1992.

7.6.4 Khutaha Village Protection Scheme

Erosion in this reach has been going on since 1974-75 and since then anti-erosion works like construction of spurs, dampeners, bed bars, bank pitching and revetment with falling apron and with end-anchorage have been executed at considerable cost. But in each succeeding flood, the Ganga has continued to erode its right bank and in the process has caused heavy damage to these protection works which are being maintained at a huge cost.

7.7 ANTI-EROSION WORKS

7.7.1 The Ganga is a major river which flows through almost middle of Bihar from west to east. In Bihar, the plain in which it flows is generally alluvial and hence the river is erodable in nature having meandering tendency. Severe bank erosion is reported on its bank near Buxar, Patna, Barahiya, mahnar, Barauni, Khagaria, Narayanpur, Kursela etc. Where anti-erosion measures have been carried out in the past and are being resorted to every year at a huge investment to protect towns, villages, roads, railway lines etc. A list of completed anti-erosion works on the river Ganga in Bihar, costing more than Rs 25 lakhs are enclosed at Annex 9.

7.8 DRAINAGE SCHEME

7.8.1 The Mahi Drainage Scheme.

The Mahi drainage scheme is situated in Gopalganj and Saran districts. The basin suffers from acute surface drainage congestion and crops in vast area are damaged almost every year due to congestions in trunk drains and in absence of link drain from different chaurs to trunk drains.

The work on Mahi drainage scheme estimated to cost Rs 272 lakhs (approx) was taken up prior to Sixth plan(1980-85) and it continued upto March, 1987.Only the excavation of a portion of main trunk drain could be completed till then and further work was stopped due to financial constraints. It has been reported that an amount of Rs 229.349 lacs including the cost of establishment had already been spent till March, 1987. A new estimate amounting to Rs 338 lakhs, to complete the residual work of the original scheme has been prepared by the Chief Engineer concerned. The area suffering from drainage congestion during Kharif and Rabi seasons in the Mahi river basin is 8,240 ha and 1,940 ha respectively. It is expected that on completion this scheme is likely to benefit 3770 ha during Kharif and 1940 ha during Rabi season. It is further reported that only 40 ha during Rabi season has been benefited up to March 92.

7.8.2 The Gandaki Drainage Scheme

The Gandaki drainage scheme is situated in the district of Gopalganj, Siwan and Saran. This basin suffers from surface drainage congestion and crops in vast area are damaged almost every year due to congestion in main channel and due to non-availability of link drains from different chaurs to the main channel. The work on Gandaki Drainage Scheme was taken up prior to the Sixth plan(1980-85) at an estimated cost of Rs 507 lakhs. The work continued till 1987 and since then is almost stopped due to financial constraints. It is reported that only a portion of the earth work of the main channel has been done sofar and the expenditure incurred till March 1987 is Rs 355 lakhs including the cost of establishment.

A new estimate amounting to Rs 927 lakhs has been prepared by the Chief Engineer concerned to meet the cost of balance work.

The area suffuring from drainage congestion in this basin during kharif and Rabi season are 31,680 ha and 2,930 ha respectively. On completion, the scheme envisages removal of drainage congestion from 15,430 ha during Kharif and 2930 ha during Rabi seasons. It is further reported that an area of 4020 ha during Kharif and 790 ha during Rabi season has been benefited by this scheme by the end of March 1992.

7.8.3 The Ghoghari Drainage Scheme.

The Ghoghari drainage scheme situated in Gopalganj, Saran and Siwan districts of Bihar was taken up for execution prior to Sixth Plan (1980-85) at an estimated cost of Rs 89 lakns for removal of drainage congestion from an area of 24,700 ha during Kharif and 6,600 ha during Rabi season. The work continued till March 1987 and the expenditure incurred was Rs 40 lakhs including the cost of establishment. Further work had to be stopped due to financial constraints. The area benefited upto March, 92 has been reported as 7400 ha during Kharif and 1200 ha during Rabi season.

A new estimate amounting to Rs 354 lakhs has been prepared by the concerned Chief Engineer to meet the cost of residual work of this scheme.

7.8.4 The Dhamati Drainage Scheme.

The Dhamati drainage scheme is situated in Gopalganj, Siwan and Saran districts of Bihar. The river in its entire length flows through a number of loops and zig-zag course through thickly populated areas and fertile land. A number of low lying areas and depressions exist in the basin and the river channal is almost silted up resulting in inadequate cross section at most places. Natural drainage through the channel is obstructed due to a number of man made intrusions causing drainage congestion in the basin.

The work on Dhamati drainage scheme was taken up at an estimated cost of Rs 340 lakhs in the end of Sixth Plan (1980-85) and practically no progress was made as would be evident from the fact that an insignificant amount of Rs 2.76 lakhs was spent till March 1987. This estimate has been revised to Rs 392 lakhs in the year 1985 due to omission of certain works which were considered unnecessary.

The area within this basin suffering from drainage congestion during kharif and Rabi season is 13,170 ha and 3,460 ha respectively. On completion, the schemes envisages removal of drainage congestion from an area of 9400 ha during Kharif and 3380 ha during Rabi season.

7.8.5 THE GHAGHRA DRAINAGE SCHEME

(a) Phase-I

The Ghaghra river originates from village Jafrabad in the Vaishali district and outfalls into the Baya river after traversing a distance of 71 km. The Ghaghra drainage scheme invisages improvement of Ghaghra and Malmalia rivers along with their tributaries and provision of link drains from the chaur to the trunk drains. The work on this scheme was taken up in the Sixth Plan (1980-85) at an estimated cost of Rs 110 lakhs. The estimate was revised to Rs 329.54 lakh in 1983. It is reported that the expenditure incurred up to March 1988 was Rs 137.09 lakh. A new estimate anounting to Rs 370 lakhs was prepared in the year 1988 for completion of the residual work of the scheme.

The drainage area of the Ghaghra river basin is 752 Sq Km out of which an area of 14,780 ha during Kharif and 11,500 ha during Rabi season suffers from drainage congestion. The scheme, on completion, is expected to benefit an area of 1,275 ha during Kharif and 10,365 ha during Rabi season by removal of drainage congestion. About 2000 ha during Rabi season has been reported to have benefited so far.

(b) Phase-II

The total length of the Ghaghra drainage channel is 71 km in which 51.63 km has been included under Phase-I and the rest under Phase II.

The estimated cost of the Ghaghra Drainage Scheme, Phase-II is Rs 129.08 lakhs, which envisages removal of drainage congestion from an area of 6680 ha during Rabi season only.

7.8.6 THE UPPER BAYA DRAINAGE SCHEME

The upper Baya drainage scheme is situated in the district of East Champaran and Muzaffarpur. It consists of the following drainage nala (i) Tilawe Nala (ii) Govindganj Nala (iii) Dhangarha Nala (iv) Bengahi Nala (v) Mekhwa Nala (vi) Baya river (vii) Mania Nala (viii) Raghwa Nala.

The work on this scheme was taken up prior to Sixth Plan(1980-85) at an estimated cost of Rs 597 lakhs (approx.) for removal of drainage congestion from an area of 22000 ha during kharif and 12600 ha during Rabi season. The scheme is almost at a grinding halt since April 1987 due to financial constraints. It is reported that an amount of Rs 268 lakhs has been spent till June 1987 on this scheme. The area reported to have benefited so far is 1984 ha during Kharif and 789 ha during Rabi season.

A new estimate amounting to Rs 621 lakhs (approx) has been framed by the Chief Engineer concerned for completion of the residual left over works of this scheme.

7.8.7 THE LOWER BAYA DRAINAGE SCHEME

The lower Baya drainage scheme is situated in the district of Muzaffarpur, Vaishali, Samastipur and Bagusarai. The length of the river Baya from the crossing of the Vaishali Branch Canal of the Gandak Canal System upto its outfall in the Ganga is known as the Lower Baya. The lower Baya basin suffers from acute drainage congestion due to existence of large number of saucer shaped chaurs and local depressions in its drainage area and due to non-availability of link drains from such Chaur and depression to the main Baya river. The drainage area of this basin is 720 Sq Km and the area suffering from drainage congestion during Rabi is 29370 ha. An estimate amounting to Rs 1349 lakhs had been framed for removal of drainage congestion from an area of 29730 ha during Rabi season. The scheme has not yet been sanctioned by the State Government.

7.9 FLODD FORECASTING AND FLOOD WARNING

7.9.1 Floodforecasting and flood warnings are meant for forewarning the people and the flood fighting agencies well in advance of the oncoming flood in order to enable them to organise all their activities sufficently in advance of the advent of the flood so as to minimise the loss of lives and property, to plan advance action to safeguard the engineering structures built across the river at high cost and to afford time to civil administration for planning and providing relief and evacuation works, it needed. Such warnings are based on estimation of future stages of floods and its time sequence at selected points along the river during various stages of floods. Utility of such forecasts depends up on both accuracy and timeliness. The issue of forecast has to be followed by efficient arrangement of its dissemination to the beneficiaries concerned within shortest possible time.

7.9.2 Flood forecasting operations on the main Ganga river are maintained by the River Management Wing of the Central Water Commission. At present they are maintaining 18 flood forecasting stations on the main Ganga river out of which 10 are located in Uttar Pradesh, 7 in Bihar and one in West Bengal. In Bihar these forcasting stations are located at Buxar, Patna (Digha ghat), Patna (Gandhi Ghat), Hathidah, Munger, Bhagalpur and Kahalgaon. These forecasting stations are well connected by wireless network with the base stations and sub-divisional and divisional head quarters of CWC. The forecasts are disseminated to the concerned authorities through wireless and other conventional modes of communication like telephone telegraph etc. It is also broad cast in the local news bulletin of All India Radio (Akashvani). The forecast is treated to be accurate if the actual stage achieved in the river at the indicated time is within plus minus 15 cm.The accuracy of flood forecasts of stages on the river Ganga at the aforesaid stations have been more than 90 per cent which is considered as very good performance.

Computerisation of network data and subsequent programming for the forecasting works by developing mathematical models gained momentum during 1989. With the use of computerised and more advanced methodology having self recording raingauges, telemetry system etc, accuracy of forecasts is likely to improve further and more lead time would be available for the flood forcasts.

8.0 FUTURE APPROACH

In the main Ganga stem basin in Bihar, many flood control and drainage improvement measures have been adopted in the past which have provided a reasonable degree of protection to an area of about 1.88 Lha and have improved drainage congestion in an area of about 13,414 ha. Inspite of all these measures taken in the past, a lot of flood and drainage congestion problems still exist in this basin which are identified as follows:-

a Spilling of banks due to more discharge and silt loads as compared to the carrying capacities of the river sections and flooding of low lying areas close to the river banks.

b Bank erosion at/near Patna, Begusarai, Barahiya, Munger, Khagaria, Mansi, Narayanpur, Karhagola etc.

c Meandering of river causing destruction of land, property and life.

d Drainage congestion in the area due to inadequate drainage system, inadequacy of trunk drains, non-linking of chaurs to trunk drains, improper or nonfunctioning of anti-flood sluices provided in the embankments etc

e Water logging in the chaurs and low lying areas.

f Flooding of towns, cities etc, located on the river banks.

In order to find suitable solution to the above problems, the following measures are worth considering:-

8.1 RESERVOIRS

According to numerous experts, a properly operated flood control reservoir, combined with efficient flood forecasting, offers the most dependable flood control. But, in case of the main Ganga stem basin in Bihar, no suitable dam site exists either on the main river Ganga or on its tributaries included in the Main Ganga Stem. However, some dams are under construction on the tributaries of the Ganga in the upper hilly catchment, but it is apparent that those could not provide any help by way of flood moderation to the areas lying in Bihar.

8.2 EMBANKMENTS

8.2.1 Although a short term measure, construction of embankment is the quickest and cheapest measure being generally adopted for flood management in this Country. Inspite of having a number of drawbacks this measure has been adopted for flood management in this river basin also. The important drawbacks are indicated below:-

a The embankments prevent silt laden water from spilling over the land resulting in reduced moisture and fertility.

b Embankments are considered satisfactory measure of protection only when the river is non-aggrading and the embankments are properly designed, executed and maintained.

c It is also apprehended that the embankments may shift the problems of floods from one area to another.

d Reduction of cross-sectional area of flow of channel in the post-embanked condition.

e Cutting off the valley storage, previously available for flood moderation during the pre-embanked condition.

f Interference in country-side drainage.

g Drainage congestion at tributary junctions.

h Vulnerability of embankment due to breaches caused by bank erosion, overtopping etc.

On the main Ganga river in Bihar, some embankments have already been constructed, as indicated in paragraph 7 of this report. These are, however, not continuous in length and provide reasonable degree of protection from floods to a very small area only compared to the total flood prone area of the basin in Bihar . Frequency of flooding in the reach from Buxar to Farakka is 4 years and more out of nine years. It is, therefore, considered desirable to protect such flood prone areas in the Main Ganga Stem basin by providing embankments on both banks in the spilling zone of the river Ganga and these embankment be extended along its tributaries also to contain the back water flow from the Ganga into its tributaries. Most of the works on these tributaries have already been completed or are under execution. As far as the main Ganga river is concerned, the following embankment schemes are under consideration of the State Government from quite long time back.

Table 13

Sl No	Name of the scheme	District	Approx. cost in lakh Rs	Length in Km	Area to be benefited in '000 ha
1	Chapra-Sonepur embankment Scheme	Saran	1690.00	29.40	81.377
2	Narayanpur-Kursela embankment scheme	Katihar	1312.72	39.00	284.900
3	Lakhminia-Khagaria embankment scheme	Khagaria	113.38	27.00	20.00
4	Patna-Hathidah road dowel (Mokama Tal Phase II)	Patna	117.16	89.00	–
5	Ganga-Gumani embankment scheme		352.57	–	–
6	Right bank embankment on the Baya river		88.58		10.0
7	Road dowel from Lakhisarai to Sahebganj	Munger Bhagalpur	500.00	170.00	
8	Manihari and Tapra embankment	Katihar	83.61		46.62
9	Ganga right embankment (Mirza chowki to Mangal hat)		353.00		
10	Ganga Right embankment (Champanagar to Mirza chowki)		135.00		
11	Durgawati Embankment	Rohtas	540.00		
12	Karmanasa Embankment	Rohtas	100.00		

8.2.2 The existing embankments are being frequently threatened due to bank erosions at various points/reaches and sometimes embankments have breached due to such erosion of river banks in the past. Although, from time to time, various anti erosion measures had been taken and are still being taken at specific vulnerable locations, the river starts attacking at another locations. Anti erosion works on a river of the size like the Ganga are generally costly both in initial construction as well as in subsequent maintenance.If such measures are not planned properly, adverse effects are likely to result either the up stream or on the downstream or both reaches of the river.It is for this reason that such measures are normally restricted to only such places,where valuable properties ,important lines of communications,vital installations etc. are in danger and their relocation is either very costly or not possible.It is considered desirable not to execute anti-erosion/river training works on adhoc basis as is being done from year to year at present but it should be executed on the basis of results of model studies to be carried out in totality so as to avert possible disaster at a location other than protected by such works. Short-cut method approach in such situations is likely to be cost prohibitive and may not solve the problem permanently.

8.2.3 There are a number of sluices constructed or under construction in embankments to prevent entry of flood spills into the protected area through the existing drains and also to relieve pressure on the embankments during high floods by releasing regulated discharge through them.Several anti-flood sluices have also been provided for draining out accumulated water on the country side as soon as the river level permits in order to remove drainage congestion from the protected area.

The condition of most of the existing sluices have been seriously deteriorated making them completely ineffective.This is due to choking of their vents,malfunctioning of gates or silting of channels on the river side or river edge having been moved far away from the embankments.

It is suggested that detailed studies be under taken to find out the effectiveness and adequacy or otherwise of the existing sluices in the embankments and remedial measures be taken on priority basis to make them function properly as envisaged earlier and as is considered necessary at present. If found necessary, more sluices may be provided for proper and efficient drainage of the countryside and also for providing irrigation to the areas on the countryside in case of drought.

8.2.4 It is likely that with the construction of the proposed embankments on both banks of the river Ganga to close the existing gaps in the reach where the river spills its bank causing flooding of the area ,the existing valley storage would be reduced considerably and there may be corresponding accentuation in the flood peaks of the Ganga.It would have been desirable to have some detention basins at suitable places to partly moderate the peak floods of 25 years frequency and above. There is, however, no such depression available in the main Ganga stem basin except the areas covered under Mokama Groups of Tals.The area is very fertile and bumper Rabi crops are being grown. The local people are demanding early drainage of the Tal area, preferably by the end of October.In view of this as well as considering the insignificant relief that might accrue in the lower reaches from the flooding of the mighty river Ganga even using the whole of Tal areas as flood detention basin this possibility is ruled out.

8.3 TOWN PROTECTION SCHEMES

There are many towns situated on both banks of the river Ganga in Bihar which are threatend by over bank spills of the river .In order to protect these towns from flood, several town protection schemes had been formulated by the State Government. Some of them have been completed and the rest are under construction as indicated in paragraph 7 of this report. The following town protection schemes have not yet been taken up due to some reason or the other:-

Table 14

Sl No	Name fo Scheme	Approximate estimated cost (Rs lakh)
1	Buxar town protection scheme	88.58
2	Chapra town protection scheme	132.87
3	Barauni town protection scheme	88.58
4	Barh town protection scheme	44.29
5	Sultanganj town protection scheme	88.58
6	Munger town protection scheme	177.16
7	Bhagalpur town protection scheme	177.16
8	Kahalgaon town protection scheme	60.00
9	Sahebganj town protection scheme	45.00
10	Rajmahal town protection scheme	24.15

It is suggested that hydraulic model studies for finalising the design type and location of suitable anti-erosion works be carried out in the Irrigation Research Institute, Khagaul and the Scheme be reviewed and finalised on the basis of such study before being taken up in the existing circumstances.

8.4 DRAINAGE IMPROVEMENT

8.4.1 Some drainage schemes have been taken up to remove drainage congestion in the Main Ganga Stem basin in Bihar, mainly in the Baya and the Mahi sub-basins, but it appeares that none of them have been completed in all respects. Very few link channels have been completed and very little work has been done on various drainage schemes and the work has been brought to almost grinding halt at present due to financial constraints. Details of these schemes are given in the statement at Annex-10

8.4.2 Some 'Chaur' drainage schemes have been completed by providing link channels from "Chaurs" to trunk drains. It is observed that the benefits accruing from the completed schemes are not being properly recorded and evaluated every year at present. It is necessary to evaluate the performance of the completed drainage schemes and if it is found that these schemes are providing intended benefits, then other drainage schemes may be executed accordingly. If certain modifications are considered necessary in order to derive the maximum possible benefits then such modifications should be carried out immediately on priority.

8.4.3 There are certain drainage schemes which have been taken up for execution long back but very insignificant progress has been made so far. It is desirable that all such schemes for drainage improvement in the basin which are lingering since long without accrual of any benefit should be reviewed on priority basis and completed, if found useful on such review as early as possible to realise full benefits in order to make use of the investments already made as well as to prevent large scale escalation in their costs due to any further delay.

8.4.4 Future drainage schemes should be planned, designed and executed only on the basis of the results of the post-facto evaluation of completed drainage schemes.

8.4.5 There are certain low lying pockets in the deepest portion of the 'Chaurs' or local depressions which can not be drained by gravity due to existing outfall conditions in the main and trunk drains. Such areas may be delineated on the village maps and developed for aquaculture and pisciculture as the case may be. Draining such low pockets by pumping is not considered economically viable. Even the availability of power in the area at present is not at all satisfactory.

8.5 SALINITY AND ALKALINITY

From the data made available to this Commission, it is observed that there is no rise in sub-soil water table in a large portion of the Main Ganga Stem basin due to canal irrigation, but such rise has been reported in certain portion due to excessive water use, faulty soil and water management, seepage from canals, high monsoon rainfall and recurring floods , mainly in the Mahi and the Baya sub-basins. Such a condition has also rendered some areas unproductive on account of secondary salinisation.

The alkaline areas, however, have been observed to be scattered over a large tract. Relatively small tracts of highly alkaline areas are interspersed with areas having moderate to mild alkalinity and some areas unaffected by alkalinity. The problem is also influenced by topo/sequence with low lying areas generally remaining unaffected by alkalinisation process. The process of alkalinisation is apparent in both canal irrigated areas as well as tubewell irrigated areas. In both cases, the irrigation water quality is good, still secondary salinisation is being commonly evidenced.

It has been found that reclamation process to restore soil health will be scattered and at semi-micro level. The role of drainage both horizontal as well as vertical also assumes importance in view of shallow water table and drainage congestion in the entire area. It is, therefore, felt that an action research programme be undertaken to generate basic parameters for land reclamation in the existing socio-economic environment in two pilot project areas of around 500 ha each, one in canal command area of Gandak Project and the other outside canal command in the agro-climatic Zone-I. These areas should form a mini- watershed. It has been reported that Gandak Command Area Development Agency is doing some work in this direction.

Full scale proposal for undertaking reclamation work in the larger areas of the Gandak Canal Command, with proven Methodology can be prepared on the basis of the results of such studies and implemented on a larger scale to derive optimum production and economic benefit from the investment.

[Extract taken from Pilot Project for reclamation of alkaline soil in Gandak Command Area, by GADA]

8.6 SOIL CONSERVATION

Under an Integrated Action Plan for Flood Management in Indo-Gangetic plain, watershed treatment and soil conservation measures were taken up in a few flood prone catchment due to limited availability of funds. These measures are still limited to pilot and experimental applications. Their effectiveness in reducing the peak flood during monsoon is yet to be established. However, soil conservation and watershed treatment measures are likely to have beneficial impact by way of reduction in the quantities of silt flowing into the river. A large portion of the catchment of the Ganga lies in the hilly areas, are mostly out side Bihar, but water-shed treatment to those areas will give benefit to Bihar also by reducing the quantum of silt being carried down the river in lower reaches which induces meandering tendency in the river. The State Government can only press for these works in upper catchment with concerned States at national level.

8.7 MAINTENANCE OF EXISTING WORKS

While new structural measures as suggested above are necessary for solution to the residual flood and drainage problem in the basin, it is equally important to properly and adequately maintain the assets already created so that they can with stand the pressure exerted due to excessive discharge being carried through the river and consequent rise in flood levels. Besides regular supervision and necessary repair of embankments well before the onset of the monsoon season, the following points deserve special attention.

During past few years the highest flood stages in the river at different locations have been noticed to have gone up resulting in encroachment in the free board of the existing embankments. A systematic survey and investigation of the existing embankments of the river and its tributaries is required to be carried out every year after the flood season and encroachment, if any, in the free board in any portion should be made good by raising the height of embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of hydraulic model studies to hold the river in order to keep the flowing channel away from the embankment. In the portion where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or at least provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently during emergent situations.

8.8 CONSTRUCTION OF RAISED PLATFORMS

During the flood season, breaches sometimes occur in the embankments as a result of which protected areas get flooded.Submergence of the protected area is also caused due to heavy precipitation on the countryside coinciding simultaneously with high stages in the outfall channels.The affected persons take shelter on the embankments alongwith their livestock and properties in such situations. As a result, not only the embankments get damaged but the works like flood fighting and rehabilitation get hampered. Generally, people do not go back to their original living place even after the flood subsides and continue to live on the embankments endangering its safety and hampering regular maintenance. It is, therefore, suggested that:-

i Occupation of embankments and the lands acquired should be got vacated effectively to avert any danger or risk to the flood management embankments and to the people living in the protected areas.

ii Raised platforms above the highest flood level may be constructed in areas liable to inundation near villages on Government or acquired lands.These could be also constructed on the countryside of the embankments abutting the same .Such platforms should preferably be connected with all weather roads and should also be provided with necessary facilities for warehousing, community living ,sanitary and potable water supply installations, space for keeping cattles and storing fodder,telecommunications facilities etc in order to obviate likely inconveniences to the people residing on such platforms during floods.These should be handed over to Local Bodies/Panchayats for being utilised as community property and kept free from enchroachement for its desired use when needed.

8.9 NON-STRUCTURAL MEASURES

8.9.1 Flood Plain Zoning.

The question of introducing flood plain zoning measures has been under consideration since long .In view of the increasing pressure of population and consequent greater encroachment of flood plain, zoning has assumed added significance.The flood damage in recent years is primarily due to greater encroachment into flood plains. The zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As a major portion of the flood prone areas in the main

Ganga stem basin is either protected or protection embankments are under execution, such zoning regulations should be introduced in the unprotected areas first and for developments in the protected areas hence forth.

It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15,000 with contour interval of 0.3 metre for implementation of this measure.Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of floods such as 100 years,50 years and 25 years.Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain,corresponding to a 50 years and 25 years rainfall will also have to be prepared.

8.9.2 Flood Forecasting and Flood Warning.

Flood forecasting and warning has proved to be a great help in issuing warning to the people in flood prone areas,organising flood fighting and safety measures for the engineering works, timely evacuation of people from affected areas and salvation of moveable properties besides mobilising relief operations.

The Central Water Commission issues flood forecasts for the Buxar, Patna(Dighaghat) Patna (Gandhighat), Hathidah, Munger, Bhagalpur and Kahalgaon sites on the river Ganga in Bihar. The existing flood forecasting arrangements are considered adequate and are proving quite useful during high stages in the river. These are being utilised by the District Administration as well as Engineering Authorities for taking necessary precaution during emergency.

Although there is wide application of the flood forecasting system and warnings issued by the CWC, there is very little feed back on the procedures specified or evolved by the Civil Administration and the Engineering Organisations for undertaking relief /rescue/precautionary action on the basis of the forecasts. It is also not known as to how effectively the necessary advice is being given to the people.

On receipt of the forecast,its dissemination to the local population in terms of likely depth of inundation and its duration in the area by the Administrative Authorities is very important so that affected population, cattle, moveable properties etc.are evacuated before the area gets submerged by flood water which would cause damage. For this, a network of wireless stations and telephone system are necessary in the basin near critical/vulnerable reaches of embankments and towns etc, specially where other means of communication are not dependable or adequate. Flood warning to smallar areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for the level indicated in the flood forecasts.Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property.This training programme should become a regular feature before the flood season every year.

8.9.3 Disaster Mitigation System and Preparedness.

This is an important measure which directly influences the damage prevention,if managed efficiently, at all levels according to the prescribed procedures and guide lines.Improper management could also result directly in increased damage. The State Government should, therefore, ensure that all routine exercises and necessary drills are carried out systematically before every flood season and departmental instructions, manuals and rules in this regard should be widely circulated so as to make these available to all concerned.It is observed that disaster mitigation system and the preparedness programme usually get activated only just before and during the flood season and no attention is paid during the rest of the year.Experience has shown that the activity has to be maintained continuously and there is a need for increased flood awareness in the Officers and staff of the concerned departments as also in the public and voluntary organisations to deal with flood emergencies

It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation.The training programmes,including education and publicity should be got arranged by the Civil Authorities with active participation of the Officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio(Akashvani), Doordarshan or Transmitted through other channels and the effective followup of such messages into appropriate actions should be taught to all people in the flood prone areas.

8.10 A map of the Main Ganga Stem basin in Bihar showing the completed,under execution and proposed flood management and drainage schemes is enclosed as Drawing No 11/01.

9.0 SUMMARY OF RECOMMENDATIONS

9.1 It is observed that there are sufficient Gauge-discharge sites in the Main Ganga, the Dharmawati and the Baya rivers in Bihar. However, at least one gauge-discharge site each in the Mahi and the Bhena rivers is required to be installed for having records of historical data for use of their water potential in future. The mode of measurement, recording of data, its analysis and study are required to be updated in order to improve the reliability of such data. For the sites maintained by the State Government, systematic and properly recorded data are not available. Attempts are now being made to collect and compile such data in "Water Year Book". Lot of initiative and concerted action are still required to be taken to compile such historical records in proper manner on continuous basis (instead of compiling haphazard and scattered data) for future use of these data. In order to satisfy the accuracy of such observations,it is suggested that in future, all the sites be maintained according to the standards (laid down by the WMO/Bureau of Indian standards and the data be observed in the prescribed manner, processed, analysed and recorded properly on continuous basis for use in the planning of water conservation and utilization schemes in the basin. The data observation procedure and method should be frequently checked by superior inspecting officers in order to ensure its accuracy.

[Para 4.7.1,4.7.3]

9.2 It is worthnoting that while from Buxar to Hathidah, the percentage of fine silt has been decreasing and those of medium and coarse silt increasing. In the reach between Hathidah to Azmabad on the downstream, the percentage of fine silt has increased from 67.91 per cent to 84.96 per cent where as those of medium and coarse silt have reduced from 23.65 per cent to 9.22 per cent and from 8.64 per cent to 5.82 per cent respectively. This is perhaps due to transportation of considerable amount of fine silt in the Ganga by the rivers of north Bihar which join between these two locations and also due to deposition of coarse silt on the way due to flatter slope of the river in this reach. This needs to be further investigated in detail and studied to arrive at some definite conclusion.

[Para 4.8.2]

9.3 The flood frequency analysis of the main Ganga river carried out by GFCC leads to the following conclusion:-

The flood for a 100 years frequency is approximately 20 per cent more than the flood corresponding to 25 years frequency. The embankments on the main river ganga may, therefore, be designed for a flood of 100 years frequency even for protecting predominantly agricultural land if the same is found economically viable and is considered as only alternative method for flood management in the area.

For the present, however, the criteria recommended by the RBA to adopt a design flood of 25 years frequency for protection of predominantly agricultural areas may be adhered.

[Para 5.3.3]

9.4 It appears that area suffering from surface drainage congestion in the basin is not being systematically surveyed and recorded every year in order to know the magnitude of the problem. It has also not been possible to delineate the areas affected by flood spills from those affected by drainage congestion as such details are not being observed. Efforts should be made to observe and keep separate records for the two aforesaid categories without any further delay.

[Para 6.2.3]

9.5 No systematic observation of ground water contour appears to have either been taken in the past or are being taken at present. The investigation carried out so far do not provide sufficient details to pin point these Zones. It is, therefore, necessary to carry out systematic field investigations regularly to pin-point Zones suffering from drainage congestion due to lack of proper sub-surface drainage.

[Para 6.2.4]

9.6 Ground water observation is not being done in a regular and systematic manner. It is therefore, suggested that the study of ground water structure should be continued in regular and systematic manner particularly in Baya and Mahi sub-basins to arrive at reliable conclusions with respect to sub-soil water table fluctuations in the basin and records be maintained for future planning of remedial measures.

[Para 6.2.7]

9.7 Post-facto evaluation studies for a few completed drainage schemes in North Bihar need to be undertaken quickly so that future planning for removal of drainage congestion in the basin is done after knowing their usefulness and efficiency.

[Para 6.2.5]

9.8 Future drainage schemes should be planned, designed and executed only on the basis of the results of the post-facto evaluation of completed drainage schemes.

[Para 8.4.4]

9.9 It is necessary to carry out review of the over all functioning as well as adequacy of the existing sluices in the embankments in the basin and to take further necessary action on the basis of such review.

[Para 6.2.6]

9.10 It is necessary that annual flood damage data are collected by the Revenue Authorities with active co-ordination of the staff of Water Resources, Agriculture, Road construction and Building construction Departments and the data are processed and compiled both district-wise as well as basin/ sub-basin wise at district and State level for future use in planning of relief measures and flood management respectively.

[Para 6.3.5]

9.11 It is observed that the flood damage statistics, which is essentially required for the benefit cost studies for any proposed flood management measures,are not being scientifically and rationally collected and compiled. The RBA had made many useful recommendations in this regard which do not seem to have been followed. This Commission recommends that the recommendations of the RBA should be followed strictly and realistic evaluation of flood damage district/river basin wise be carried out every year under the following three separately identified categories:-

i Unprotected areas,

ii Protected areas due to failure of protection works,

iii Areas between the embankments and the river.

The extent of drainage congestion in the protected and unprotected area should be indicated separately. The WRD dealing with flood management should be associated with collection and compilation of flood damage data.In order to eliminate any inconsistency, the flood damage data should be collectively reviewed by the concerned departments at the end of each year. Such reconciled long term data of flood damage is to be used in economic viability study for any future flood protection management scheme in the area.

[Para 6.3.7]

9.12 On the main Ganga river in Bihar, some embankments have already been constructed which are, however, not continuous in length and provide reasonable degree of protection from floods to a very small area only compared to the total flood prone area of the basin in Bihar. Frequency of flooding in the reach from Buxar to Farakka is 4 years and move out of 9 years. It is, therefore, considered desirable to protect such flood prone areas in the Main Ganga stem basin by providing embankments on both banks in the spilling zone of the river Ganga and these embankments be extended along tributaries also to contain the back water flow from the Ganga into its tributaries.

[Para 8.2.1]

9.13 Although, from time to time various anti erosion measures had been taken and are still being taken as specific vulnerable location, the river starts attacking at another location. Anti erosion works on a river of the size like the Ganga are generally costly both in initial construction as well as in subsequent maintenance. So, these are normally restricted to only such places,where valuable properties,important lines of communications, vital installations etc are in danger and their relocation is either very costly or not possible.It is considered desirable not to execute anti erosion/river training works on adhoc basis as is being done from year to year at present but it should be executed on the basis of results of model studies to be carried out in totality so as to avert possible disaster at a location other than protected by such works.Shortcut method approach in such situations is likely to be cost prohibitive and may not solve the problem permanently.

[Para 8.2.2]

9.14 Detailed studies should be under taken to find out the effectiveness an adequacy or otherwise of the existing sluices in the embankments and remedial measures be taken on priority basis to make them function properly as envisaged earlier and as is considered necessary at present. If found necessary, more sluices may be provided for proper and efficient drainage of the country side and also for providing irrigation to the areas on the country side in case of drought.

[Para 8.2.3]

9.15 It would have been desirable to have some detention basins at suitable places to partly moderate the peak floods of 25 years frequency and above. There is, however,no such depression available in the Main Ganga Stem basin except the area covered under Mokamah Group of Tals. The area is very fertile and bumper Rabi crops are being grown. The local people are demanding early drainage of the Tal area, preferably by the end of October. In view of his, as well as considering the insignificant relief that might accrue in the lower reaches from the flooding of the mighty river Ganga, even using the whole Tal areas as flood detention basin, this possibility is ruled out.

[Para 8.2.4]

9.16 In order to protect towns from flood, several Town Protection schemes had been formulated by the State Government. Some of them have been completed,some are under construction and some have not yet been taken up due to some reason or the other. It is suggested that hydraulic model studies for finalising the design, type and location of suitable anti-erosion works for the proposed Town protection schemes be carried out in the Irrigation Research Institute, Khagaul and the scheme be reviewed and finalised on the basis of such study being taken up in the existing circumstances.

[Para 8.3]

9.17 Some "Chaur" drainage schemes have been completed by providing link channels from "Chaurs" to trunk drains. It is observed that the benefits accruing from the completed schemes are not being properly recorded and evaluated every year at present.It is necessary to evaluate the performance of the completed drainage schemes and if it is found that these schemes are providing intended benefits, then other drainage schemes may be executed accordingly.If certain modifications are considered necessary, in order to derive the maximum possible benefits,then such modifications should be carried out immediately on priority.

[Para 8.4.2]

9.18 There are certain drainage schemes which have been taken up for execution long back but very insignificant progress has been made so far.It is desirable that all such schemes for drainage improvement in the basin which are lingering since long without accrual of any benefit should be reviewed on priority basis and completed,if found useful on such review,as early as possible to realise full benefits in order to make use of the investments already made as well as to prevent large scale escalation in their costs due to any further delay. Future drainage schemes should be planned,designed and executed only on the basis of the result of the post facto evaluation of completed schemes.

[Para 8.4.3,8.4.4]

9.19 There are certain low lying pockets in the deepest portion of the "Chaurs" or local depressions which can not be drained by gravity due to existing outfall conditions in the main and trunk drains.Such areas may be delineated on the village maps and developed for aquaculture and pisciculture as the case may be.Draining such low pockets by pumping is not considered economically viable.Even the availability of power in the area at present is not at all satisfactory.

[Para 8.4.5]

9.20 Some areas in the basin on the northern side have become unproductive on account of secondary salinisation.It is recommended to takeup action research programme to generate basic parameters for land reclamation in the existing socio-economic environment in two pilot project areas of around 500 ha each,one in canal command area of Gandak Project and the other outside canal command in the agro-climatic Zone 1.These areas should form a mini-watershed.It has been reported that Gandak Command Area Development Agency is doing some work in this direction.Full scale proposal for under taking reclamation work in the larger areas with proven methodology,can be prepared and implemented on a larger scale to derive optimum production and economic benefit from the investment.

[Para 8.5]

9.21 Soil conservation and watershed treatment measures are likely to have beneficial impact by way of reduction in the quantities of silt flowing into the river. A large portion of the catchment of the Ganga lies in the hilly areas,which are mostly outside Bihar,but watershed treatment to those areas will give benefit to Bihar also by reducing the quantum of silt being carried down the river in lower reaches which induces meandering tendency in the river.The State Government can only press for these works in upper catchment with concerned States at national level.

[Para 8.6]

9.22 A systematic survey and investigation of the existing embankments of the river and its tributaries is required to be carried out every year after the flood season and encroachment,if any,in the free board in any portion should be made good by raising the height of embankments correspondingly. Suitable protection works should be provided in the portion where the active river channel is flowing very close to the toe of the embankment and river training works may be carried out on the basis of hydraulic model studies to hold the river in order to keep the flowing channel away from the embankment.
[Para 8.7]

9.23 In the portion where the embankments have been eroded or are likely to be eroded, suitable retired embankment should be constructed to prevent flooding of the area already protected by the embankments. It is also necessary that the top of the embankment should have a water bound macadam road or at least provided with brick soling so that the embankments could be conveniently patrolled during the high flood condition in the rainy season and flood fighting materials could be transported conveniently during emergent situations.
[Para 8.7]

9.24 Occupation of embankments and land acquired should be got vacated effectively to avert any danger or risk to the people living in the protected area. Raised platforms above the highest flood level may be constructed in areas liable to inundation,near villages on Government or acquired lands. These could also be constructed on the countryside of the embankment. Such platforms should preferably be connected with all weather roads and should be provided with facilities to make living on them easy during floods. Such raised platforms should be handed over to Local Bodies/Panchayats for being utilised as community property and kept free from any kind of encroachment for its desired use when needed.
[Para 8.8]

9.25 The flood damage in recent years is primarily due to greater encroachment into flood plains.The flood plain zoning measures will be useful in both protected as well as unprotected areas as they prevent indiscriminate growth in unprotected areas and help in regulating the development activities in the protected areas so that unduly heavy damage is not caused in the event of failure of flood protection measures. As a major portion of the flood prone areas in the main Ganga Stem basin is either protected or protection embankments are under execution,such zoning regulations should be introduced in the unprotected areas first and for developments in the protected areas hence forth.

It would be necessary to procure contour maps of the flood prone area of the basin to a scale of 1:15000 with contour interval of 0.3 metre for implementation of this measure. Flood risk maps will have to be prepared by carrying out necessary hydrological analysis of the historical data and further hydraulic computations to identify areas prone to flood for different frequencies of floods such as 100 years,50 years and 25 years. Similar risk maps for the submersion caused due to drainage congestion as a result of water level likely to attain,corresponding to a 50 years and 25 years rainfall will also have to be prepared.
[Para 8.9.1]

9.26 On receipt of the forecast,its dissemination to the local population in terms of likely depth of inundation and its duration in the area by the Administrative Authorities is very important so that affected population,cattle,movable properties etc.are evacuated before the area gets submerged by flood waters which would cause damage. For this,a network of wireless stations and telephone system are necessary in the basin near critical /vulnerable reaches of embankments and towns etc.,specially where other means of communication are not dependable or adequate. Flood warning to smaller areas in villages may be conveyed through public address system or in its absence by beat of drums. Specific advice should be given to the people regarding evacuating the areas likely to be affected and also about the locations which could be considered safe for level indicated in the flood forecasts. Necessary training in this regard should be imparted to the concerned officials on a regular basis so that they are well versed in the interpretation of the forecast and taking precautionary measures in the event of an imminent threat to the life and property. This training programme should become a regular feature before the flood season every year.

[Para 8.9.2]

9.27 The State Government should ensure that all routine exercises and necessary drill are carried out systematically before every flood season and departmental instructions,manuals and rules in regard to " Disaster Mitigations System and Preparedness" should be widely circulated so as to make these available to all concerned. It is essential that training programme and exercises are regularly held to improve the preparedness of officials and the public. This will develop confidence amongst all concerned to manage any emergency situation. The training programmes,including education and publicity should be got arranged by the Civil Authorities with active participation of the Officers incharge of flood management and voluntary organisations. The interpretation of distress codes and signals and flood warning messages being broadcast over All India Radio (Akashvani),Doordarshan or transmitted through other channels and the effective followup of such messages into appropriate actions should be taught to all people in the flood prone areas.

[Para 8.9.3]

Annex 1
[Para 4.5]

NORMAL RAINFALL (1901-1950) FOR I M D STATIONS LOCATED IN THE MAIN GANGA STEM IN BIHAR

Sl no	Name of district	Name of the Rain Gauge Station	Geo co-ordinate Latitude	Geo co-ordinate Longitude	No. of Years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Patna	Patna(obsy)	25° 37'	85° 10'	50	15.5	22.1	9.4	8.4	30.0	158.0	276.1	340.4	237.7	54.6	8.9	5.3	1166.4
2	Patna	Dinapur	25° 38'	85° 03'	50	14.5	20.3	9.1	7.9	24.4	140.2	259.1	326.9	211.8	51.3	12.9	4.6	1083.0
3	Patna	Barh	25° 29'	85° 43'	50	12.5	20.3	9.1	8.1	26.9	140.2	236.8	265.4	185.4	43.9	8.6	3.3	962.5
4	Patna	Bakhtiarpur	25° 27'	85° 32'	36	19.1	27.2	13.2	10.4	32.5	125.7	294.6	351.8	224.3	49.3	9.9	2.0	1160.0
5	Bhojpur	Buxar	25° 34'	83° 59'	49	19.3	22.1	8.6	5.6	16.5	125.0	286.8	308.6	194.8	51.3	6.9	5.3	1050.2
6	Bhojpur	Arrah(obsy)	25° 34'	84° 40'	50	17.8	24.6	9.1	7.4	23.1	143.0	315.5	331.0	223.0	58.9	9.7	4.3	1167.4
7	Bhojpur	Ramnagar	25° 25'	84° 15'	50	15.5	22.1	9.7	6.3	20.6	117.6	277.6	287.3	170.2	45.7	9.7	6.1	988.4
8	Rohtas	Chenari	24° 55'	83° 48'	41	24.4	28.5	10.9	6.3	15.2	141.0	399.8	385.8	252.5	55.9	11.7	5.8	1337.8
9	Rohtas	Koath	25° 20'	84° 15'	50	17.3	23.6	8.6	7.1	18.3	123.2	280.9	337.1	193.3	54.1	11.7	4.6	1079.8
10	Rohtas	Sikraul	25° 26'	84° 08'	50	17.8	23.1	8.6	5.6	11.2	129.8	283.2	321.3	197.4	41.9	8.1	5.1	1053.1
11	Vaishali	Mahua	25° 48'	65° 24'	50	12.5	19.8	8.4	9.1	35.8	172.0	279.7	321.6	236.5	56.1	7.6	3.1	1162.2
12	Munger	Monghyr	25° 23'	86° 28'	49	12.5	18.3	9.4	15.5	45.7	174.0	263.4	324.9	212.3	55.4	11.2	4.1	1146.7
13	Bhagalpur	Bhagalpur	25° 15'	87° 00'	50	11.9	19.8	12.5	17.3	57.4	173.0	245.6	268.2	194.8	71.6	9.1	2.0	1083.2
14	Bhagalpur	Colgong	25° 16'	87° 14'	50	10.7	20.3	12.9	24.4	71.9	214.1	286.3	282.2	218.7	71.4	9.9	2.0	1224.8
15	Bhagalpur	Sultanganj	25° 15'	86° 45'	34	12.9	18.0	6.4	15.0	39.1	168.4	285.5	281.7	193.0	67.6	9.1	2.0	1100.7
16	Santhal-Pargangas	Rajmahal	25° 03'	87° 50'	50	9.7	20.6	15.7	30.5	94.0	228.6	307.6	302.8	253.2	96.3	11.9	2.3	1373.2
17	Santhal-Pargangas	Mahagama	25° 03'	87° 19'	50	10.0	16.2	12.2	17.5	61.2	156.7	244.1	258.8	193.3	72.4	7.9	2.5	1024.3
18	Santhal-Pargangas	Sahibganj	25° 15'	87° 38'	50	9.1	20.1	13.2	21.8	81.8	239.5	309.4	316.2	277.4	102.1	10.9	1.3	1402.8

[Source: Comprehensive Plan of Flood Management for the Main Ganga Stem Basin prepared by GFCC in July 1990]

Annex – 2
[Para 4.5]

Average annual and monsoon rainfalls of different districts lying in the Main Ganga stem Basin in Bihar

Sl No	Name of District	Average Annual Rainfall (mm)	Average Monsoon Rainfall (mm)
1	2	3	4
1	Patna	1092.98	993.90
2	Bhojpur	1068.90	978.80
3	Rohtas	1035.10	1048.78
4	Vaishali	1162.20	1065.90
5	Munger	1146.70	1030.00
6	Bhagalpur	1149.30	1016.00
7	Santhal Parganas	1370.00	1195.92
8	Gopalganj	1233.40	N.A.
9	Siwan	1131.40	N.A.
10	Saran	1127.90	N.A.

[Source: Comprehensive Plan of Flood Management for the Main Ganga Stem Basin prepared by GFCC in 1990; Directorate of statistics and evaluation, Government of Bihar]

Annex 3
[Para 4.7.1]

List of Existing sites, maintained by CWC & State Govt, their type and period of data availability in the Main Ganga Stem Basin in Bihar

Sl No	River/ Tributary	Name of Site	Maintained by	Type	Period of data availability
1	Ganga	Buxar	CWC	GDSWQ	1960-1987
2	Ganga	Taranpur	CWC	G	nil
3	Ganga	Patna(Digha)	CWC	G	nil
4	Ganga	Patna(Gandhighat)	CWC	GDSWQ	1965-1986
5	Ganga	Hathidah	CWC	GDSWQ	1948-1984
6	Ganga	Munger	CWC	G	nil
7	Ganga	Bhagalpur	CWC	G	nil
8	Ganga	Kahalgaon	CWC	G	nil
9	Ganga	Azamabad	CWC	GDSWQ	1957-1987
10	Ganga	Maharajpur	CWC	G	nil
11	Ganga	Rajmahal	CWC	G	nil
12	Ganga	Chamtha	WRD	G	nil
13	Ganga	Barh	WRD	G	nil
14	Ganga	More	WRD	G	nil
15	Ganga	Khutaha	WRD	G	nil
16	Ganga	Dakara	WRD	G	nil
17	Ganga	Sultanganj	WRD	G	nil
18	Ganga	Sabour	WRD	G	nil
19	Ganga	Narayanpur	WRD	G	nil
20	Ganga	Mahadeopur	WRD	G	nil
21	Baya	Bishunpur	WRD	GD	1991-1992
22	Baya	Wazitpur	WRD	G	nil
23	Ganga	Sinhaghat	CWC	GD	nil
24	Baya	Mahua	CWC	GD	nil
25	Ganga	Surajgarha	WRD	G	nil
26	Ganga	Jamania Pump	WRD	G	nil
27	Dharmawati	Pump site	WRD	GD	nil
28	Dharmawati	Panjraw	WRD	GD	nil
29	Kao	G.T. Road	WRD	GD	nil
30	Kao	Ara Mohania crossing	WRD	GD	nil
31	Kao	Malai Barrage	WRD	GD	nil
32	Ganga	Fatuha	WRD	G	nil
33	Ganga	Khusrupur	WRD	G	nil
34	Ganga	Bidhipur	WRD	G	nil
35	Ganga	Bakhtiyarpur	WRD	G	nil
36	Ganga	Piparia	WRD	G	nil
37	Ganga	Shivnar	WRD	G	nil
38	Ganga	Mahendrapur	WRD	G	nil
39	Ganga	Hemeja	WRD	G	nil
40	Ganga	Barari	WRD	G	nil
41	Bhena	Rly Bridge	WRD	G	nil
42	Ganga	Mirzachowki	WRD	G	nil
43	Ganga	Pirpainti	WRD	G	nil
44	Ganga	Radhanagar	WRD	G	nil
45	Ganga	Rajmahal	WRD	G	nil

Note G – Gauge
GD – Gauge and Discharge
GDSWQ – Gauge, Discharge, Silt and Water Quality

[Source: Comprehensive Plan of Flood Management for the Main Ganga Stem Basin prepared by GFCC in 1990, Water Year Book of 1991, by State Hydrology Cell of WRD, Government of Bihar.]

Annex 4

Monthly Average Silt data in Monsoon period for the Main Ganga Stem Basin for the years from 1971 to 1987

Site – Buxar

Sl No	Month	Average Monthly Sediment load in tonnes	Graded %age of sediment to total			Remarks
			Coarse in %	Medium in %	Fine in %	
1	June	847496	0.00000	1.32870	98.67130	
2	July	154313000	1.81158	5.84642	92.34200	
3	August	1132740000	1.99689	17.80710	80.19610	
4	September	480723000	1.70609	7.59769	90.69620	
5	October	190578000	1.23279	4.00992	,94.75730	

Site – Patna

Sl No	Month	Average Monthly Sediment load in tonnes	Graded %age of sediment to total			Remarks
			Coarse in %	Medium in %	Fine in %	
1	June	8777270	2.63236	9.38106	87.98660	
2	July	283488000	3.57262	13.32150	83.10590	
3	August	1066820000	.4.64051	14.66580	80.69370	
4	September	982531000	3.60381	16.29500	80.10120	
5	October	231402000	2.75773	11.24250	85.99990	

Site – Hathidah

Sl No	Month	Average Monthly Sediment load in tonnes	Graded %age of sediment to total			Remarks
			Coarse in %	Medium in %	Fine in %	
1	June	17499500	11.46650	25.40210	63.13140	
2	July	427271000	9.63814	15.12990	75.23190	
3	August	1341050000	8.38472	28.14300	63.47230	
4	September	1452600000	10.18370	24.35740	65.45890	
5	October	540863000	3.51416	24.20580	72.28000	

Site – Azmabad

Sl No	Month	Average Monthly Sediment load in tonnes	Graded %age of sediment to total			Remarks
			Coarse in %	Medium in %	Fine in %	
1	June	26920000	4.84466	6.16728	88.98810	
2	July	430696000	5.31685	8.08814	86.59500	
3	August	1447510000	7.15189	15.22980	77.61840	
4	September	1215800000	5.29027	8.66955	86.04020	
5	October	670260000	6.51233	7.93410	85.55360	

[Source: Comprehensive Plan of Flood Management for the Ganga Sub-basin prepared by the GFCC in July 1990]

Annex – 5
[Para – 5.3.1]

Maximum discharge recorded in the years with date and corresponding gauge, Peak gauge recorded with respect to GTS

River: Ganga Site: Buxar

Sl No	Year	Date	Peak Discharge in cumecs	Corresponding gauge in m	Date	Peak Gauge in m	Remarks
1	2	3	4	5	6	7	8
1	1960	NA	24700	NA	NA	60.222	
2	1961	NA	24741	NA	NA	60.746	
3	1962	NA	39805	NA	NA	60.300	
4	1963	NA	30405	NA	NA	59.659	
5	1964	NA	34219	NA	NA	59.669	
6	1965	NA	20700	NA	NA	59.172	
7	1966	NA	24166	NA	NA	59.188	
8	1967	NA	40800	NA	NA	61.201	
9	1968	NA	22740	NA	NA	59.121	
10	1969	NA	43085	NA	NA	60.206	
11	1970	NA	33490	NA	NA	60.171	
12	1971	3-8-71	38700	60.636	15-9-71	61.036	
13	1972	1-9-72	24659	59.288	2-9-72	59.371	
14	1973	13-9-73	33056	60.081	5-9-73	60.281	
15	1974	26-8-74	31305	59.991	27-8-74	60.078	
16	1975	26-8-75	26587	60.131	25-8-75	60.171	
17	1976	18-8-76	26082	58.716	18-9-76	60.131	
18	1977	12-8-77	26885	59.560	22-9-77	59.931	
19	1978	11-9-78	35357	61.401	11-9-78	61.401	
20	1979	14-8-79	16530	57.251	22-7-79	57.796	
21	1980	2-9-80	32483	60.739	3-9-80	60.756	
22	1981	24-9-81	20501	58.851	25-8-81	59.257	
23	1982	4-9-82	42847	61.031	4-9-82	61.031	
24	1983	16-9-83	45933	60.896	16-9-83	60.896	
25	1984	11-9-84	30068	59.861	11-9-84	59.861	
26	1985	14-8-85	37629	60.048	14-8-85	60.048	
27	1986	1-8-86	59754	60.156	2-8-86	60.718	
28	1987	12-9-87	24156	59.486	3-9-87	59.491	
29	1988	–8-88	26248*		NA	59.550	*Maximum
30	1989	–9-89	13904*		6-9-89	57.940	of 10 days
31	1990	–9-90	20313*		23-9-90	60.230	average
32	1991	–9-91	20794*		31-8-91	60.430	
33	1992	NA			NA	60.580	

Annex – 5 (contd)

Maximum discharge recorded in the years with date and corresponding gauge, Peak gauge recorded with respect to GTS

River: Ganga Site: Patna

Sl No	Year	Date	Peak Discharge in cumecs	Corresponding gauge in m	Date	Peak Gauge in m	Remarks
1	2	3	4	5	6	7	8
1	1965	NA	24500	NA	NA	48.244	
2	1966	NA	32528	NA	NA	48.259	
3	1967	NA	46221	NA	NA	49.079	
4	1968	NA	25619	NA	NA	48.484	
5	1969	NA	42043	NA	NA	49.239	
6	1970	NA	23343	NA	NA	48.874	
7	1971	4-9-71	56658	48.884	30-7-71	49.657	
8	1972	2-9-72	33026	48.097	2-9-72	48.097	
9	1973	4-9-73	44615	48.884	15-8-73	49.014	
10	1974	28-8-74	50840	48.869	29-8-74	48.909	
11	1975	NA	56980	49.832	24-8-75	49.959	
12	1976	19-9-76	59192	49.042	18-9-76	49.839	
13	1977	2-8-77	36333	48.354	10-8-77	48.909	
14	1978	12-9-78	66800	49.689	NA	49.794	
15	1979	30-7-79	22088	47.569	25-7-79	47.969	
16	1980	17-8-80	58126	49.664	17-8-80	49.664	
17	1981	26-8-81	27606	48.494	26-8-81	48.494	
18	1982	6-9-82	60155	49.979	3-9-82	50.034	
19	1983	19-9-83	61200	49.574	19-9-83	49.614	
20	1984	7-9-84	52500	49.114	7-9-84	49.114	
21	1985	13-8-85	35800	48.669	25-8-85	48.669	
22	1986	4-8-86	46200	49.049	24-8-86	49.049	
23	1987				NA	50.120	
24	1988				NA	49.070	
25	1989				7-9-89	47.880	
26	1990				17-8-90	48.970	
27	1991				2-9-91	50.100	
28	1992					49.410	

Annex – 5 (contd)
[Para – 5.3.1]

Maximum discharge recorded in the years with date and corresponding gauge, Peak gauge recorded with respect to GTS
River: Ganga Site: Hathidah

Sl No	Year	Date	Peak Discharge in cumecs	Corresponding gauge in m	Date	Peak Gauge in m	Remarks
1	2	3	4	5	6	7	8
1	1948	NA	69303	NA	NA	43.000	
2	1949	NA	48110	NA	NA	41.968	
3	1950	NA	57255	NA	NA	42.288	
4	1951	NA	36079	NA	NA	41.053	
5	1952	NA	47733	NA	NA	42.038	
6	1953	NA	42167	NA	NA	41.632	
7	1954	NA	40609	NA	NA	41.437	
8	1955	NA	43922	NA	NA	41.925	
9	1956	NA	52931	NA	NA	42.123	
10	1957	NA	39154	NA	NA	41.544	
11	1958	NA	35809	NA	NA	41.757	
12	1959	NA	46327	NA	NA	42.000	
13	1960	NA	43044	NA	NA	41.887	
14	1961	NA	52238	NA	NA	42.227	
15	1962	NA	59747	NA	NA	42.005	
16	1963	NA	47152	NA	NA	41.795	
17	1964	NA	46285	NA	NA	41.965	
18	1965	NA	33541	NA	NA	41.385	
19	1966	NA	34094	NA	NA	41.315	
20	1967	NA	54128	NA	NA	42.220	
21	1968	NA	44821	NA	NA	41.720	
22	1969	NA	73530	NA	NA	42.715	
23	1970	NA	48781	NA	NA	42.165	
24	1971	12-8-71	66990	43.000	7-8-71	43.151	
25	1972	20-9-72	32750	40.145	4-9-72	41.285	
26	1973	20-8-73	49248	42.125	20-8-73	42.125	
27	1974	29-8-74	50835	42.275	29-8-74	42.275	
28	1975	26-8-75	65185	42.965	25-8-75	42.985	
29	1976	20-9-76	65430	43.035	20-9-76	43.035	
30	1977	27-8-77	54497	40.295	11-8-77	42.195	
31	1978	17-8-78	63228	42.930	17-8-78	42.930	
32	1979	31-7-79	33310	40.915	21-8-79	40.993	
33	1980	17-8-80	65760	42.854	18-8-80	42.865	
34	1981	27-8-81	40380	41.490	30-8-81	41.915	
35	1982	6-9-82	66974	42.932	5-9-82	42.982	
36	1983	20-9-83	54900	42.520	20-9-83	42.520	
37	1984	7-9-84	53300	42.310	7-9-84	42.310	
38	1985				25-8-85	41.945	
39	1986				3-8-86	42.175	
40	1987				15-9-87	42.650	
41	1988					42.000	
42	1989				7-9-89	40.680	
43	1990				17-8-90	41.740	
44	1991				3-9-91	42.560	
45	1992					42.120	

Annex – 5 (contd)
[Para – 5.3.1]

Maximum discharge recorded in the years with date and corresponding gauge, Peak gauge recorded with respect to GTS

River: Ganga Site: Azmabad

Sl No	Year	Date	Peak Discharge in cumecs	Corresponding gauge in m	Date	Peak Gauge in m	Remarks
1	2	3	4	5	6	7	8
1	1957	NA	22781	NA	NA	30.617	
2	1958	NA	23913	NA	NA	30.709	
3	1959	NA	49333	NA	NA	31.513	
4	1960	NA	24500	NA	NA	31.336	
5	1961	NA	57918	NA	NA	31.601	
6	1962	NA	65476	NA	NA	31.320	
7	1963	NA	59685	NA	NA	31.122	
8	1964	NA	38850	NA	NA	31.414	
9	1965	NA	31835	NA	NA	30.926	
10	1966	NA	34688	NA	NA	30.979	
11	1967	NA	54264	NA	NA	31.651	
12	1968	NA	39260	NA	NA	31.246	
13	1969	NA	58420	NA	NA	32.026	
14	1970	NA	52540	NA	NA	31.346	
15	1971	NA	83046	NA	NA	32.396	
16	1972	4-9-72	48506	30.636	7-9-72	30.741	
17	1973	NA	74131	NA	NA	31.321	
18	1974	NA	68453	NA	NA	31.326	
19	1975	8-7-75	63965	29.411	29-9-75	31.571	
20	1976	22-9-76	40891	32.246	22-9-76	32.246	
21	1977	5-8-77	58932	31.166	12-8-77	31.446	
22	1978	21-8-78	64200	32.316	20-8-78	32.376	
23	1979	25-8-79	31000	30.266	1-9-79	30.386	
24	1980	6-9-80	66700	32.206	6-9-80	32.206	
25	1981	30-7-81	38600	29.996	NA	30.996	
26	1982	20-9-82	38500	30.100	12-9-82	31.910	
27	1983	21-9-83	55600	31.300	21-9-83	31.300	
28	1984	14-9-84	52700	31.261	14-9-84	31.261	
29	1985	28-8-85	52900	30.846	28-8-85	30.846	
30	1986	5-8-86	56124	31.046	5-8-86	31.046	
31	1987	18-9-87	68500	31.636	18-9-87	31.636	
32	1988	–8-88	45462				
33	1989	–9-89	24625*				*Maximum of 10 days average
34	1990	–8-90	34486*				
35	1991	–9-91	53190*				
36	1992	–9-92	26150*				

[Source: Comprehensive Plan of Flood Management of the Main Ganga Stem Basin prepared by GFCC in 1990]

Annex-6
[Para-6.1.5]

HISTORY OF PAST FLDODS IN THE MAIN GANGA STEM BASIN IN BIHAR

The river Ganga passes through almost middle of Bihar from west to east and it is master drain of Bihar. The areas beside the river in almost whole length of Bihar is flood prone and they are threatened almost every year from floods. According to the district gazetteer of Patna, the floods of 1901, 1913, 1923, 1948 and 1967 in Patna were severe in this century and thereafter, there were very heavy floods in Patna in 1971 and 1975. Yearwise history of floods, as available, are given below:

1901 This year flood occurred due to rise in water level simultaneously in the Ganga and the Sone rivers. Nearby areas of patna district were flooded. In all 257 villages were affected, thousands of houses were damaged in Diara areas and the entire Kharif crops got damaged.

1913 The flood of 1913 in Patna was due to continuous and heavy rain from 7th to 11th August of the year. The water from the districts of Gaya and Hazaribagh also came simultaneously into the Ganga, which resulted in heavy flood in Patna, Barh and Bihar Sub-divisions. 40 persons and 547 cattle were lost and 23,360 buildings were damaged.

1948 There were two floods in the Ganga in that year, one in August and the other in September. In Saran district, a number of Villages in Sabalpur Diara of Sonepur Police Station, in the vicinity of Sitalpur and Dighwara Railway Stations were inundated. An important bundh on Mehura nala was washed away and the entire Sonepur village got submerged. Due to flood in the Ganga, discharge of the Kosi river into the Ganga was locked, which resulted in spilling of water in Purnea district. Due to heavy rains in last week of August, large areas in Patna city, Danapur and barh subdivisions were flooded.

1954 In 1954, it was exceptional that the floods in almost all the rivers of the country seem to have occurred more or less at the same time in that year creating an unprecedented situation in respect of duration, extent and intensity. Various meteorological factors during the last ten days of July and again at the end of August combined to cause heavy rainfall over and near the entire stretch of the eastern Himalayas, resulting in an excessive spilling of the tributaries of the Ganga. Practically the whole of the north Bihar was liable to submersion during the floods. Saran district was visited by one of the worst floods of recent years. In Purnea district, the area between Kursela to Bhawanipur appeared like a vast sheet of water. The flood water, spilling over the banks, inundated the area on the country side and damaged the standing crops.

1956 The Gogri Narayanpur marginal embankment was breached in its 32nd Km near village Salarpur due to bank erosion. A loop bund was constructed but it could not stand on the rush of water and gave way. The river also attacked the bund in 35th – 37th Km and caused a breach near village Mathurapur.

1967 Patna was visited by a severe flood through Punpun river. Rajendra Nagar and Kankarbagh area in particular were under water for about two weeks. There was no evidence of loss of human life, But many cattle were lost and there was a heavy loss of Government and private properties.

1971 Patna experienced a very severe flood. The Ganga was above the danger level for 57 days from 21st July. In that period the Sone river experienced three heavy floods which affected the floods in the Ganga too. Digha, Maner and surrounding areas were flooded due to rise in water level of the Ganga. Water was flowing 0.3 m above the Digha-Maner road. The Combined waters of the Sone and the Ganga had headed up near Patna Canal, but due to quick repair works in western bund of Patna Canal the water could not enter Patna.

1975 Patna and its surrounding areas experienced the worst flood so far in the last week of August, 1975 when almost entire Patna town was in one to three metres deep water. This situation was for one week or more. due to which there was heavy loss of private and Government properties.

Due to high flood level in the Ganga at Digha, the combined water of the Sone and the Ganga were flowing over Digha Maner road in a depth of 30 to 60 cm for several days from 22nd August. The Maner distributary was breached at 11 places through which a large amount of water was flowing over the Bihta-Maner road, Bihta Maner embankment and Khagaul-Danapur road and lastly the Water got headed up on the left side of Patna canal. As a result both sides of Patna canal were breached in the night and the water entered patna and its surrounding areas. The capital Patna and its adjoining areas were under 1 m to 3 m depth of water. No arrangement could be done immediately to drain out the water due to high water level of the Ganga and inadequate waterways. Some villages remained under flood even for 15 days also.

1987 In this flood, Chapra, Arrah, Buxar and Bhagalpur town and nearby areas were affected. This flood established new highest Flood Level of 50.12 m at Patna (Gandhighat) site on 12th September. It remained above danger level at patna, Hathidah, Munger, Bhagalpur, Kahalgaon for 3 to 10 days.

1990 The river exerted heavy pressure on Chak ring bandh of Gupta- Lakhminia emabnkment at ch 98 and damaged the bed bar. However no damage to life and property was caused.

1991 The river flowed above danger mark from 29.8.91 to 14.9.91 at Dighaghat, from 26.8 to 14.9 at Gandhighat, from 30.8 to 13.9 at Hathidah and from 30.8 to 16.9 at Kahalgaon. It exerted heavy pressure on Chak ring bandh below ch, 20 and damaged revetment work near Ballahpur.

1992 The river flowed above danger level at Buxar from 16.9 to 18.9, at Gandhighat from 29.8 to 31.8 and 15.9 to 20.9, at Hathidah from 16.9 to 20.9 and at Kahalgaon from 16.9 to 21.9. The river exerted presure on Gupta-Lakhminia embankment between 4 and 6 km and there was severe erosion in 60 m length. The embankment was saved by resorting to flood fighting work.

1993 There was some presure on Gupta-Lakhminia embankment between 4 and 6 km, on Hazipur-Bazitpur embankment between ch 1060 and 1065 and on Narainpur embankment between ch 50 and 55. Embankments were saved by flood fighting work.

[Source: Comprehensive Plan of Flood Management in the Main Ganga Stem Basin prepared by GFCC in 1990]

FLOOD DAMAGE DATA FOR THE MAIN GANGA STEM BASIN
(CONVERTED FRDM THE AVAILABLE FIGURES FDR THE DISTRICTS IN THE BASIN)

Sl No	Year	Area Affected in Lha	Damage to Crops			Damage to Houses			Cattle Lives Lost in nos	Human Lives Lost in nos	Damage to Public Utility in Rs. Lakh		Total Damage in Rs. Lakh	
			Area in Lha	Value in Rs Lakh: At then current price	Value in Rs Lakh: At 1991 constant price	Numbers	Value in Rs Lakh: At then current price	Value in Rs Lakh: At 1991 constant price			At then current price	At 1991 constant price	At then current price	At 1991 constant price
t	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1968	1.03	0.08	104.80	629.27	8395	9.80	58.84	749	2	0.00	0.00	114.60	688.11
2	1969	2.04	0.29	235.90	1344.78	28600	48.20	274.77	212	10	15.70	89.50	299.80	1709.05
3	1970	2.31	0.64	483.50	2607.27	6584	10.10	54.46	39	2	3.10	16.72	496.70	2678.45
4	1971	10.00	3.35	3887.70	20858.48	282347	910.30	4883.99	450	24	859.10	4609.29	5657.10	30351.75
5	1972	0.00	0.00	0.00	0.00	0	0.00	0.00	0	0	0.00	0.00	0.00	0.00
6	1973	2.06	0.65	782.40	3220.94	25854	54.70	225.19	1	3	20.30	83.57	857.40	3529.70
7	1974	5.33	2.98	4699.40	15351.71	71494	616.10	2012.64	59	7	0.00	0.00	5315.50	17364.35
8	1975	4.30	2.13	2471.10	8153.90	59355	252.10	831.86	809	46	0.00	0.00	2723.20	8985.76
9	1976	8.49	2.34	2692.40	9509.34	148247	853.40	3014.14	1224	50	0.00	0.00	3545.80	12523.47
10	1977	2.63	0.48	274.50	851.07	2240	6.00	18.60	4	1	0.40	1.24	280.90	870.92
11	1978	6.12	2.19	2071.80	6482.94	66946	209.10	654.30	46	48	0.00	0.00	2280.90	7137.24
12	1979	1.29	0.45	330.50	974.96	5121	18.60	54.87	0	1	2.70	7.96	351.80	1037.80
13	1980	3.28	1.93	2032.90	5390.86	19619	100.90	267.57	19	31	29.50	78.23	2163.30	5736.66
14	1981	1.26	0.78	952.60	2210.69	6733	43.20	100.25	2	3	21.90	50.82	1017.70	2361.77
15	1982	2.32	0.97	2222.80	4909.90	17290	173.40	383.02	1	13	236.60	522.62	2632.80	5815.54
16	1983	2.94	1.13	385.30	760.51	3884	23.50	46.38	3	11	44.80	88.43	453.60	895.32
17	1984	2.56	1.12	728.35	1308.16	22799	96.90	174.04	5	2	207.80	373.22	1033.05	1855.42
18	1985	0.48	0.27	144.76	253.36	3271	108.90	190.59	13	3	30.40	53.21	284.06	497.15
19	1986	0.92	0.50	432.60	620.09	1453	43.00	61.64	0	0	22.30	31.97	497.90	713.69
20	1987	7.16	3.41	9131.30	13088.89	253247	2809.10	4026.59	898	87	1628.50	2334.31	13568.90	19449.78
21	1988	1.92	0.93	1156.58	1530.59	2526	69.92	92.53	9	21	27.24	36.05	1253.74	1659.17
22	1989	0.59	0.28	59.23	73.40	739	16.20	20.08	0	1	1.64	2.03	77.07	95.51
23	1990	1.57	0.45	257.9	293.22	2051	32.23	36.64	15	9	14.15	16.09	304.29	345.95
24	1991	2.63	1.05	646.67	646.67	2758	83.33	83.33	27	16	43.07	43.07	773.07	773.07
25	1992	0.29	0.04	46.39	46.39	67	2.16	2.16	0	0	0.00	0.00	48.55	48.55
TOTAL		73.52	28.44	36231.39	101117.39	1041620	6591.14	17568.48	4585	391	3209.20	8438.31	46031.73	127124.18
AVERAGE		2.94	1.14	1449.26	4044.70	41664.80	263.65	702.74	183.40	15.60	128.37	337.53	1841.27	5084.97

[Source 1 Comprehensive plan of Flood Management for the main Ganga stem Basin prepared by GFCC in 1990 (up to 1987)
2 From 1988 to 92, converted on above basis from the data obtained from Relief & Rehabilitation Department, Govt of Bihar]

Annex-8
[Para 7.3.5]

LIST OF FLOOD CONTROL WORKS COMPLETED OR UNDER EXECUTION IN THE MAIN GANGA STEM BASIN

Sl No	River/ Tributary/ Sub-tributary	Name of the Scheme	Nature of the Scheme ie Embankment, Anti erosion etc	Date of start	Date of comp-letion	Capital cost in Rs lakh		Monitary Value of average annual benefit (Rs lakh)		Lengths of embankments (Km)			Benefits from embankment (000 ha)			No of Town/ Village protected	No of Village raised or No raised P.form	District Benifited	Remarks
						Esti-mated	Actual	Esti-mated	Actual	Right bank	Left bank	Total	Right bank	Left bank	Total				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A Completed Schemes																			
1	Ganga	Chandpur & Hatta bund (Left)	Embankment	NA	NA	NA	NA	NA	NA		5.90	5.90		1.27	1.27			Samastipur	
2	Ganga	Kasba Rupnagar Embankment (L)	Embankment	1957	NA	4.11	NA	NA	NA		9.20	9.20		1.30	1.30			Begusarai	
3	Ganga	Munger Embankment (L)	Embankment	NA	NA	NA	NA	NA	NA		20.00	20.00		4.40	4.40			Begusarai	
4	Ganga	Kasba Rupnagar (L)	Embankment	NA	NA	NA	NA	NA	NA		8.80	8.80		1.20	1.20			Begusarai	
5	Ganga	Gupta Bandh Embankment (L)	Embankment	NA	NA	NA	NA	NA	NA		13.20	13.20		3.25	3.25			Begusarai	
6	Ganga	Gupta Lakhminia Embankment(L)	Embankment	1958	NA	24.85	NA	NA	NA		20.00	20.00							
7	Ganga	Chak Ring bundh (L)	Embankment	NA	NA	NA	NA	NA	NA		5.00	5.00		4.20	4.20			Begusarai	
8	Ganga	Old Gogari Embankment (L)	Embankment	NA	NA	NA	NA	NA	NA		8.00	8.00		2.70	2.70			Khagaria	
9	Ganga	Azampur Karhagola Embankment (L)	Embankment	1955	NA	NA	NA	NA	NA		8.40	8.40						Katihar	
10	Ganga	Shankar Embankment (L)	Embankment	1955	NA	NA	NA	NA	NA		18.80	18.80		19.43	19.43			Katihar	
11	Ganga	Karhagola Jaunia Second Retired Line	Retired line.	NA	NA	NA	NA	NA	NA		5.70	5.70		0.91	0.91			Katihar	
12	Ganga	Gogri Narayanpur (L)	Embankment	1955	NA	21.45	NA	NA	NA		44.20	44.20		14.40	14.40			Khagaria	
13	Baya	Bajidpur Embankment (L)	Embankment	NA	NA	NA	NA	NA	NA		28.00	28.00		4.40	4.40			Samastipur	
14	Mahi	Mahi Embankment (L)	Embankment	NA	NA	NA	NA	NA	NA		20.80	20.80						Saran	
15	Mahi	Mahi Embankment (R) (malahi to confluence)	Embankment	NA	NA	NA	NA	NA	NA	19.20	-	19.20			10.50			Saran	
16	Ganga	Mansi-Mungerghat Protection Scheme.	Antierosion Scheme	1973-74	1982-83		368.92	NA	NA									Khagaria	
17	Ganga	Patna town protection Scheme	Town Protection	1975	1992	2713.00	4065.52	NA	NA	143.96		143.96	81.80		81.80	1		Patna	
18	Ganga	Rajmahal Town Protection Scheme	Town Protection	NA	NA	NA	15.60	NA	NA							1		Sahebganj	
19	Ganga	Sahebganj Town Protection Scheme	Town Protection	NA	NA	NA	10.00	NA	NA							1		Sahebganj	
20	Ganga	Khutaha Village protection Scheme	Town Protection	NA	NA	NA	456.37	NA	NA							1		Munger	
21	Ganga	Ballabhpur Village Protection Scheme	Town Protection	NA	NA	NA	136.57	NA	NA							1		Begusarai	
B Ongoing Schemes																			
1	Ganga	Buxar Koilwar Embankment	Embankment	1974		10031.96	4728.58	NA	NA	218.37		218.37	135.86		135.86			Bhojpur	
2	Ganga	Hajipur Bajidpur Embankment	Embankment	1981		1681.00	458.72	NA	NA		93.00	93.00		80.33	80.33			Vaishali	
3	Ganga	Barahiya Town Protection Scheme	Town Protection	1974		NA	695.94	NA	NA				10.00		10.00	1		Samastipur Munger	

[Source: Comprehensive Plan of Flood Management of the Main Ganga Stem Basin, prepared by GFCC in 1990, Report submitted by the Chief Engineers Siwan, Motihari, Muzaffarpur and Samastipur, Administrative Report of 1991-92 of WRD, Government of Bihar]

Annex 9
[Para 7.7]

LIST OF COMPLETED ANTI-EROSION WORKS, RETIRED EMBANKMENTS
(costing more than 25 lakhs) in the MAIN GANGA STEM BAASIN

Sl no	Name of Scheme	Type of Scheme	Cost of Scheme in Rs lakh	Remarks
1	2	3	4	5
1	Karhagola anti-erosion works	A/E	115.07	
2	Anti-erosion work at Jarlahi on left bank of river Ganga	A/E	100.00	
3	Improvement and modernisation of Kotakoch Naurasia retired line (from ch 162 to 352) in a length of 45 ch.	Improvement of retired line	25.00	
4	Boulder pitching on river side slope between ch 10 to 50 and 135.50 to 190 of Jaunia Kursela embankment	A/E	34.00	
5	Anti-erosion works at Malkhachak site on left bank of Ganga	A/E	40.00	
6	Construction of spur at ch 25 of Chak ring bundh on left bank of river Ganga	A/E	45.00	
7	Construction of Spur at ch 77 of Sanha Gorgawan embankment	A/E	59.00	
8	Anti-erosion work at village Chhitarchak on the left bank of river Ganga under Sonepur block	A/E	30.00	
9	Anti-erosion work for construction of bull-headed spurs at ch 10 & 60 of Jarlahi retired line	A/E	70.00	
10	A/E work near village Lalbathani at ch 176 & 210 of Kota Kosh Haurasia retired line embankment on the left bank of Ganga	A/E	80.00	
11	Construction of Karhagola Jaunia embankment (4th retired line)	R/S	28.00	
12	Modernisation of Karhagola Azampur embankment from ch 0 to 848	Modernisation of Embankment	30.00	
13	Modernisation of Kari Kosi embankment	Modernisation of Embankment	25.00	
14	Modernisation of Jaunia Kursela embankment from ch 0 to 322	Modernisation of Embankment	25.00	
15	R/S of Sanha Gorgawan embankment from ch 0 to 405	Modernisation of Embankment	25.00	
16	R/s of Kota-kosh Naurashia retired line embankment	Modernisation of Embankment	35.00	
17	Protection work of Buxar-Koilwar embankment at Neknam tola	A/E	45.00	
18	i Buxar Kila protection Scheme ii Train drainage water to fall in canal and not directly into Ganga iii Pitching of the lower portion on similar lines in block as done South of canal		40.00	

[Source: Comprehensive Plan of Flood Management of the Main Ganga Stem, Prepared by GFCC in July 1990]

Annex 10
[Para 8.4.1]

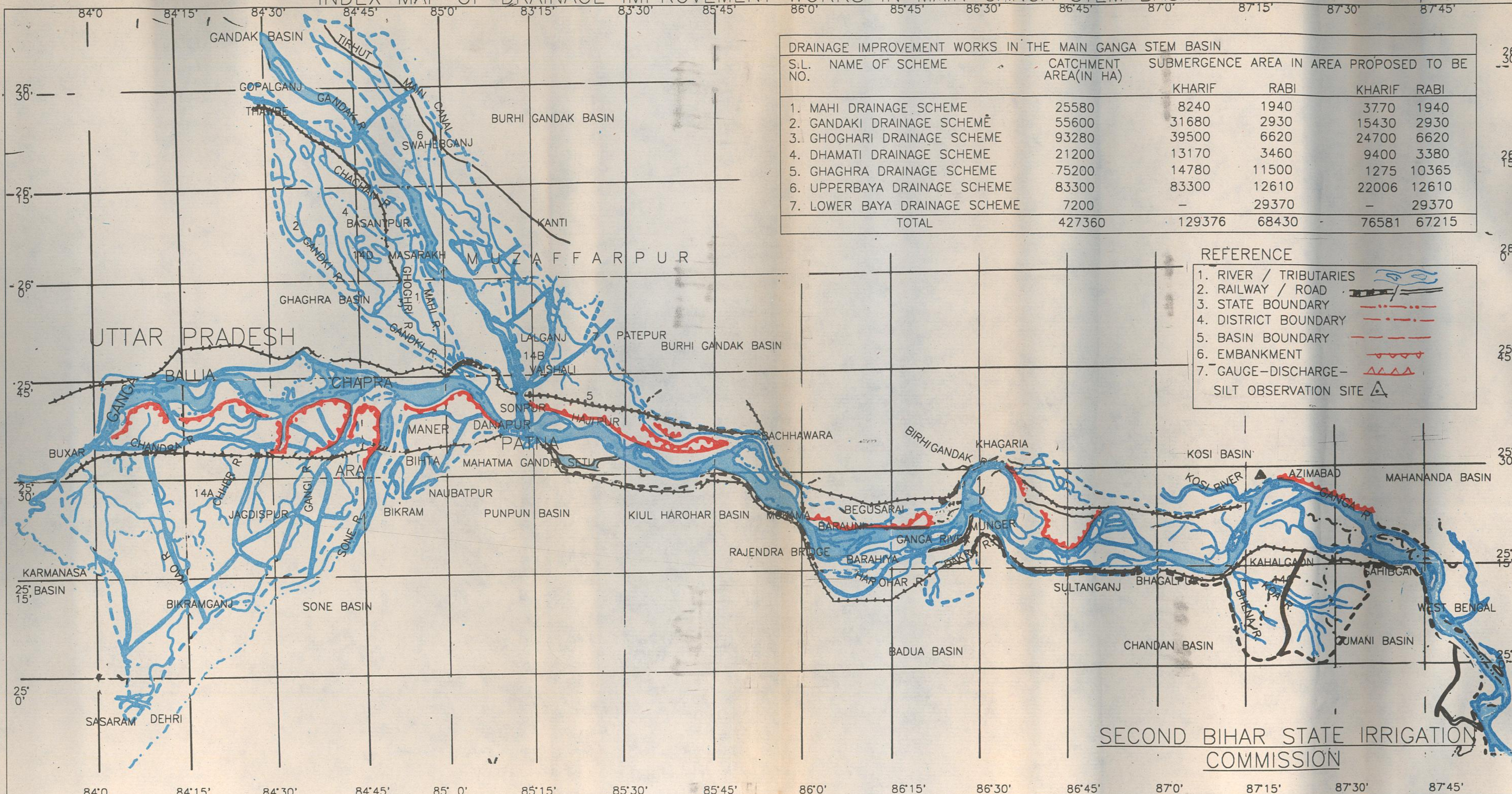
LIST OF DRAINAGE SCHEMES COMPLETED/UNDER EXECUTION IN THE MAIN GANGA STEM BASIN

Sl No	Name of Scheme	District	Length in Km	Drainage area in ha	Estimated Rs lakh	Expenditure upto Rs lakh	Submergencve area in ha		Area proposed to be drained in ha		Actual Area drained up to march 92		Remarks
							Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Mahi drainage scheme	Gopalganj Saran	91	25580	337.19	229.35	8240	1940	3770	1940		40	
2	Gandaki Drainage scheme	Gopalganj, Siwan, Saran	163	56800	922.93	354.64	31680	2930	15430	2930	4020	790	
3	Ghoghari Drainage scheme	Gopalganj, Siwan, Saran	95	93280	353.81	40.17	39500	6620	24700	6620	7410	1230	
4	Dhamati Drainage scheme	Gopalganj, Siwan, Saran	71	21200	302.13	2.76	13170	3460	9400	3380			
5	Ghaghra Drainage scheme	Vaishali	71	75200	499.21	137.09	14780	11500	1275	10365		2024	
6	Upper Baya Drainage scheme	E Champaran, Muzaffarpur	23	83300	620.67	268.19	22006	12610	22006	12610	1984	789	
7	Lower Baya Drainage Scheme	Muzaffarpur, Vaishali, Samastipur, Begusarai	211	72000	1349.28			29370		29370			proposed
		Total	725	427360	4385.22	1032.20	129376	68430	76581	67215	13414	4873	

[Source: Compiled from the Master Plan of Drainage scheme in Gandak Project 1980; Revised Estimate for Gandak project (Phase II), 1988; the report submitted by the Chief Engineers, WRD Siwan, Muzaffarpur & Motihari and Project Report, Drainage scheme in the Irrigation Commands of Gandak & Kosi Projects in North Bihar, Jan 1988 by P P Cell, WRD, Patna]

INDEX MAP OF DRAINAGE IMPROVEMENT WORKS IN MAIN GANGA STEM BASIN

DRG. 11/01



DRAINAGE IMPROVEMENT WORKS IN THE MAIN GANGA STEM BASIN

S.L. NO.	NAME OF SCHEME	CATCHMENT AREA(IN HA)	SUBMERGENCE AREA IN KHARIF	SUBMERGENCE AREA IN RABI	AREA PROPOSED TO BE KHARIF	AREA PROPOSED TO BE RABI
1.	MAHI DRAINAGE SCHEME	25580	8240	1940	3770	1940
2.	GANDAKI DRAINAGE SCHEME	55600	31680	2930	15430	2930
3.	GHOGHARI DRAINAGE SCHEME	93280	39500	6620	24700	6620
4.	DHAMATI DRAINAGE SCHEME	21200	13170	3460	9400	3380
5.	GHAGHRA DRAINAGE SCHEME	75200	14780	11500	1275	10365
6.	UPPERBAYA DRAINAGE SCHEME	83300	83300	12610	22006	12610
7.	LOWER BAYA DRAINAGE SCHEME	7200	–	29370	–	29370
	TOTAL	427360	129376	68430	76581	67215

APPENDIX 12

QUESTIONNAIRE

Appendix 12/1

QUESTIONNAIRE TO WATER RESOURCES DEPARTMENT.

8.1 Please furnish basin/sub-basin maps of the rivers causing flood (Scale 1 to 1 million or larger scale, if required, for severely flood affected basins) showing areas flooded during the period 1954 onwards. The areas flooded may be shown by distinctive lines with the years marked thereon.

Please also furnish a separate map basin/sub-basinwise showing area prone to floods having frequencies of once in 5, 10, 25, 50 and 100 years.

Please also furnish regime plan of such rivers in suitable scale showing flood control/protection works executed from beginning till date.

8.2 Has any study been carried out to identify the flood problems of each such river basin/sub-basin? If so, please supply six copies of the reports along with relevant maps.

8.3 Has any comprehensive plan been prepared for flood management of such river basin/Sub-basins? If so, please furnish copies of such comprehensive plans with a comprehensive note on the follow-up action taken so far on such comprehensive plans of flood management.

8.4 Has any action plan been formulated for implementation in accordance with the recommendations of various High Level Committees on floods and related problems appointed by the Central/State Government including those of the Rashtriya Barh Ayog and the Committee on the Flood Management in the State of Bihar, West Bengal, UP and Orissa? If so, please furnish six copies of such action plan with details of action taken so far against each of relevant recommendations concerning flood management in Bihar of all such Committees.

8.5 Has any post facto evaluation of flood management schemes executed already been carried out? If so, please furnish six copies of such reports alongwith a detailed note on the action taken as a result of such studies.

8.6 . Please furnish a resume of flood control/protection measures implemented at Governmental level upto 1954, mentioning therein the nature of works implemented, the rivers on which such works have been carried out, their benefits and performance in general and the nature of development in the protected areas before and after implementation of the works.

Please furnish details in proforma 8.6 basin-wise/sub-basin-wise with details of each scheme costing more than Rs 25 Lakhs. Please furnish a map to the scale 1 to 1 million (or to a larger scale if required) showing the various river basins/sub-basins and the works implemented upto 1954.

8.7 Please give a resume of the flood control/protection measures since 1954, stating the nature of works implemented, their locations, performance and benefits in general and the nature of development in the protected area before and after implementation of the works basin-wise/sub-basin wise.

Please furnish details in proforma 8.7 basin-wise/Sub-basin-wise for the works completed separately for each of the following periods:-

(a) April 1954 to end of March 1961

(b) April 1961 to end of March 1966

(c) April 1966 to end of March 1969

(d) April 1969 to end of March 1974

(e) April 1974 to end of March 1980

(f) April 1980 to end of March 1985

(g) April 1985 to end of March 1990

(h) April 1990 to end of March 1992

Information may please be supplied for each scheme costing above Rs 25 Lakhs and other schemes may be grouped together.

Please furnish maps to the scale of 1 to 1 million (or to a larger scale if desired) showing the completed works in each river system (as a whole or individually for large sub-basins) separately for the period indicated above.

8.8 Some flood control/protection schemes have been suggested by the Committees/ Experts constituted by the Central/ State Government. Please list the schemes chronologically from 1954 onwards in proforma 8.8 indicating the nature of the schemes and the benefits etc.

Please supply six copies each of the reports of the Committee/Experts appointed by the Central/State Government.

8.9 Have any flood control/protection plans in the various river basins been prepared on the lines suggested by the High Level Committee on floods and the subsequent Committees on flood control? please give a note indicating the broad features of the plan for each river basin as a whole or by parts as convenient. Please supply six copies of the Plan.

8.10 Are the works implemented so far in accordance with the overall plan and according to the priorities indicated therein? If not, the reasons therefor.

Has any revised plan been prepared indicating new priorities? If so, please supply six copies of the revised plan.

8.11 Have any socio-economic surveys been carried out in the areas protected and reports prepared? Please furnish six copies of each report. If no reports have been brought out, a concise note may please be furnished for each survey.

8.12 For technical and economical reasons, it is not possible to provide flood protection under all conditions of flow and for all time to come. As such, is there any policy/practice by which developmental activities in the protected areas are regulated? Please furnish a note, quoting examples.

8.13 EMBANKMENTS

8.13.1 Please furnish a not indicating the method of fixation of the design flood for the embankments and the degree of protection provided (in terms of frequency of floods or any other criterion) for (a) predominantly agricultural area (b) town protection works and (c) protection of important industrial establishments, assets and lines of communication.

8.13.2 What are the general standards adopted in the design of embankments:

(a) Top width (b) Type of top surfacing (c) Free board (d) Side slopes (indicating the basis of fixation) (e) Slope protection (indicating the governing factors)?

Note: Where masonry walls have been provided, their standards may please be indicated.

8.13.3 Where embankments are provided on both banks, the method by which the distance between the embankments is fixed may please be indicated.

8.13.4 Is the embankment system planned for the entire river tributary system and the implementation taken up in a phased manner?

Please furnish a note indicating the practice and priorities of implementation.

8.13.5 Have the benefits of inundation and deposition of silt in the protected areas been taken into account while planning the embankments and while working out the benefits?

Please furnish a note on methodology.

8.13.6 Has any necessity been felt for providing water for irrigation of crops in the area protected which used to be inundated previously? If so, has the cost of such irrigation scheme been included in the cost of the flood protection scheme?

Please detail schemes where this has been done and in what manner.

8.13.7 Are any embankments being used as public highways? If so, please state the length and locations.

Please state the experience in this behalf in maintenance, patrolling during floods, breaches etc.

Is any portion of expenditure borne by the Road Construction Department?

8.13.8 Please indicate whether any study has been carried out of the effect on the soil properties of the embankments due to age and industrial effluents/waste discharged/dumped into the rivers. If so, Please furnish a note.

8.13.9 Please give in proforma 8.13.9 detailed information in respect of all embankment schemes costing more than Rs 25 Lakhs each completed upto the end of March, 91 (including those completed prior to 1954). Schemes costing Rs 25 Lakhs or less but forming part of a continuous embankment should also please be included.

8.13.10 Any other comments and suggestions of the State Government particularly on the assessment of the benefits/draw backs of marginal embankments on river regime, effects on downstream works/ areas, protected area etc and about the desirability, location where suitable and other relevant matters, relating to embankments.

8.14 DRAINAGE (STORM WATER) SCHEMES

8.14.1 Based on the data collected from 1954 onwards,please furnish information relating to the areas which were affected by surface drainage congestion indicating duration with dates and the extent of areas affected by such drainage congestion.

Please furnish a map to the scale of 1 to 1 million (1 to 250000, where desirable) showing the drainage basins and the areas which experienced the above drainage congestion. The areas affected may be shown by distinctive lines with the year marked thereon.

8.14.2 Please give a note detailing the basis on which the design discharges for storm water drainage system are determined indicating whether it is on the basis of cost-benefit analysis, taking into account the frequency and intensity of rainfall, cropping pattern and the permissible depth of inundation or on the basis of any specified frequency of rainfall, cropping pattern and tolerance of crops or on adhoc basis.

What is the criteria adopted in the design of drainage for:

(a) Predominantly agricultural areas;

(b) Urban areas; and

(c) Important industrial complexes etc?

8.14.3 Is the planning of the drainage system done for the entire basin and implementation taken up in a systematic manner? Please furnish a note indicating the practice and priorities for implementation.

Please supply six copies of the plan with maps for each basin/sub-basin where so prepared.

8.14.4 While investigating individual drainage scheme, is the possibility of using drainage water (in part or whole) to supplement canal flows or for storing in depressions etc considered? Has such use been made anywhere in the State? If yes, please furnish details with maps of relevant areas.

8.14.5 Has any study of drainage in various basins of the State been made by any Committee/ Experts? If so, please supply a note covering the problems and the recommendations basin/sub-basin-wise.

Please furnish six copies of the reports.

8.14.6 What is the effect of drainage system of water logging and ground water table? Please furnish a note with details.

8.14.7 Has any drainage system been planned and implemented covering more than one State? What have been the problems that have been experienced in the planning, implementations and operation of such systems? Please furnish a detailed note.

8.14.8 Please furnish detailed information in proforma 8.14.8 in respect of drainage schemes costing more than Rs 25 Lakhs each.

Note: (1) Schemes costing Rs 25 Lakhs or less forming a stage of a bigger one should be included in the proforma and covered by an explanatory note giving reference to the map vide item 8.14.3.

(2) In case there are no schemes costing more than Rs 25 Lakhs, information in respect of schemes costing more than Rs 10 Lakhs each may be given.

8.15 ANTI-EROSION WORKS

8.15.1 What is the general policy of the State Government for undertaking anti-erosion works?

8.15.2 Are the various alternatives of protection considered before a decision on the nature of measures is taken?

8.15.3 Please list the types of anti-erosion works undertaken in the state detailing the performance of atleast two of each type.

8.15.4 Are any model experiments undertaken before carrying out anti-erosion works to investigate the possible effects of such works upstream and downstream and on the opposite side?

Please furnish a note giving specific examples where such model experiments have been carried out indicating performance of the prototypes compared with the results of such experiments.

8.15.5 Has the experience of anti-erosion measures implemented so far led to any economical method of protection and design? Please furnish a note.

8.15.6 Please give detailed information in proforma 8.15.6 in respect of anti-erosion works costing more than Rs25 Lakhs each. Please supply detailed plans of a few typical schemes.

8.16 RESERVOIRS

Reservoirs for providing flood control only have not so far been constructed in the country. However, multipurpose reservoirs providing specific flood control storage have been constructed, of which the important ones in Bihar are Maithon and Panchet in Damodar valley and Chandil dam on the Subarnrekha.

8.16.1 Please furnish information in proforma 8.16.1 in respect of the multipurpose dams where flood control storage has been specifically provided.

8.16.2 In respect of reservoirs with no flood control component please state if any flood moderation is assumed. If so, please give a note with specific examples.

8.16.3 What was the basis of fixing the dead storage and the life of the reservoir in the project report?

Have any studies been carried out either by computation of inflow and outflow of the silt charge or by reservoir capacity surveys on the extent of siltation and the consequent loss of storage capacity since the reservoir came into operation? Please furnish a detailed note indicating the results of such studies for each reservoir with six copies of relevant reports, if any.

8.17 CHANNEL IMPROVEMENTS

Channel improvements were visualised in the short term stage of the National Flood Control Policy.

8.17.1 Please furnish a note giving the following information as from 1954 onwards:

(a) The rivers/tributaries where channel improvements have been accomplished, the locations and details like the date, method adopted, length, width, capital cost etc, of each. Also please supply details of maintenance expenditure, year by year from the date of completion.

Please supply a map or maps to a suitable scale showing those details.

(b) Whether such works were undertaken after model experiments. If yes, please supply six copies of each such report.

(c) Whether such improvements have achieved the results visualised or otherwise.

(d) Whether any modification were required after completion. If yes, the nature thereof, the cost and the results achieved.

(e) Comments on the suitability of such measures and locations and conditions where they could prove beneficial.

8.18 ZAMINDARI AND/OR UNAUTHORISED EMBANKMENTS

The earliest effort of protection against floods were mostly those of the individuals/ zamindars who constructed embankments for the protection of their private properties. These works were usually constructed in haphazard manner without due regard to the effect of such construction on the upstream and downstream areas as also on opposite banks. Such lack of planning may equally apply to some embankments constructed under the test relief programme usually executed at short notice to provide immediate employment opportunities to flood affected people. Many such substandard works are likely to have been superseded by subsequent construction of regular embankments during the Plans while some others may still be in existence.

8.18.1 Please furnish details of Zamindari/Test relief embankments (separately) in proforma 8.18.1 in respect of those which have not been superseded by embankments constructed under the flood control sector. Please also furnish a plan to the scale of 1 to 250000 showing the locations of important embankments.

8.18.2 Please give a general assessment on the utility of the embankments referred to in 8.18.1. Has any separate assessment of the damage caused by breaches, overtopping etc. of these embankments been made? If so, please furnish information in proforma 8.18.2.

8.18.3 Has any Committee/Expert been constituted to review the existing Zamindari/Test Relief embankments in order to assess their utility or otherwise in mitigation of the flood problem and to recommend their take over by the Water Resources Department for remodeling and maintenance as per standard norms and practices. If so, please furnish six copies of reports of such Committees giving a note on their recommendations, those accepted by the State Government and action taken so far.

8.18.4 Has any plan been formulated to replace these unsuperseded embankments or remodelling them as part of the overall plan of flood control.

Please furnish a note relevantly indicating alternatives considered, costs and benefits.

8.18.5 Please furnish information in proforma 8.18.5 for each of the Zamindari/Test relief embankments which provided protection to more than 1000 hectares. Please supply a map to the scale of 1 to 50000 showing the embankments for which the detailed information have been furnished.

8.18.6 Are the Zamindari/Test relief embankments superseded by the regular embankments, allowed to remain intact or demolished? If not demolished, reasons therefor.

Please supply informations in proforma 8.18.6, in respect of such embankments which have not been demolished.

8.19 Aggravating of floods due to construction of Roads, Highways, Railways, Canals etc.

8.19.1 Please furnish a note indicating the procedure adopted by State Government in working out the waterway and checking the waterways proposed by Railways/National Highways.

8.19.2 Are the waterways at the Railway and National Highway crossing provided by the concerned authorities in consultaion with the State Government?

Is there similar consultations by the concerned State Departments with the State Department incharge of Flood Control while providing waterways at the road and canal crossings.

8.19.3 Are there any specific areas which experience distress frequently at Railway and/or National Highway Crossings? Please furnish a note indicating the locations where such conditions have been experienced and number of times these have occurred during last 15 years.

Please also furnish a map to the scale of 1 to 1 million showing the Railways and the National Highway Crossings and the location of the distress area. Large scale maps for each of the specific areas showing the extent of flooding and the years in which the flooding has occurred may also please be supplied.

8.19.4 Information and maps similar to those in 8.19.3 may please be supplied in respect of distress areas at the crossings of State roads/canals/drains.

8.19.5 Has the Central/State Government made any investigation into the causes for the distress conditions in the specific areas referred to in 8.19.3 and 8.19.4? If so, have the conclusions of these investigations been brought to the notice of the concerned authority and with what result? Please furnish a note giving details of the specific cases.

8.19.6 Has any Committee/Expert(s) studied the drainage congestion and adequacy of waterways for the bridges and made any recommendation? To what extent have the recommendations been implemented? What are the reasons for non-implementation of the recommendations in specific cases, if any? Please supply a detailed note. Please also furnish six copies of the report(s) of the Committee(s)/ Expert(s).

8.19.7 Has the State Government met/shared the cost of widening any waterway of Railway and/or National Highway bridges? Please give details of specific cases.

8.19.8 Has the State Government any view/suggestion on the bearing of cost and maintenance of additional waterways necessitated as a result of development works, construction of embankments, canalisation etc upstream of Railway/National Highway bridges? Please furnish a note.

8.19.9 Has the State Government enacted any legislation prohibiting encroachment into drainages (Natural or excavated)? If so, Please supply six copies of legislation. If not, please state whether and what administrative measures are taken and whether they are adequate to prevent such encroachments.

8.19.10 Does the State Government permit cultivation of beds and berms of rivers and natural drainage channels and construction of temporary bunds for irrigation and/or fishing across drainage channels/ drains which may cause obstruction to flow? If so, under what condition? Please furnish a note.

8.19.11 What is the practice adopted in the State in providing bridges over drains? In case where bridges are not provided at all crossings, what are the measures taken by the State in preventing unauthorised crossings which may lead to obstruction or deterioration of drains?

8.19.12 Please give a general assessment of the problem caused by the construction of railways, national highways, roads etc and the coordination amongst the various departments and suggestions, if any, in this regard.

8.20 ANALYSIS OF THE COST AND BENEFIT OF FLOOD PROTECTION MEASURES

8.20.1 What is the procedure of benefit-cost analysis presently adopted by the State Government? In this analysis, are the nature and magnitude of the flood problem to be solved precisely identified, all the viable alternatives (such as reservoirs, embankments, drainage, flood plain zoning etc) and their benefits and costs worked out in detail and the administrative, legal, technical and financial aspects considered in arriving at the best possible solution to the problem? Please furnish a detailed note.

8.20.2 Are benefits and costs discounted? If not, why not? If yes, what is the discounting rate in use and basis thereof?

8.20.3 What is the procedure adopted in the case of multipurpose projects with flood control component? Please furnish a detailed note on the data and procedure adopted for a few completed projects, showing how the benefits and cost are worked out for each component.

8.20.4 While calculating benefits, are the following taken into account? If so, how are they estimated?

(a) Value of the extra produce from agriculture that may be attributed to flood control.

(b) While estimating extra produce, are other supporting conditions, technological and institutional, taken into account? What is the time interval after which the full benefits are supposed to accrue?

(c) What prices (ie wholesale, retail, farm, mandi local, national etc) of inputs and outputs are used for valuing the benefits?

(d) Increase in the value of land.

8.20.5 What are the direct benefits that are considered for flood protection scheme? Are they estimated from the annual assessment of the flood damage in the area to be protected (agency carrying out and cross checking the assessment may be indicated) or by carrying out detailed surveys and determining the areas liable to flood of different frequencies or any other method? Are the remission of land revenue, cost of flood relief operations etc taken into account in the estimation of direct benefits? Please furnish a note giving details of the actual method adopted for assessing the average annual benefits.

Are secondary benefits taken into account? What are the nature of such benefits and how are they computed? If not, are there any constraints in not including the secondary benefits?

8.20.6 Are any socio-economic studies conducted for determining direct and indirect benefits? If so, please indicate the agencies and methodology? Please supply six copies of a typical report.

8.20.7 What are the various components going into the cost of the project? Do they include secondary costs which are required to obtain secondary benefits?

8.20.8 Are the risks, uncertainties, price changes etc, during the economic life of the project taken into account while working out the costs and benefits? If so, how?

8.20.9 Is allowance made for the benefits accruing without the protection due to inundation and deposition of silt during floods?

8.20.10 Please furnish six copies each of the typical schemes implemented by the State Government in operation for about 10 years (or the longest period if a shorter duration) for different categories of works such as reservoirs, embankment, drainage, anti-erosion, town protection etc, which explain fully the benefit-cost analysis that has been made.

The assessment of benefits both physical and monetary achieved from the schemes during the period of operation may be compared with the benefits envisaged at the time of formulation of the project.

The benefit-cost ratio at the time of formulation of the project may also be compared with the present benefit-cost ratio which may be worked out, at constant prices as included in the project taking into account any additional costs incurred subsequently for stabilisation of the benefits.

8.20.11 Taking into account the experience gained so far, have you any suggestions in regard to the methodology for cost-benefit analysis of flood protection and multi purpose projects with flood control component?

8.21 Criteria for taking up flood protection works and means of mobilising resources therefor.

8.21.1 Please state whether flood control and storm water drainage schemes are undertaken under any Act(s). If so, please supply six copies of the relevant Act(s).

8.21.2 Are any criteria (whether different for different types and regions) adopted by the State Government for sanctioning flood protection schemes? If so, please furnish a note mentioning the rationale and difficulties, if any.

Would you suggest any modification to the criteria?

8.21.3 Have any measures (betterment levy, flood cess, enhancement of land revenue/capital charge/ crop charge etc) been adopted for a levy on the benefited area (including villages, public and private industries etc) under the various types of schemes? If so, please supply six copies of the legislation/ administrative orders.

If legislation/administrative orders have not been enacted, issued or implemented, please furnish a not indicating the reasons therefor with suggestions, if any.

8.21.4 Please furnish basis and details of the total area (including villages, public and private industries etc) under levy and amount collected during each of the financial year for the State as a whole along with their capital costs and annual maintenance charges.

8.21.5 Other comments/suggestions, if any.

8.22 ARRANGEMENTS FOR MAINTENANCE OF FLOOD PROTECTION WORKS.

8.22.1 Are the instructions relating to maintenance of embankments contained in the Embankment Manual issued by the Central Water Commission being followed? Is a detailed drill laid down for each of the embankment systems for maintenance and operation during floods, post floods, season and immediately before the floods? please supply six copies of the drill laid down stating whether any difficulty is experienced in the implementation thereof.

8.22.2 Are gauges provided at stipulated intervals along the embankments for recording flood levels and arrangements made for their systematic observation during the floods? Please supply details.

8.22.3 Have you any suggestions for modification of the instructions contained in the Embankment Manual on the basis of the experience gained during the last thirty years in the maintenance of the embankments?

8.22.4 In the case of other flood protection works such as drainage channels and river training works, please furnish a note indicating the nature of maintenance done and the norms adopted for estimating the funds required for maintenance during the year.

8.22.5 please furnish details of the estimated requirements for maintenance as worked out by the Department, amount provided in budget for the annual maintenance and the actual expenditure on the maintenance of flood control works for each year from Fourth Five Year Plan and onwards upto 1991-92, for the State as a whole in the following proforma (separately for each type- reservoirs, embankments, drains, river training works, town and Village protection works etc)

Financial Year	Estimated requirements for maintenance as worked out by the Department (Rs Lakhs)	Amount provided for maintenance in the budget (Rs Lakhs)	Actual Expenditure (Rs Lakhs)
1	2	3	4
1969-70			
1970-71			
1971-72			
1972-73			
1973-74			
1974-75			
1975-76			
1976-77			
1991-92			

8.22.6 Does the State Government obtain the cooperation and assistance of the public of the locality in the patrolling and maintenance of flood protection works and also in tackling emergent situations? What is the response and the comment of State Government on its utility? Please furnish a note and six copies of regulations/orders in this behalf, if any.

8.22.7 Are suitable approaches provided to the flood protection works for their inspection as well as for use during emergent situation? Please furnish a detailed note.

8.22.8 Has the State Government other specific suggestion on the maintenance of flood protection, drainage and anti-erosion works etc?

8.23 Proper land use in the flood plains with a view to minimise damage and to ensure overall increase in agricultural production.

8.23.1 What is the progress made in the preparation of contour plans of the flood plain areas and demarcation of flood zones affected by flood for different frequencies? Please furnish a note indicating the extent of areas requiring preparation of contour plans and the areas for which the maps have been prepared. If not completed, please state the reasons, the present status and further programme for completing this works.

8.23.2 Has the State Government examined the draft Flood Plain Zoning Bill circulated by the Central Ministry of Water Resources? What are its views thereon?

8.23.3 Has land use regulation been attempted for complementing the engineering works in the areas provided with protection by controlling land use and encouraging more intensive use of the protected area?

8.23.4 Describe (locationwise, if necessary) the present land use in the unprotected flood plains for each river basins/sub-basins in the State.

Has any study been made on the pattern of floods, their duration and the nature of crops grown in these areas? If so, please supply six copies of such study reports.

Has any attempt been made for devising suitable crops patterns for reducing the damage due to floods and to increase agricultural production? Please furnish a note in detail.

8.23.5 Has the possibility of relocating flood vulnerable settlements been examined by the State Government? If so, please supply details.

8.23.6 Has the State Government any suggestions on the land use pattern in flood plains (separately for protected and unprotected) for reducing the overall flood damage and to achieve optimum benefits?

8.23.7 Will it be adequate if land use regulation is confined to the flood plains or should it be extended to the catchment area as well? What is the pattern of land use required/suggested in the catchment? please furnish a note.

8.23.8 Has any study been made in the State on the beneficial aspects of flood deposition? If so, the position may please be briefly indicated with supporting data.

8.23.9 Do you have any suggestions on the alternate cropping strategy for increasing agricultural production by suitable adjustments and adoption of new technology such as advancing sowing date, choice of substitute crop varieties, relay multiple cropping etc?

8.23.10 Please State the main constraints in implementing the post-flood agronomic measures in recovering the growth of submerged crops or raising alternate or substitute crops in making good the agricultural production.

8.23.11 Please state if any consideration has been given to providing some irrigation facilities during flood free periods in flood prone areas. If so, please furnish a list and map showing areas where this has been implemented.

8.23.12 Are there any approved codes for Flood/Agricultural relief work? If so, six copies may please be furnished. In case there is no such code the views of the State Government on developing Flood Manual/Code for agricultural programme may please be given.

8.23.13 Fuel and fodder supply in flood plain areas are generally not adequate and the situation worsens with flood occurrence. In appreciation thereof, state the present position of fuel and fodder supply in the flood prone areas giving the human/livestock population and their demand for fuel and fodder. The planned projections of the State Government on the subjects may please be furnished.

8.23.14 Please give a list of the grass and forest species which can stand annual floods and can be grown in flood plains on a commercial scale, especially along the stream banks.

8.23.15 Please furnish a comprehensive note on research and development programmes for pisciculture/ aquaculture in the ponds, lakes, tals and chaurs in the flood plains.

8.23.16 Are there any existing local organisation in the flood plain areas for implementing suitable agricultural programmes or are there any proposals in this regard?

8.24 ADMINISTRATIVE AND ORGANISATIONAL SETUP FOR FLOOD CONTROL IN THE STATE

8.24.1 Please furnish a note detailing the existing administrative and organisational set-up for flood control/protection (including flood forecasting and warning, flood fighting) in the State. Is the present arrangement adequate or are there any proposals for effecting improvements?

8.24.2 Investigation and planning of Flood Control/protection Works.

8.24.2.1 Please furnish a note indicating the procedure of collection of gauge and discharge data, supervision and checking the method of observation, intervals in which data collected is transmitted to the processing centre, examination and reconciliation of the data collected to ensure its accuracy and coordination, compilation and publication of the processed data.

Please also include in the note the type and qualifications of the personnel making the gauge and discharge observations, the number of stations supervised by each Subdivision and number of stations under a Division and whether the Sub-divisional and Divisional Officers are exclusively for the data collection or carry out this work in addition to other duties (Please indicate the other duties).

Has the data been published in the form of Water Year Books or any other form? If so, please furnish six copies of the published data for the two latest years.

8.24.2.2 What is the set-up in the State for investigation, planning and designing of flood protection works? Please furnish the information in the form of a chart of the organisation, including interdisciplinary personnel etc. Please furnish a note broadly detailing the duties and functions at each level.

Is the present set-up adequate to meet requirements? If not, please state if you have any suggestions.

8.24.2.3 Is the present procedure of processing schemes for sanction through the Technical Advisory Committee, State Flood Control Board, Planning Commission, etc satisfactory or are there any suggestion for modifications?

8.24.3 Execution of Flood Protection Works

8.24.3.1 What is the set-up in the State for execution of flood protection works both at the administrative and technical level? Please furnish information in the form of an organisation chart. Please furnish a note regarding other duties handled, if any, by the aforesaid set-up.

8.24.3.2 Are the existing laws and regulations regarding land acquisition adequate? Please furnish a note and six copies of relevant laws/regulations.

8.24.3.3 Are modern techniques like CPM (Critical Path Method) and PERT (Programme Evaluation and Review Techniques) applied to implementation of flood protection works? Any comments?

8.24.3.4 What is the present system of allocation of funds for flood protection works form year to year? Does the system present any difficulty in the implementation of the works? Are there any suggestions for improvement? Do you have any comments on the present accounts procedures?

8.24.3.5 What is the policy and procedure for compensation and rehabilitation of persons displaced/ affected by flood protection works? Is the arrangement satisfactory or is any improvement required? Please furnish a note.

8.24.3.6 Are there any delays in implementation of flood protection works on account of want of proper delegation of financial, administrative or other powers to the project authorities? If yes, please furnish two or three examples with suggestion in this regard.

8.24.3.7 Is a periodic review of the performance of the flood protection works made to assess benefits achieved against those projected? If yes, please furnish six copies of such evaluation reports for two works of each category.

8.24.3.8 What is the policy and procedure in the State for obtaining public participation in the execution and maintenance of flood protection and drainage schemes and what is the actual experience in this regard? Please furnish a note.

8.24.4 Operation and Maintenance

8.24.4.1 What is the present organisational setup for the maintenance of flood protection works? Please furnish a chart and a note with your comments and suggestions regarding its adequacy and functioning.

8.24.5 Flood Forecasting and Warning

8.24.5.1 Are there any flood forecasting units set up by the State? If so, please furnish an organisation chart indicating the rivers on which and the sites for which the flood forecasts are issued.

Is there any proposal for extending flood forecasting arrangements? Have you any suggestion to improve its functioning?

8.24.5.2 Have proper arrangements been made for fixing warning/ danger levels and predetermining the areas likely to be affected at different levels?

8.24.5.3 What is the arrangement made for communication of warnings to the people? Who is responsible for disseminating the warning? Is the present arrangement satisfactory? Are there any proposals for improvement? Is a liaison kept with the Water Resources Department/Flood Forecasting/Warning Organisation in this regard? Please furnish a detailed note.

8.24.6 Flood Fighting

8.24.6.1 Has any Manual for Flood Fighting been prepared by the State Government or any orders issued in this behalf? If so, please supply six copies of the Manual/Orders. If not, then please furnish a detailed note on the prevalent practice alongwith reasons for non-preparation of such manual.

8.24.6.2 What is the organisation available in the State for flood fighting? Which are the State Government Departments concerned with flood fighting and how is coordination among these effected?

8.24.6.3 What are the arrangements made for training/orientation of concerned personnel in the matter of flood fighting techniques?

8.24.6.4 Is any arrangement made for public cooperation in flood fighting?

Is there any legislation/regulation empowering the Government to commandeer local residents for flood works in emergencies like repairs of breaches, raising embankments during floods etc? If Yes, Please supply six copies.

8.24.6.5 Comments/suggestion which the State Government may like to add.

8.25 ASSESSMENT OF FLOOD DAMAGE

8.25.1 Is the procedure adopted in the State for assessing flood damages in accordance with that recommended by the National Council of Applied Economic Research?

If so, please supply six copies each of reports of two such surveys undertaken so far. Also state if norms for indirect damages as suggested in the report of the National Council of Applied Economic Research have been evolved.

8.25.2 If the procedure recommended by the National Council of Applied Economic Research has not been adopted, the reasons therefor may please be indicated. Please state if any other alternative method has been adopted and furnish six copies of the details thereof.

8.25.3 Which Department of the State is in charge of the collection and publication of flood damage data? Does it associate the Water Resources Department or any other Department (indicate the same) within this work? If so, please state in what manner.

8.25.4 Does the State Water Resources Department (incharge of Flood Control/Protection Works) send out field teams to inspect the flooded areas, to contact the revenue and other officers and local population and make an independent assessment of the flood damage in the flood affected areas? Please give a note detailing the manner in which this assessment is made.

8.25.5 Please furnish individually the details of the assessment of flood damage made in five flood affected basins/sub-basins for two worst flood seasons since 1954. Please also furnish a map to the scale of 1:50,000 showing the area affected by these floods. The basis of computations of monetary value of damages to crops and houses may also please be indicated with suggestions for improvements, if any.

8.26 FINANCING FLOOD PROTECTIDN WDRKS

8.26.1 Please describe the existing pattern of financing of Capital/Maintenance/Special Repairs works relating to flood protection and removal of drainage congestion.

Please state if there are any comments /suggestions in this behalf.

8.26.2 Please furnish a note indicating whether there is any scope for attracting institutional finance in the light of comprehensive approach to the flood problem.

8.27 ENVIRONMENTAL ASPECTS OF FLOOD PROTECTION AND DRAINAGE WORKS

8.27.1 Are adverse effects (eg creation of stagnant pools in borrow areas, creation/augmentation of swamps, pollution by human and industrial waste etc) of flood protection works and drainage improvement schemes etc listed and remedial measures provided in the designs?

If yes, please furnish a detailed note stating specific projects and the nature of measures taken/proposed.

8.28 RIVER CONSERVANCY

8.28.1 Has the State enacted any legislation on river conservancy? If yes, please state how it has functioned and supply six copies of the legislation.

If not, please state what measures, if any, are taken in this behalf, also, if you have any suggestions in the matter.

8.29 INTER-STATE AND STATE-CENTRE WORKS

8.29.1 What is the present mechanism of co-ordination for implementation at various stages and sharing of costs of flood protection/drainage works affecting interests of more than one State and State-Central Departments? Please state how this mechanism is functioning and offer suggestions, if any.

8.30 CENTRAL ORGANISATION AND BOARDS

Ganga Flood Control Board and Ganga Flood Control Commission have been set up by the Government of India for planning and processing of flood management and drainage schemes in the Ganga basin.

Please furnish a detailed note on the advantages derived from these Organisations and also indicate your suggestions, If any, for making these Organisations more effective.

8.31 DAMAGE CAUSED BY FLOOD AND THE AREAS REQUIRING IMMEDIATE FLOOD PROTECTION MEASURES

8.31.1 Please list giving reasons the areas which require urgent flood protection.

Please furnish a map to the scale of 1 to 1 million (or larger scale, if required) showing these areas.

8.31.2 Please furnish in proforma 8.31.2 details of the damage caused each year in the areas referred to in para 8.31.1 from 1974, as well as in the State as a whole.

If the damage during the last 10 years has shown an increasing trend, please state reasons therefor.

8.31.3 Please furnish in proforma 8.31.3 the extent of damage in the protected areas due to breaches, overtopping or drainage congestion.

8.31.4 Was any Committee(s)/Expert(s) appointed by the State Government since 1974 to examine the damage caused by floods and suggest measures?

If so, please give a note indicating the recommendations and the action taken thereon. Please supply six copies of the report(s)

8.31.5 Has any scheme for protection of the area identified in 8.31.1 taken up? Has provision been made in State plans for the implementation of these schemes? How many such schemes have already been completed or are nearing completion?

Please furnish details of such schemes in Proforma 8.31.5.

PROFORMA 8.6 RIVER.....

FLOOD PROTECTION WORKS IMPLEMENTED BY THE GOVERNMENT UPTO 1954

Sl No	River/ tributary/ sub-tributary	Name of the scheme	Nature of the scheme (eg embankment, anti-erosion etc)	Date of start	Date of completion	Capital Cost	
						Estimated (Rs Lakhs)	Actual (Rs Lakhs)
1	2	3	4	5	6	7	8

Monetary value of average annual benefits		Length of embankment or drainage channel (kms)			Benefits from embankment or drainage channel ('000 ha)			No of towns or villages protected
Estimated (Rs Lakhs)	Actual (Rs Lakhs)	Right bank of river	Left bank of river	Total	Right bank of river	Left bank of river	Total	
9	10	11	12	13	14	15	16	17

No of villages raised or No of raised platforms constructed.	Area benefited from flood moderation in reservoirs (000 ha)	Districts benefited	Remarks
18	19	20	21

Notes: (1) Please furnish information separately for each river system (main, tributary, sub-tributary) listing the works in the order of embankments, drainage channels, river protection works, Town protection works, raising of villages and flood control reservoirs or multipurpose reservoirs with flood control benefits.

(ii) For each category, information may be furnished for individual schemes, casting over Rs 25 Lakhs each and all other schemes may be grouped together, giving information in columns 7,8,9,10,13,16,17,18 and 19.

(iii) The sub totals for each basin/sub-basin may be given at the end of each category of work with grand totals for each river system.

(iv) Benefits from the schemes to the Railways, National Highways, State Highways, Industrial Complex, State Utilities and strategic places etc may be indicated in remarks column.

PROFORMA 8.7

RIVER.....

FLOOD PROTECTION WORKS IMPLEMENTED BY THE GOVERNMENT AFTER 1954

Sl No	River/ tributary/ sub-tributary	Name of the scheme	Nature of the scheme (eg embankment, anti-erosion etc)	Date of start	Date of completion	Capital Cost	
						Estimated (Rs Lakhs)	Actual (Rs Lakhs)
1	2	3	4	5	6	7	8

Monetary value of average annual benefits		Length of embankment or drainage channel (kms)			Benefits from embankment or drainage channel ('000 ha)			No of towns or villages protected
Estimated (Rs Lakhs)	Actual (Rs Lakhs)	Right bank of river	Left bank of river	Total	Right bank of river	Left bank of river	Total	
9	10	11	12	13	14	15	16	17

No of villages raised or No of raised platforms constructed.	Area benefited from flood moderation in reservoirs (000 ha)	Districts benefited	Remarks
18	19	20	21

Notes: (i) Please furnish information separately for each river system (main, tributary, sub-tributary) listing the works in the order of embankments, drainage channels, river protection works, Town protection works, raising of villages and flood control reservoirs or multipurpose reservoirs with flood control benefits.

(ii) For each category, information may be furnished for individual schemes, costing over Rs 25 Lakhs each and all other schemes may be grouped together, giving information in columns 7,8,9,10,13,16,17,18 and 19.

(iii) The sub totals of each basin/sub-basin may be given at the end of each category of work with grand totals for each river system.

(iv) The information may be given separately for each of the following periods

(a) April 1954 to end of March 1961
(b) April 1961 to end of March 1966
(c) April 1966 to end of March 1969
(d) April 1969 to end of March 1974
(e) April 1974 to end of March 1980
(f) April 1980 to end of March 1985
(g) April 1985 to end of March 1990
(h) April 1990 to end of March 1992

(v) Benefits from the schemes to the Railways, National and State Highways, Industrial Complex, State Utilities and strategic places etc may be indicated in remarks column.

Appendix 12/18

PROFORMA 8.8

SCHEMES SUGGESTED BY COMMITTEE/EXPERTS(CHRONOLOGICALLY FROM 1954)

Sl No	Name of scheme	Sl No of the scheme in proforma 8.7	Name of the Expert/Committee recommending the scheme	Brief details of the scheme
1	2	3	4	5

Cost (Rs Lakhs)		State of implementation of the scheme	Benefits (Av Annual)		If not undertaken reasons thereof or whether proposed to be dropped	Remarks
Estimated	Actual		Estimated	Actual		
6	7	8	9	10	11	12

PERFORMA

EMBANKMENT SCHEMES COSTING MORE THAN Rs 25 LAKHS EACH

1 Name of the Scheme

2 Location indicating the river, tributary etc

3 Length of embankment (Km) Right side
Left side

4 Design features:

(a) Design flood magnitude (cumec)

(b) Frequency of design flood

(c) Distance between the embankments (metres) (where on both sides)

(i) Maximum

(ii) Minimum

(iii) Average

(d) Basis for fixing design flood level

(e) Free-board above design flood level (metres)

(f) Top width (metres)

(g) Height of embankment (metres)

(i) Maximum

(ii) Average

(h) Side slopes: River Side
Country side

(i) Nature of side protection, if any, with details

5 Date of start

6 Date of completion (a) Targeted
(b) Actual
(c) Reasons for early/delayed completion

7 Estimated cost (Rs Lakhs) (a) Projected
(b) Revised with date indicating reasons for decrease/increase in cost and change in scope, if any.

8 Has the estimate been closed? If so, what is the completed cost? If not, the reasons therefor and whether the routine maintenance is still being charged to the project estimate.

9 What is the booked capital cost for the scheme as on 31.3.92

10 How many times since its completion has the embankment breached or been overtopped? Please give details indicating the number of breaches, year of occurrence of breaches/overtopping and the cost of repairs and further measures undertaken for raising and strengthening of the embankments and the damage caused during each of these events.

Have the reasons for breaches/overtopping been investigated each time? Please state the results of such investigations in each case.

11 Has any necessity arisen for the retirement of the embankment on account of river attack? If so, how many retirements have been effected and at what cost? what is the reduction in the protected area on this account please furnish a large size index map showing the locations of the original embankments and retirements with dates.

Have there been any problems in the provision of retirements? Please detail.

12 If retirements considered advisable have not been effected for any reason, river training/protection works may have been necessary. What is the cost of such protection works and the amount spent on their yearly maintenance?

Please furnish details Up-to-date. How does this cost compare with the assessed cost of the retirements?

13 What was the nature of development in the protected area before the construction of the embankment? Please give details alongwith the estimated assets eg buildings, roads, industries, railways etc and the extent of area cultivated/irrigated crop-wise during the flood season and the Rabi season, before and after the completion of the scheme.

14 Have the benefits contingent upon inundation soakage and silt deposition in the flooded area before embanking been taken into account in working out the financial analysis of the scheme?

15 Has any problem of drainage congestion been felt after construction of the embankment? How many times has this occurred since completion of the schemes? If so, please state dates of occurrence, the average depth, duration and extent of protected area affected each time?

16 Please detail the annual benefits physical (by crop acreage etc) and monetary-visualised in the project and the benefits derived year by year uptodate since the completion of the scheme and the average thereof.

17 Is the development following the security provided by the embankment being regulated? Has the protected area been properly demarcated for development of different categories such as cultivation/irrigation, industrial development and urbanisation?

18 Has any evaluation been made in quantitative terms of the economic conditions in the protected area before and after construction of the embankment? Please furnish a note indicating the production, nature of assets, lines of communication etc and also the overall prosperity or otherwise, in the area before and after.

19 What are the benefits that have accrued from the scheme in the shape or increase in revenue, saving of expenditure during floods and relief etc to:-

i Local bodies

ii State Government, and

iii Other agencies?

iv Please furnish a note

20 Has the scheme resulted in creating additional flood problem either on upstream or on the down-stream or the opposite side of the area?

Has any evaluation of such effects been made? If so, please supply physical and monetary details.

21 Are the records of observations of river behaviour during the floods being kept for taking necessary action thereafter?

22 Are post-monsoon surveys including cross sectional areas carried out regularly for the study of river conditions in the embanked reach for undertaking remedial measures if necessary?

Are the longitudinal and cross-sections of the embankment taken after the floods every year for assessing the adequacy of the free board?

Please state the date of physical completion of the scheme and the years when raising/ strengthening has been undertaken and the cost thereof each time.

If no raising/strengthening has been undertaken, please state factors contributing to this situation.

23 Have the river surveys indicated any rise/fall in flood levels for the same discharge (please state the bench mark location) indicating aggradation/degradation? Has there been any formation of shoals or cutting across of meander bends? Please furnish a note.

24 Please furnish information of the amount spent during the years, compared with the estimated requirements, commencing from 1980-81 according to Embankment manual or any other yard stick (which may please be detailed) in respect of routine maintenance, replenishment of consumable items etc as below (information may please be given separately for each year):

(i) Year

(ii) Engineering works covering, raising and strengthening, widening, special repairs, protective works etc:

(a) Estimated requirements

(b) Actual amount spent

(iii) Routine maintenance:

(a) Estimated requirements

(b) Actual amount spent

(iv) Patrolling:

(a) Estimated requirements

(b) Actual amount spent

(v) Replenishment of stock of consumable materials and T and P:

(a) Estimated requirements

(b) Actual amount spent

(vi) Temporary land acquisition:

(a) Estimated requirements

(b) Actual amount spent

(vii) Total:

(a) Estimated requirements

(b) Actual amount spent

(viii) Remarks

25 Please furnish a not detailing how the scheme was economically (benefit-cost ratio or other method) and/or otherwise considered justified, and comments on its actual performance since completion.

26 (a) Please state how the embankment was selected as the best measure in this reach. Whether measures like raising of or ring bunds around villages, change of crop pattern, flood plain zoning etc considered as alternatives or in conjunction?

(b) Have any sluices been provided in the embankment for use for controlled flooding/reverse drainage/inundation canals/leading water to depressions on land side etc?

(c) Please furnish a detailed note covering the above and other relevant points which were (or not) considered at the time of planning the embankment.

PROFORMA 8.14.8

COMPLETED DRAINAGE SCHEMES COSTING MORE THAN Rs 25 LAKHS EACH

Notes: (i) Please supply information for schemes costing more than Rs 10 Lakhs each in case there are no schemes costing more than Rs 25 Lakhs each.

(ii) Schemes costing Rs 25 Lakhs or less, forming a stage in a bigger scheme should please be included.

1 Name of the Scheme

2 Location indicating the basins/and the districts benefited

3 Design features:

(a) Catchment area (Sq Km)

(b) Catchment characteristics (shape, vegetal cover, relief sflope etc)

(c) Design frequency and intensity of rainfall

(d) Run-off index (indicate the basis on which this has been fixed)

(e) Crops grown: (i) Before the Scheme;

(ii) As visualised post-scheme;

(f) Depth and duration of inundation permitted

(g) Discharge per Sq Km and its basis

(h) Bed slope

4 Date of start

5 Date of completion

(a) Targeted:

(b) Actual:

(c) Reasons for early/delayed completion

6 Estimated cost in Rs Lakhs

(a) Original

(b) Revised with date

(c) Reasons for decrease/increase in cost with change and nature of scope, if any.

7 Benefits (as visualised in the scheme)

(a) Physical

(b) Monetary

8 Has the project estimate been closed? If so, what is the completed cost? If not, the reason therefor and whether routine maintenance is being charged to the project estimates?

9 What was the booked capital cost at physical completion (state the date) of the scheme? What is the booked cost as on 31.3.92?

10 How many times after completion of the scheme, has drainage congestion been experienced? Please state years of such occurrences and the extent of benefit actually realised during these years. Have the reasons for drainage congestion been investigated? Please furnish a note or six copies of published reports, if any.

11 Have periodic surveys of the longitudinal and cross sectional area of the drainage channel been carried out? If so, please furnish a note on the findings.

12 Is the deterioration, if any, of the drainage channels due to inadequate maintenance, remaining inoperative on account of adopting high design standard or encroachments, cross bunding, bed cultivation or any other cause? Please furnish a note.

13 Has any necessity been felt after completion to remodel the drainage channel? If so what is the improvement done and at what cost?

14 What was the nature of development in the area benefited before implementation of the scheme? Please give details along with estimated assets and extent of area cultivated/irrigated crop-wise during the flood season and the Rabi season (in case of reclamation scheme) before and after completion of the scheme.

15 Has the implementation of the scheme affected the ground water table? If so, please supply details.

16 What are the benefits actually derived during the operation of the scheme and what is the average annual benefit (physical and monetary) compared to that shown in the scheme report?

17 Has any evaluation been made in quantitative terms of the economic conditions in the area benefited before and after completion of the scheme? Please furnish a note indicating the production, value of assets, communications in the area before and after and also overall prosperity or otherwise.

18 What are the benefits that have accrued in the shape of additional revenue and other benefits to (i) local bodies (ii) State Government (iii) other agencies? Please furnish a note.

19 Has the scheme caused any special problem of drainage in adjoining areas? Has any evaluation of the areas thus affected been made? Please furnish details.

20 What is the amount spent on annual maintenance of the scheme starting from 1980-1981? Please give details of expenditure separately each year for special repairs and routine maintenance.

Appendix 12/25

PROFORMA 8.15.6

ANTI EROSION WORKS (COSTING OVER Rs 25 Lakhs EACH)

1 Name of the scheme with brief description

2 Location

3 objective of the protection measure

4 Basis on which the type of work was decided

5 Date of start

6 Date of completion (a) targeted

(b) actual

Reason for early/delayed completion

7 Estimated Cost - (a) Original

(b) Revised, with date

Reasons for revision of estimate, decrease/increase in cost indicating change in scope of work, if any.

8 Has the estimate been closed? If so, what is the booked cost on completion? If not, the reasons for not closing the estimate. Is the routine maintenance being still charged to the project estimate?

9 Year-wise expenditure incurred after the completion of the scheme as revised.

Expenditure in Rs Lakhs

Year	Special repairs	Routine maintenance	Nature of special repairs
1	2	3	4

PROFORMA 8.16.1

MULTIPURPOSE RESERVOIRS WITH FLOOD CONTROL STORAGE

Name of the scheme

1 Gross storage (Million Cubic metres)

2 Dead storage (Million Cubic metres)

3 Live storage (Million Cubic metres)

4 (i) Flood storage (cushion) (Million Cubic metres)

(ii) Area submerged between the flood storage levels (hectares)

5 What is the average and the maximum (designed and actual so far) inflow at the dam site

(a) during the monsoon period, and

(b) during the entire year.

6 What is the planned utilisation (irrigation/hydro power) during the monsoon period from the dam?

7 Have any operation rules been drawn up for the regulation of the reservoir for the evaluation of floods? Have they been revised? If so, reasons therefor. Please supply six copies of the original and revised operation rules.

8 After the completion of the dam, has there been any revision in the flood storage to meet the increased demands of irrigation and power? Please detail.

9 What has been effect of the construction of the dam on the river characteristic in the lower reach?

10 Due to the reduction in the flows downstream by the moderation at the dam, has there been any encroachment into the flood plains leading to greater flood hazards in times of higher releases from the dam? Have there been any instances after the completion of the dams of such releases causing significant damage? Please furnish a note.

11 What were the flood moderation benefits envisaged in terms of area benefited and monetary value as given in the project and as actually obtained after completion?

12 Have flood embankments been planned and implemented to contain the releases from the dam to provide protection to downstream areas?

What is the criteria for design of embankments in such cases ie What is the design-flood, whether it is the maximum release expected from the dam or releases corresponding to floods of the frequencies of 50/100 years?

Have the added flows from the uncontrolled catchment below the dam been taken into account?

Appendix 12/27

PROFORMA 8.18.1

Area in '000 ha
Population in '000

ZAMINDARI AND TEST RELIEF EMBANKMENTS AND OTHER WORKS (WHICH HAVE NOT BEEN SUPERSEDED BY EMBANKMENTS CONSTRUCTED UNDER THE FLOOD CONTROL SECTOR)

River basin/ Sub-basin	District	No of embankments	Total length of embankments (Km)	Area Protected	Population Protected
1	2	3	4	5	6

No of villages protected	Works other than embankments	Purpose and benefit of work in Col 8	Remarks
7	8	9	10

PROFORMA 8.18.2

DAMAGE CAUSED BY BREACHES, OVERTOPPING ETC, OF ZAMINDARI/TEST RELIEF EMBANKMENTS

River basin/ Sub-basin	District	Year	Area affected ('000 ha)	Cropped area affected ('000 ha)	Damage to crops Rs Lakhs	Population affected ('000 Nos)	No of villa-ges affected Rs Lakhs
1	2	3	4	5	6	7	8

Amount spent on relief (Rs Lakhs)	Amount spent on repairs (Rs Lakhs)	Remarks
9	10	11

PROFORMA 8.18.5

ZAMINDARI/TEST RELIEF EMBANKMENTS WHICH PROVIDE PROTECTION TO MORE THAN 1000 HA EACH

1 Name of the embankment

2 Location-River/Tributary/Sub-tributary

3 Details:

(a) Top width (metres)

(b) Side slope: Water side

Land side

(c) Height of embankment (metres)

(d) Length of Embankment (Km)

(e) Nature of protection to embankment, if any

(f) Area protected in hectares, district-wise

(g) Cultivated area protected in hectares district-wise

(h) Population protected, district-wise

(i) No of villages protected, district-wise.

4 Number of times, the embankment has been breached or overtopped since 1975, indicating the years when overtopped or breached.

5 What is the extent of damage caused during each of these events (loss of crop and population affected etc)?

6 What is the amount spent on special repairs and relief in each of the years of breaches/over-topping mentioned in (4) above.

7 What is the amount spent yearwise on maintenance since 1980?

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PROFORMA 8.18.6

ZAMINDARI AND TEST RELIEF EMBANKMENTS SUPERSEDED BUT NOT DEMOLISHED

River basin/ Sub-basin	District	Number of embankments	Total length of embankments (Km)	Remarks
1	2	3	4	5

Appendix 12/31

PROFORMA 8.31.2

DAMAGE CAUSED IN THE AREAS NEEDING URGENT FLOOD PROTECTION

YEAR

Sl No	Location of area district (whole/part)	River/ Tributary/ Subtributary	Area affected (ha)	No of village affected	Population affected	Cropped area under the villages (ha)
1	2	3	4	5	6	7

*Cropped area affected (ha)	Crop damage (Rs Lakhs)	No of houses damaged	Value of houses damaged (Rs Lakhs)	No of human lives lost	No of cattle heads lost
8	9	10	11	12	13

Loss of public utilities	Total loss (Rs Lakhs)	Expenditure on relief and rehabilitation (Rs Lakhs)	Remarks
14	15	16	17

Total damage in the area requiring urgent flood protection (Total of cols 4-16)	
Total damage in the State during the year including other areas (Cols 4-16)	

*If more than once in the same year, please state the area affected each time and strike total

Notes: (i) Name of crops damaged may be indicated in the Remarks Column.

(ii) Source of data may be indicated.

PROFORMA 8.31.3

DAMAGE CAUSED IN THE PROTECTED AREAS

Year	Area affected (ha)	No of villages affected	Population affected	Cropped area under the villages (ha)
1	2	3	4	5
1974-75				
1975-76				
— — —				
— — —				
1991-92				

Cropped area affected* (ha)	Crop damaged (Rs Lakhs)	No of houses damaged	Value of houses damaged (Rs Lakhs)	No of human lives lost
6	7	8	9	10

No of cattle heads lost	Loss of public utilities (Rs Lakhs)	Total loss (Rs Lakhs)	Expenditure on relief and rehabilitation (Rs Lakhs)	Remarks
11	12	13	14	15

*If more than once in the same year, please state the area affected each time and strike total.

Notes: (i) Name of crops damaged may be indicated in Remarks Column

(ii) Source may be indicated.

Appendix 12/33

PROFORMA 8.31.5

URGENT FLOOD PROTECTION WORKS PROPOSED/TAKEN UP

Sl No	Name and location of scheme	River basin/ sub-basin	District(s) to be benefited	Estimated sanctioned project cost (Rs Lakhs)
1	2	3	4	5

Estimated benefits			Annual monetary value (Rs Lakhs)	Date of start	Targeted date of completion	Expenditure to end of 7th plan (Rs Lakhs)
Area (ha)	No of villages	No of towns				
6	7	8	9	10	11	12

Expenditure/provision in 8th plan (Rs Lakhs)			Remarks
1990-91	1991-92	1992-97	
13	14	15	16

9.1 Has the State evolved a comprehensive approach/plan to the problem of floods, keeping in view the need for optimum and multipurpose utilisation of water resources of the State? If so, please supply six copies thereof.

9.2 Has the feasibility of providing storage reservoirs for multipurpose development/flood detention been investigated in the flood-prone river basins? If so, please supply the information as in Proforma 9.2

Please supply a map to the scale 1 to 1 million showing the location of the proposed storage sites and embankments in conjunction, if any.

9.3 Are any of the storages proposed located in foreign countries? If so, have the problems that might arise in the planning, construction, maintenance and operation of the storages besides the time factor in achieving the benefits, specially, flood control, been taken into account? Please furnish a short note.

9.4 Are there any natural depression, mauns, chaurs, lakes tals etc in the various flood-prone river basins? How are they being utilised at present? Has the possibility of utilising the storage capacity of such depression etc in storing surface drainage water and waters diverted from the rivers during floods (for use, if possible, for irrigation, pisciculture, acquatic crops etc) been investigated? Has any study been made of the capacities and the effect of such diversions on the flood moderation and the cost thereof? Please supply the information basinwise/sub-basinwise in proforma 9.4

Please supply a map (to a suitable scale) showing locations of large depression, lakes, tals, chaurs, mauns etc.

9.5 Has the possibility of providing diversions in pre-determined areas with the object of reducing flood intensities/recharging of the ground water/utilisation of irrigation (inundation canals,control flooding etc) been investigated? Please furnish short notes basinwise/ sub-basinwise indicating the quantum, cost, purpose and benefits (physical and monetary) of diversion(s) envisaged. Please supply a map to the scale of 1 to 1 million showing the locations of diversions.

9.6 The role of soil conservation measures in flood control has been mentioned from time to time. Have any studies been carried out at actual site locations regarding the effect of soil conservation measures on the normal floods and the high floods and also the sediment load carried by the rivers?

Please furnish notes including quantitative assessment. Please supply six copies or the reports, if any, of these studies.

Are there any river valley project catchments in the State where soil conservation measures have been carried out either by State Government or under Centrally Sponsored Programme? If so, please furnish a note indicating the progress made on these measures and the evaluation of the implementation of these works on the sedimentation in the reservoirs. The method of computation of silt in reservoirs may also be indicated.

Please supply six copies of the evaluation report, if any.

9.8 Which agency carries out the soil conservation measures? Does it coordinate this work with the State Water Resources Department (incharge of Flood Control Works) and if so, how?

9.9 Taking into account the area to be covered, its cost and the experience of implementation of soil conservation works during the past several years, what is the likely time required for effectively implementing the whole programme? Please give a forecast of the planning stating the areas proposed to be covered and the anticipated cost of each stage. Please supply the information basin/sub-basinwise separately for the upper catchment (hilly areas) and the lower catchment.

9.10 Has any scientific study been made to establish the effects of forest cover on rainfall-runoff, silt charge and flood flow? Please furnish a note and six copies of report, if any, on the subject giving relevant data from field studies, alongwith views of the State Government on the subject.

9.11 Has any study been made on the extent of deforestation and its effect on the flood flow and sediment load in each of flood prone river basin/sub-basins? Please furnish a note and also census of forest acreages basin/sub-basinwise as in Proforma 9.11

9.12 Is there a policy of afforestation and forest management for the hills and plains in the State? If so, please furnish a note indicating details and status of its implementation.

9.13 Is there any legislation/regulation by which deforestation in private land is regulated? If so, has it been successfully implemented? Please supply six copies of the relevant legislation/regulation.

9.14 What is the extent of catchment area of river basins/sub-basins in foreign countries? Please give details basinwise/ sub-basinwise.

9.15 What would be the implications, of keeping in view the multipurpose utilisation of water in the comprehensive approach to the problems of flood in the administrative and organisational set-up for investigations/ planning and implementation of flood control works? Please furnish a detailed note and also indicate whether it would be necessary to set up River Basin Authorities with involvement of variety of disciplines such as engineering, forestry, agriculture, economics, soil conservation etc.

9.16 Comments and suggestions, if any.

PROFORMA 9.2

PARTICULARS OF STORAGE RESERVOIRS FDR MULTI-PURPOSE DEVELDPMENT/FLOOD DETENTIDN

Note:- Please supply information separately for each storage reservoir.

1 River basin/sub-basin

2 Location of storage site

3 Catchment Area: In the State In other States/Countries Total

i at storage site (sq km)

ii total river basin (sq km)

4 Live storage proposed (Million Cubic metres)

5 Storage earmarked for flood detention (Million Cubic metres)

6 Estimated effect of the storage on flood peaks (per and post project figures)

a with the storage earmarked for flood control;

b without specific flood storage

7 Area of land submerged (hectares):

a between FRL and MWL

b between flood storage levels

8 Are embankments proposed in conjunction with storage?

9 Flood affected area likely to be benefited by the flood detention (hectares)

a without embankments

b with embankments (if proposed)

10 Estimated cost of the storage (Rs Crores)

Flood Control component of the Cost (Rs Crores)

11 Estimated cost of embankments, if proposed (Rs crores)

12 Has any provision been made for soil conservation measures in the reservoir catchment? If yes, the amount.

13 Annual benefits:

a Irrigation (hectares)

b Hydropower (MW)

c Others

d Total monetary benefits (Rs Lakhs)

PROFORMA 9.4

PARTICULARS OF NATURAL DEPRESSIONS, LAKES MAUNS, CHAURS, TALS ETC IN FLODD PRDNE RIVER BASINS

Note: Please supply information individually for each river system basin/sub-basinwise.

1 Total number of Depressions, Lakes, Chaurs etc
(Please give the names of important ones)

2 Total Capacity (Cubic metres)
(Please indicate individual capacity of large ones)

3 Total area of lakes, chaurs, depressions etc (hectares)
(Please give details of large ones)

4 How are the depressions, lakes, chaurs etc being utilised at present?

PROFORMA 9.11

CENSUS OF FOREST ACREAGES

River Basin/ Sub-basin (mention districts covered)

Year	Forest Area (ha)			Area deforested (ha)			Remarks
	Hills	Plains	Total	Hills	Plains	Total	
1	2	3	4	5	6	7	8
1961							
1966							
1971							
1976							
1981							
1986							
1991							

Notes: i Please furnish information separately for each basin/sub-basin

ii Source of information may be given.

QUESTIONNAIRE TO GANGA FLOOD CONTROL COMMISSION

8.1 In connection with the preparation of the comprehensive plan of flood management in the Ganga basin, the GFCC would have collected from the State Government of Bihar annual flood reports and maps showing the areas affected by floods and drainage congestion.

8.1.1 **a** Has any assessment of area prone to floods been made basinwise/sub-basinwise?

b Please furnish a statement of the extent of areas prone to floods (indicating the definition of "area prone to floods") basinwise/sub-basinwise and a map to the scale of 1 to 1 million (larger scale if required) showing these areas. The flood protection measures implemented and the areas benefited may also be shown in the map.

8.1.2 **a** Have any areas liable to drainage congestion (indicating the definition of "area liable to drainage congestion") been estimated?

b Please furnish details of the areas subject to drainage congestion basinwise/sub-basinwise.

c Please also furnish a map to the scale of 1 to 1 million (larger scale if required) showing the areas, the drainage works implemented and the areas benefited by them.

8.2 Please supply in proforma 8.2 the basinwise/sub-basinwise details of the area and population affected by floods in Bihar State from 1954 onwards on the basis of the flood damage statistics collected in connection with preparation of comprehensive plans for flood management.

8.3 Has the Ganga flood Control Commission obtained reports of periodical river surveys for making the evaluation of the changes in the river regime, from the State Government of Bihar, for preparation of comprehensive plans for flood management as has been stressed by the various Committees on floods? If so, please furnish a note on the observations and conclusions arrived at by the Ganga Flood Control Commission, particularly with regard to the effect of embankments, anti-erosion works, etc, mentioning specific locations, periods of observations, etc, leading to the conclusions.

8.4 **a** How many flood control/protection and surface drainage Master Plans for the main river basin/sub-basins have been received from the Government of Bihar for examination?

b Have these been prepared in accordance with the guidelines and suggestions made by the High Level Committee on Floods (1957) and subsequent Committees on Floods?

Please furnish a note giving your observations/ comments on such plans received.

8.5 Based on your experience in examination of flood management schemes received from the Government of Bihar, please furnish the following informations:-

a Whether the schemes are prepared in accordance with the approved guidelines issued by the Ganga Flood Control Commission. Please supply six copies of such approved guidelines.

b What deficiencies are generally observed in the investigation, planning and design of the schemes?

c Is the method of protection decided after examining the various alternatives and taking into account the costs and benefits of each alternative or are the schemes prepared for a preconceived method of protection?

d Since for technical and economic reasons, it is not possible to provide flood protection under all conditions of flow and for all time to come, have any guidelines been issued by the Ganga Flood Control Commission to the State Government of Bihar for regulating developmental activities in the protected areas? If so, please furnish six copies and state if the guidelines are followed.

If not, please state whether, at the time of examination of the schemes, the Ganga Flood Control Commission makes suggestions regarding regulation of developmental activities in the protected areas. Please furnish copies of suggestions made/implemented for two schemes in Bihar.

8.6 Embankments

8.6.1 **a** Are the observations/suggestions made by the Ganga Flood Control Commission communicated to the State Government and incorporated in the scheme report before they are sanctioned and implemented? How the Ganga Flood Control Commission ensures that the schemes are implemented accordingly?

b Have any instances come to the notice of Ganga Flood Control Commission where schemes have been implemented by Bihar Government without complying with its observations/ suggestions? Please furnish a list of such schemes indicating briefly the points that have not been complied with.

c Have any instances come to the notice of the Ganga Flood Control Commission where some important feature/scope of a scheme as approved has been modified by the Bihar Government during its implementation? If so, please furnish a list of such schemes indicating the modifications that have been made and your views on the advisability of the modifications carried out.

d Have the above been brought to the notice of the Government of Bihar and what has been the resultant action?

8.6.2 Have any breaches/overtopping been reported in embankments listed in 8.6.1 which could be attributed to non-compliance with the observations/suggestions made by the Ganga Flood Control Commission and/ or modifications carried out by the State Government in the approved scheme during implementation? If so, please furnish details with your observations.

8.6.3 **a** Are the likely adverse effects of embankment schemes on the upstream/downstream and the opposite side investigated by model experiments or otherwise and remedial measures proposed simultaneously? If so, do they form an integral part of the embankment scheme?

b In what situations are model experiments carried out or suggested?

8.6.4 Are there cases where retiring embankments would have been technically/economically preferable to heavy protection/anti-erosion works? If so, was the alternative studied and adopted? Please quote specific instances.

8.6.5 Have any instances come to the notice of the Ganga Flood Control Commission during the examination of revised estimates of schemes or in any other connection where maintenance of works has been or is being charged to capital account.

Please furnish note quoting specific instances and the action taken by the Ganga Flood Control Commission thereon.

8.6.6 **a** Does the Ganga Flood Control Commission get reports of the enquiries on breaches/

overtopping of embankment conducted in Bihar?

b What are the impressions gained from these reports and what are the views/suggestions of Ganga Flood control Commission in this regard?

Please furnish a note.

8.6.7 Please furnish a note on the problems that have been experienced in the planning, implementation and operation of inter-state embankment schemes quoting specific cases, and, your suggestions to improve such situations.

8.6.8 Please furnish a note with illustrative examples, if possible giving your suggestions and the basis thereof on the degree of protection to be provided in terms of frequency of floods or any other criterion for:-

i predominantly agricultural areas

ii town protection works

iii important industrial complexes, assets and lines of communications.

8.6.9 a Please furnish a note giving your assessment and views on the benefits/drawbacks of embankments, discussing the various factors involved.

b Also please describe situations/locations where you could consider them suitable/ preferable/unavoidable.

8.6.10 a Please state whether the use of embankments should be restricted to inspection vehicles and transportation of men and materials during emergent situations or whether their use may be allowed as public highways.

b In the latter case, please give your views in a detailed note regarding at what locations, under what conditions, construction standards capital and maintenance expenditure, control etc.

8.7 DRAINAGE SCHEMES (SURFACE)

8.7.1 a Are the observations/suggestions made by the Ganga Flood Control Commission to the Bihar Government incorporated in the schemes before they are sanctioned and implemented?How the Ganga Flood Control Commission ensures that the schemes are implemented accordingly?

b Have any instances come to the notice of the Ganga Flood Control Commission where schemes have been implemented by the Bihar Government without incorporating its observations/ suggestions? Please furnish a list of such schemes indicating briefly the points that have not been complied with.

c Please furnish a list of such drainage schemes in Bihar where some important feature/ scope of a scheme as approved has been modified during its implementation indicating the modifications made and your views on the advisability of such modifications.

d Have the above been brought to the notice of the Government of Bihar and what has been the resultant action?

8.7.2 Are the likely adverse effects of the upstream drainage works on the lower areas of the scheme or other State investigated and remedial measures proposed simultaneously?

Are such remedial measures incorporated in the main schemes?

Please furnish specific instances either way.

8.7.3 Have any instances come to the notice of the Ganga Flood Control Commission during the examination of the revised estimates of schemes or in any other connection where maintenance costs have been or are being charged to Capital account?

Please furnish a note quoting specific instances and the action taken by the Ganga Flood Control Commission thereon.

8.7.4 Please furnish a note on the problems that have been experienced in the planning, implementation and operation of inter-state drainage schemes quoting specific cases.

Please offer your suggestions to meet such situations.

8.7.5 **a** Do the guidelines, if any, issued by the GFCC suggest the possibility of utilising drainage waters partly or fully to supplement canal flows or for storing in depressions?

b If not, are suggestions made in this regard during the examination of drainage schemes? Please quote specific cases where such suggestions have been made/implemented.

8.7.6 Based on the experience gained so far, please furnish a note with illustrative examples, if possible, giving your suggestions on the basis on which the design discharges of storm water drainage systems may be determined and the criteria to be adopted in the design of drainage for:-

i Predominantly agricultural areas

ii Urban areas

iii Important industrial complexes etc.

8.7.7 Please furnish a note giving your assessment and views on the effect of drainage schemes on water-logging and ground water table, changes in crop patterns, amelioration of the area etc.

8.8 ANTI-EROSION WORKS

8.8.1 **a** Are the observations/suggestions made by the GFCC incorporated in the schemes before they are sanctioned and implemented by the Bihar Government? How the GFCC ensures that the schemes are implemented accordingly?

b Have any instances come to the notice of the GFCC where schemes have been implemented by the Government of Bihar without incorporating its observations/suggestions? Please furnish a list of such schemes indicating briefly the points that have not been complied with. Have such instances been brought to the notice of the State Government and what have been the resultant actions?

8.8.2 Are anti-erosion schemes prepared on the basis of model experiments or based on the experience of past works? If the former, under what situations?

8.8.3 Have any instances of failure of anti-erosion works, come to notice or been reported which could be attributed to the non-compliance of observations/suggestions made by the GFCC or having been implemented without taking into account the recommendations made as a result of model experiments and/or modifications carried out by the State Government in the approved scheme during implementation?

If so, please furnish details with your observations.

8.8.4 Are the likely adverse effects of anti-erosion works, upstream, downstream and on the opposite side, studied and remedial measures proposed simultaneously?

If yes, are they incorporated in the project? Please quote some specific cases.

8.8.5 Are there any instances where soon after the implementation of the original scheme, further measures by way of extensions/strengthening/improvements have been necessitated?

If so, please furnish details of some specific cases (with details of the original scheme and further measures), the reasons for further measures, the cost of the original scheme and that of further measures. Please state your views, in each case, whether the further measures were such, the need of which could have been foreseen and taken care of at the design stage of the original scheme.

8.8.6 Please furnish a note on the problems that have been experienced in the planning, implementation and maintenance of inter-state anti-erosion works quoting specific cases. Please offer your suggestions to meet such situations.

8.8.7 Please furnish a note giving your assessment and views on the performance of anti-erosion works and their drawbacks, if any, and situations/locations where these works are suitable/preferable/ unavoidable.

8.9 CHANNEL IMPROVEMENTS

8.9.1 Please furnish a list of channel improvement works undertaken in Bihar indicating the methods used and situations in which a particular method has been adopted.

8.9.2 Were these works planned after carrying out model experiments?

8.10 Please furnish a note indicating your experience of village raising works and why there is less emphasis on the use of this method these days.

8.11 Is there any arrangement in the GFCC for making periodical evaluation of the flood protection/ drainage schemes? Please furnish a note quoting specific examples giving your assessment of the physical and monetary benefits to the benefited areas after the implementation of the flood protection programmes.

8.12 Please furnish a note giving your views/suggestions regarding the present procedure for examining and processing of flood control/protection and drainage schemes for approval of the Planning Commissions.

8.13 **a** What is the general assessment of the GFCC regarding utility of the existing Zamindari/ Test Relief embankments in Bihar? Please furnish a note.

b Are there instances where these embankments have aggravated the flood problem? Please furnish a note giving your suggestions for remedial measures.

8.14 **a** Has the GFCC identified areas where chronic drainage congestion been caused as result of the construction of roads, highways, railways etc?

If so, please furnish a note indicating these areas basinwise/sub-basinwise and the action taken thereon.

b Please also furnish a map (to a suitable scale) indicating the areas and the roads, national highways, railwaylines etc, which have caused the problem.

c The GFCC is making an assessment of the existing ventways under rail and road bridges and recommending additional waterways to be provided for reducing the drainage congestion to reasonable limits. In view of the above, please state:-

i If, in your experience, the norm suggested by the Khosla Committee of Engineers (1957) for design flood is adequate and has been adopted by you. If not, have you developed an alternative norm, which please detail with reasons.

Please supply a map (to a suitable scale) of the Ganga basin in Bihar, showing the zones/ regions alongwith the formula adopted for design floods in each. The details and source of the formula adopted for working out design flood in each zone/region may please be indicated.

ii The number of existing ventways(railways, national highways, State highways, canal crossings etc) in Bihar State for which the necessary assessment has been made, the action taken and the result achieved.

If a complete assessment has not yet been made, please state when it is expected to achieve the same.

d The GFCC is represented on the State Committee of Engineers set up in Bihar. What are your views in regard to the functioning and effectiveness of such Committees especially in regard to matters relating to the distress caused by inadequate waterways? Please furnish a note also indicating your suggestions, if any.

8.15 **a** Has any procedure been laid down by the GFCC for the analysis of benefits and costs of flood control/protection schemes? If so, please furnish a detailed note with examples.

b To what extent is this procedure followed in schemes prepared by Government of Bihar?

c If no procedure has been laid down by the GFCC, please furnish a note indicating the procedure adopted in the flood control/protection schemes in Bihar along with your views/suggestions in this regard.

8.16 **a** What are the criteria adopted by the GFCC for clearing flood control/protection schemes? Please furnish a note also giving the basis thereof.

b The High Level Committee on Floods (1957) had recommended the pattern of priorities for taking up flood control/protection schemes. Are these being followed? If not, please furnish a note on the alternative pattern adopted with reasons and suggestions for improvement, if any.

c Please furnish a note giving your views/suggestions on the matter of mobilising resources for financing flood control/protection schemes.

8.17 **a** While collecting information for the preparation of comprehensive plans, has the GFCC obtained details of the progress made in the preparation of Contour Plans of the flood plain areas and demarcation of flood zones affected by floods of different frequencies in Bihar?

Please furnish a note indicating the extent of areas (basinwise) requiring the preparation of Contour plans and the areas for which maps have been prepared.

b Please furnish a note giving your suggestions on the land use in flood plains in Bihar (separately for protected and unprotected areas) for reducing the overall flood damage and achieving the optimum benefits.

c Do you consider it adequate if land use regulation is confined to the flood plain or should it be extended to the catchment area as well? Please furnish a note with your suggestions on the pattern of land use in the catchments.

8.18 **a** From your past experience, please state your views regarding efficient control, execution and funding of maintenance of flood protection/drainage works.

b Please furnish a note on flood protection/drainage schemes in Bihar where, in your opinion the maintenance is not adequate alongwith assessment (personnel, techniques, annual grants etc) of the reasons and suggestions for improvement.

8.19 **a** Has the GFCC laid down any procedure for assessing flood damage? Is it being followed in Bihar? If not, what is the procedure being followed in Bihar?

b Please furnish a note on your views/suggestions on procedure for assessing flood damage.

8.20 **a** Land slides may lead to changes in the river courses and increase in silt load. Does the GFCC keep track of the occurrence of major land slides and obtain report on their effects on the river conditions and the remedial action suggested/undertaken by the concerned authorities?

b If so, please furnish a note indicating locations of the river basins/sub-basins in Bihar where land slides are frequent, stating the nature of remedial measures that are generally adopted and the views/suggestions of the GFCC.

c Please furnish a note giving the views of the GFCC on the effect of river bed cultivation in the non-monsoon months on river conditions and flow during floods.

d Would the GFCC suggest promulgation of River Conservancy Acts? If so, please outline in brief the important provisions which may be incorporated.

e Are environmental aspects of flood control/protection and drainage works covered in the project reports and remedial measures as considered necessary provided therein? If not, does the GFCC consider these aspect and suggest measures while clearing the projects? Please furnish a detailed note with specific examples.

f Please furnish a note on the views/suggestions of the GFCC regarding environmental aspects relating to flood control/protection and drainage works and their ancillaries.

g There are a number of abandoned channels, lakes, Tal, depressions, chaurs, mauns, etc in Bihar. Are they being put to any beneficial use at present?

Do you think, they could be developed for profitable pisciculture, acquaculture etc?

8.21 **a** Has the GFCC made any analysis of the flood damage in Bihar from 1974 onwards and identified the areas requiring urgent attention?

b If so, please supply list of such areas basinwise/sub-basinwise stating the basis of the categorisation.

c Please furnish a map to a suitable scale showing these areas.

d Please furnish in proforma 8.21(d) the details of the damage caused each year in the areas referred to above from 1974 onwards.

e Has the figure of damage from 1974 onwards shown an increasing trend. If so, please indicate the reasons therefore?

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PROFORMA- 8-21 (d)

DAMAGE CAUSED IN THE AREAS IN BIHAR NEEDING URGENT ATTENTION

YEAR

Sl No	Location of area (list district whole/part)	Main river/tributary/ sub-tributary causing damage	Area affected (ha)	No of villages affected	Population affected
1	2	3	4	5	6

Cropped area* under the villages (ha)	Cropped area affected (ha)	Crop damage (Rs Lakhs)	No of houses damaged	Value of houses damaged (Rs Lakhs)
7	8	9	10	11

No of human lives lost	No of cattle heads lost	Loss of public utilities (Rs Lakhs)	Total loss Rs Lakhs)	Expenditure on relief and rehabilitation (Rs Lakhs)
12	13	14	15	16

Remarks
17

Damage in the area requiring urgent attention ____________________

Total damage in the State during the year ____________________

Note: i *If cropped area affected (Col 8) is more than once in the same year, please indicate area affected each time and strike total.

ii Names of Crops damaged may be indicated in Remarks Col

iii Source of data may be indicated.

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PROFORMA 8.2
Area - '000 ha
Population – million

FLODD DAMAGE IN BIHAR

Name of main tributary/ sub-tributary basin	Geographical area of (1)	Name of districts falling within (1)	Area prone to floods
1	2	3	4

Total area affected

1954-61 Maxm	Av	1961-66 Maxm	Av	1966-74 Maxm	Av	1974-80 Maxm	Av	1980-85 Maxm	Av	1985-90 Maxm	Av	1990-92 Maxm	Av
5	6	7	8	9	10	11	12	13	14	15	16	17	18

Cultivated area affected

1954-61 Maxm	Av	1961-66 Maxm	Av	1966-74 Maxm	Av	1974-80 Maxm	Av	1980-85 Maxm	Av	1985-90 Maxm	Av	1990-92 Maxm	Av
19	20	21	22	23	24	25	26	27	28	29	30	31	32

Population affected

1954-61 Maxm	Av	1961-66 Maxm	Av	1966-74 Maxm	Av	1974-80 Maxm	Av	1980-85 Maxm	Av	1985-90 Maxm	Av	1990-92 Maxm	Av
33	34	35	36	37	38	39	40	41	42	43	44	45	46

Note i Information may please be furnished in order – Main tributary, Sub-tributary from the head downwards.
ii Source of data may be furnished.

9.1 From the examination of flood control/protection plans and schemes prepared by the State Government of Bihar and taking into account the topography, rainfall pattern, magnitude and duration of floods in the Ganga and its tributaries in Bihar, what are views of the GFCC on the following:-

(Note: Please quote examples in support of the views expressed and specify locations where each may be applicable)

(i) The scope of utilisation of natural depressions, tals, lakes, chaurs, mauns etc. for moderation of floods:

(ii) Scope for diversion of flood water to other basins or in the same basin for storage and utilisation:

(iii) Possibility of storing flood waters underground;

(iv) Allowing controlled flooding behind embankments through sluices. Should reverse drainage be effected through the same sluices or special drainage channels?

(v) Technical and economic possibility of construction of storage dams in the upper catchments and their likely effect on floods; and

(vi) Scope of pumping as a measure for relieving drainage congestion.

(vii) Other feasible measures like check dams and soil/water conservation measures.

9.2 (a) Has the GFCC evolved a comprehensive approach towards the flood problems in the Ganga basin and its tributaries in Bihar keeping in view the need for optimum and multipurpose utilisation of water resources as also the role of soil conservations and afforestations in flood control.

If so, please supply six copies thereof.

(b) If not, please furnish a note giving your views/suggestions in this regard.

9.3 Has the GFCC prepared comprehensive plans for flood control in the Ganga basin and its major tributaries in Bihar?

If so, please supply six copies thereof.

QUESTIONNAIRE TO THE ROAD CONSTRUCTIDN DEPARTMENT

8.1 Please furnish six copies of the extracts from the relevant National Highways Act which lays down the procedure for consultation with the State Governments in regard to alignment of National Highways, provision of waterways for the crossings of rivers, streams, drains, etc, and stipulates the liability of the National Highways and the State Government for bearing the cost of later augmentation of waterways for bridges.

8.2 Is there any standing instruction for consultation with the Water Resources Department (incharge of flood management) in regard to alignment of State Highways, and other roads in the State, provision of waterways for the crossings of rivers, streams, drains, etc?

If so, please furnish six copies of such standing instructions. If there is no such instructions then what is the prevalent practice in such cases? Please give your views/suggestions with a detailed note.

8.3 Is there any manual or memorandum issued by the Road Construction Department which lays down the methodology for determining the design discharge and fixing the waterways for Road Bridges across alluvial and other rivers?

If so, please supply six copies of the same.

8.4 **a** If there are no manual or memorandum, please indicate the formulae that are being adopted for determining the design discharge of road bridges and the methodology for fixing waterways.

b Please supply a map of Bihar to a suitable scale showing the zones/regions in which the State has been divided for the purpose and formulae adopted for each also showing the district boundaries, National and State Highways, major railways line, cities, etc.

c Please State the basis of each formula, as also what and why changes, if any, have been made in the basis and formula (e) in the past.

8.5 **a** Taking into account the formulae adopted, have the Road Construction Department made a review of the waterways of their bridges in the past?

b Please furnish a note giving the results of such review, indicating the number of bridges reviewed, number of bridges where waterways were found inadequate/excessive. Also please state the numbers in which it was considered necessary to augment/reduce the waterway provided. The information may please be supplied by giving totals of each type in the zone/region referred to in question 8.4 (b).

c Have there been any complaints from the State Water Resources Department (incharge of Flood Management)/ Railways regarding distress caused to the areas upstream of the road bridge (designed for discharge exceeding 3000 cumec) on account of the design flood or the design HFL being exceeded ? If so, please furnish a detailed note for each of the bridges (designed for discharge exceeding 3000 cumec) indicating their location, original design flood discharge, design flood discharge after review, original design HFL, design HFL after review, number of times the maximum discharge and HFL has been observed more than the original and reviewed design discharge and HFL. The reasons for the distress conditions, if analysed and action taken/ proposed to be taken should also please be indicated.

8.6 **a** What are the measures taken to keep the waterways clear of silt and obstruction so that they are effective whenever the design flood occurs?

b Upto what distance upstream and downstream of the road bridges do the Road Construction Department carry out surveys and maintenance/conservancy operations? At what interval of time are such surveys carried out?

8.7 **a** Are there any specific areas (other than those mentioned in 8.5 above) brought to the notice of the Road Construction Department by the Water Resources Department/Railways where distress conditions have been experienced by flooding/drainage congestion due to inadequacy of waterway at a road bridge, obstruction of drainage by the road embankments, silting of the link drains, etc? Please furnish informations basinwise/sub-basinwise with a detailed note on the action taken thereon and subsequent results.

b Please also furnish a map of Bihar to a suitable scale showing the areas where the distress conditions have been pointed out by the Water Resources Department/Railways, also showing there on the concerned roads and bridges in these area.

8.8 **a** Where Railway/State Highway/National Highway bridges/ Canal Crossings are located in close vicinity on the same river, please state if mutual consultations are held between the concerned organisations while fixing the waterways for such bridges.

b Have there been any instances where such consultations have not been held and consequently adverse flow conditions have occurred at any Road bridge? If so, please supply necessary details in each case, the action taken in this behalf and the results thereof.

8.9 **a** Do the road Construction Department carry out observations of discharges at selected Road bridges? Please furnish informations in proforma 8.9 (a) of the gauge and discharge sites maintained by the Road Construction Department.

b The location of these sites may be shown on a map of suitable scale.

c Please furnish a note on the method of computation of flood discharges at these sites.

8.10 At the sites where discharge observations are being carried out, have the reasons for exceeding the design flood level at discharges less than the design discharge, if such has ever been the case, been investigated? Please furnish a note giving the location of such cases and the reasons assessed.

8.11 **a** Please furnish in proforma 8.11 (i) the damage where caused to any of the Road bridges from 1981 onwards and in proforma 8.11 (ii), the details of damage caused by major disruptions due to floods/failure of upstream works.

b Where there have been major disruptions due to breaches and washing away of bridge(s), have the reasons been investigated? If so, please furnish notes for each of the major disruptions.

8.12 Have there been any instances where flood protection works like embankments, spurs, drainage channels, etc, and other works which might affect National Highways/State Highways have been constructed by the concerned Department of the State Government/Railways without consulting the Road Construction Department? If so please list them Departmentwise/Railwaywise, mentioning the adverse effects, if any, action taken and the results thereof.

8.13 Are matters relating to distress caused by inadequate waterways discussed at the meetings of the Bihar State Committee of Engineers/Technical Advisory Committee of the Bihar State Flood Control Board? Does the representative of the Road Construction Department participate in these meetings regularly? Have these Committees been helpful in achieving the desired results?

Please furnish a note detailing the position river basinwise/sub-basinwise with your comments and suggestions, if any.

8.14 Are there any areas/zones in Bihar where National Highways/State Roads have experienced severe conditions of silting/aggradation/blocking of their bridges?

If so, please furnish a note thereon indicating your views/reasons/remedial measures etc.

PROFORMA 8.9 (a)

GAUGE AND DISCHARGE SITES MAINTAINED BY THE ROAD CONSTRUCTION DEPARTMENT

Sl No	Name of the river/sub-basin	Location of bridge and name of road	District	Catchment area in sq km upto observation site	Nature of observation	
					Gauge	Discharge
1	2	3	4	5	6	7

Year of start of observation		Design flood discharge of the bridge (cumec) and design HFL (GTS)	Maximum flood discharge observed/ recorded (cumec) with date and corresponding gauge (GTS)	Maximum flood level attained (GTS) with date and corresponding discharge in cumec	Remarks
Gauge	Discharge				
8	9	10	11	12	13

PROFORMA 8.11 (i)

DAMAGE CAUSED TO NATIONAL HIGHWAYS/ STATE ROADS DURING FLOOD/ FAILURE OF UPSTREAM WORKS

Year	Total number of breaches	Total number of bridges washed away	Cost of restoration (Rs in Lakhs)	Other losses, if any, estimated Rs in Lakhs)	Total loss (Rs in Lakhs)	Remarks
1	2	3	4	5	6	7
1981						
1982						
1983						
1991						

PROFORMA 8.11 (ii)

DAMAGE AND MAJOR DISRUPTION TO NATIONAL HIGHWAYS/ STATE ROAOS DUE TO FLOODS/ FAILURE OF UPSTREAM WORKS

Sl No	Location of disruption	River/tributary basin	Nature of disruption (whether due to breaches or damage/ washing away of the bridges)	Cause of damage (floods/failure of upstream works)	Period of disruption date (s)
1	2	3	4	5	6

Rs in Lakhs			Remarks
Cost of restoration	Other losses, if any, estimated	Total loss	
7	8	9	10

QUESTIONNAIRE TO ZONAL RAILWAYS OPERATING IN BIHAR STATE

8.1 Please furnish copies of the relevant Railway Act or extracts thereof which lays down the procedure for consultation with the State Government in regard to the alignment of railway lines, provision of waterways at crossings of rivers, streams, drains etc, and stipulates the liability of the Railways and the State Government for bearing of costs of later augmentation of waterways for bridges.

8.2 Is there any manual or memorandum issued by the Railways which lays down the methodology for determining the waterways for railway bridges across alluvial and other rivers? If so please supply six copies of the same.

8.3 **a** As suggested by the Khosla Committee of Engineers (1957), studies for evolving formulae for the determination of design discharges were to be carried out under short-term and long-term plans for use by Railways and other concerned organisations. Please furnish a note on the progress made so far in this regard.

b Please supply a map of Bihar to a suitable scale showing the zones/regions and the formulae and the constants derived for each of the zones/regions under the short-term plan. What frequency flood do the constants evolved in the formulae correspond to? Please also indicate whether these formulae have been evolved in coordination with the Central Water Commission, Ganga Flood Control Commission and other Organisations concerned.

c Please supply a similar map showing the formulae derived on the basis of the studies carried out so far under the long-term plan.

8.4 **a** Taking into account the formulae developed for different regions, have the Railways made review of the waterways of bridges?

b Please furnish a note giving the results of such a review, indicating the number of bridges reviewed, number of bridges where waterways have been found to be inadequate and the number of bridges where the design discharge provided having been found excessive, it has been considered desirable to reduce the waterway provided.

8.5 **a** arising out of 8.4 above, please supply information in proforma 8.5 (i) and 8.5 (ii) regarding bridges (designed for discharges exceeding 3000 Cumecs) where according to review, waterways were found to be inadequate/ excessive respectively.

b In the case of bridges reviewed and listed in proforma 8.5 (i) and 8.5 (ii), have there been any subsequent complaints from the State Government of Bihar regarding distress caused to the areas upstream of the bridges on account of the design flood or the design HFL being exceeded? If so, please furnish information in proforma 8.5 (iii) and also a note for each of the bridges indicating the reasons for the distress conditions, if analysed and action taken/ proposed to be taken.

8.6 **a** What are the measures taken to keep the waterways clear of silt and obstruction so that they are effective whenever the design flood occurs?

b Upto what distance upstream and downstream of the railway bridges to the Railways carry out surveys and maintenance of conservancy operations? At what intervals of time are such surveys carried out?

8.7 Are there any specific areas (other than those mentioned in 8.5 above) brought to the notice of the Railways by the Bihar Government where distress conditions have been experienced by flooding/ drainage congestion due to inadequacy of waterway at a railway bridge, obstruction of drainage by the railway embankments, etc and request made for providing additional waterways, new openings, etc? Please furnish information river basinwise/ sub-basinwise from 1980 onwards and the action taken there on alongwith a map to a suitable scale showing the areas where distress conditions have been pointed out by the State Governments as well as the railway lines and bridges in these areas.

8.8 Have any cases been brought to the notice of the Railways by the Bihar Government of adverse effects caused by railway bridges in their vicinity by way of erosion, change of the course of the river, etc? Please furnish information river basinwise/ sub-basinwise from 1981 onwards and the action taken by the Railways.

8.9 **a** Under the longterm plan, the Khosla Committee had recommended that the Railways should arrange observation of discharge and hourly gauge records at selected railway bridges during floods. Please furnish in Proforma 8.9 informations of observations at such bridges. The location of these bridges may be shown on a map of suitable scale.

b Please furnish a note on the method of computation of flood discharge at these sites.

8.10 **a** Are there any cases of discharge observation sites, where the design flood levels have been reached/exceeded at discharges lower than designed?

b If yes, please furnish, for each case, details like location, design and concerned, discharges and flood levels, the reasons assessed for the phenomenon, and, remedial measures proposed.

8.11 **a** Please furnish in proforma 8.11 (a) the damage caused to the Railways in each zone in Bihar from 1981 onwards and in proforma 8.11 (b) the details of the damage caused by major disruptions due to floods/failure of a railway affecting work.

b Where there have been major disruptions due to breaches and washing away of bridges, have the reasons been investigated? If so, please furnish notes for each of the major disruptions.

8.12 **a** Are the Technical Advisory Committee of the Bihar State Flood Control Board and the Bihar State Committee of Engineers adequate for effecting the necessary coordination and ensuring that the works undertaken by one agency do not affect those of the others?

b Have there been any instances where flood protection works like embankments, spurs, drainage channels, etc, and other works which might affect the Railways have been taken up by the Bihar Government without consulting the Railways? If so, please list them river basinwise/sub-basinwise mentioning the adverse effects, if any, the action taken by the Railways and the results thereof.

8.13 Are matters relating to distress caused by inadequate waterways discussed at the meeting of the Bihar State Committee of Engineers? How many times has this Committee met since April 1981? Have such meetings helped in achieving the desired results?

Please furnish a note detailing the position river basinwise/sub-basinwise, also comments/ suggestions, if any, on the functioning of this Committee.

8.14 **a** What is the present arrangement for the settlement of disputes regarding the extent of additional waterways to be provided in railway bridges and the sharing of costs?

b If so, is the present arrangement satisfactory or do you consider any improvement necessary? If so, please furnish a note indicating suggested improvements.

8.15 Have the Railways got any system of their own for alerting the authorities incharge of Railway sections/bridges of the likely situations resulting from floods/failure of works upstream and passing of such information to the State Government of Bihar and other Engineering and Administrative authorities concerned? Is there similar arrangement of obtaining information on the flood situation from the State Government by the Railways?

Please furnish a note.

8.16 Has a Coordinating and Planning Committee, as recommended by the Khosla Committee, been constituted for reviewing and publication of the studies carried out under the long-term plan? Have any of the studies, particularly those relating to flood discharges in different river basins which would be of interest to the Water Resources Department of Bihar Government also, been published? If so, please supply six copies of the same.

PROFORMA – 8.5 (i)

RAILWAY BRIDES (IN BIHAR STATE) WITH INADEQUATE WATERWAYS

Sl No	Railway Zone	River/ Tributary	Location of bridge (No Section)	District	Date of review	Design discharge
1	2	3	4	5	6	7

Waterway (Clear width)		Status of augmentation of waterways	Remarks
Previous	Proposed after review	Actual/ Anticipated date of completion	
8	9	10	11

Note:- Waterway on the spill berms wherever provided may also be included in Cols 8 and 9.

PROFORMA 8.5 (II)

RAILWAY BRIDGES (IN BIHAR STATE) WITH EXCESSIVE WATERWAYS

Sl No	Railway Zone	River/ Tributary	Location of bridge (No Section)	District	Date of review	Design discharge (Cumecs)
1	2	3	4	5	6	7

Waterway (clear width)		Status effecting reduction in waterway	Remarks
Previous	Proposed after review	Actual/Anticipated date of completion	
8	9	10	11

Note: Waterway on the spill berms wherever provided may also be included in Cols. 8 and 9.

PROFORMA 8.5 (iii)

BRIDGES REVIEWED WHERE DISTRESS CONDITIONS HAVE BEEN POINTED OUT BY THE BIHAR GOVERNMENT

Sl No	Railway Zone	River/ Tributary	Location of bridge (No Section)	Reference to Sl No in Proforma		Design flood discharge (Cumecs) after review
				8.5(i)	8.5(ii)	
1	2	3	4	5	6	7

Design HFL after review (GTS)		No of times, if any, when the flood discharge has exceeded the design discharge since augmentation/ reduction (give discharge, gauge (GTS), date and year)	No of times, if any, when the flood level has exceeded the design HFL since augmentation/reduction (give gauge (GTS), discharge, date and year	Remarks
U/S	D/S			
8	9	10	11	12

Note: Ref Col 7 – Please state in the remarks column if this is the 50 year or a higher observed flood.

PROFORMA 8.9
RAILWAY ZONE

GAUGE AND DISCHARGE SITES MAINTAINED BY THE RAILWAYS IN BIHAR

Sl No	Name of the river/tributary	Location of site (Bridge No on Section etc)	District	Catchment area in Sq Km upto observation site	Nature of observation	
					Gauge	Dischcharge
1	2	3	4	5	6	7

Year of start of observation		Design flood discharge of the bridge (Cumecs) and design HFL (GTS)	Maximum flood discharge recorded after start of observations (Cumecs with date) and corresponding gauge (GTS)	Maximum flood level attained (GTS with date) and corresponding discharge in cumecs	Remarks
Gauge	Discharge				
8	9	10	11	12	13

Note: i Please indicate the number of times, if any when the flood discharge has exceeded the design discharge since 1975 (give discharge, gauge (GTS) and date)

ii Please also indicate the number of times, if any when the flood level has exceeded the design HFL since 1975 (give gauge (GTS), discharge and date)

PROFORMA 8.11 (a)
RAILWAY ZONE

DAMAGE CAUSED TO RAILWAYS (IN BIHAR) DURING FLOOD/FAILURE OF UPSTREAM WORKS

Year	Total No of breaches	Total No of bridges washed away	Rs in Lakhs			Remarks
			Cost of restoration	Loss in earning due to disruption	Total loss	
1	2	3	4	5	6	7
1981						
1982						
1991						

PROFORMA 8.11 (b)
RAILWAY ZONE:-
YEAR:-

DAMAGE AND MAJOR DISRUPTION DUE TO FLOODS ON THE RAILWAYS IN BIHAR

Sl No	Location of disruption	River/ Tributary basin	Nature of disruption (whether due to breaches or damage to bridges)	Cause of damage (floods/failure of U/S works	Period of disruption (with dates)
1	2	3	4	5	6

Rs in Lakhs			Remarks
Cost of restoration	Loss of Railway earnings	Total Loss	
7	8	9	10

QUESTIONNAIRE
(FOR CENTRAL WATER AND POWER RESEARCH STATION, PUNE)

8.1 **a** What is the role of CWPRS in the matter of hydraulic analysis pertaining to river behaviour and flood control?

b Please furnish a note giving the details of the nature of research and model experiments that are being done in CWPRS on river behaviour and control problems, effect of flood protection and other works on river regime and other relevant matters relating to floods and flood control.

8.2 **a** Please furnish six copies each of the reports of model experiments carried out by the CWPRS for two items in each category of flood control/protection works (embankments, anti-erosion, channel improvements, etc) which have been in operation for atleast five years.

b Please also furnish six copies each of the recent "Specific Notes" on the model studies carried out for flood control, river training and anti-erosion works on the rivers Ganga, Kosi and Gandak in Bihar.

c Please furnish the following informations in each of the cases referred to in (b) above:-

i Where the works were not likely to be completed within one season, whether the model was retained, further experiments carried out and recommendations modified from season to season. Please specify such instances with your comments.

ii Whether the works have been inspected annually or periodically after completion of the above schemes to assess their performance. Please quote specific cases with notes.

iii Whether any additional works have been necessitated soon after the completion of the works. If so, please detail the same and the need therefor.

8.3 **a** Have CWPRS issued any guidelines broadly specifying the data required for specific types of flood protection works? If so, please supply six copies of the same.

If not, do you think such a measure feasible and whether it would assist in timely completion of model experiments and implementation of works?

b Please state whether complete requisite data is supplied by the project authorities in Bihar while requesting for model experiments. If not, please quote examples of some important works, the action taken, the time lost and the resulting adverse effects.

c Where the works are to be spread over more than one season, are the reports about the performance of the works, and changes in the river conditions from season to season received in good time to enable further experiments and indicate modifications in the programme of works earlier recommended? If this has not always been the case, please quote examples of some important works.

8.4 Have hydraulic models of the Ganga River System (including tributaries like the Gandak, the Kosi etc) in Bihar been laid and experiments carried out? If so, please supply six copies of the reports of the experiments.

If not, is there any proposal for setting up such models in near future?

8.5 Referring to CWPRS's work in general, please state in the case of flood protection/drainage works:

i If there is a regular practice of assessing prototype behaviour vis-a-vis the results obtained in model experiments.

ii Have there been any instances of significant variations and/or adverse effects on either bank or in the river behaviour upstream/downstream?

If so, please specify some important cases with details of the analysis made and further action suggested/taken.

8.6 Have any hydraulic design criteria for various types of flood control, drainage, anti-erosion and river training works been published by the CWPRS? If so, please supply six copies.

8.7 Based on the results of your basic research, model experiments, the experience of prototype behaviour and the experience in other countries, please furnish a note stating the suitability, effectiveness, location/situation where applicable of the following type of works:

(i) Embankments, (ii) Anti-erosion works (iii) Channel improvements, (iv) River training works.

8.8 Please furnish a note describing the studies made (in India or abroad) regarding the effect of embankments on river regime, giving specific examples.

8.9 Please furnish your views/suggestions on the manner in which deterioration in river regime conditions downstream of a reservoir can be kept to the minimum.

8.10 Has any study been made in the CWPRS on the effect of soil conservation measures on the run-off pattern and sediment load? If so, please furnish a note with the results and your observations.

8.11 Have any studies been made regarding the effect of river structures in close proximity to each other on the river regime? If so, please furnish a note or six copies of the Report (s), if any.

If no such studies have been carried out, please furnish a note of your views and suggestions relating to such situations on the basis of your experience.

8.12 Do exchange of ideas regarding techniques of research or model experiments take place amongst research workers in the country? Please furnish a detailed note.

QUESTIONNAIRE
[FOR IRRIGATION RESEARCH INSTITUTE, KHAGAUL]

8.1 **a** What is the role of IRI in the matter of hydraulic analysis pertaining to river behaviour and flood control?

b Please furnish a note giving the details of the nature of research and model experiments that are being done in Irrigation Research Institute, Khagaul on river behaviour and control problems, effect of flood protection and other works on river regime and other relevant matters relating to floods and flood control.

8.2 **a** Please furnish six copies each of the reports of model experiments carried out by the Irrigation Research Institute, Khagaul for two items in each category of flood control/protection works (embankments, anti-erosion, channel improvements, etc) which have been in operation for atleast five years.

b Please also furnish six copies each of the recent "Specific Notes" on the model studies carried out for flood protection, river training and anti-erosion works on the rivers Ganga, Kosi and Gandak in Bihar.

c Please furnish the following informations in each of the cases referred to in (b) above:-

i Where the works were not likely to be completed within one season, whether the model was retained, further experiments carried out and recommendations modified from season to season. Please specify such instances with your comments.

ii Whether the works have been inspected annually or periodically after completion of the above schemes to assess their performance. Please quote specific cases with notes.

iii Whether any additional works have been necessitated soon after the completion of the works. If so, please detail the same and the need therefor.

8.3 **a** Have Irrigation Research Institute, Khagaul issued any guidelines broadly specifying the data required for specific types of flood protection works? If so, please supply six copies of the same.

If not, do you think such a measure feasible and whether it would assist in timely completion of model experiments and implementation of works?

b Please State whether complete requisite data is supplied by the project authorities while requesting for model experiments. If not, please quote examples of some important works, the action taken, the time lost and the resulting adverse effects.

c Where the works are to be spread over more than one season, are the reports about the performance of the works, and changes in the river conditions from season to season received in good time to enable further experiments and indicate modifications in the programme of works earlier recommended? If this has not always been the case, please quote examples of some important works.

8.4 Have hydraulic models of the Ganga River System (including tributaries like the Gandak, Kosi etc) in Bihar been laid and model experiments carried out? If so, please supply six copies of the reports of the experiments. If not, is there any proposal for setting up such models in near future?

8.5 Referring to Irrigation Research Institute's works in general, please state in the case of flood protection/drainage works:

i If there is a regular practice of assessing prototype behaviour vis-a-vis the results obtained in model experiments.

ii Have there been any instances of significant variations and/or adverse effects on either bank or in the river behaviour upstream/downstream?

If so, please specify some important cases with details of the analysis made and further action suggested/taken.

8.6 Have any hydraulic design criteria for various types of flood control, drainage, anti-erosion and river training works been published by the Irrigation Research Institute, Khagaul? If so, please supply six copies.

If not, when do you propose to publish such design criteria?

8.7 Based on the results of your basic research, model experiments, the experience of prototype behaviour and the experience in other countries, please furnish a note stating the suitability, effectiveness, location/situation where applicable of the following type of works:

(i) Embankments, (ii) Anti-erosion works (iii) Channel improvements, (iv) River training works.

8.8 Please furnish a note describing the studies made (in Bihar or other States of India) regarding the effect of embankments on river regime, giving specific examples.

8.9 Please furnish your views/suggestions on the manner in which deterioration in river regime conditions downstream of a reservoir can be kept to the minimum.

8.10 Has any study been made in the Irrigation Research Institute, Khagaul on the effect of soil conservation measures on the run-off pattern and sediment load? If so, please furnish a note with the results and your observations.

8.11 Have any studies been made regarding the effect of river structures in close proximity to each other on the river regime? If so, please furnish a note or six copies of the Report (s), if any.

If no such studies have been carried out, please furnish a note of your views and suggestions relating to such situations on the basis of your experience.

8.12 Do exchange of ideas regarding techniques of research or model experiments take place amongst research workers in the country? Please furnish a detailed note.

ITEMS DN WHICH INFORMATION WAS REQUESTED FROM THE AGRICULTURAL UNIVERSITIES (PUSA AND SABOUR)

8.1 **a** Please furnish a note on the research programmes carried out so far in the field of watershed hydrology, land use pattern, soil conservation etc alongwith the major findings relating to rainfall- runoff relation, soil loss, crop yield, etc.

b To what extent have these findings been applied in the field in the completed soil conservation schemes and with what results? Please furnish a note.

8.2 Based on your research findings, has there been any appropriate technology developed to improve agricultural production in the flood-prone areas of the State specially in North Bihar? If so, please furnish a note detailing the agronomic practices, crops/varieties, cropping patterns, agricultural implements/machinery, as well as alternate land use, if any, for livestock, pisciculture, aquaculture, horticulture etc.

8.3 **a** Based on your research findings and results from field verification studies, please furnish a note listing the flood tolerant crops and varieties alongwith their agronomic practices introduced in the flood prone areas of Bihar, specially in North Bihar.

Please also furnish a note describing their performance as compared with traditional crop varieties.

b Similar information may please be furnished for areas suffering from drainage congestion. Please also supply information regarding deep water paddy.

c Has any research study been done, or is being done, on the effect of deposition of silt during floods on soil fertility/ productivity?

If so, please furnish six copies of the report or furnish a note detailing the studies and the conclusions arrived at.

8.4 A number of tals, lakes, chaurs, mauns as also other inland water bodies occur in the flood plains of rivers. Please State if you have developed any appropriate technology to utilise these water bodies for profitable pisciculture/aquaculture.

Please furnish a note on your recommendations. Please also State whether such developments would be successful if these inland water bodies are subject to periodical flooding with silt-laden flood waters.

8.5 Please furnish a note detailing suggestions, if any, for evolving a comprehensive approach to the problem of floods in the State and the appropriate organisational set-up therefore at the State level.

8.6 Agricultural problems in flood prone areas are location specific. Developing suitable crops/ varieties, new agro-technique and methods to meet the challenge of recurring floods, warrants systematic research on continued basis. In appreciation thereof the present position of the organisational infrastructure for research and development (Universities/Agricultural Research Institutes or Centres) may be furnished along with planned projections for the future with respect to each flood prone area of the basins/sub-basins of the State.

Six copies of the relevant research and development publication which give the achievements in these field may please be furnished.

ITEMS ON WHICH INFORMATION WAS REQUESTED FROM THE AGRICULTURE DEPARTMENT (GOVERNMENT OF BIHAR)

8.1 a Please furnish a note indicating the role of the Agriculture Department in the problems of flood and drainage congestion in the State.

b Please detail the role specifically with regard to the soil conservation/ afforestation in the river valley catchments.

What is the mechanism to ensure continued benefits from these works?

What is the organisational set up for the above?

8.2 What are the major agricultural problems limiting production in the flood prone areas of the State as a whole and by river basins?

Please furnish a note on the above problems and the possible remedial measures, taking into account the prevailing agro-climatic conditions of the regions and the available infrastructure for promoting suitable production programmes in the flood-prone areas.

8.3 a Have any cropping strategy and contingent crop plans been developed and recommended for adoption during the flood and the post flood seasons in the frequently flooded areas of the State?

Please furnish a note on the above recommendations giving the crops/varieties, agronomic practices etc, to be followed under the different agro-climatic conditions in the flood plains.

b Are there any standing code(s)/technical guide(s) prepared at the State level on contingent crop plains, to be followed in the event of flood occurrence? If so, please supply six copies thereof.

8.4 Please furnish production analysis for Kharif and Rabi season crops for selected flood prone districts in the State from 1981-1991.

8.5 a Have soil and water conservation/ afforestation measures been undertaken in the catchment area of any of the river valley projects in the State? If so, please furnish details thereof.

b If any quantitative evaluation has been made of the benefits (physical and monetary) accrued from these schemes in terms of increase in crop yields, moderation of flood flows and reduction in silt discharge, please supply six copies each of such evaluation reports. Otherwise, please furnish a note giving your observations on the above mentioned benefits obtained in the field from these schemes.

8.6 Have soil and water conservation programmes been undertaken in the upper catchments of the flood-prone rivers? If so, please furnish information regarding the same showing aggregate figures as follows:

- i Total critical area.
- ii Total estimated cost of the treatments.
- iii Area treated upto 31.3.1992.
- iv Expenditure incurred upto 31.3.1992.
- v Target date of completion of treatment of the total critical area.
- vi Benefits (physical and monetary) accrued from these works.

8.7 Please furnish a copy each of the projects for area development programmes implemented in the flood-prone areas of the State indicating their latest progress reports.

8.8 Does the Department make any assessment of flood damages to agriculture in the State? If so, please furnish a note indicating the methodology and suggestions for improvement, if any.

Has the Department suggested any guidelines in this regard and ensured its implementation? If so, please supply six copies of guidelines alongwith a note on its implementation.

8.9 Has the Department laid down a procedure for working out benefit-cost analysis of soil conservation/afforestation projects?

Are there any manuals or guidelines issued by the Department in this connection? If so,please furnish six copies of each. If not, what is the procedure being followed for such schemes? Please also furnish two illustrative examples of the analysis.

8.10 The soil conservation/afforestation works continue till now as Government programmes executed mostly with Government funds.

Please furnish a note indicating the steps taken to encourage the local people to take up these measures on their own.

8.11 Please furnish a note detailing suggestions, if any, for evolving a comprehensive approach to the problem of floods in the country and the appropriate organisational set-up therefor at the State level.

8.12 The role of soil conservation measures in flood control has been mentioned from time to time. Have any studies been carried out at actual site locations regarding the effect of soil conservation measures on the normal floods and the high floods and also the sediment load carried by the rivers? Please furnish notes including quantitative assessment. Please supply six copies of the reports, if any, to these studies.

8.13 Please list in proforma 8.13, the types of soil conservation measures (contour bunding, gully plugging, check dams, terracing etc) undertaken on catchment basis, their cost and area benefited/ covered, during the Plan periods.

Please give an assessment of their performance (reduction in run-off and silt load and increase in crop yields) and suggestions, if any.

Please furnish six copies of evaluation report,if any. Please also mention if the measures taken have been tampered with or otherwise became ineffective.

8.14 Taking into account the area to be covered, its cost and the experience of implementation of soil conservation works during the past several years, what is the likely time required for effectively implementing the whole programme in the State?

Please give a forecast of the planning stating the areas proposed to be covered and the anticipated cost of each stage. Please supply the information basin/sub-basinwise separately for the upper catchment (hilly areas) and lower catchment.

8.15 Describe (location-wise, if necessary) the present land use in the unprotected flood plains for each river basin/sub-basin in Bihar.

Has any study been made on the pattern of floods, their duration and the nature of crops grown in these areas? If so, please supply six copies of the study.

In the light of these studies, has any attempt been made, for devising suitable crops patterns for reducing the damage due to floods and to increase agricultural production? Conclusions and recommendations of the State Government may please be furnished.

8.16 Has the Department any suggestions on the land use pattern in flood plains (separately for protected and unprotected) for reducing the overall flood damage and to achieve optimum benefits?

8.17 Will it be adequate if land use regulation is confined to the flood plains or should it be extended to the catchment areas as well? What is the pattern of land use required/suggested in the catchment? Please furnish a note.

8.18 Please furnish a note on the general soil descriptions and properties of the flood prone areas in Bihar basin/sub-basinwise. A soil map(s) of the area(s) may be attached.

8.19 Has any study been made by the Department on the beneficial aspects of flood deposition? If so, the position may please be briefly indicated with supporting data.

8.20 Do you have any suggestion on the alternate cropping strategy for increasing agricultural production by suitable adjustments and adoption of new technology such as advancing sowing date, choice of suitable crop varieties, relay multiple cropping etc?

8.21 Please State the main constraints in implementing the post-flood agronomic measures in recovering the growth of submerged crop or raising alternate or substitute crops in making good the agricultural production.

8.22 Are there any approved codes for Flood/Agricultural relief work? If so, six copies of the same may please be furnished. In case there is no such Code, the views of the Department on developing Flood Manual/Code for agricultural programme may please be given.

8.23 Are there any existing local organisations in the flood plain areas for implementing suitable agricultural programmes or are there any proposals in this regard?

8.24 Please State the present position of fuel and fodder supply in the flood prone areas of Bihar State giving the human/ livestock population and their demand for fuel and fodder during floods. The planned projections in this regard may please be furnished.

8.25 Please give a list of the grass and forest species which can stand annual floods and can be grown in flood plains on a commercial scale, especially along the stream banks.

8.26 Implementation of soil conservation and land use measures involves public relations, propaganda, cooperation of local land owners and others and, therefore, its success will depend upon local co-operation. Is such co-operation forthcoming or is there any low or regulation by which this can be ensured? Please supply six copies of the law/regulations.

8.27 Please furnish a comprehensive note on research and development programmes for pisciculture/ aquaculture in the ponds, lakes, chaurs, tals, mauns, local depressions, etc in the flood plains of the State.

PROFORMA 8.13

SOIL CONSERVATION MEASURES IN BIHAR DURING THE PLAN PERIODS (MEASURES INCLUDING CONTOUR BUNDING,GULLY PLUGGING, CHECK DAMS, TERRACING ETC)

River Basin -----------
Area – '000 ha
Cost – Rs Lakh

Plan period	Critical area of the catchment needing soil conservation measures	Area treated in the catchment						Total		Remarks
		Type	Area	Cost	Type	Area	Cost	Area	Cost	
1	2	3	4	5	6	7	8	9	10	11
1951-56										
1956-61										
1961-66										
1966-69										
1969-74										
1974-77										
1977-80										
1980-85										
1985-90										
1990-92										

Note: 1 Type refers to soil conservation measures adopted
2 Source of information may be given.

ITEMS ON WHICH INFORMATION IS REQUESTED FROM THE FOREST AND ENVIRONMENT DEPARTMENT, BIHAR

8.1 **a** The National Forest Policy, 1952, had prescribed that in the country as a whole, one-third of its total land should be maintained under forest. Accordingly, afforestation programmes might have been undertaken in Bihar during different Plan periods to achieve the prescribed goal.

Please furnish informations in the attached proforma 8.1(a) for the upper catchments of the river valley projects in Bihar.

b If any quantitative evaluation (physical and monetary, if possible) has been made of the benefits accrued from the above afforestation works on moderation of flood flow, reduction in silt discharge, timber yield, etc, please furnish six copies of each of these reports.

If no evaluation report is available, please furnish a note with relevant supporting data on the benefits of the afforestation works.

8.2 **a** Please furnish a note on the policy for controlling deforestation and timber extraction in general and specifically as applicable to the river valley projects in the State.

b Please also furnish your assessment of the effects of such deforestation on the increase in the silt discharge and the measures adopted for minimising the same.

8.3 What criteria have been adopted so far for determining the total outlay on soil conservation/afforestation and for sanctioning individual schemes?

8.4 **a** How are soil conservation/afforestation programmes in river valley catchments financed? Would you suggest any modification in this procedure?

b Can the programmes of soil conservation/afforestation in the river valley catchments be taken up with the assistance of institutional finance?

8.5 The soil conservation/afforestation works are being taken up as Government programmes executed mostly with Government funds. Please furnish a note indicating the steps, if any being taken to encourage the local people to take up these measures on their own.

8.6 **a** Please furnish a list of soil conservation/afforestation schemes (with their salient features) which have been completed/under progress/proposed from the flood control point of view.

b Where substantial progress has been made in any catchment, please furnish notes mentioning the effects of the measures taken and the basis for conclusions reached in respect of sediment load, reduction in peak flows, etc.

8.7 Has the Department evolved a comprehensive approach specifying the role of soil conservation and afforestation in flood control.

If so, please supply six copies thereof. If not, please furnish a note giving your views/suggestions in this regard.

8.8 Have any studies been carried out at actual site locations regarding the effect of soil conservation and afforestation measures on the normal floods and the high floods and also the sediment load carried by the rivers? Please furnish notes including quantitative assessment.

Please supply six copies of the reports, if any, of these studies.

8.9 Has there been any scientific study made to establish the effects of forest cover on rainfall-runoff, silt charge and flood flow? Please furnish a note and six copies of report, if any, on the subject giving relevant data from field studies, alongwith the views of the Department on the subject.

8.10 Has any study been made on the extent of deforestation and its effects on the flood flow and sediment load in each of the flood-prone river basins/sub-basins? Please furnish a note and also census of forest acreages basin/sub-basinwise as indicated below:

CENSUS OF FOREST ACREAGES

River basin/sub-basin
(Mention districts covered)

Year	Forest Area (ha)			Area deforested (ha)			Remarks
	Hills	Plain	Total	Hills	Plain	Total	
1	2	3	4	5	6	7	8
1961							
1966							
1971							
1976							
1981							
1986							
1991							

(Please indicate source of data and furnish information separately for each basin/sub-basin)

8.11 Is there a policy of afforestation and forest management for the hills and plains in the State? If so, please furnish a note indicating the details and status of implementation.

8.12 Is there any legislation/regulation by which deforestation in private land is regulated? If so, has it been successfully implemented? Please supply six copies of the relevant legislation/regulation.

8.13 Please give a list of the grass and forest species which can stand annual floods and can be grown in flood plains on a commercial scale, specially along the stream banks.

8.14 Please furnish a note detailing suggestions, if any, for evolving a comprehensive approach to the problem of floods and waterlogging in the State so far as the Department of Forest and Environment is concerned and the appropriate organisational set up at the State level. The role of soil conservations and afforestation in flood control may please be brought out with supporting facts and figures.

PROFORMA 8.1(a)

FOR FOREST AND ENVIRONMENT DEPARTMENT PROGRESS OF AFFORESTATION IN RIVER VALLEY CATCHMENTS IN BIHAR STATE

Area – 1000 ha
Cost – Rs Lakhs

Sl No	Name of the river valley project	Area in Catchments			Anticipated completion date of Col 5	Expenditure		Remarks
		Total	Under forest as on 31.3.91	Addl. proposed for afforestation		As upto 31.3.91	Future anticipated	
1	2	3	4	5	6	7	8	9